Iranica Journal of Energy & Environment
Journal Homepage: www.ijee.net
IJEE an official peer review journal of Babol Noshirvani University of Technology, ISSN:2079-2115

Feasibility Study of a Zero Energy Building Based on Photovoltaic-Low Speed Wind-Battery Hybrid System: A Case Study in Golestan-North of Iran

N. Mirrashid[1]*, S. M. Rakhtala[2]

[1] Faculty of Engineering, Department of Electrical Engineering, University of Zabol, Zabol, Iran
[2] Faculty of Engineering, Department of Electrical Engineering, Golestan University, Gorgan, Iran

PAPER INFO

Paper history:
Received 26 July 2023
Accepted in revised form 30 October 2023

Keywords:
Environmental features
Hybrid system
Photovoltaic-wind-battery zero energy system
Rate of return

ABSTRACT

In this paper, a feasibility study is conducted on a photovoltaic-low-speed wind turbine-battery zero-energy building for a 175 m^2 residential house in Gorgan. First, the climatological data of Gorgan City related to the amount of solar radiation and wind speed for the past 50 years have been extracted and then they are analyzed annually, monthly, and hourly using Climate Consultant software to check how Renewable resources can be used to produce clean energy. To determine the number of devices required, the annual energy requirement of the residential unit should be estimated. For this purpose, the power and energy consumption of the residential unit has been estimated based on its consumption data in the last year and analyzed using RETScreen[1] software. The designed zero energy system has energy exchange with the grid and sends excess energy to it. The results of climate data analysis show that there is a possibility of wind and solar energy efficiency in this region. Although the price of energy in the region is low, due to economic efficiency, the lack of non-renewable energy resources, and the need to replace these resources, the use of wind turbines and solar panels to supply the required electrical energy is necessary.

doi: *10.5829/ijee.2024.15.03.02*

INTRODUCTION

The world is facing a major energy crisis. Fossil fuels are becoming increasingly expensive and their use is contributing to climate change. Renewable energy sources, such as solar and wind power, are becoming more affordable and reliable, but they are still not widely adopted. Wind energy is a popular source of electrical energy due to its many advantages. It is renewable, clean, and abundant all over the world. It also produces fewer greenhouse gases than fossil fuels. However, the performance of wind turbines depends on the wind speed. When the wind speed is low, wind energy alone cannot always produce the maximum power required. To improve the performance of a wind turbine system, a hybrid system can be used. A hybrid system combines wind energy with other sources of energy, such as solar power or batteries. This can help to ensure that the system always has the power it needs, even when the wind speed is low. One example of a hybrid system is a photovoltaic/battery/home wind turbine system. This system uses solar panels to generate electricity during the day, and a wind turbine to generate electricity at night. The electricity is stored in batteries for use when needed. Hybrid systems are becoming more and more popular as a way to improve the reliability and efficiency of wind energy systems. They can help to reduce the impact of intermittent wind power and provide a more consistent source of electricity (1).

Many studies have been conducted on the analysis of solar and wind energy resources. The conducted research can be categorized based on the type of renewable energy source, zero energy buildings, zero energy systems, smart renewable energy systems, etc. Shayan et al. (2) proposed a new method for optimizing the operation of a multi-microgrid system. The proposed method uses a Markov prediction chain and a dynamic decision algorithm to minimize the cost of electricity while ensuring that the

---

*Corresponding Author Email: n.mirrashid@uoz.ac.ir (N. Mirrashid)

[1] Renewable Energy and Energy Efficiency Technology Screen

Please cite this article as: Mirrashid N, Rakhtala SM. Feasibility Study of a Zero Energy Building Based on Photovoltaic-Low Speed Wind-Battery Hybrid System: A Case Study in Golestan-North of Iran, Iranica Journal of Energy and Environment, 2024 July, 15(3): 235-47. Doi: 10.5829/ijee.2024.15.03.02

power demand of all microgrids is met. Rouhani et al. (3) proposed a new method for using demand response to regulate power system frequency. The proposed method uses a modified active disturbance rejection control (M-ADRC) algorithm to ensure that the demand response signal is accurate and responsive to changes in the power grid. Esmaeili Shayan et al. (4) conducted a techno-economic analysis of flexible photovoltaic systems on non-conventional surfaces. The analysis considers the cost of the Photovoltaic system, the cost of installation, and the expected savings from the electricity generated. Esmaeili Shayan et al. (5) proposed a new design for a near-zero-emissions building. The proposed design uses a smart hybrid renewable microgrid to provide the building with electricity and heat. Also, interested readers may refer to literature (6–9), to name a few. In terms of the feasibility of building zero energy buildings, we can refer to da Graça et al. (10). They used the Homer software to design a 10-kW wind turbine for a house in Newfoundland, Canada. The turbine met the annual energy consumption of the house, with a final cost of $44,000. A zero-energy system was designed for a residential unit in southern Europe (10). The initial cost of the project was estimated at €9,900 and €23,500 for the lowest and highest annual demand, respectively. The benefit of the project was calculated to be between €10,600 and €17,800 over 20 years. Eshraghi et al. (11) designed a zero-energy system for a residential building in Tehran, Iran. They first reduced the amount of required energy by using a thrombus wall, roller shadow, and thermal mass. They also designed the building to maximize the use of daylight. The remaining energy demand was met using solar energy and batteries. Alfieri et al. (12) implemented a zero-energy system for a residential house in Rome, Italy. They supplied the building's energy needs with solar energy and a battery storage system. Their results showed that the photovoltaic system was economically viable due to the heavy use of heating equipment. Liu et al. (13) examined the feasibility of using a renewable energy system in the Qinghai-Tibetan Plateau area. They aimed to achieve a moderate temperature of 20 to 25°C, which they found was possible with 16.1 kWh/m^2 (year) of energy. The designed system met the desired goals and achieved the desired results. Regarding the feasibility of zero energy systems, Nematollahi et al. (14) explored the possibility of using solar energy in various areas of South Korea. They calculated the annual radiation characteristics for 24 stations over five years and created a geographic information map for each month of the year. They found that the central and southern regions of South Korea have the highest levels of received radiation and are suitable for solar panels. Lutchman et al. (15) examined the climate conditions of a site in Cofimvaba, South Africa, and tried to use geothermal energy to achieve a moderate temperature between 18 and 20°C in a building. They concluded that the project was not feasible. Gholami et al. (16) designed a zero-energy system for a dairy farm in Shahroud, Iran. They used the Homer and RET Screen software to analyze the economic and environmental impacts of the project. They found that the geothermal and solar energy in the area could be used, and the cost of setting up the system would be recovered in 5.5 years. The system could also sell 1062 MWh of electricity to the grid, over and above the dairy farm's electricity demand. The power grid is facing a number of challenges, including increasing demand, aging infrastructure, and climate change. To address these challenges, there is a need to develop new and innovative technologies. One promising technology is microgrids. Microgrids are small, localized power grids that can operate independently of the main grid. They are becoming increasingly popular as a way to improve energy efficiency and reliability. Esmaeili Shayan et al. (17) proposed a new method for optimizing the operation of a multi-microgrid system. The proposed method uses a Markov prediction chain and a dynamic decision algorithm to minimize the cost of electricity while ensuring that the power demand of all microgrids is met. Esmaeili Shayan et al. (18) proposed a new method for storing thermal energy using phase change materials (PCMs). The proposed method involves mixing the PCM with chloride salt graphite foam. For more research on smart Grid, can be refer to literature (19–21).

