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Article

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Research paper

Stand-alone hybrid energy systems for remote area power generation

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ABSTRACT

Energy accessibility especially electrical energy is considered as one of the most appealing factors to achieve energy sustainability. The purpose of this study is to investigate energy sustainability using renewable energies for two high potential cities in the south-east of Iran until the year 2030. In this regard, Homer software is used to evaluate economic and technical analyses of PV-wind-diesel hybrid system for the two cities by the data gathering which was collected from Iran's meteorological organization. Therefore, the average of solar radiation per month for Zabol and Zahak were about 9 and 9.1 (h/d). Also, mean wind speeds are calculated 5.35 m/s and 4.7 m/s for Zabol and Zahak respectively which proposed that these cities have high potential in order to electrical production by a hybrid system. Furthermore, the amount of electricity production by PV array for Zabol and Zahak were 1700 (kWh/yr) and 1669 (kWh/yr) respectively, and the amount of electricity production by wind turbine were 9036 (kWh/yr) and 7263(kWh/yr) for Zabol and Zahak respectively. Consequently, it is of elaborated that the investments on solar and wind energy sectors for both cities would be economically justified.

1. Introduction

Sustainable development consists of economic, society and environment parts that have a close relation with renewable energy. Renewable energy is one of the main factors to reach sustainable development (Omer, 2008). On the contrary, application of renewable energy to reduce environmental issues and global warming is widely reported in the literature. Nowadays, there are positive attitudes to replace them instead of fuel fossils soon (Mardani et al., 2015). The use of renewable energies to generate electricity is the most important performance for meeting human's future energy needs (Heidari et al., 0000). The excessive emission of greenhouse gases which are mainly produced by human activities has caused the fundamental alterations in the global climate structure (Casper, 2010). The potentially hazardous effects of greenhouse gases which exposed to global warming would cause a significant loss for the environment (Qolipour et al., 2017). A wide range of human activities has increased the greenhouse gases concentration by passing the production time in numerous industries which have mainly due to the carbon dioxide release. In order to reduce greenhouse gases emission and environmental pollution, various novel solutions such as more utilization of renewable energy are taken into consideration (Khojasteh et al., 2017; Bogdanov and Breyer, 2016).

1.1. Literature review

In this regard, some of the results of recent works can be mentioned which are performed by different researchers in the world to encourage energy planners and policymakers for applying renewable energies. The use of more renewable energy instead of fossil fuels would be of great help to the environment as the air pollution reduction (Mehrpooya et al., 2018). Various types of renewable energies are used to provide energy that is considered to be the most important wind and solar energy (Tudu et al., 2014). Wind turbines and solar panels play a significant role in supplying electricity resources around the world.

Furthermore, renewable energies play a significant role in sustainable urban development; in respect to the way, sustainable development could start from rural areas to cover the entire community (Cebotari et al., 2017). Today, different countries around the world have struggled the sustainable urban development with a renewable energy approach (Shafiullah et al., 2018). In the field of renewable energy, the approach to the administration of new technologies especially wind turbines are rapidly increased, Said et al. (2017). Wind turbines and solar panels have been installed in cities such as Manjil, Binaloud which provide part of the energy

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Abbreviation

NPC	Net present cost
CRF	Capital recovery factor
COE	Energy cost balance
k	Shape Parameter
c	Scale Parameter
P_{pv}	Power panel
NOCT	Normal Operational Cellular Temperature
T_a	Ambient temperature
P_R	Rated power of the wind turbine
V_{ci}	Cut-in wind speed
f	The function of Weibull distribution
V_r	Rated wind speed
V_{co}	Cut-out wind speed
C_p	Coefficient of performance
A	Swept area
V_w	Wind speed
p	Air density
n_r	Reference module efficiency
A (m)	PV generator area
G (t)	Solar irradiation in tilted module plane
G	Solar irradiation Solar radiation at a standard temperature condition
G_{ref}	The temperature at reference conditions
T_{ref}	The temperature coefficient of the PV module
K_T	Ambient temperature
T_{amp}	Potential voltage
V_{mpp}	V_{mpp} at standard condition (V)
$V_{mpp,ref}$	Panel's current at standard condition
$I_{mpp,ref}$	Short circuit current at standard condition
$I_{sc,ref}$	Open circuit (V/°c) temperature coefficients
$P_{v,oc}$	Wind speed at the height of h
V_t	Wind speed at the height of *hr*
$V_{r(t)}$	Fuel quantity
m_f	Fuel heating value(MJ/L)
HV_f	Total annual cost (in dollars)
$Ctann$	Carbon emission factor (ton carbon/TJ)
CEF_f	Oxidized carbon fraction
X_C	Nominal interest rate
I	Number of years
n	Electrical energy
Eis	Amount of electricity sold to the grid
Egrid	Amount of CO2 emissions
tCO_2	The temperature of a panel at the standard operational condition
	The operational temperature of the panel

