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Analysis and Optimization using Renewable Energies to Get Net-Zero Energy Building for Warm Climate

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Abstract

Due to low energy price, economic optimization of consumption has no justification for users in Iran. Nowadays, the issue of ending fossil fuels, production of greenhouse gases and the main role of building in consumption of considerable amount of energy has drawn the focus of global researches to a new concept called net zero energy building. In this study, modeling, simulation and energy analysis have been used for considered building in Zahedan weather condition which has a dry and warm climate to draw the related equations and perform analysis. Multi-Objective optimization has been performed for simultaneous reduction of total energy consumption and total cost where the main decision making variables including thermal comfort, cooling, heating and lighting systems and other variables have been influential. The comparison of an ordinary optimized building and the intended optimized building which uses renewable energy resources indicates that it is possible to get to net zero energy building in addition to selling surplus 2 *MWh* electrical energy to electricity grid with simultaneous use of solar and wind renewable energies.

Keywords:

Net-Zero Energy Buildings (NZEB), Optimization, Energy Analysis, Renewable Energies.

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1. Introduction

From the time when human communities succeeded in exploration of fossil fuels such as oil and coal, the use of new technologies, dependent on these energies, such as automobile, railway, airplane and factories consuming these energies and at the highest level, home consumption for more convenience increased considerably [1]. Although increased consumption of fossil fuels has provided convenience of a modern life at high level, no one even noticed that the cost of this modernization would be air pollution, global warming, polar ice melting and ozone layer depletion; the issue that is now considered by all researchers even ordinary people.

The increased rate of energy consumption in the world along with its consequent environmental damage due to misuse of fossil energy consumption has raised concerns among researchers, engineers and even politicians. In so far as the buildings consume more than 40% of primary energy usage and 70% of electricity energy usage, the policy makers in realm of energy should use appropriate policies to reduce energy usage in buildings. The adverse effects of energy use of buildings include 38% of CO_2 emission to the atmosphere, 52% of SO_2 and 20% of total NO_X emission to the environment. Moreover, concerning the increasing population and economic growth, the energy usage of buildings will also follow an increasing trend in future. Therefore, actions should be taken for energy sustainability which requires minimization of energy usage of buildings such that the energy efficiency of buildings increases without scarifying their comfort and convenience level. To design efficient buildings in terms of energy, several studies have been carried out dealing with various factors including the shape of building, thermal insulators, size and age of building, lighting system and its control, weather condition, Heating, Ventilation and Air Conditioning (HVAC) equipment, the orientation of building, urban texture and other applicable factors for energy consumption reduction [1].

Marszal et al reviewed the definitions and computational methods of net zero energy building and showed that various definitions required for ZNEB should be analyzed through various approaches [2]. Deng et al explained how to achieve efficiency in ZNEB through extensive studies. They reviewed and examined previous research works and considered NZEB from various aspects [3]. Kneifel et al carried out a study on prediction of the energy efficiency of a ZNEB using real data through statistical approach and concluded that it is possible to precisely predict the consuming energy of buildings through this statistical method [4]. Congedo et al obtained economically optimum design for net zero energy official buildings in hot weather [5]. Guillen-Lambea studied the convenience parameters of a NZEB and investigated the effect of thermal comfort parameters on NZEB demand and air conditioning in hot weather. Their study showed that the effect of thermal energy demand in winter is much less than cooling energy demand in summer [6]. Ascione et al used a new methodology for optimum price analysis using multi-objective optimization for energy efficiency of buildings. In another study, they showed the energy efficiency of a NZEB in Germany and found great gap between designed and measured energy demand for summer and winter weeks and reported its reason in relation to the behavior of people living in the buildings. In another study on an educational building in Italy, economic optimization was performed using renewable energies and building energy retrofitting cost. They results showed that in addition to renewable energies, the building retrofitting energy should be considered in achieving ZNEB objective [7-9]. Simulating EnergyPlus software, Boyano et al studied energy demand and saving in European official buildings and concluded that the capability of energy saving will increase in average 3 to 6% due to proper orientation of building [10]. Concerning life cycle cost analysis and the possibility of global warming, Moran et al to examine whether renewable energy consumption or insulation is better for NZEB. They concluded that since increasing thermal resistance and preventing air infiltration are the ways to get NZEB, the use of renewable energy for heating purposes should be considered as used for power generation [11].

Delgarm et al performed optimization for thermal comfort and energy consumption simultaneously using EnergyPlus simulation software for four different weather conditions in Iran [12]. Berry et al explained the concept of NZEB that has been used so far and reported that in different seasons, thermal comfort of these buildings differs [13]. Marta et al studied the energy demand of existing buildings and the possibility of their retrofitting. These studies showed that retrofitting of some buildings is worthwhile and some others are worthless to be retrofitted [14]. Olatomiwa et al comprehensively reviewed energy management strategies for a building using renewable energy systems such as solar energy, wind energy, fuel cell and etc. Fuzzy logic system was reported as the best energy management strategy (EMS) [15]. Brinks et al expanded economic optimization concept for an industrial steel NZEB and concluded that energy saving for industrial buildings is possible using optimization of thermal bridges and closing air vents while increased thickness of insulators is less effective [16]. Braulio-Gonzalo et al optimized the thickness of insulators in walls of a building. They performed sensitivity analysis by changing energy demand scenarios and concluded that by over-increase of insulator's thickness, thermal energy demand doesn’t decrease further [17].