This paper is focused on Photovoltaic-Wind-Battery systems as renewable energy sources to supply the required energy of a residential house with all equipment. The rest of the paper is organized as follows. Section 2 is evaluated the climate of the region in terms of sunlight and wind. Section 3 is devoted to estimating the energy consumption of the residential house by the electricity bills. Finally, in section 4, the Photovoltaic-battery-wind hybrid system is designed.

FEASIBILITY STUDY FOR USING WIND TURBINE AND SOLAR PANEL (CASE STUDY IN GORGAN)

Natural gas and petroleum have the largest share of energy resources in Iran. As shown in Figure 1, the share of renewables and clean energy is less than 1%.

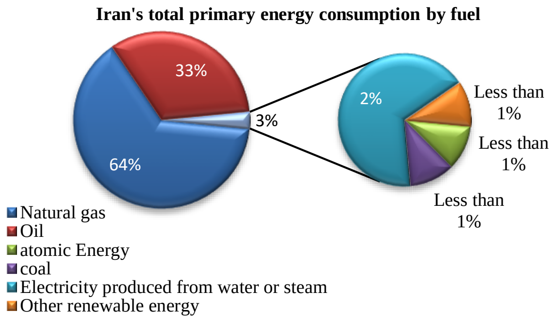

Figure 1. Consumption of various energy sources in Iran (22)

Analyze the meteorological data of Gorgan by using Climate Consultant 5.4

In this subsection, as part of the feasibility study, we analyzed the meteorological data of Gorgon using Climate Consultant 5.4 software. The Climate Consultant data is available in the Data Availability section. Figure 2 shows that the average hours of sunshine per year is more than 50%. This figure also shows the cloud cover and sunshine hours for each month. For example, in April, the maximum cloud cover is 100%, and the average cloud cover is 85%. The minimum cloud cover is 18%, which indicates that the weather is completely sunny and the sky is clear.

Figure 3 shows that the cloud cover in April between 11 AM and 2 PM is 60-80%, and in July between 7 PM and 12 PM, it is 30-60%. Figure 4 shows the average wind speed per month and year in miles per hour. For example, the annual average wind speed is 5 miles per hour (equal to 2.23 m/s). Figure 5 shows the distribution of the average wind speed over 24 hours. It can be seen that in 57% of the year, the wind in Gorgan blows at an average speed of 5-10 miles per hour.

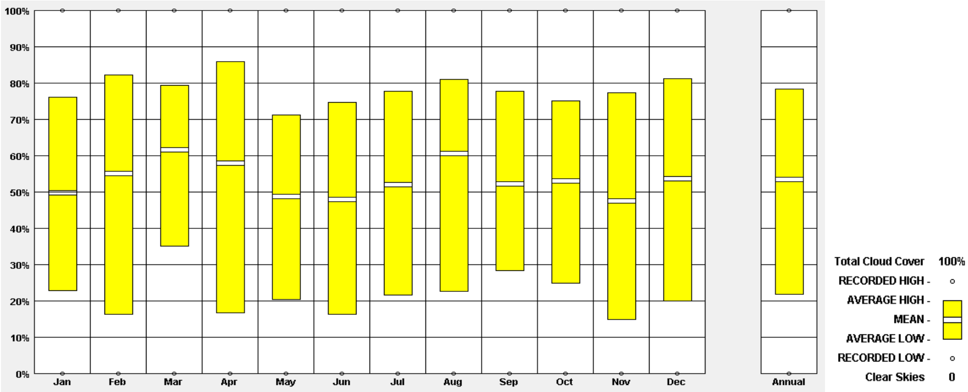

Figure 2. Sunny hours - cloud cover in the sky (Monthly)

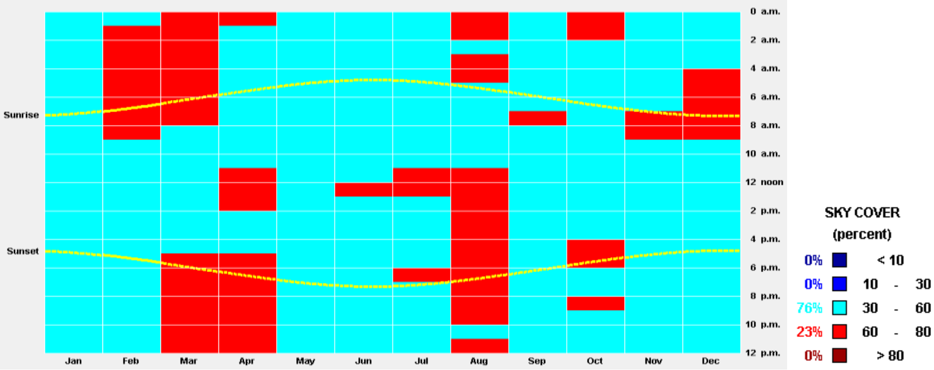

Figure 3. Sunny hours - cloud cover in the sky (Hourly)

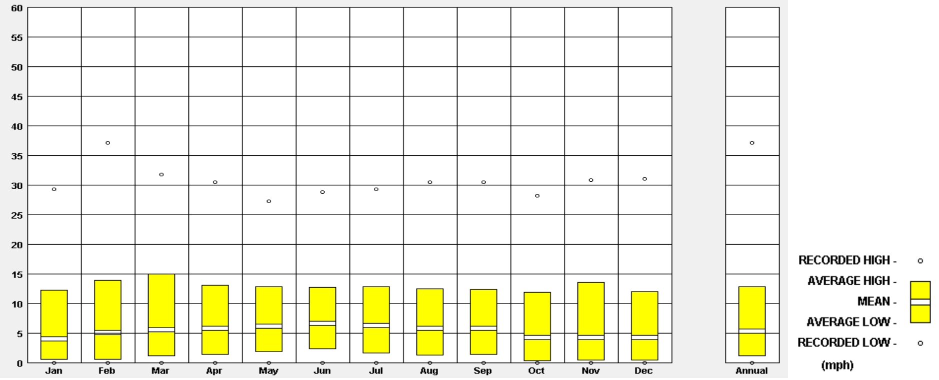

Figure 4. Wind speed average (Monthly)