they need (Mostafaeipour and Abarghooei, 2008). The evaluation of wind power generation using a hybrid system for households in Ardabil province was evaluated (Qolipour et al., 2016). Investigation and analysis of electrical energy-saving technologies in potentially power system operation with emphasis on cost and investment (Nikolaidis and Poullikkas, 2018). The process of energy production in Iran and its impact on sustainable development (Tofigh and Abedian, 2016). Analysis of Energy Status in Iran for Sustainable Energy Design Roadmap and even research on the development of renewable energy in rural areas of Iran has also been carried out completed (Afsharzade et al., 2016). Also, economic and technical analyses of a hybrid system for using in a mine in Ghana has been done (Ansong et al., 2017).

Although energy sustainability depends on a variety of factors and is a very broad topic, it should be considered from a variety of perspectives. Indeed, energy sustainability has become a global goal. Hence, there are important reasons to write this research which can be cited several of them. First of all, this study provides a comprehensive discussion of sustainable development and the importance of energy sustainability through the use of renewable energies. Second of all, the study intends to increase the number of investors and the amount of investment in renewable energy by showing potential energy regions. Third of all, all of this research shows that renewable energy has a high potential for power generation for residential areas with positive environmental impacts. Fourth of all, this paper with a technical and software analysis given their political power and authority of policymakers and energy planners in Sistan and Baluchistan province can show that they can provide a good opportunity to energy supply, employment creation and development approaches for the residents of those regions. That this is the most important goal of this scientific work.

2. Sustainable development and renewable energy

Although Sustainable development is based on the three community pillars, economy, and environment, which strive to bring together these three important principles in order to maximize the welfare of the present human being, it should present and implement practical solutions to the ability of future generations to meet the needs of the future (Sachs, 2012). Sustainable development embodies the idea of the constraints imposed by the economic, social and environmental situation, which shows the goals of sustainable development to be defined in each country in a practical and specific way (Anand and Sen, 2000). On the other hand, sustainable development is based on the human consciousness towards itself and towards the natural resources of the planet like a new style of sustainable living for all humans, consumption of a wide variety of resources, waste of resources, and neglecting of future generations (Aslani and Wong, 2014). The role of renewable energies in sustainable development is remarkable enough due to the utilization of renewable energy that would increase the economic development of the community. Moreover, the use of renewable energies increase has led to a reduction in gaseous fossil fuels that are mainly produced by fossil fuels (Aslani et al., 2014).

2.1. Energy supply by solar and wind energy in the world

Energy supply is one of the most important issues for all governments and the needs of different countries in the world especially in the case of renewable energy (Razmjoo and Davarpanah, 2019). However, providing of energy by fossil fuels has many expenditures and has negative effects to the environment, the use of renewable energy such as wind and solar energy can both contribute to the energy supply (Kassem et al., 2018).

2.2. Investments on the renewable energy

In the coming years, different countries have decided to invest more in renewable energies (Wüstenhagen and Menichetti, 2012). Developed and developing countries had been a remarkable growth to invest and use of solar and wind energy than other energy sources, which reflects the importance and the emphasis