Buonomano et al obtained a new computer model for prediction of energy demand of non-habitant buildings with Phase Change Material (PCM) for Mediterranean weather [18]. In another study, Cuce et al optimized the insulator thickness and analyzed energy demand reduction by adding aerogel to the walls of a building. The optimum aerogel thickness for the wall was obtained as 22 to 62 mm leading to decreased emission of CO_2 in a range of 55.2% to 86.4% [19]. Eshraghi et al performed a feasibility study for the use of solar energy in a NZEB in Tehran and concluded that the combination of photovoltaic panels and solar collectors, in addition to passive design of building could supply the electricity demand and hot water of NZEB where 4 people live [20]. Ferrara et al performed the simulation of dynamic energy for cost analysis and optimization of a NZEB and concluded that the wooden view has the best efficiency for NZEB. Moreover, in another study, they concluded that getting economic points in a NZEB is highly dependent on the building design; while, less dependent on energy system of that building [21, 22]. In addition, as HVAC system management is one of the main concerns of designers of efficient buildings, many studies have dealt with the effects of HVAC system management on energy consumption of building [23-25]. Good et al compared the photovoltaic/thermal (PVT), photovoltaic and thermal solar systems and concluded that buildings with just photovoltaic panels are better in getting NZEB [26].

Lin et al performed some studies on the thermal efficiency and optimization of buildings were PCM and PVT were used and concluded that the use of PVT and PCM for heating purposes in winter increases the efficiency of building [27].

Pikas et al performed some investigations using extra cost analyses in two apartments to get low energy and almost zero energy building. They concluded that concerning the improved structural condition of building, there is the possibility of less energy consumption; however, to get zero energy building, other strategies should also be used. In another study, this group performed an optimum economic analysis using photovoltaic panel for a NZEB and concluded that the use of PV technology is effective both for public and private environments [28, 29].

Most studies have focused on a certain form of energy consumption and each tried to investigate simulation and analysis of implementation of certain components on energy demand of that building. As one of the main objectives of this study is to design a high efficient building in terms of energy, it is required to simultaneously study all main factors influencing the energy consumption of building from optimization analysis to the best replacements. To this end, it is required to study the optimization of effective parameters on energy, installation cost and thermal convenience for these buildings. Achieving this objective requires designing of better alternatives that satisfy the efficiency of contradictory parameters such as the contradiction on economic and environmental efficiency that allows the designers overcome simulation problems.

1.1. Net-Zero Energy Building (NZEB)

NZEB is used to refer to a building which ideally shares the available renewable energy technologies using structural techniques of effective energies. The main idea of NZEB is that buildings supply their maximum energy demands using low-cost, locally accessible and un-contaminating renewable resources. It's difficult to find really the first NZEB, since "zero energy" is just a new name for decreasing trend of energy consumption in building. In a net-zero energy building, no fossil fuel is used and its annual energy consumption equals to its annual energy production. A NZEB might be connected to the utility grid or not; the one with no connection to utility gird usually uses some equipment such as battery for energy saving which depending on the shape and type of battery saving, part of circuit might remain intact; whereas in the one connected to grid, no intact circuit is used. A NZEB connected to grid might generate electricity beyond its demand. During the time when the building doesn’t require produced energy (when using the energy saved in batteries), it produces its required energy and meanwhile ensures the owners of the security of extra energy reserve.

As previously mentioned, many studies have dealt with NZEB including Torchilini et al. who explained that NZEB has no definite concept[30]. They claimed that the concept of NZEB could be defined concerning the project's objective and in fact the project's objective explains the project's concept. The aim of NZEB in the present study is to reach a point where the building's on-site electricity production can supply its entire electricity demand as seen in eq. (1). Finally, it should be mentioned that NZEB should be considered a realistic achievable objective for reduced energy consumption and CO_2 emission rather than just a theoretical idea.

$$\begin{aligned} &Net\ Zero\ Energy = \left|Output\right| - \left|Input\right| = \\ &\sum_i Output\ Energy\,(i)\times W\,(i) - \\ &\sum_i Deliverd\ Energy\,(i)\times W\,(i) \geq 0.0 \end{aligned} \tag{1}$$

In eq. (1), i is energy type counters. Fig. 1 presents the use of renewable energies in the building modeled of in present study and the manner of electrical energy exchange with utility grid and battery. As it is observed in Figure 1, solar and wind energies are the continuous power input in building. The interesting point is that contrary to thermal energy, storage of electrical energy is almost impossible. To this end, the surplus energy will be stored in a battery designed for this purpose after it is converted to a form that could be stored. In this study, first generated power is stored in the battery through some devices connected to it (after supplying electricity demand of building), then, the surplus energy will be transferred to the power grid so that in peak hours, first the stored energy on the battery will be used and after complete discharge, any additional required electricity will be supplied from the power grid.

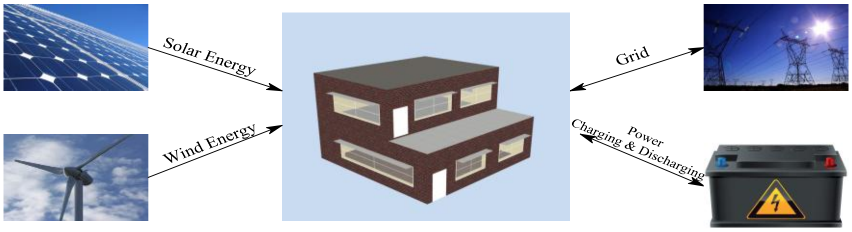

Figure 1. Input electricity from renewable resources and exchange with battery and utility grid

1.2. Renewable energies

1.2.1. Solar energy

In this study, photovoltaic panels are used for utilization of solar energy. These panels convert radiant energy of sun to electrical energy without any mechanical interface and generate DC electricity. The electrical power (P_{PV}) produced by photovoltaic panels is calculated by eq. (2); however, by electricity loss due to inverter efficiency (η_{inv}),

$$P_{PV} = (\eta_{PV} . I_m^{ext}) . \eta_{inv} . A_{PV} \tag{2}$$

where I_m^{ext} is the global incident solar radiation transmitted through the glass cover, A_{PV} is PV cover area and η_{PV} is PV efficiency.