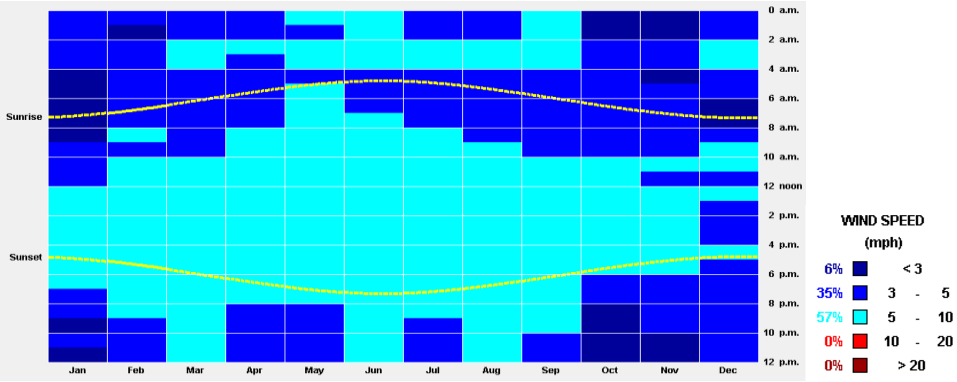

Figure 5. Wind speed average (Hourly)

ENERGY CONSUMPTION CALCULATION FOR THE SAMPLE APARTMENT

An apartment with an area of 175 m^2 in Gorgan is selected to be analyzed for its annual energy consumption (the building has central heating). The plan of the building is given in Figure 6.

Electricity bill

The customer's annual energy consumption is calculated based on the latest power consumption receipts for the past 12 months. The electricity consumption of the residential house is shown in Table 1. The customer can determine their annual energy consumption by adding up the power consumption for each month of the past year. The results are shown in Table 1.

Analysis in RETScreen

Based on the software analysis, we see that the consumption in the warm months of the year is 1.5 times higher than the consumption in the mild months, and 0.5 times lower in the cold months. The results are shown in Figure 7.

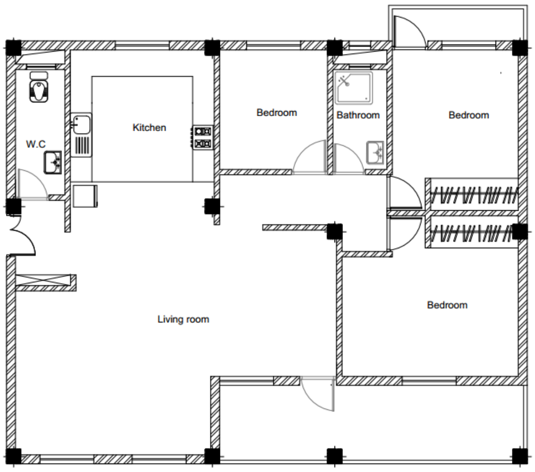

Figure 6. The plot of the corresponding building

Figure 7 shows that the highest annual energy consumption is in July and August, with 661 kWh consumed over 60 days. The lowest annual energy consumption is in November and December, with 295 kWh consumed over 60 days. The annual average energy consumption per month is 227 kWh, as shown in Table 2.

The average daily consumption throughout the year is 7 kWh, as shown in Table 2. To cover the total cost required, we will assume the maximum daily consumption to be 10 kWh, which is similar to the consumption in the warm season.

Table 1. Energy bills residential units

The start date of the billing period	The expiration date of the billing period	The number of days of the billing period	Total consumption (kWh)
09/01/2019	25/02/2019	47	313
25/02/2019	23/04/2019	58	423
23/04/2019	21/06/2019	59	420
21/06/2019	21/08/2019	61	661
21/08/2019	19/10/2019	59	603
19/10/2019	18/12/2019	60	295

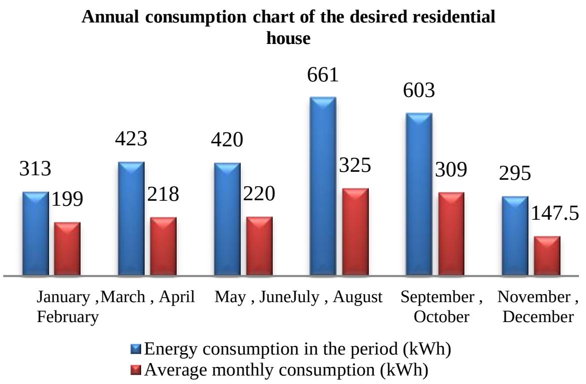

Figure 7. The amount of energy consumption of a residential house during one year and in different months

Table 2. Divide energy consumption by different months of the year based on Figure 7

Consumer evaluation	Months	Average monthly energy consumption (kWh)	Average energy consumption in 24 hours (kWh)
High consumption months	July, August, September, October	317	10
Medium consumption months	March, April, May, June	211	7
Low consumption months	November, December, January, February	152	5

In addition, we can estimate the energy consumption of the residential house and the values of energy-consuming of devices.

Estimation of energy consumption of electrical devices
The pattern of home devices consumption is as Table 3.

DESIGN OF THE HYBRID SYSTEM FOR RESIDENTIAL HOUSE

In this section, energy-causing components (photovoltaic and wind turbines) are selected. According to Figures 8 and 9, the maximum energy consumption for the studied residential house is 10 kWh per day. Since we used two energy sources, it is important to determine the share of each producer. Based on meteorological information, to

Table 3. Electrical devices used in the house with power consumption and duration of use