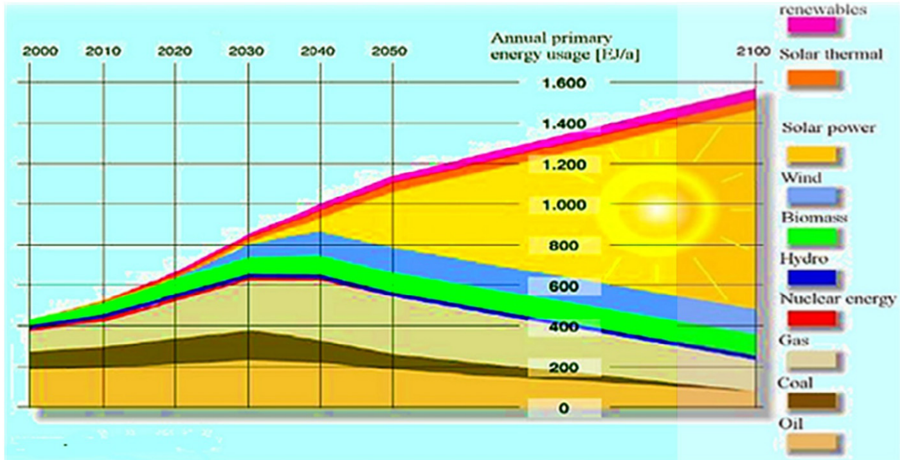

Fig. 1. A prediction of global consumption of different types of energies from 2000 to 2100 (Mostafaeipour et al., 2016).

Table 1
CO_2 emission by region (million tons of CO_2) (Panwar et al., 2011).

Region	1971	1995	2010	2020
OECD	9031	10763	13,427	14,476
Transition economic	3029	3135	3852	4465
China	875	3051	5322	7081
Rest of the world	1435	4791	8034	11,163
World	14,732	22,150	31,189	37,848

on the use of this energy (Boomsma et al., 2012). Also, in recent years, many research has been done to invest in renewable energy in Iran which depicts the special attention to this issue (Aslani et al., 2012; Afsharzade et al., 2016).

2.3. Role of renewable energy to reduce greenhouses gases

Fossil fuels have polluted the environment due to their high combustion rates of CO_2 and high energy release. Considering the increase of energy consumption in the world has constantly risen, and the production of CO_2 would potentially enhanced. As can be seen in Table 1, CO_2 emissions in different regions were explained from 1971 to 2020.

By expanding the use of renewable energies, carbon consumption and greenhouse gases emissions can be significantly reduced (Qolipour et al., 2016). Also, renewable energy has a significant contribution to global energy supply due to its consistent nature with the environment and low pollution. Fig. 1 shows a prediction mode by USA Electric Power Research Institute on the global consumption of different types of energies from 2000 to 2100. As it is evident, the renewable energy will also reduce carbon consumption and CO_2 emission in addition to providing a significant portion of electricity.

2.4. Fuel fossils consumption in Iran

Iran is a wealthy country in the case of numerous energy sources, one of the world's leading oil exporters, and has the world's second-largest proven reserves of natural gas (Mollahosseini et al., 2017). Fossil fuels have the greatest share in energy supply of the Iran demand. The existence of numerous oil and gas refineries producing fossil fuels has resulted in the release of a significant amount of gaseous fossil fuels in recent years in Iran (Bakhoda et al., 2012). Fig. 2 shows the various energy consuming sectors, and their related shares form Iran's total energy consumption. As can be seen, the highest consumption of fuel fossils is belonging to the transportation system which subsequently resulted that the approach change in this sector (using renewable energy vehicle) will be prevented of more pollutions.

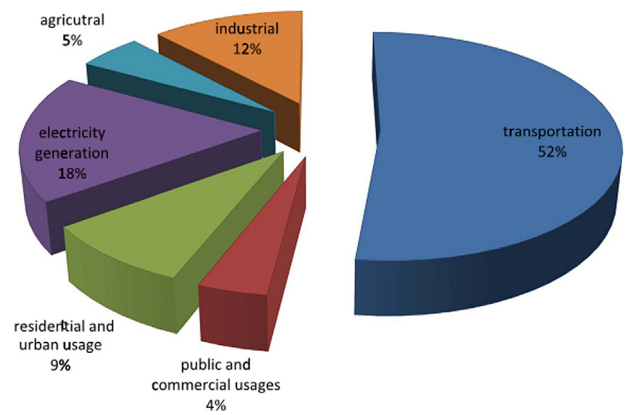

Fig. 2. Various energy consuming sectors and their related shares form Iran's total energy consumption (Mollahosseini et al., 2017).

3. The renewable energy situation in Iran

Due to the special weather conditions for Iran and the availability of windy and sunny areas, it has a high potential for renewable energy production. In recent years, the approach to increase the use of renewable energy in Iran has increased over the past few years, and there has been a lot of technical and economic evaluation in many parts of the country for the establishment of renewable power plants (Tofigh and Abedian, 2016).