1.2.2. Wind energy

As previously mentioned, concerning the wind energy potential in Zahedan city, in the present study, wind turbine is also used which converts kinetic energy to electrical energy. Despite PV where annual data are used for calculation of produced energy, here, for precise calculation of produced energy by wind turbine, hourly data are used. Eq. (3) shows the modified calculated wind speed (v) [1]:

$$v = \left(\frac{h}{h_0} \right)^{a_r} \times v_0 \tag{3}$$

where, v_0 is the initial wind speed measurement based on 10-meter height, h_0 is the primary presumed height (usually 10 meter) and a_r is roughness coefficient depending on the surrounding landscape [31].

For calculation of total annual power output (TPO) of wind turbine, the modified speed in eq. (4) should be used;

$$TPO = \sum_{v=1} n_v \times P(v) \tag{4}$$

where, n_v is the number of hours per year that wind turbine rotates by speed v and $P(v)$ is the generated power by turbine at this speed v.

2. Methodology

The general methodology of this study is illustrated in Fig. (2), where different steps taken in this study to achieve a NZEB are schematically shown.

As observed in Fig. (2), all procedures and steps begin from the modeling of building, then energy analysis will be performed and optimization will be done for designing an efficient building. At the next stage, solar and wind energies are added to existing energy resources of the building and the results of their effects on building will be studied. The important point in solving the present problem is that first the building energy consumption should be minimized (passive design), then, energy production by renewable energies should be added (active design). In other words, adding electricity and power generation by renewable energies to a building with high rate of energy consumption is not considered a proper strategy to achieve NZEB.

2.1. Modeling, simulation and energy analysis

The main loads that could be analyzed in a building are heating and cooling loads. In a building, the sum of gains and losses of heat energy should be equal which is presented in eq. (5) [7].

$$-Q_{HVAC} = Q_{Total\ Site\ Energy\ Consumption} = \sum_{i=1}^{Nsj} \dot{Q}_i + \sum_{i=1}^{Nsurface} h_i.A_i.(T_{si} - T_z) + \sum_{i=1}^{Nzones} m_i.c_p.(T_{zi} - T_z) + m_{\inf}.c_p.(T_{ext} - T_z) \quad (5)$$

where, $\sum_{i=1}^{Nsj} \dot{Q}_i$ is total loads due to indoor heat exchange, $\sum_{i=1}^{Nsurface} h_i.A_i.(T_{si} - T_z)$ is the heat exchange due to zone surfaces, $\sum_{i=1}^{Nzones} m_i.c_p.(T_{zi} - T_z)$ is heat transfer due to inter-zone air mixing and $m_{\inf}.c_p.(T_{ext} - T_z)$ is heat transfer due to outdoor air infiltration

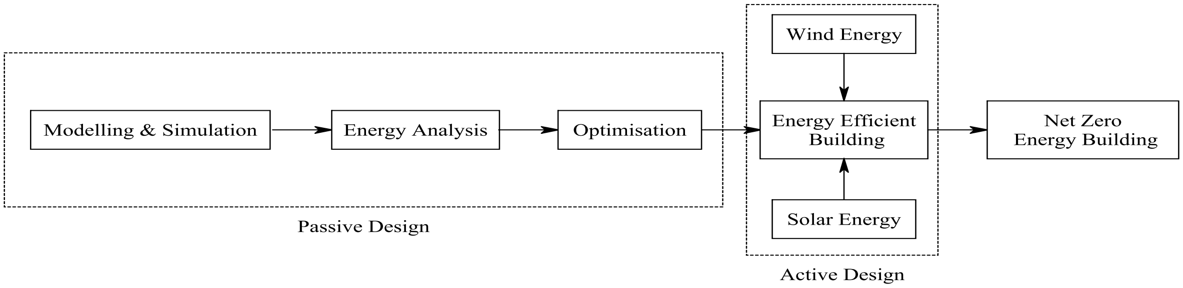

Figure 2. The analysis and problem solving strategies to achieve NZEB

Heat transfer due to building's component will affect the indoor areas' temperature (T_{si}); thus, heat exchange between building surfaces and indoor air is presented in eq. (6):

$$-q''_{conv} = q''_{LWX} + q''_{SW} + q''_{LWS} + q''_{sol} + q''_{ki} \quad (6)$$

Where, q''_{LWX} is radiating flux between surfaces with long-wave lengths, q''_{SW} is radiating flux between surfaces and light emitters and q''_{LWS} is radiated heat transfer between surfaces and emitters. Moreover, q''_{sol} is solar radiating flux and q''_{ki} is heat transfer conducted from the building surrounding area. Eq. (7) could be used for calculation of q''_{ki}:

$$q''_{ki}(t) = -Z_o T_{i,t} - \sum_{j=1}^{nz} \dot{Z}_j T_{i,t-j\delta} + Y_o T_{o,t} + \sum_{j=1}^{nz} Y_j T_{o,t-j\delta} + \sum_{j=1}^{nq} \psi_j q''_{ki,t-j\delta} \quad (7)$$

Where, T is temperature, i and o are respectively indicative of inner and outer surfaces of building, t is indicative of time in one stage and Z, Y and Ψ are internal, cross and flux coefficients.

The annual demand energy of building for cooling is obtained from eq. (8) which is in terms of kWh/m2.year.

$$CN_{usf} = \frac{1-\eta_c}{A} \times Q_{gn,c} \quad (8)$$

where, η_c is devices loss factor, A is the useful cooled area of building and $Q_{gn,c}$ is total internal and solar heat gains.