Number	Device type	Power consumption (W)	Consumption time	Energy consumption 1 month (kWh)	Coefficient of coincidence	Requested energy in 1 month (kWh)
1	Refrigerator	150	11 hours a day	49.5	0.4	19.8
2	Toaster	1100	15 minutes a day	8.25	0.4	3.3
3	Energy saving light bulb	4×40	30 minutes a day	2.4	0.6	1.44
4	Shaving machine	15	2 times a week, 1 hour	0.12	0.4	0.048
5	Laundry	2000	2 times a week, 1 hour	16	0.4	6.4
6	Dishwashing	2000	2 times a week, 1 hour	16	0.4	6.4
7	Vacuum Cleaner	1000	2 times a week, 15 minutes	2	0.4	0.8
8	Mobile charger	10	3 times a week, 90 minutes	0.18	0.4	0.072
9	Rice Cooker	650	1 time per month, 1 hour	0.65	0.4	0.26
10	Mixer	800	4 times a week, 5 minutes	1.066	0.6	0.64
11	Electric Kettle	1800	2 times a day, 10 minutes	18	0.4	0.72
12	Hood	260	2 times a day, 10 minutes	2.6	0.4	1.04
13	24000 air conditioner	1500	2 months of summer: 4 hours a day	180	1	180
14	Television	75	5 hours a day	11.25	0.4	4.5
15	Home player	81	1 time a week, 90 minutes	0.486	0.4	0.194
16	Digital Receiver	28	5 hours a day	4.2	0.4	1.68
17	Ironing	1100	20 minutes a day	11	0.4	4.4
18	Wireless modem	50	12 hours a day	18	0.4	7.2
19	Halogen	20×60	5 hours a day	180	0.6	108
20	Hairdryer	1200	10 minutes a day	6	0.4	2.4
21	Laptop	50	5 ours a day	7.5	0.4	3
22	Fluorescent lamps	3×60	2 hours a day	10.8	0.6	6.48

The amount of energy required during 1 month (non-hot season)	178.774 (kWh)
The amount of energy required during 1 day (non-hot season)	178.774 (kWh) ÷30=5.959 kWh
The amount of power requested during 1 hour (non-hot season)	5.959 ÷24=0.2482 kWh
The amount of energy required during 1 month (hot season)	354.774 (kWh)
The amount of energy required during 1 day (hot season)	354.774 (kWh) ÷30=11.959 kWh
The amount of power requested during 1 hour (hot season)	11.959 ÷24=0.498 kWh

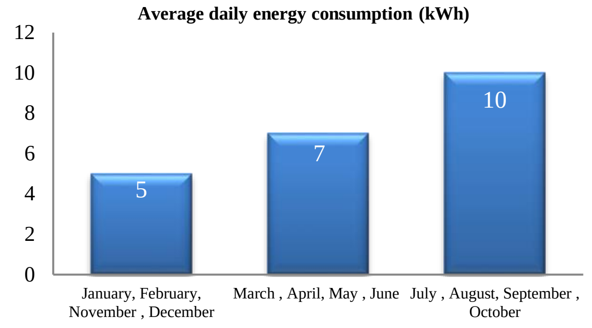

Figure 8. Average power consumption according to Table 2

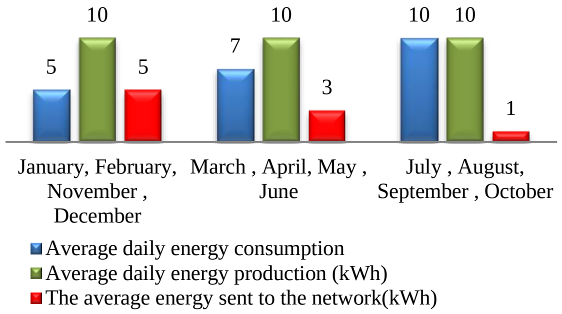

Figure 9. Average daily energy consumption and sent to the network (kWh)

determine the share of producers according to the existing constraints (cost, space required, weather constraints against radiation), the scenario of 70% wind turbine and 30% solar cell was considered. Figure 10 shows the plan of the proposed system.

Design based on Table 3

It is assumed that the daily energy requirement is as shown in Table 3. The hybrid system does not exchange energy with the grid. Thus, all energy needs must be met by the photovoltaic system, wind turbine, and battery.

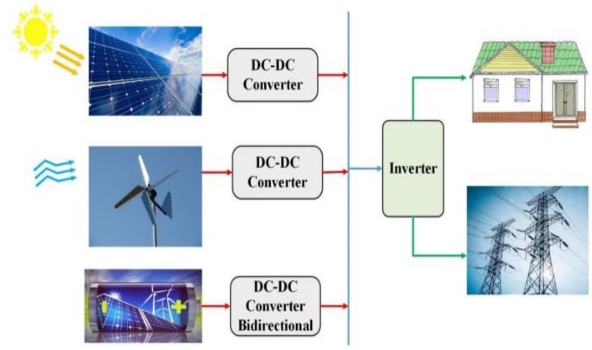

Figure 10. General structure and components of the proposed hybrid system

Regardless of the air conditioner (non-hot season)

Since the amount of consumed energy of the air conditioner is not considered due to economic savings, the amount of required energy for a residential house is 6 kWh. According to the default method (30% photovoltaic and 70% wind turbine), the required number of components are as follows:

<u>A: Number of batteries</u>

Battery capacity should provide the required energy in case of a lack of sunlight. The total ampere-hour of the battery is obtained by multiplying the required ampere-hour per day by the number of cloudy days. The ampere-hour is calculated as follows:

$$\frac{6\ \text{kWh}\times 1.42}{48} = 177.5\ \text{Ah} \qquad [1]$$

where 1.42, 48, and 6 kWh are the loss coefficient, the voltages of photovoltaic arrays, and the requested energy, respectively. Assuming that the number of cloudy and windless days is 3, and the battery provides the load in these days, we will have:

$$177.5\text{Ah}\ \times 3 = 532.5\ \text{Ah} \qquad [2]$$

Assuming that the battery discharge rate is 0.8, the storage ampere-hour is as follows:

$$532.5\ \text{Ah} \div 0.8 = 665.62\ \text{Ah} \qquad [3]$$

Battery output is dependent on battery and environment temperature. If the average temperature is 10 degrees in winter, then the temperature dependence coefficient is 1.19:

$$665.62\ \text{Ah}\ \ \times 1.19 = 792.09\ \text{Ah} \qquad [4]$$

If the battery has characteristics of 1000 Ah and 24 volts, we will have:

$$792.09\ \text{Ah} \div 1000\ \text{Ah} = 0.79 \qquad [5]$$

So, for this residential house, we need one battery of 1000 Ah or two batteries of 500 Ah.

