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Article

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International Journal of Energy Economics and Policy

IJEEP

INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY

EJ EconJournals

ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

EJ EconJournals

International Journal of Energy Economics and Policy, 2017, 7(2), 255-261.

Economic Feasibility of Power Supply Using Hybrid System for a Hotel in Cold Climate

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ABSTRACT

Today, renewable resources are used growingly due to environmental impact of fossil fuels. Solar and wind energies are of the largest renewable resources which are increasingly used to generate the power. In this paper, firstly, power and speed of wind and potential of solar radiation in Iran, especially in Tabriz, were examined. Then, using this analysis, an appropriate hybrid system was provided to meet the energy consumption of a hotel in Tabriz Town which is not connected to the electricity network. For this, firstly, thermal load of heating and cooling required for a building in Tabriz Town was accurately calculated by energy plus software and then, four hybrid system scenarios were determined and examined by Homer software. The results of data analysis of economic feasibility showed that wind-diesel hybrid system with a storage battery is the most efficient system for power supply of a hotel.

Keywords: Energy Plus, Hybrid Systems, Homer, Feasibility
JEL Classifications: Q4, Q54

1. INTRODUCTION

In recent years, producing greenhouse gases and also, other air pollutants has caused global warming and also climate change. This climate change has concerned the world. Also, development of technology and progress of industries have constantly increased the energy demand, especially the electricity. In addition, the shortage of fossil fuels (oil and gas) has forced the researchers to use clean and renewable energies such as solar, wind, biomass, geothermal energy, etc., since 1970, with the onset of oil crisis and increase in fossil fuel price, the cost of renewable technology has gradually decreased and this has increased the investment and research in this new area, especially wind and solar. Figure 1 shows the total installation capacity of wind and solar energies from the beginning to 2014 and also shows that in recent years, particularly using wind energy has significantly increased so that the capacity of wind energy has significantly increased from 6100 MW in 1997 to 350 GW in 2014. Also, the installation capacity and use of solar energy has increased from 7 GW in 2006 to 180 GW in 2014. In remote areas and where energy resources and transporting power lines are not affordable, renewable energies are directly used (Castronuovo et al., 2007; Slootweg and Kling, 2003; Milliken, 2007). Given the seasonal variation and the frequency of each system, the use of wind-solar hybrid system is one of the advantage of renewable energies compared to the separate use of them (Yang et al., 2008) so that the strength of one covers the weakness of another one and hybrid system can be used as a reliable power generation system. In the past, solar-wind hybrid system was used in remote locations such as radio and communication stations and impassable areas, but, today, it can be used with other systems together and a safe system can be created (Celik, 2003; Zhou et al., 2008; Yang et al., 2009; Diafa et al., 2008).

In recent years, many studies have been conducted on the feasibility of using hybrid power of wind and solar energies. Zhou et al. (2010) have studied on the optimization and direct control of hybrid energy systems using wind-solar energies and battery storage. Some feasibility studies as well as the studies on heating and cooling have been done in different places with different climate in the world, for example in 2012, Essalaimeh has performed feasibility study on heating and cooling in Oman and Jordan using hybrid power system and concluded that it is more affordable in terms of science and technology

(Essalaimeh et al., 2013). Wei tan and Shanngan have analyzed the hybrid system and simulated it with Homer software in a town of Malaysia and showed that using wind-solar-battery- diesel hybrid system is economically and environmentally more affordable and it is a good alternative to a diesel system (Ngan and Tan, 2012). Bekele and Palm have assessed wind-solar hybrid system in a community of thousand people located in a village of power network in Ethiopia and reached a desired result (Arribas et al., 2010). Demiroren and Yilmaz (2010) have examined the electrification for a resort island in Turkey using renewable energies (Bekele and Palm, 2010). In 2010, studies showed that electrification for remote areas in Iraq and Saudi using renewable systems is economically useful (Demiroren and Yilmaz, 2010).