3.1. Solar energy potential in Iran

Iran with the area of 1,648,195 km^2 has 300 sunny days per year with solar radiation average of 4.5–5.5 kWh/m^2Day (Mollahosseini et al., 2017). It is located on the Sun Belt means that it receives the highest level of sun radiation. According to the renewable energy agency of Iran, the potential of solar energy is estimated around 40,000 GW. Iran's daily energy research estimates more than 9 million MW of energy that can be achieved by planning and executing operations also the nominal capacity of 139996 MW of solar energy annually by Iran by 2030 can be achieved. Provinces such as Yazd, Kerman and, Fars have high solar energy potential (Fadai, 2007).

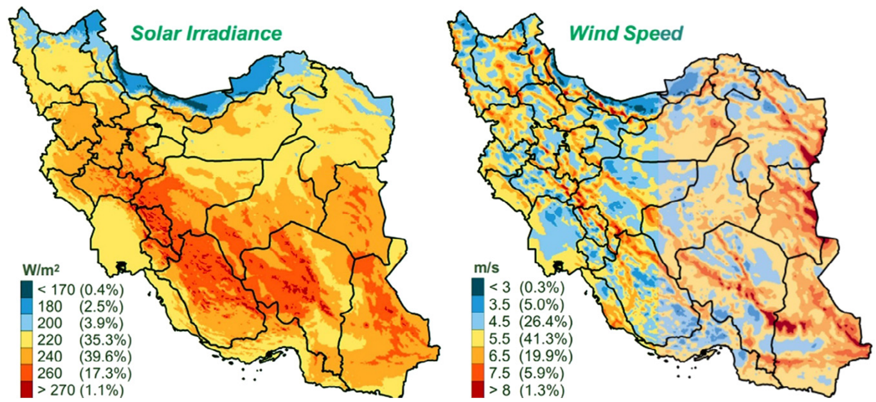

Fig. 3. Maps of Iran's annual average global horizontal irradiance (GHI) and wind speed.

Table 2
The renewable energy plants (Solar-Wind).

Solar power plant	Capacity (kW- MW)	Type	Wind power plant	Capacity (MW)
Shiraz	250 (kW)	Integrated solar combined cycle	Manjil	61.18
Yazd	467 (MW)	Concentrating solar power	Binaloud	28.34
Mashhad	432 (kW)	PV solar power plant	Takestan	20
Mallard	365 (kW)	PV solar power plant	Ovn Ebnali Tabriz	1.98
Hamedan	14 (MW)	PV solar power plant	Lootak Zabol	0.66
Isfahan	10 (MW)	PV solar power plant	Baba Kohi Shiraz	0.66
Arak	1 (MW)	PV solar power plant	Mahashar	0.66
Abhar	110 (kV)	PV solar power plant	–	–
Kerman	20 (MW)	PV solar power plant	–	–

3.2. Wind energy potential in Iran

Iran has a suitable situation for the utilization of wind energy which is estimated of 6500 MW (Tofigh and Abedian, 2016). In recent years, major steps have been taken to develop wind power production in Iran, and the number of wind farms has increased for energy production. Some of the areas of Iran such as Manjil, Binaloud, Zabol, and Zahak are well-known zones with high potential for wind energy. Based on projections, the amount of wind energy that can be economically estimated to be 18,000 MW (Mollahosseini et al., 2017). Table 2 shows the renewable energy plants (Solar-Wind).

Fig. 3 shows the Maps of Iran's annual average global horizontal irradiance (GHI) and wind speed.

4. Case studies

In this paper, two cities are considered that have located in the north of Sistan and Baluchistan province in Iran. In the following location, population, weather, etc., about them will be mentioned.

4.1. Zabol and Zahak cities

Zabol and Zahak cities are located in the Sistan and Baluchistan province. The population of Zabol and Zahak are 166,666 74,896 respectively in the year 2016. Zabol is located at the coordinates of 31°01′N and 61°30′′E, and an altitude of 483 m meters above sea level, and Zahak is located at the coordinates of 30°56′N and 61°41′′E and an altitude of 494 m meters above sea level. There is the dry and hot climate in summer, and a cool climate in winter is the characteristic of the climate for these regions. Furthermore, these cities have a long summer, sweltering, arid, extremely windy and cool climate in winter. Also, these areas are well-known with 120-days wind and intense solar radiation. Table 3 shows the geographical coordinates of these two cities.