<u>B: Number of photovoltaic modules</u>

The coefficient of 0.1 is the battery charge rate, which varies according to the characteristics of the used battery.

$$\begin{aligned} &\text{Icharging}=1\times 0.1\times 1000=100\text{Ah} \\ &\text{EB}=(100\text{Ah})\times 24\text{V}=2.4\text{kWh} \\ &\text{ET}=6\ \text{Kwh}+\text{EB}=6+2.4=8.4\ \text{kWh} \end{aligned} \qquad [6]$$

where I_{ch}, EB, ET are the required ampere-hour to charge the battery, required energies for charge the battery, and the total energy, respectively. Therefore, the total energy that must be produced by the photovoltaic system and wind turbine is 8.4 kWh. The effect of losses on the photovoltaic array and the efficiency of the converter are assumed to be 5% and 92%, respectively, so the amount of daily required energy is as follows:

$$8.4\ \text{kWh} \div 0.95 \div 0.92 = 9.61\ \text{kWh} \qquad [7]$$

Table 4. Battery list

Model	Current (A)	Voltage (V)	Output power (W)	Number	The price of each number (Dollar$)
Solarex	10	12	120	7	36.10
Solarex	18	12	216	4	65.92
Solarex	70	12	840	1	221.87
NEWMAX PNB 12400	40	12	480	2	183.3
NEWMAX	100	12	1200	1	401.475
Unikor VT 12250	40	12	480	2	556.5

Assuming 30% of the energy is extracted from solar energy and 70% from wind energy, we will have:

$$9.61\ \text{kWh} \times 0.3 = 2.883\ \text{kWh} \qquad (8)$$
$$9.61\ \text{kWh} \times 0.7 = 6.727\ \text{kWh}$$

On average, Gorgan has an annual solar radiation average (PSH) of 4 hours, so the most required energy from a photovoltaic array is as follows:

$$2.883\ \text{kWh} \div 4\ \text{PSH} = 720\ \text{W} \qquad (9)$$

Some factors such as fman output error (approximately ±5%), pollution and dust effect (fdirt) (about 5%), and temperature effect (about 0.8875) are affected on the output power of the photovoltaic module. As a result, the output power of a 265 watt module reaches 212.3 watts after applying the effect of temperature, dust, etc. The number of 265 watt modules is calculated as follows:

$$N = 720 \div 212.3 = 3.39 \approx 3 \qquad [10]$$

where N is the number of required modules. The required area to install these modules is multiplied by the number of modules in the area of each module.

C: Selection of charging controller:

The number of sunny days between two cloudy days (n_{rc}) is important to select the charge controller (the number of days in which the batteries can be charged). In this design, assuming that n_{rc} is equal to 4, we have:

$$(792.09\ \text{Ah} \div 4) + 792.09 = 990.112\ \text{Ah} \qquad [11]$$

With divided by PSH, the current of the charge controller is obtained.

$$990.112 \div 4 = 247.528 \approx 248 \qquad [12]$$

D: Power and number of wind turbines:

The amount of energy that must be supplied by a wind turbine in a day is equal to 6.72 kWh. By considering 4 hours of wind blow per day, the amount of energy that must be supplied per hour is equal to 1.681 kWh, which is equivalent to 4 turbines with a characteristic of 400 watts.

E: Number and type of converter:

The minimum number of modules is equal to 3 and the nominal power of each of them is 265 watts, so the maximum power of the photovoltaic array is calculated as follows:

$$3 \times 265 = 0.795\ \text{kW} \qquad [13]$$

The minimum capacity for the selected converter for photovoltaic power will be equal to 0.795 kW. Now, if we consider the power of wind energy, the minimum capacity of the converter for the obtained power from the wind turbine is:

$$4 \times 400 = 1.6\ \text{kW} \qquad [14]$$

Table 9 summarizes the list of required equipment.

Table 5. Solar panel list

Model	Dimensions (mm)	Weight (Kg)	Output power (W)	Number	The price of each number (Dollar$)
Sharp NDAH 320	1956×992×40	22.5	320	3	347.81
Sharp NDAH 315	1956×992×40	22.5	315	3	316.25
(Shinsung solar) mono SS-DP310	1944×992×40	22	310	3	271.25
Yingli solar	1965×922×50	25	300	3	375
(Shinsung solar) monoSS-BM270NM	1644×992×35	18	270	3	305.31
Ja Solar JAP6 60	1625×990×40	20	250	3	250
Yingli solar	1625×990×40	21	250	3	250
Yingli solar	1335×990×35	20	200	4	218.75

Table 6. Charge controller list

Model	Current (A)	Voltage (V)	Number	The price of each number (Dollar$)
Lumiax (MPPT)	60	24	4	175
eTracer (Epever) (MPPT)	60	24	4	306
Sunchonglic (MPPT)	60	24	4	112.36
Carspa (MPPT)	50	24	5	81.6

Table 7. Wind Turbine list

Model	Minimum and maximum speed (m.s)	Weight (Kg)	Output power (W)	Number	The price of each number (Dollar$)
Altinel Energy	2-12.5	29	1500	1	2093.75
Homer	3-9	32	1000	2	2259.37
Newsky MAX1200	2-12	36	1200	2	2365.12
Newsky MAX800	1.5-12	30	800	2	1906.34
Newsky MAX600	1.5-12	28	600	3	1565.16
iSTA-BREEZE i-500	3-12.5	4.5	500	3	827.5
Newsky MAX400	1.5-11	23	400	4	1217.34

Table 8. Inverter list

Model	Power (W)	Voltage (V)	Number	The price of each number (Dollar$)
Carspa P1500 12V	1500	12	3	275
Darda	3000	48	1	647.11
Carspa (CAR800)	800	24	4	36
Carspa (YK-3000L)	3000	24	1	249

Table 9. List of equipment regardless of the air conditioner

Equipment	Type	Number	The price (Dollars $)
Batteries	1000 Ah (or 500 Ah)	1 (2)	401.475
Photovoltaic module	265 watt	3	915.93
Charge controller	248 amps	1	700
Wind turbines	400 watt	4	4869.36
Converter capacity for photovoltaic	0.795 kW	1	36
Converter capacity for wind turbines	1.6 kW	1	275
			Total Cost: 7197.765

Table 10. List of equipment considering air conditioner

Equipment	Type	Number	The price (Dollars $)
batteries	1000 Ah (or 500 Ah)	2 (3)	401.475
Photovoltaic module	265 watt	6	1831.86
Charge controller	496 amps	1	1400
wind turbines	400 watt	7	8521.38
converter capacity for photovoltaic	1.590 kW	1	275
converter capacity for wind turbines	2.8 kW	1	647
			Total Cost: 13076.715

Considering the air conditioner (hot season)

In this case, we must provide 11.959 kWh or 12 kWh energy; according to the method (30% photovoltaic and 70% wind turbine), the number of the required equipment is listed in Table 10.

Design based on electricity bill data (Table 2)

We consider the method (30% photovoltaic and 70% wind turbine) for the corresponding calculations.

Determining the power consumption

According to the estimate of the house bill, we consider the amount of required energy for one day, 10 KWh. According to the default method, we must supply 3 kWh by the solar panel and 7 kWh by the wind turbine. The list of equipment of hybrid system based on electricity bill data is given in Table 11.