2. WIND AND SOLAR ENERGIES IN IRAN

Islamic Republic of Iran is located in the western part of the plateau in the Southwest of Asia. It area is 1648195 km and it is located between 44-99 E and 25-99.39 N and more than half of its area is consisted of mountainous areas. It has a variety of climate. Iran has gas and oil resources and due to environmental impact and also emissions, power generation using wind energy, 2nd renewable source used for power energy, has been started since 1994. According to Iran's fifth development plan (2010-2015), the capacity of power generation using wind energy should be reached 1650 MW and also, it should be installed and operational (Rahimi et al., 2014).

According to the wind atlas of Iran provided by New Energies Organization of Iran and data gathered from 60 stations across Iran, total nominal capacity of these places is about 60000 KW that utilization of about 18000 MW of it is economically affordable, as shown in Figure 2 (Iranian Renewable Energy Organization [SUNA]).

Iran is located in the areas of radiation and according to experts, in two-third of Iran, there is this technology with 300 sunny days and average radiation of 4.5-5.5 KWh/m^2, so it is a high potential country in terms of solar energy. According to the studies by DLR (Germany), in an area of more than 2000 Km, there is a possibility of installing solar thermal power plant with 60000 MW (Iranian Renewable Energy Organization [SUNA]).

3. TABRIZ TOWN

Tabriz is one of the major cities in Iran with an area of 237.45 km and also it the largest city of the northwest part of Iran. It is known as administrative, communication, commercial, political, cultural and industrial pole of this region. It is located in 46.25 E and 38.2 N and at the altitude of 1350 m. it has a semi-arid climate with cold winters and temperate summers.

4. ESTIMATION OF ENERGY CONSUMPTION

In this study, firstly, a 4-storey building in which each floor has an area of 600 m, was modeled using energy plus software. Its land use was considered hotel and accordingly, type of materials was selected and the effect of electrical equipment on thermal load of building was considered. The number of people in building based

Figure 1: Annual utilization capacity of wind and solar energies in the world from 1996 to 2011 (Iranian Renewable Energy Organization [SUNA] Tehran, 2013)

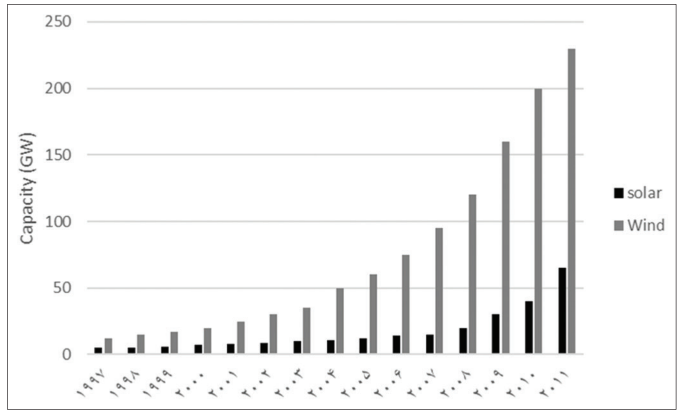


Figure 2: Wind atlas of Iran at the of height of 80 m above the ground level (Iranian Renewable Energy Organization [SUNA])