As seen for heating, solving these equations requires adjusting the heating temperature on a certain point during cold seasons. To obtain $Q_{gn,c}$ from eq. (9), we have:

$$Q_{gn,c} = Q_{opq} + Q_s + Q_i \quad (9)$$

where, Q_{opq} is internal heat gain due to occupants, equipment and lightings; Q_s is solar heat gain from transparent environments (such as window) and Q_i is solar heat gain from opaque environment.

Finally, heat loss from external walls (Q_{loss}) is obtained from equation (10):

$$Q_{loss} = U(T_t - T_{md}) \quad (10)$$

where, U is overall heat transfer coefficient, T_t is constant internal temperature and T_{md} is mean daily temperature calculated from equation (11):

$$T_{md} = \frac{T_{air} + T_{rad}}{2} \quad (11)$$

where, T_{air} is air temperature and T_{rad} is radiative temperature.

For modeling purpose, a real two-story building in Zahedan city has been used with 149 m^2 area and occupied area of 513 m^3. 3D design of this building is presented in fig. 3 and the designing details in table 1.

In the next stage, the designed model was examined for energy analysis. Department of Energy of America (DOE) has recommended various instruments and software for design purposes. One of the main and most applicable proposed software is EnergyPlus that is designed for simulation and estimation of total energy consumption of building [32]. The researchers, architects and engineers could be the users of EnergyPlus for modeling energy consumption of building including heating, cooling, lighting and air conditioning and etc. [33] that allows substation of most of these parameters; however, it uses text file for reading inputs and printing outputs that is time consuming and difficult. For energy analysis, after modeling building and entering inputs, energy stimulation will be done. To this end, cooling and heating loads, lighting loads, the number of people, type of activity and even their clothes in the building will be studied.

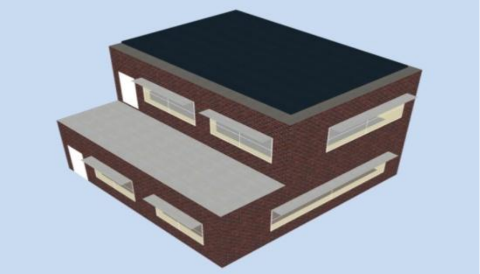

Figure 3. The modeled building for analysis

Table 1. Modeled Building's Specification & Site Location

Parameters	Values/Types
Program Version	EnergyPlus, Version 8.5.0-c87e61b44b
Hours Simulated [hrs]	8760
Weather File	Zahedan Airport - IRN ITMY WMO#=408750
Latitude [deg]	29.48
Longitude [deg]	60.91
Elevation about sea level [m]	1378
Site orientation [deg]	0
HVAC	GSHP Water to Water heat Pump, Heated Floor, Chilled Beams, Nat Vent
Lighting	Compact fluorescent (CFL)
Gross Window-Wall Ratio [%]	19.55
Window Opening Area [m2]	50.63
Gross Wall Area [m2]	259

2.2. Optimization

In most scientific issues and subjects, this question arises that what is the best way to achieve desired objective. The process of getting the best state from the possible states for a system is called, "optimization". This selection is based on various criteria or a combination of them and is done such that maximum demand is fulfilled with the minimum effort. "Optimization criterion" is a subject of "decision variables" that indicate the status of intended system. This special criterion is called "objective function" and is explained as a mathematical function of proper variables of system. It could be said that optimization is the process whereby, the terms and values of variables will be determined for minimization or maximization of objective function [1].

The process of finding the best design parameters is difficult, especially on that they might be contradictory in function problems such as environment maintenance and efficiency of economic issues. To solve this contradiction, that method should be used where the use of optimization of several objective functions provides a proper area for objective function. In the present study, NSGA-II advanced optimization algorithm has been used for optimization of multi-objective optimization. The interesting point is that although the optimization answer could not provide a precise solution, it would yield an approximate and acceptable solution for that issue [1].

More than half of consumed energy in buildings is related to HVAC and lighting systems; however, the conditions might yield different values concerning varying weather condition. This study has been done with consideration of weather condition of Zahedan where the consuming loads of most buildings are cooling and lighting loads. Thus, to optimize energy consumption of building, more emphasis is put on the investigation of various HVAC and lighting systems to find optimum solution for reducing energy consumption of building. The total cost equation is in form of eq. (12):

$$C_G(\tau) = CI + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i) \right) - V_{f,\tau}(j) \right] \qquad (12)$$

where, $C_G(\tau)$ capital cost of starting year, CI is the initial installation cost, $C_{a,i}(j)$ is the annual cost for j^{th} component at year i, $R_d(i)$ is discount rate for year i and $V_{f,\tau}(j)$ is final value of component j at the end of calculation period.

The discount rate coefficient R_d used in eq. (12) is as follow where R_r is real interest rate at year i.

$$R_d = \frac{1}{(1+R_r)^i} \tag{13}$$

Fig. 4 shows the analysis of optimization with objective functions and decision variables through NSGA-II optimization method. The results of this method show the most acceptable values in Pareto Front. As could be seen, various symbols are drawn in the graph, each sample indicating an independent design for HVAC and lighting system. Generally, in consumption optimization of a building, three general quantities should be studied: comfort and convenience level, total costs (On the Great British Pound criterion) and total consumed energy of building. It is clear that convenience should increase whereas total cost and total consumed energy should be decreased. Using high efficiency systems makes reduction in energy consumption of building; however increases the total cost of building. On the other hand, increased convenience level of inhabitants of building probably leads to increased energy consumption and total cost of building. Thus, its logical to consider convenience as a constraint and not as an objective function.

In order to solve the optimization problem, 4000 decision making points have been considered out of which 4 points have been selected as optimum points concerning the obtained results. The summary of these four points is presented in table 2.