Table 11. List of equipment of hybrid system based on electricity bill data

Equipment	Type	Number	The price (Dollars $)
Batteries	1000 Ah (or 500 Ah)	2 (3)	401.475
Photovoltaic module	265 watt	6	1831.86
Charge controller	407 amps	1	1225
Wind turbines	400 watt	5	6086.7
Converter capacity for photovoltaic	0.848 kW	1	36
Converter capacity for wind turbines	2 kW	1	249
			Total Cost: 9830.035

CONCLUSIN

Zero-energy buildings are a way to save energy and fossil fuels. To design them, the climatic conditions of the region should be considered. A feasibility study of using zero-energy buildings in the Gorgan region was conducted. The climate was analyzed using Climate Consultant software, and the energy consumption of a residential unit was estimated using Renewable Energy and Energy Efficiency Technology Screen software. The number of needed equipment was also estimated. It should be noted that with a grid connection, the costs can be substantially reduced. The paper aims to design a hybrid system without grid exchange. The designed system is most efficient under certain conditions (3 days without sunlight and wind). Given the current inflation and low energy prices in Iran, the payback period is long. Therefore, investing in zero energy construction in this region can only be justified when the interest rate is low or the energy price is closer to its real price.

DATA AVALIBALITY

The data that support the findings of this study are openly available in Iran Meteorological site (23, 24). Meteorological data are also summarized inTables 12 and 13.

a. Average wind speed in knots (KNOT) of the last 60 years in Gorgan (23)

b. Solar radiation data

Refer to reference (24).

c. Climate Consultant software data

Table 12. Average wind speed in knots (KNOT) of the last 60 years in Gorgan

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1953	2.1	2.1	2.4	2.5	***	***	***	***	***	***	***	***	***
1954	***	***	***	***	***	***	***	***	***	***	***	***	***
1955	***	***	***	2.4	2.1	2.1	2.1	2.0	2.0	1.9	1.1	1.6	***
1956	2.1	2	2.8	2.3	2.1	2.3	2.2	2.4	2.3	2.4	2.7	2.2	2.3
1957	2.2	2.2	2.7	2.5	2.6	2.5	3.7	6.4	8.2	5.3	5.3	3.3	3.9
1958	2.8	3.7	5.5	5.2	4.3	3.8	3.1	2.7	3.2	2.8	1.3	1.6	3.3
1959	1.7	2.1	2.5	2.5	2.9	3.9	3.8	3.5	2.5	3.1	3.5	3	2.9
1960	2.7	2.5	2.8	1.3	2.8	2.2	1.3	1.8	1.3	1.7	1.9	1.7	2
1961	2	2.3	2.3	2.1	3.6	3.5	3.8	4.5	4	2.7	0.7	2.1	2.8
1962	0.8	1.1	2.6	2.3	2.8	2.6	3.2	3.8	2.4	1.4	2	1.6	2.2
1963	1.3	1.4	1.7	2.5	4.6	4.8	3.5	4.4	3	1.3	1.4	1.1	2.6
1964	2.3	1.8	2.9	3	4.2	3.3	4	2.5	3.3	2.5	1.8	0.7	2.7

1965	2	2.2	3.5	4.5	5.8	6.4	5.5	5.6	5	3	1.5	3.3	4
1966	1.8	2.6	2.9	3.6	3.9	4.9	4.2	4.6	2.6	1.5	1.2	1.8	3
1967	1.3	2	3.2	2.2	3.7	4	4.2	3.6	2.7	2	1.2	1.2	2.6
1968	2	2.4	2.8	2	1.7	3.9	2.6	3.1	2.3	2.3	0.8	1.4	2.3
1969	1.5	1.6	2.2	3.6	3.2	3.2	3.6	2.4	1.7	1.3	1.6	1	2.2
1970	0.8	1.3	1.8	2.3	2.1	3	3.4	2.1	2.3	1.6	1.4	1.4	2
1971	1.5	1.9	1.6	2.3	2.6	3.5	3.5	2.9	1.8	1.6	1.2	1.3	2.1
1972	1.3	1	1.5	1.7	2.4	2.8	2.7	3.4	1.8	1.2	1.2	0.8	1.8
1973	0.8	1.6	1.8	1.8	2	2.7	3.2	2.5	1.9	1.2	1.4	0.8	1.8
1974	0.9	1.3	1.6	3	3.2	3.8	3.6	3.3	2.4	0.7	1.5	0.8	2.2
1975	0.7	1.4	2.1	1.4	3.1	1	1.6	1.4	0.9	0.5	0.6	0.5	1.3
1976	0.3	0.8	1.7	1.6	2.1	0.8	0.6	1.2	1.2	0.6	0.4	0.8	1
1977	0.5	0.7	1.1	1.2	1.1	1.3	1.2	1.2	0.3	0.6	0.6	0.9	0.9
1978	0.8	0.9	0.8	1.2	1.3	1.6	1	1.1	0.4	0.7	0.3	0.4	0.9
1979	0.1	0.2	0.3	0.8	0.9	1.1	0.8	0.6	0.5	0.1	0.2	0.3	0.5
1980	0.2	0.2	0.7	0.8	1.2	0.6	0.5	0.9	0.7	0.5	0.7	0.6	0.6
1981	0.3	0.8	0.8	0.8	1.4	1.2	1.1	2.1	1.2	0.7	1.1	1.3	1.1
1982	1.1	1	1.3	1.7	1.6	2.3	2.6	1.8	1.5	1.3	1.1	0.8	1.5
1983	1.4	1.3	1.5	1.6	1.1	1.3	1.2	1.5	1.7	1.2	1.4	1.2	1.4
1984	1.8	1.2	2.6	3.3	1.6	3	2.5	1.4	0.7	0.7	0.5	0.7	1.7
1985	1.8	3.3	3.1	4	4.2	5.8	5.2	4	1.1	1.2	0.5	1.1	2.9
1986	1.2	1.5	1.3	1.3	2.2	2.5	1.9	1.5	1.1	1	0.8	0.9	1.4
1987	0.9	1.8	2.3	2.3	1.9	2.4	2.4	1.6	1.1	0.8	1	1.2	1.6
1988	1.3	1.2	2.5	1.6	1.7	2.6	2.1	1.9	1.5	1.1	1.1	1.1	1.6
1989	0.7	1	1.5	1.1	1.1	1.3	1.1	0.8	0.5	0.5	0.4	0.5	0.9
1990	0.6	0.8	1.3	1.6	1.5	1.4	1.2	0.9	0.9	0.7	0.5	0.4	1
1991	0.8	1.1	1.2	1.2	1.6	2.1	1.6	1.2	1	0.7	0.7	0.9	1.2
1992	1.2	1.3	1.3	1.6	1.1	1.6	1.2	1.2	0.9	0.8	0.8	0.6	1.1
1993	1.2	1	1.6	1.5	1.7	1.8	1.7	1	0.9	0.8	1	0.6	1.2
1994	1.1	1.1	1.2	1.1	1.5	1.5	1.9	0.8	1.7	0.8	0.8	1.5	1.2
1995	1.6	1.3	2.4	3	3.5	2.7	1.1	0.9	1.1	1.2	1.3	0.6	1.7
1996	0.7	1.3	1.4	2	1.8	2.3	1.5	1.7	1.2	1.4	1	1.3	1.4
1997	1.4	1.8	2.3	2.1	2.2	1.6	1.7	1.4	1.7	1.6	1	1.3	1.7
1998	1.3	1.2	1.6	1.3	2	2.5	1.5	1.6	0.9	0.8	0.5	0.7	1.3
1999	1.1	1.2	1.3	2	2.1	2.3	1.7	1.2	1.2	1.2	1.3	0.9	1.5
2000	1.6	2.2	1.9	1.8	2.8	4.2	3.5	3.5	3.3	1.7	2	3.5	2.7
2001	3.8	4.9	5.1	5.1	5.7	6.2	5.2	5.4	4.1	3.5	3.8	3.4	4.7
2002	3.8	4.3	4.2	4.6	4	5	4.8	3.9	3.1	3.4	3.1	3.3	3.9
2003	3.2	4.1	4.4	5.3	4.9	5.4	4.5	4.4	5	4.1	3.8	3.5	4.4
2004	3.9	4.7	4.1	4.9	5.7	5	5.3	4.5	5.4	3.7	3.7	4.4	4.6
2005	4.1	3.8	4.3	4	4.7	5.2	5.1	5	3.8	3.9	3.7	4	4.3
2006	3.1	4.5	4.3	4.3	4	5.6	5.7	4.3	5.1	4.1	3.7	2.9	4.3
2007	4.6	5.4	6.7	6.5	5.1	6.5	6.8	6	5.6	3.3	4.1	3.8	5.4
2008	3.2	4.5	5.8	6	7.4	7.5	6.9	6.2	6	3.9	2.5	4.1	5.3
2009	4	5.8	6.3	6.6	6.1	7	7.3	7.3	5.8	4.3	4.1	3.8	5.7
2010	4	6.4	5.9	6.3	6.2	7.4	7.1	6.4	5.2	4.8	2.5	3.3	5.5