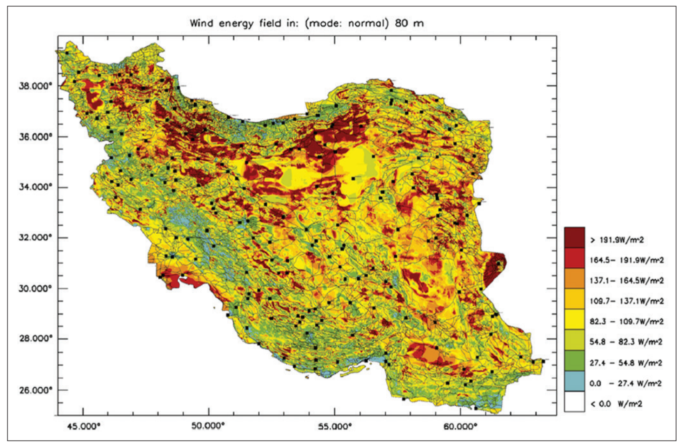
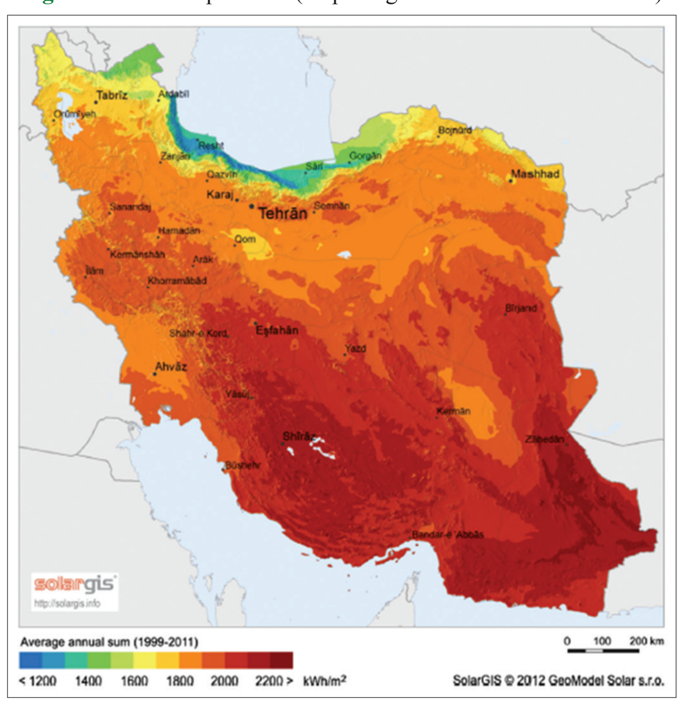
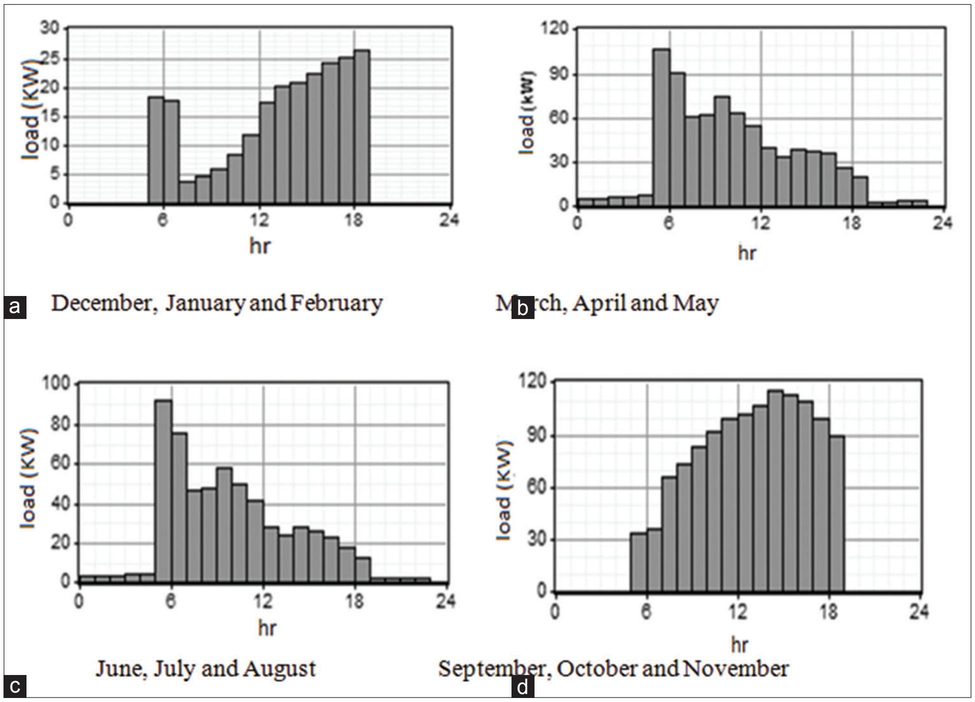