2.3. Energy supply systems

As discussed in previous sections, in order to supply part or all consumed energy of a NZEB, energy generation in that building should be used including electrical and heating energies. However, the previous studies have shown that for energy analysis in a mechanical system, it is possible to convert these energies to each other with some coefficients [34]. As seen in fig. 1, concerning the weather condition of Zahedan city, in this study photovoltaic solar energy and wind energy have been used. The specifications of the used photovoltaic and turbine are presented respectively in tables 3 and 4.

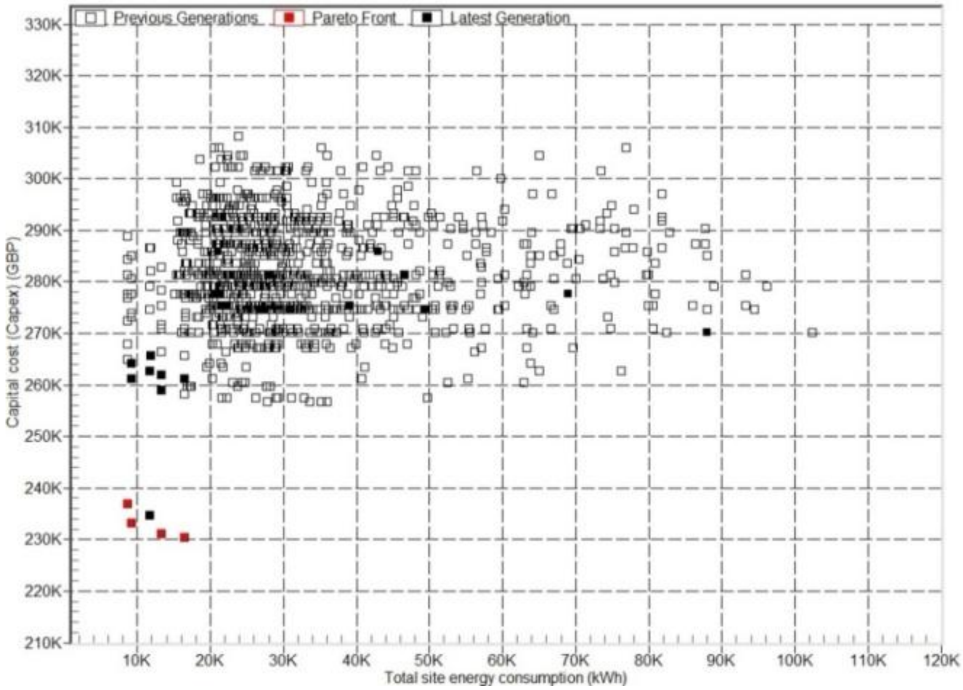

Figure 4. The optimization results and determination of Pareto front for most optimized points

Table 2. Optimization Pareto Front

	Total site energy consumption (kWh)	Capital cost (Capex) (GBP)	Cooling system COP	HVAC	Lighting
1	16380.1	230344.5	3.4	Natural ventilation - No Heating/Cooling	Fluorescent, compact (CFL)
2	24471.8	281366.5	3.8	Natural ventilation - No Heating/Cooling	T5 (16mm diam) Fluorescent, triphosphor, high-frequency control
3	9181.8	233325.3	4.75	Natural ventilation - No Heating/Cooling	T5 (16mm diam) Fluorescent, triphosphor high-frequency control, LINEAR dimming daylighting control
4	8663.6	237051.3	3.95	Natural ventilation - No Heating/Cooling	LED with linear control

Table 3. Photovoltaic Panel Specifications

Parameters	Values/Types
Total area [m2]	54
Fraction of surface with active PV	0.9
Efficiency [%]	15
Material	Bitumen felt
Heat transfer integration	Decoupled
Inverter efficiency [%]	90
Availability schedule	On 24/7

Table 4. Wind Turbine Specifications

Parameters	Values/Types
Rotor type	Horizontal Axis Wind Turbine
Power control	Variable Speed Fixed Pitch
Overall height [m]	11
Number of blades	3
Overall wind turbine system efficiency [%]	83.5
Availability schedule	On 24/7

3. Results and Discussion

As we know, the generated power by photovoltaic panels depends on the hour, day, season, sun radiation and the angle of installed PVs. To make the simulation more real and the results more precise, all these items have been considered in the present study. In fig. (5), the location of sun in 9:30 AM of 14thAugust is drawn.

3.1. The results of total consumed energy analysis

Moreover, in order to use wind turbines, an area with high gradient of wind speed is required; Zahedan city benefits from such potential. Table 5 presents the site data and thermal comfort for different seasons.

3.2. The results of total consumed energy analysis

Concerning eq. (5) to (11), fig. 6 shows the results of energy analysis on the intended administrative building in various seasons of the year. This diagram gives the possibility of comparing the consumed energies of building whether thermal or electrical and as could be seen, some energies (lighting, electrical equipment and etc.) are relatively fixed during the seasons of the year and some vary.

3.3. Analysis of electrical energy

In analysis of electrical energy for the intended building, three different scenarios have been analyzed: a building without energy production, a building with just photovoltaic energy and a building with photovoltaic and wind turbine and the specifications of photovoltaic and wind turbine are presented in table 3 and 4 and the results are presented in fig. 7 to 10. In the first scenario, as seen in fig. 7, the diagram of consumed load is presented (the building without electrical energy production). It is obvious that the peak energy consumption occurs in hot seasons, that is mainly due to loads used for cooling purpose. In fig. 8, the diagram of total consumed and produced loads in the building connected to photovoltaic panel could be seen (Scenario 2). As seen in the figure, the electricity efficiency and production of photovoltaic panels is more in hot seasons due to sun radiation; however, it is clear that the produced energy by these panels is not sufficient for NZEB. The results show that total received annual energy for this building from photovoltaic panel has been 13338.2 *kWh*. In fig. 9, the results of electrical and consumed energies are presented with implementation of third scenario. As could be seen, the obtained electrical energy from wind turbine is considerable and could compensate the power deficiency of photovoltaic panel in cold seasons.