Table 12. Climate Consultant software data

Weather Data Summary:
Location: Gorgan, Golestan, Iran
Latitude/Longitude: 36.81º North, 54.46 East,
Time Zone from Greenwich 4.
Data Source: MN7 407380 WMO Station Number,
Elevation 508 ft

Monthly Means	**DEC**	**NOV**	**OCT**	**SEP**	**AUG**	**JULY**	**JUNE**	**MAY**	**APR**	**MAR**	**FEB**	**JAN**	
Global Horiz Radiation (Avg Hourly)	81	97	110	128	136	138	134	119	127	109	87	74	Btu/sq.ft
Direct Normal Radiation (Avg Hourly)	114	107	100	100	108	97	95	84	121	119	120	108	Btu/sq.ft
Diffuse Radiation (Max Hourly)	35	44	52	63	61	69	67	63	54	44	35	33	Btu/sq.ft
Global Horiz Radiation (Max Hourly)	188	225	266	291	317	301	301	308	291	249	189	166	Btu/sq.ft
Direct Normal Radiation (Max Hourly)	305	289	281	308	288	239	275	258	296	291	295	285	Btu/sq.ft
Diffuse Radiation (Max Hourly)	91	109	127	156	142	158	156	150	139	118	93	81	Btu/sq.ft
Global Horiz Radiation (Avg Daily Total)	795	1031	1315	1664	1902	1998	1921	1598	1561	1210	880	704	Btu/sq.ft
Direct Normal Radiation (Avg Daily Total)	1117	1136	1190	1300	1514	1404	1357	1119	1467	1322	1207	1030	Btu/sq.ft
Diffuse Radiation (Avg Daily Total)	345	475	620	822	855	1000	964	852	672	493	360	316	Btu/sq.ft
Global Horiz Illumination (Avg Hourly)	2545	3053	3509	4101	4364	4475	4410	3945	4173	3533	2807	2347	Footcandles
Direct Normal Illumination (Avg Hourly)	2957	2807	2673	2617	2867	2460	2460	2127	3303	3180	3099	2759	Footcandles
Dry Bulb Temperature (Avg Monthly)	44	47	53	60	69	77	81	83	77	67	55	47	Degrees F
Dew Point Temperature (Avg Monthly)	37	40	45	52	58	63	68	70	66	57	48	42	Degrees F
Relative Humidity (Avg Monthly)	77	76	75	76	69	64	65	66	71	71	77	81	Percent
Wind Direction (Monthly Mode)	70	210	210	210	200	240	210	260	240	200	60	70	Degrees
Wind Speed (Avg Monthly)	4	5	5	5	6	6	6	5	5	4	4	4	mph
Ground Temperature (Avg Monthly of 1 Depths)	58	55	53	55	58	64	69	73	74	73	69	64	Degrees F

REFERENCES

1. Erdem ZB. The contribution of renewable resources in meeting Turkey's energy-related challenges. Renewable and Sustainable Energy Reviews. 2010;14(9). Doi: 10.1016/j.rser.2010.07.003.
2. Shayan ME, Najafi G, Ghobadian B, Gorjian S, Mamat R, Ghazali MF. Multi-microgrid optimization and energy management under boost voltage converter with Markov prediction chain and dynamic decision algorithm. Renewable Energy. 2022;201:179–89. Doi: 10.1016/j.renene.2022.11.006.
3. Rouhani SH, Mojallali H, Baghramian A. Accurate demand response participation in regulating power system frequency by

Modified Active Disturbance Rejection Control. Mathematical Methods in the Applied Sciences. 2022;45(12):7685–99. Doi: 10.1002/mma.8271.