Figure 3: Solar map of Iran (maps of global horizontal irradiation)



Source: (http://solargis.info./doc/71)

Figure 4: Seasonal energy load for hotel, (a) December, January and February, (b) March, April and May, (c) June, July and August, (d) September, October and November



on different times of day was simulated. Other schedules (timing lights) and type of air conditioning system were also considered and simulated. Heating and cooling schedules were considered 6 months of the year separately. Simulation was performed based on noted items and energy consumption of building was estimated. The peak energy consumption was estimated equal to 201 KW. Figure 3 shows that each floor was considered as one zone. Simulation was done using energy plus software. This software simulates the energy of building in instable mode and a building can be simulated in real mode and the energy consumption of building can be estimated using the climatic data of the region, Tabriz Town in this study (Figure 4).

Figure 5 shows the monthly and daily data of solar radiation in Tabriz Town according to SUNA statistical center. Average daily solar radiation is between 23.8 KWh/m and 24.5 KWh/m and average annual solar radiation is 24.3 KWh/m.

4.1. Wind Speed

According to the data of meteorological stations. The average wind speed in recent years was achieved based on following Figure 6. This data is based on wind speed at a height of 10 meters above the ground and the timeframe is 3 h. According to the observation, average wind speed is in a range of 3-4.8 m/s.

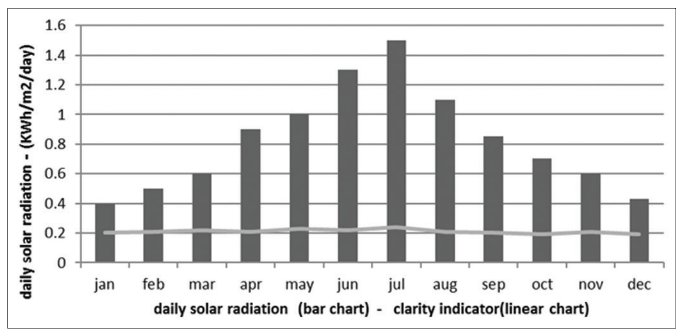
4.2. Analysis of Wind-PV-battery-diesel Hybrid System

In this study, hybrid energy system was considered based on renewable energies and energy storage. Figure 7 shows the diagram of energy flow schematically.

4.3. Modeling in Homer Software

Detailed information of hybrid system is listed in Tables 1 and 2. These are model, size, lifetime, purchase cost, replacement cost and repair and maintenance cost.

Figure 5: Daily global horizontal daily solar radiation and clarity indicators for Tabriz Town, Iran



Source: Iranian Renewable Energy Organization (SUNA)

It should be noted that in order to calculate economic parameter and also, to use software, the parameters, of net present cost (NPC) and cost of energy (COE) are required that following equations are used to define them:

$$NPC=\frac{C_{tot}}{CRF(i\,T_p)} \quad (1)$$

$$CRF(i,n)=\frac{i(1+i)^n}{(1+i)^{n-1}} \quad (2)$$

$$COE=\frac{C_{tot}}{E_{tot}} \quad (3)$$

Where:

C_{tot}: Total annual cost

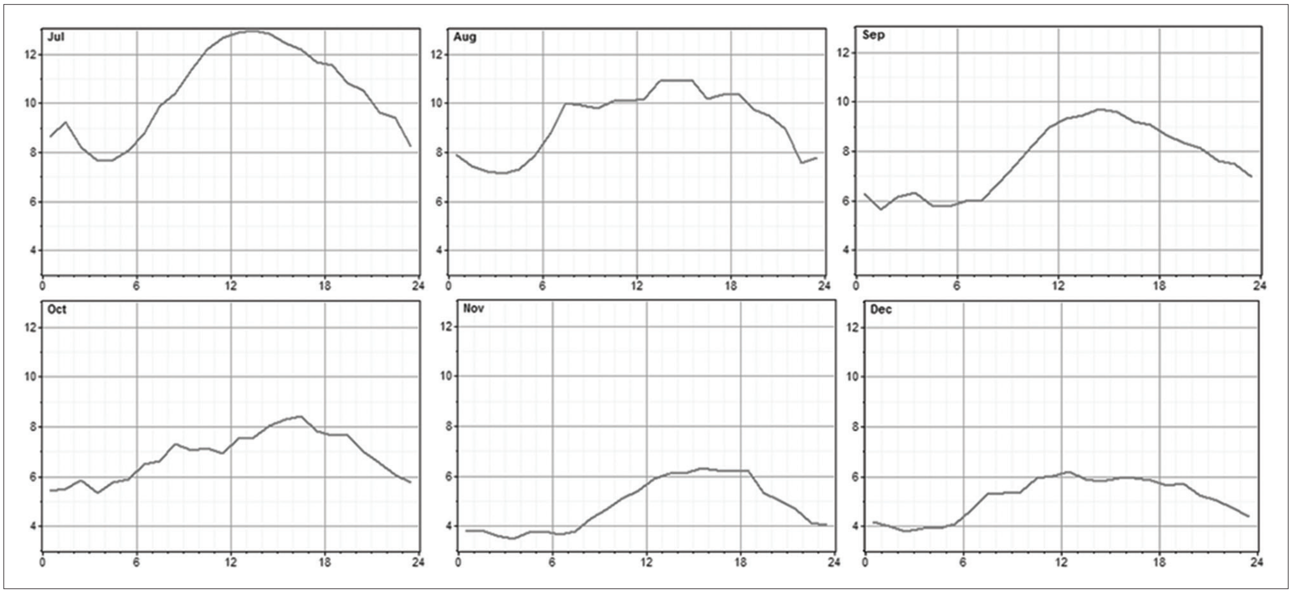
T_p: Lifetime of project

CRF: Capital recovery factor

i: Annual real interest rate

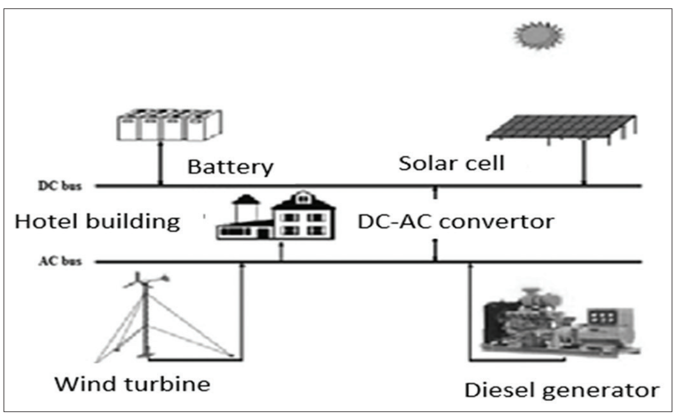
E_{tot}: Total annual power consumption.

Figure 6: Profiles of monthly data on wind speed in day for Tabriz Town, Iran



Source: Iran Meteorological Organization

Figure 7: Energy flow in hybrid energy system



4.4. Diesel Generator

In this study, two generators with the capacity of 600 and 650 KW was embedded to cover the energy load at peak times (Nfah et al., 2007).

4.5. Wind Turbine

According to speed and conditions of the region, turbine (Model: Generic) was selected. In order to simulate the model, 8 design models of turbine were entered the software (0, 1, 2, 3, 4, 5, 6, 8, 10). The lifetime of turbines was considered 20 years (Bekele and Palm, 2010).

4.6. PV System

The installation cost of 1 KW PV in Iran is about 3500-4000 dollars. In this study, 4 sizes were considered for PV arrays. The sizes are 10, 50, 100 and 150. The lifetime of PV system was considered 20 years (Rehman et al., 2012).