In fig. 10 where both photovoltaic and wind turbine are used (third scenario), the detailed monthly electrical energy consumption including the energy used for the inhabitants' activity and all equipment and appliances except lighting, consumed electrical energy for lighting, consumed electrical energy for cooling and consumed electrical energy for hot water is presented. As previously mentioned and concerning Zahedan weather condition, the highest energy consumption is for cooling purposes in hot seasons such that the highest cooling load for this building had been in July as 1227 *kWh*. The annual used electrical energy for the inhabitants of this building and all equipment except lighting, consumed electrical energy for lighting, consumed electrical energy for cooling and consumed electrical energy for hot water had been respectively 6459.8 *kWh*, 9335.8 *kWh*, 8860.5 *kWh* and 584.5 *kWh*; while the annual electrical energy production is 27308.4 *kWh*. In fig. 11, the results of annual consumed electrical load of building and annual power production by renewable energies could be seen.

4. Conclusion

The applications and benefits of a NZEB include:

- Decreased thermal variation in these buildings is related to various factors including appropriate insulation and provides the conditions for thermal comfort;
- Energy supply even in case of power failure;
- Immunity from increased rate of energy price;
- Lower production of greenhouse gases;
- Energy saving.

In this study, modeling, stimulation and analysis of primary energy for intended building have been extracted in Zahedan weather condition and the results have been analysis. Then, using optimization of two objective functions, the best possible condition of reduction of total energy consumption and total cost of entire building has been determined and the energy demand of building has been obtained using secondary energy analysis. Although in hot months of the year, almost 30% of consumed energy of building is related to lighting of official building; 45% is used for cooling of building; whereas, in cold seasons, almost 50% of consumed energy is used for lighting purposes. Moreover, energy production in January is four times more than June. The net annual electrical energy is 2060 *kWh* that is about 8% of total consumed electricity of this building. However, it should be noted that this exchange with power grid is dynamic; i.e. it might happen that at peak time, electricity is taken from utility grid and at low load condition, the produced energy of building will be transmitted to utility grid. Indeed, the results indicate that after annual calculations, the building has inclined toward positive energy.

Furthermore, the results of this study showed that the use of photovoltaic panel, individually, is not enough to get NZEB and some other types of renewable energies should be used beside solar energy which in this study, concerning the wind potential in Zahedan city, wind turbine has been used. Moreover, the results indicate that the use of wind turbine for electricity generation in cold seasons in a good alternative for decreased produced power by the photovoltaic panels in seasons.