4. Shayan ME, Najafi G, Ghobadian B, Gorjian S, Mazlan M, Samami M, Shabanzadeh A. Flexible Photovoltaic System on Non-Conventional Surfaces: A Techno-Economic Analysis. Sustainability (Switzerland). 2022;14(6). Doi: 10.3390/su14063566.
5. Shayan ME, Najafi G, Ghobadian B, Gorjian S, Mazlan M. Sustainable Design of a Near-Zero-Emissions Building Assisted by a Smart Hybrid Renewable Microgrid. International Journal of Renewable Energy Development. 2022;11(2):471–80. Doi: 10.14710/ijred.2022.43838.
6. Esmaeili Shayan M, Hojati J. Floating Solar Power Plants: A Way to Improve Environmental and Operational Flexibility. Iranian Journal of Energy and Environment. 2021;12(4):337–48. Doi: 10.5829/ijee.2021.12.04.07.
7. Esmaeili Shayan M, Hayati MR. Thermal Performance and Heat Dynamics Energy and Exergy of Integrated Asphalt Collector Storage: Sources of Thermal Energy, and Thermoelectric Energy. Iranian Journal of Energy and Environment. 2023;14(1):17–25. Doi: 10.5829/ijee.2023.14.01.03.
8. Esmaeili Shayan M, Hayati MR, Najafi G, Esmaeili Shayan S. The Strategy of Energy Democracy and Sustainable Development: Policymakers and Instruments. Iranian Journal of Energy and Environment. 2022;13(2):185–201. Doi: 10.5829/ijee.2022.13.02.10.
9. Hayati MR, Ranjbar S, Abdar MR, Molaei Nasab M, Homayounmajd S, Esmaeili Shayan M. A Comparative Analysis of Solar Energy Strategies in Middle East with Rich Fossil Resources. Iranian Journal of Energy and Environment. 2023;14(3):271–88. Doi: 10.5829/ijee.2023.14.03.09.
10. Carrilho da Graça G, Augusto A, Lerer MM. Solar powered net zero energy houses for southern Europe: Feasibility study. Solar Energy. 2012;86(1):634–46. Doi: 10.1016/j.solener.2011.11.008.
11. Eshraghi J, Narjabadifam N, Mirkhani N, Sadoughi Khosroshahi S, Ashjaee M. A comprehensive feasibility study of applying solar energy to design a zero energy building for a typical home in Tehran. Energy and Buildings. 2014;72:329–39. Doi: 10.1016/j.enbuild.2014.01.001.
12. Alfieri S, Piccini S, Kermani M. Feasibility study of Nearly Zero Energy Building in a real Microgrid case study. Proceedings - 2019 IEEE International Conference on Environment and Electrical Engineering and 2019 IEEE Industrial and Commercial Power Systems Europe, EEEIC/I and CPS Europe 2019. 2019; Doi: 10.1109/eeeic.2019.8783429.
13. Liu Z, Wu D, Liu Y, Jin G, Wang Q, Han Z, Yu H. Performance and feasibility study of low energy building for pleasant indoor comfort: A case study on Qinghai-Tibetan Plateau. Sustainable Cities and Society. 2019;50. Doi: 10.1016/j.scs.2019.101691.
14. Nematollahi O, Kim KC. A feasibility study of solar energy in South Korea. Renewable and Sustainable Energy Reviews. 2017;77:566–79. Doi: 10.1016/j.rser.2017.03.132.
15. Lutchman S, Van Wyk L V. Feasibility study for a geothermal heating system: A case study. In: The Green Building Handbook South Africa. The Essential Guide; 2018. p. 48–53.
16. Gholami A, Tajik A, Eslami S, Zandi M. Feasibility Study of Renewable Energy Generation Opportunities for a Dairy Farm. Journal of Renewable Energy and Environment. 2019;6(2):8–14. Doi: 10.30501/jree.2019.95943.
17. Shayan ME, Najafi G, Ghobadian B, Gorjian S, Mazlan M. A novel approach of synchronization of the sustainable grid with an intelligent local hybrid renewable energy control. International Journal of Energy and Environmental Engineering. 2023;14(1):35–46. Doi: 10.1007/s40095-022-00503-7.
18. Esmaeili Shayan M, Najafi G, Lorenzini G. Phase change material mixed with chloride salt graphite foam infiltration for latent heat storage applications at higher temperatures and pressures. International Journal of Energy and Environmental Engineering. 2022;13(2):739–49. Doi: 10.1007/s40095-021-00462-5.
19. Esmaeili Shayan M, Esmaeili Shayan S, Nazari A. Possibility of supplying energy to border villages by solar energy sources. Energy Equipment and Systems. 2021;9(3):279–89. Doi: 10.22059/ees.2021.246079.
20. Esameili shayan mostafa, Najafi gholamhassan, Esmaeili Shayan S. Smart Micro-Grid Electrical Energy Management: Techno-Economic Assessment. Energy Engineering and Management. 2023;13(1):90–101. Doi: 10.22052/jeem.2023.113605.
21. Esmaeili Shayan M, Najafi G, Ghobadian B, Gorjian S. Modeling the Performance of Amorphous Silicon in Different Typologies of Curved Building-integrated Photovoltaic Conditions. Iranian Journal of Energy and Environment. 2022;13(1):87–97. Doi: 10.5829/ijee.2022.13.01.10.
22. Yousefi H, Hamlehdar M, Tabasi S, Noorollahi Y. Economic and thermodynamic evaluations of using geothermal heat pumps in different climate zone (Case Study: Iran). In: Proceedings, 42nd Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California. 2017.
23. http://www.chbmet.ir/stat/archive/iran/gol/GORGAN/36.asp.
24. http://www.chbmet.ir/stat/archive/iran/gol/GORGAN/37.asp.

Persian Abstract

چکیده

در این مقاله، یک مطالعه امکان سنجی بر روی ساختمان فتوولتائیک-توربین بادی کم سرعت- باتری با انرژی صفر برای یک خانه مسکونی ۱۷۵ متر مربعی در گرگان انجام شده است. ابتدا داده‌های اقلیمی شهر گرگان مربوط به میزان تابش خورشیدی و سرعت باد در ۵۰ سال گذشته استخراج شده و سپس با استفاده از نرم‌افزار Climate Consultant به صورت سالانه، ماهانه و ساعتی مورد تجزیه و تحلیل قرار گرفته تا نحوه استفاده از منابع تجدیدپذیر بررسی شود. برای تعیین تعداد دستگاه‌های مورد نیاز باید انرژی مورد نیاز سالانه واحد مسکونی برآورد شود. بدین منظور توان و انرژی مصرفی واحد مسکونی براساس داده‌های مصرف انرژی آن واحد مسکونی در سال گذشته برآورد و با استفاده از نرم‌افزار RETScreen مورد تجزیه و تحلیل قرار گرفته است. سیستم انرژی صفر طراحی شده دارای تبادل انرژی با شبکه بوده و انرژی اضافی تولیدی را به شبکه ارسال می‌کند. نتایج تجزیه و تحلیل داده‌های اقلیمی نشان می‌دهد که امکان بهره‌وری از انرژی باد و خورشید در این منطقه وجود دارد. اگرچه قیمت انرژی در منطقه پایین است، اما به دلیل صرفه اقتصادی، کمبود منابع انرژی تجدیدناپذیر و نیاز به جایگزینی این منابع، استفاده از توربین‌های بادی و پنل‌های خورشیدی برای تامین انرژی الکتریکی مورد نیاز در این منطقه ضروری است.