4.7. Storage Battery

In this study, for economic reasons, lead acid batteries were selected. Their model was Surrette 6CS25P. To determine the optimal number of batteries in battery bank used in software, following numbers were considered: 1-5-10-15-20-25-30-35-40-45-50-55-60-65 (Lau et al., 2013).

4.8. Power Converter

To maintain the current between AC, DC currents produced in different systems, energy power converter was required. Table 3 shows different hybrid energy systems proposed by software (Lau et al., 2013).

4.9. Results of Simulation

According to the outputs of Homer software and defined parameters in previous parts, all systems are practical but there are economically different in terms of optimization. Table 3 shows the results of used method. For example, fourth system represents all systems in which PV-wind-diesel-battery were used and it has the maximum energy cost compared to four other systems.

4.10. Diesel-battery

As shown in Table 4, a diesel system with a battery is the most affordable system. This system consists of a 600 KW diesel generator, 35 batteries (Surrette 6CS25P), and a 55 KW converter. The details of NPC are listed in Table 4. According to Table 4, the most important factors for lifetime cost of the system are fuel costs and return on investment. According to Table 4, the highest price is related to generator.

4.11. Wind-diesel-battery

According to the results listed in Table 4, wind-diesel system with battery storage is economically the second practical system after battery-diesel system and also the most useful hybrid system. The system consists of five 20 KW wind turbine, a 600 KW diesel generator, 35 batteries (Surrette 6CS25P) and 55 KW converter. A summary of the cash flow of NPC was shown in Figure 8 and details of annual cost are shown in Table 5. As shown in Table 5, the lowest cost is related to battery units ($ 5900) and the highest

Table 1: Input data of Homer software

Component	Model or size	Lifetime	Purchase cost	Replacement cost	Maintenance cost	Number
Diesel generator	600 and 650 KW	15000 h	1000 US$/kW	900 US$/kW	0.02 US$/h	1
Wind turbine	Generic, 20 KW	20 years	15000 US$/turbine	12000 US$/turbine	500 US$/turbine/year	0, 2, 3, 4, 5, 6, 8, 10
Photovoltaic cell	10, 50, 100 and 150 kW	20 years	3500 US$/kW	3500 US$/kW	25 US$/kW/year	_
Battery	Surrette 6CS25P (6V, 1156 Ah)	9645KWH	1100 US$/kW	1100 US$/kW	10 US$/h	1, 5, 10, 15, 20, 25, 30,35, 40, 45, 50
Convertor	10, 15, 20, 25, 30, 35, 40, 45,50, 55, 60 kW	15 years	900 US$/kW	800 US$/kW	0 US$/kW/y	_

Table 2: Selected control parameter used in Homer software

Parameter	Unit
Conversion efficiency	90%
Project lifetime	25 years
Annual real interest rate	10%
Fuel price of diesel	$0.4/l
Minimum amounts of renewable energy	0%
Shape parameter Weibull distribution, K	2
Correlation factor for wind resources	0.85
The power of daily pattern of wind resources	0.25
Time of day with peak wind speed	15
Annual interest rate in Iran	7-15%

cost is related to generator ($ 773,690). As shown in Figure 8, the highest NPCs are related to return on investment ($ 2,770,000) and fuel cost ($ 2,750,000).

4.12. Photovoltaic-diesel-battery

In addition to diesel-battery and wind-diesel battery systems, a solar system was examined with Homer software. It is an economic system. Photovoltaic-diesel hybrid system with battery storage consists of a 100 kWPV solar cell, a 600 KW diesel generator, 35 batteries (Surrette 6CS25P) and 55 KW power convertor. Total NPC of this hybrid system is shown in Table 6 and average monthly power generation using this system is shown in Figure 9.