Table 3
Geographical coordinates of these two cities.

City	Longitude	Altitude	Elevation from the sea
Zabol	31°01′	61°30′	483
Zahak	30°56′	61°41′	494

Table 4
Monthly wind speed and solar radiation presented per month.

Month	Wind speed	Solar radiation	Wind speed	Solar radiation
Jan	2.1	6.9	2.7	7.5
Feb	4.5	5.7	2.9	7.4
Mar	3.8	7.6	5	8.1
Apr	4.2	9.02	5.5	9.5
May	4.7	9.8	7.6	10.9
Jun	6.9	11.3	9.1	10.6
July	9.5	11.5	6.4	10.6
Aug	8.6	11.3	4.2	10.7
Sep	6.5	9.6	3.4	9.6
Oct	5.7	9.7	3.4	9.3
Nov	4.2	7.9	4.1	8.2
Dec	3.5	7.07	2.1	7.3
Average	5.35	9	4.7	9.1

Monthly wind speed and solar radiation presented in Table 4. It is clear that two cities have a high rate in wind speed (m/s) and solar radiation (kWh/m^2/d) in a month.

Fig. 4 shows the location two zones studied on the map of Iran.

5. Technical analyses

5.1. Analysis of output power for PV

Below equations are employed for calculating output power of PV. Actually it is an analytical model of solar energy generation (Acakpovi et al., 2015):

$$P(t) = n_r[1 - \beta(T_{c-}T_{cref})].AG(t) \quad (1)$$

Fig. 4. Location two zones studied on the map of Iran.

where, n_r is the reference module efficiency, T_{cref} is the reference cell temperature in degree Celsius, A (m) is the PV generator area and G (t) is the solar irradiation in tilted module plane. The other method which can use as follows (Olatomiwa et al., 2015);

$$P_{pv} - Out = P_{pv} - rated \times (G/G_{ref})X\left[1 + K_T(T_c - T_{ref})\right] \tag{2}$$

P_{pv} is the power output of the PV cell, P_{pv}– rated is the PV rated power at reference condition, G is solar radiation (W/m^2), G_{ref} is the solar radiation at standard temperature condition, (G_{ref} = 1000 w/m^2), T_{ref} = is cell temperature at reference conditions (T_{ref} = 25 c°), K_T is temperature coefficient of the PV module also $T_c = T_{amp} + (0.0256\times$ G),that in this equation T_{amp} is ambient temperature. For calculate the annual energy output of solar PV system the below equation can be used:

$$E_{pv} - Out = \sum_{i=1}^{8760} P_{pv} - \mathrm{Out}(i) \tag{3}$$

Also, another method that can be used as follows (Mostofi and Shayeghi, 2012);

$$P_{pv} = V_{mpp} \times I_{mpp} \tag{4}$$

$$V_{mpp} = V_{mpp,ref} \times P_{v,oc}(T_{c-}T_{c,ref}) \tag{5}$$

$$I_{mpp} = I_{mpp,ref} \times I_{sc,ref}(T_{c-}T_{c,ref}) \tag{6}$$

where P_{pv} is the panels power, V_{mpp} is the potential voltage, $V_{mpp,ref}$ is the V_{mpp} at standard condition (V), $I_{mpp,ref}$ and $I_{sc,ref}$ are the panel's current and short circuit current at standard condition, and $P_{v,oc}$ is the open circuit (V/°c) temperature coefficients.

T_{cref} is the temperature of panel at the standard operational condition that is equal to 250 °c and T_c is the operational temperature of a panel where it is defined as (Mostofi and Shayeghi, 2012):

$$T_c(t) = T_a(t) + \frac{NOCT + 20}{800}.G_t \tag{7}$$

where T_a (t) is the ambient temperature (°c), NOCT (Normal Operational Cellular Temperature), for 500 w/m^3 of solar irradiation and temperature of 20 °c is in the range of 40 to 46 °c and G_t is the average daily solar irradiation (w/m^2).