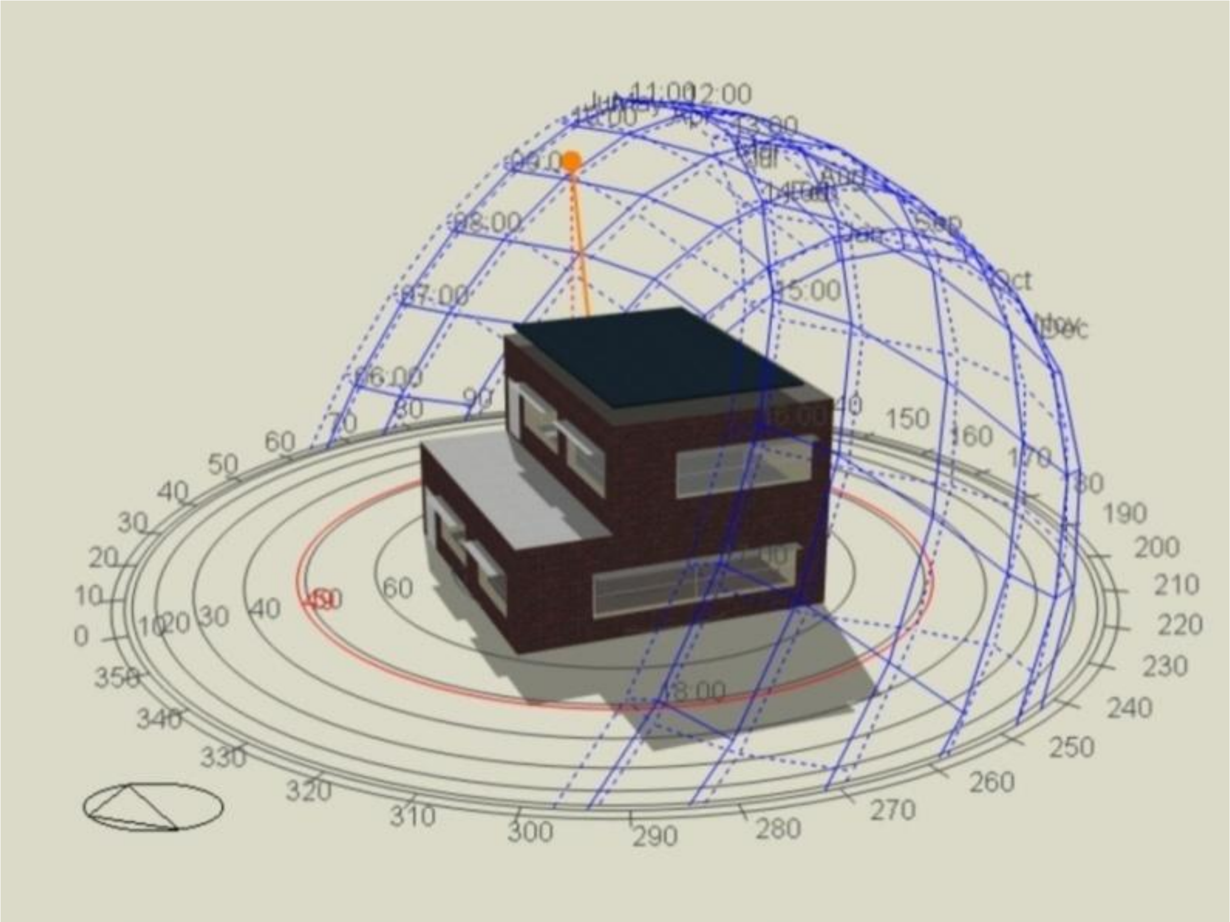

Figure 5. The schematic plan of sun radiation path in 14th August

Table 5. Site Data and Comfort for Different Months of Year

Data/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temperature	23.7	24.2	25.7	26.9	29.1	30.7	31.4	31.8	30.4	27.8	25.5	23.7
Radiant Temperature	24.9	25.6	27.3	29.1	31.4	32.8	33.6	33.7	32.5	29.8	27.1	24.8
Operative Temperature	24.3	24.6	26.5	28.0	30.2	31.7	32.5	32.8	31.5	28.8	26.3	24.3
Outside Dry-Bulb Temp. (°C)	17.9	19.1	23.2	26.6	30.6	33.0	34.2	33.3	32.0	28.8	23.4	18.5
Outside Dew-Point Temp. (°C)	9.4	12.0	15.5	18.2	22.3	24.2	26.7	27.2	24.6	20.8	13.5	11.8
Wind Speed (m/s)	2.2	2.3	3.2	2.4	3.3	2.9	3.7	4.1	3.2	1.6	2.1	2.8
Wind Direction(°)	107.3	131.2	128.5	108.0	126.8	131.2	130.3	135.3	143.5	68.4	123.6	144.7
Solar Altitude(°)	-13.0	-8.3	-1.3	6.2	11.8	14.3	13.2	8.8	2.0	-5.5	-11.5	-14.2
Solar Azimuth(°)	189.8	190.2	191.8	193.9	194.9	194.2	193.0	193.2	194.7	195.8	194.5	191.1
Atmospheric Pressure (kPa)	101.5	101.4	101.3	101.0	100.5	99.8	99.5	99.6	99.9	100.2	100.8	101.1
Direct Normal Solar (kWh)	108.5	104.8	135.9	114.9	119.3	163.6	123.2	139.9	117.3	106.8	95.2	95.0
Diffuse Horizontal Solar (kWh)	103.1	131.3	121.8	183.7	196.7	156.6	158.1	147.5	156.3	139.0	111.8	98.0