4.13. Photovoltaic-wind Turbine-diesel-battery

Fourth economic system examined with Homer software was Photovoltaic- wind turbine- diesel-battery system. Although this system is economically the third system, it is a more realistic and applicable system compared to others. It consists of a 100 KW PV array, two 20 KW wind turbines, a 600 KW diesel generator, 35 batteries and a 55 KW power convertor. The details of NPC of this system and summary cash flow of it are shown in Table 7 and Figure 10, respectively.

5. CONCLUSION

According to the outcomes of Homer software and defined parameters, all systems are practical but economically different in terms of optimization. This feasibility study was performed on the use of hybrid energy systems: Diesel system with battery, diesel-wind turbine system with battery, photovoltaic-diesel system with battery and photovoltaic- diesel-wind turbine system with

Figure 8: Cost of wind-diesel-battery hybrid system

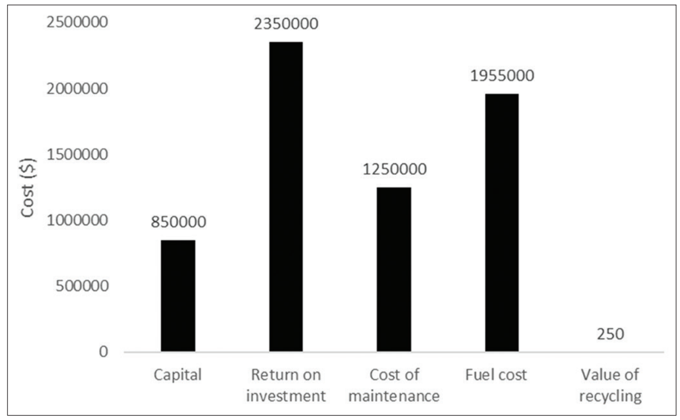


Figure 9: Average monthly power generation using PV-diesel system with battery storage

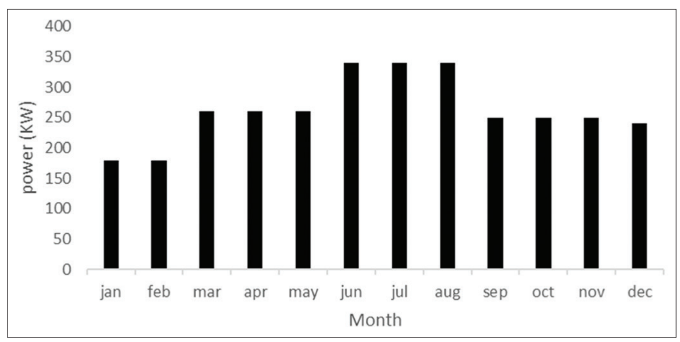


Figure 10: Cost rate of photovoltaic - wind turbine - diesel-battery system

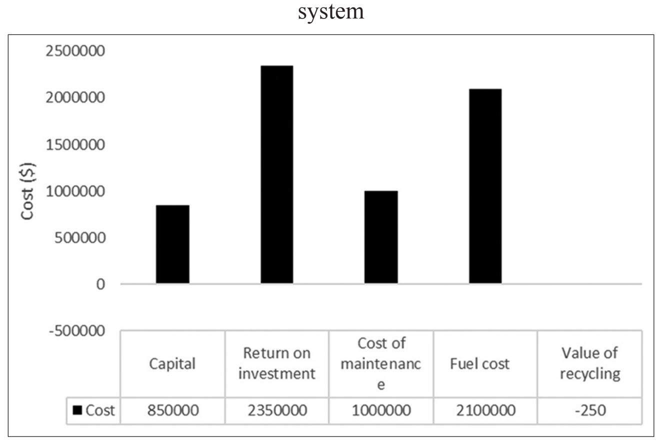


Table 3: Comparison of different hybrid energy system proposed by software

System	Model (KW) PV	Number of wind turbine	Convertor	Primary capital	Operating cost ($/year)	NPC	COE
1	1	8	60	332,500	26335	669,155	0.214
2	1	7	55	313,000	27968	670,530	0.214
3	1	8	55	328,000	26888	671,721	0.215
4	1	8	50	323,500	27287	672,315	0.215

All systems have a 600 KW diesel generator and 50 batteries (Surrette 6CS25P), NPC: Net present cost, COE: Cost of energy

Table 4: Details of NPC for diesel-battery system

Components	Capital ($)	Return on investment ($)	Cost of maintenance ($)	Cost of fuel ($)	Recycling value ($)	Total cost ($)
Generator	600,000	2,736,000	954,200	3,028,700	−19,940	5,240,000
Battery (Surrette 6CS25P)	38,500	14,700	3180	0	−2960	53,400
Convertor	49,500	10,500	0	0	−1350	58,600
System	688,000	2,761,000	957,400	3,028,700	−24,250	5,486,000

Other components such as wiring, control and monitor are neglected, NPC: Net present cost

Table 5: Details of annual cost of wind-diesel-battery hybrid system

Components	Capital ($)	Return on investment ($)	Cost of maintenance ($)	Cost of fuel ($)	Recycling value ($)	Total cost ($)
Generator	63,000	210,000	98,000	256,000	−1500	−741,200
20 kw wind turbine	8000	860	2000	0	−3800	−10,920
Convertor	3952	1050	0	0	−130	5230
System	56,000	242,000	94,000	245,000	−2150	562,000
Battery (Surrette 6CS25P)	3500	560	125	0	−238	3520

Other components such as wiring, control and monitor are neglected

Table 6: Details of annual cost for photovoltaic-diesel-battery hybrid system

Components	Capital ($)	Return on investment ($)	Cost of maintenance ($)	Cost of fuel ($)	Recycling value ($)	Total cost ($)
Generator	540,000	1,560,000	685,000	1,890,000	−15,650	3,960,000
Photovoltaic	200,000	0	16,800	0	0	275,000
Convertor	36,500	9300	0	0	−890	38,000
System	865,000	1,684,000	760,000	1,890,000	−15,800	5,843,000
Battery (Surrette 6CS25P)	23,400	10,500	1820	0	−2100	36,000

Other components such as wiring, control and monitor are neglected

Table 7: Details of annual cost of photovoltaic- wind turbine- diesel-battery system

Components	Capital ($)	Return on investment ($)	Cost of maintenance ($)	Cost of fuel ($)	Recycling value ($)	Total cost ($)
Photovoltaic	220,000	0	18,500	0	0	292,000
Wind turbine	24,000	3160	8400	0	−1250	36,000
Generator	490,000	2,000,100	834,000	1,980,000	16,420	5,468,000
System	920,000	2,156,000	860,000	1,980,000	−18,700	6,754,000
Battery (Surrette 6CS25P)	28,400	11,300	2600	0	−2100	47,200

Other components such as wiring, control and monitor are neglected

battery. This study aimed to provide the power required for a hotel in Tabriz Town, Iran. Using Homer software, the results showed that diesel-battery system with the net cost of $ 5,486,000 is the most affordable system. However, this system is not combined with renewable energy sources and given Iran's energy savings program and removal of fossil fuels subsides that reduces the costs of renewable energy systems, the renewable energy sources will become a priority over time.

Summary of the evaluation of various systems is provided as follows:

1. Diesel-wind-battery hybrid system with five 20 kW wind turbines, a 600 kW diesel and 35 batteries. Its total NPC is $ 5,620,000 and its COE is $ 0.318/KWh.
2. Diesel-PV-battery hybrid system with a 100 KWPV solar cell, a 600 kW diesel and 35 batteries. Its total NPC is $ 5,843,000 and its COE is $ 0.326/KWh.
3. Diesel-wind-PV-battery hybrid system, with a 100 KWPV solar cell two 20 kW wind turbines, a 600 kW diesel and 35 batteries. Its total NPC is $ 6,754,000 and its COE is $ 0.327/KWh.

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