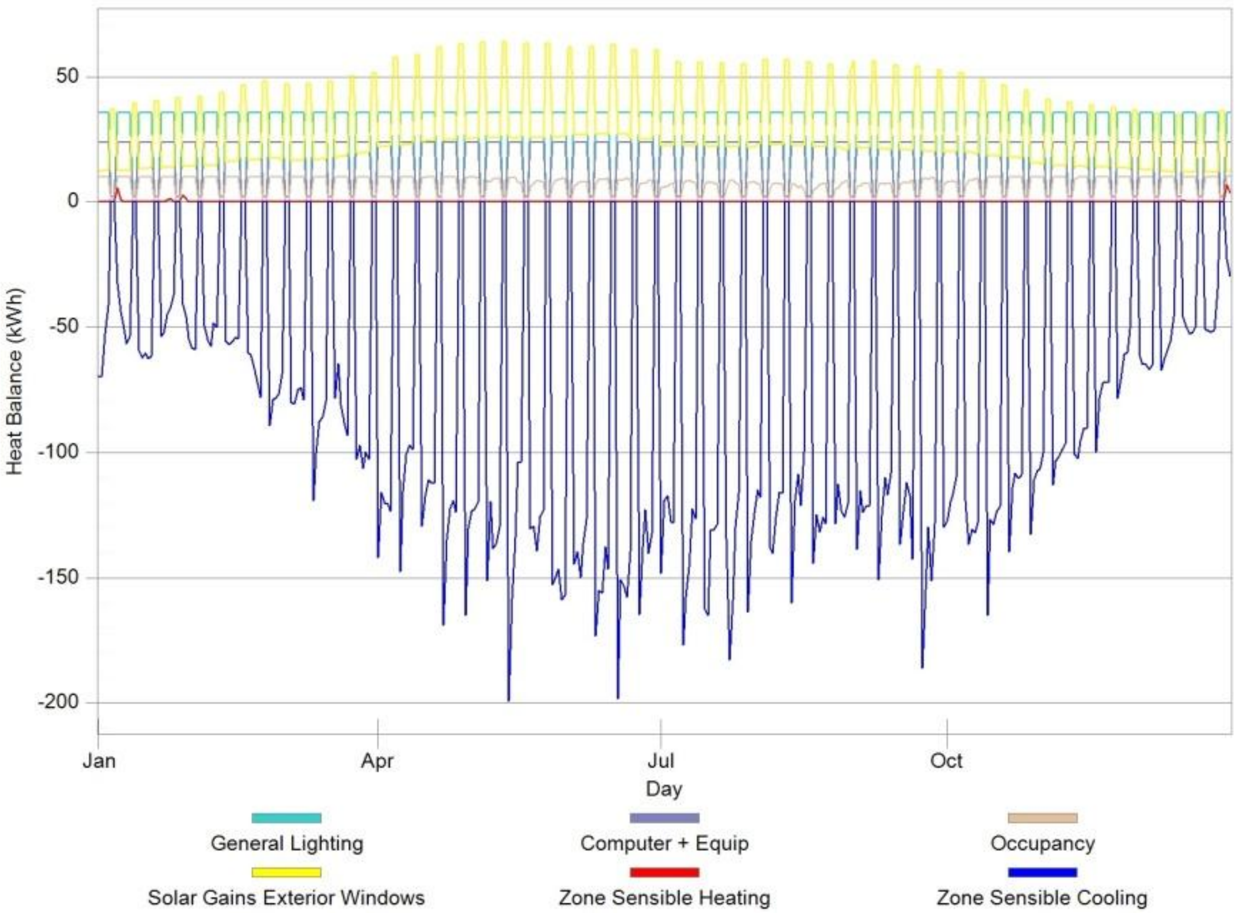

Figure6. Daily consumed energy of the building within one year

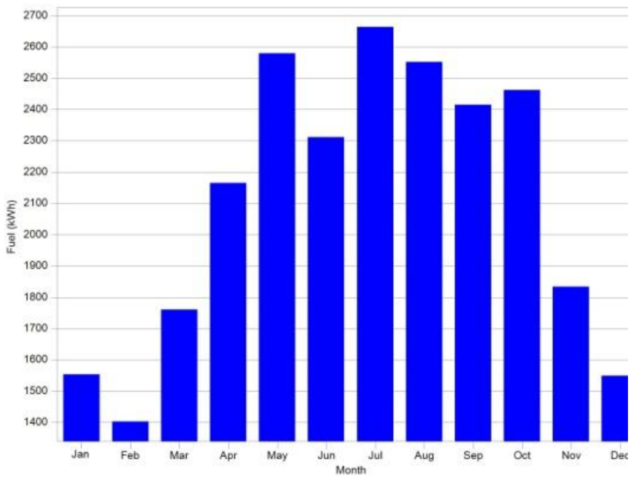

Figure 7. The total monthly consumed load of building without consideration of energy production

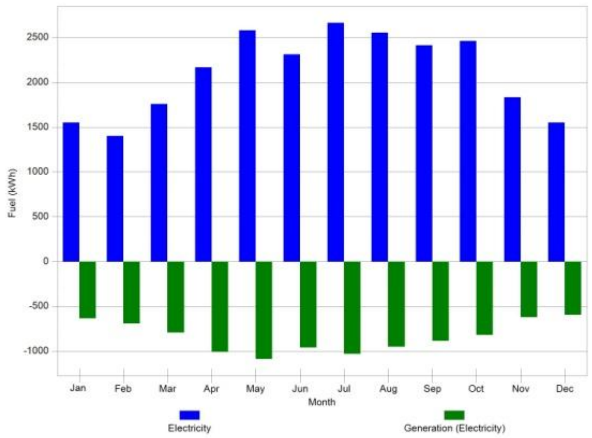

Figure 8. The total monthly consumed and produced load of building with consideration of photovoltaic panel production

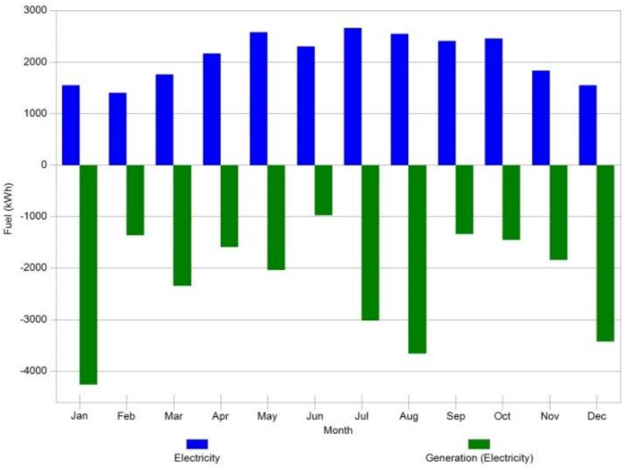

Figure 9. Total monthly produced and consumed loads of building with consideration of photovoltaic panel and wind turbine production

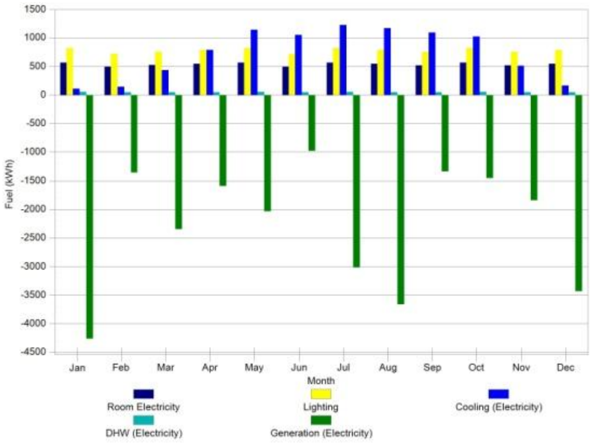

Figure 10. Monthly consumed and produced energies using renewable energies of building within a year

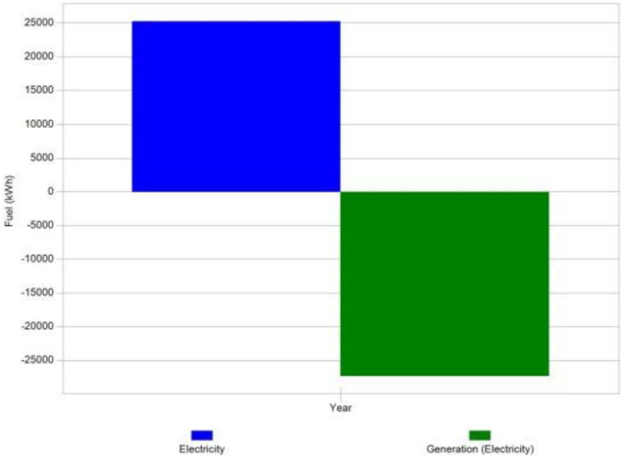

Figure 11. Total annual consumed and produced energies using renewable energies of the building

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