5.2. Wind speed analysis

To calculate wind speed, there is the main equation that can be used and the most common is the Weibull function:

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left((\frac{v}{c})^k\right), \qquad k > 0, v > 0, c > 0, \tag{8}$$

Also, another method to calculate wind speed can be used as follows (Acakpovi et al., 2015):

$$P_m(t) = \frac{1}{2}\rho AC_{pV_w}3 \tag{9}$$

where C_p is the coefficient of performance also called power coefficient, A is the swept area by the turbine' blades(m^2), p is the air density (kg/m^3) and V_w is the wind speed (m/s).

$$V_t = V_{r(t)}.\left(\frac{h}{hr}\right)^r \tag{10}$$

where V_t is the wind speed at height of h, $V_{r(t)}$ is wind speed at height of hr and r is the power-law exponent that is in the range of 0.14 to 0.25.

Wind speed also can be to calculate the output power of the turbine (Sinha and Chandel, 2015; Mostofi and Shayeghi, 2012):

$$P_{wt(t)} = \begin{cases} \mathrm{av}^3\,(\mathrm{t}) - bP_R & V_{ci} < \mathrm{V} < V_r \\ P_R & V_r < \mathrm{V} < V_{co} \\ 0 & \text{Other wise} \end{cases} \tag{11}$$

a and b can be obtained via below:

$$a = \frac{P_R}{(V_r{}^3 - V_{ci}{}^3)} \qquad , b = \frac{V_{ci}{}^3}{(V_r{}^3 - V_{ci}{}^3)}$$

where P_R is the rated power of the wind turbine (w) and V_{ci}, V_r and V_{co} are the cut-in wind speed, rated wind speed and cut-out wind speed of the wind turbine.

Fig. 5 shows a schematic of a Block diagram of a hybrid solar-wind power generation system

6. Assessment criteria in HOMER software

In this study, the HOMER simulation program has been utilized as a tool for system design. HOMER is the optimization software for renewable energy and will be able to evaluate the technical feasibility of a system to examine if it can meet the loads (electrical and thermal). Fig. 6 shows Architecture of Homer software that has divided into two parts including Input and Output that when Homer software receive main inputs will give us optimized results.

Total net present cost (NPC) of the system as follows annual cost can be calculated by the following equation (Hafez and Bhattacharya, 2012):

$$NPC = \frac{Ctann}{CRF(i,n)} \tag{12}$$

where NPC (Net present cost) is the total annual cost (in dollars), i is the annual real interest rate (the discount rate), N is the number of years, $CRF(i,n)$ is the capital recovery factor, and can be obtained by the following formula:

$$CRF(i,n) = \frac{i\,(1+i)^n}{(1+i)^n - 1} \tag{13}$$

where i is the nominal interest rate, and n is the number of years. Energy cost balance can be calculated as follows:

$$COE = \frac{Ctann}{\mathrm{Eis} + \mathrm{Egrid}} \tag{14}$$

where Eis is the electrical energy that the microgrid system serves, and Egrid is the amount of electricity sold to the grid by microgrid.

7. Result and discussions

7.1. Techno-economic analysis of wind and solar energy

By the using homer software, the technical-economic analysis in this research has been performed. Indeed, Homer software is

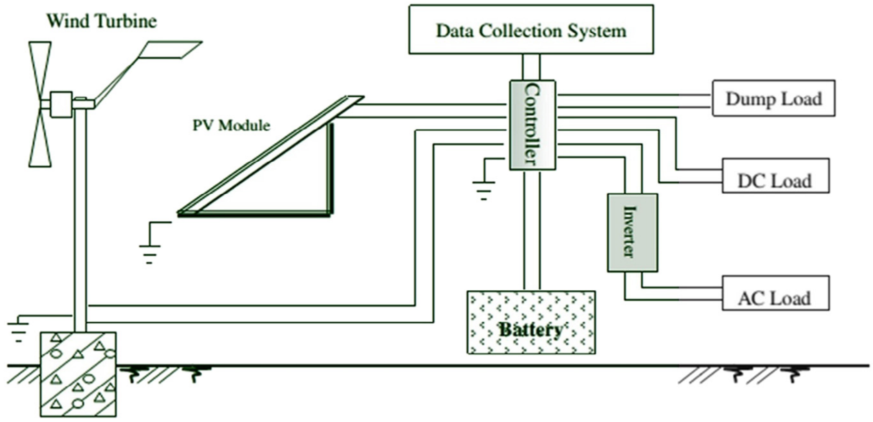

Fig. 5. Block diagram of a hybrid solar-wind power generation system (Zhou et al., 2010).

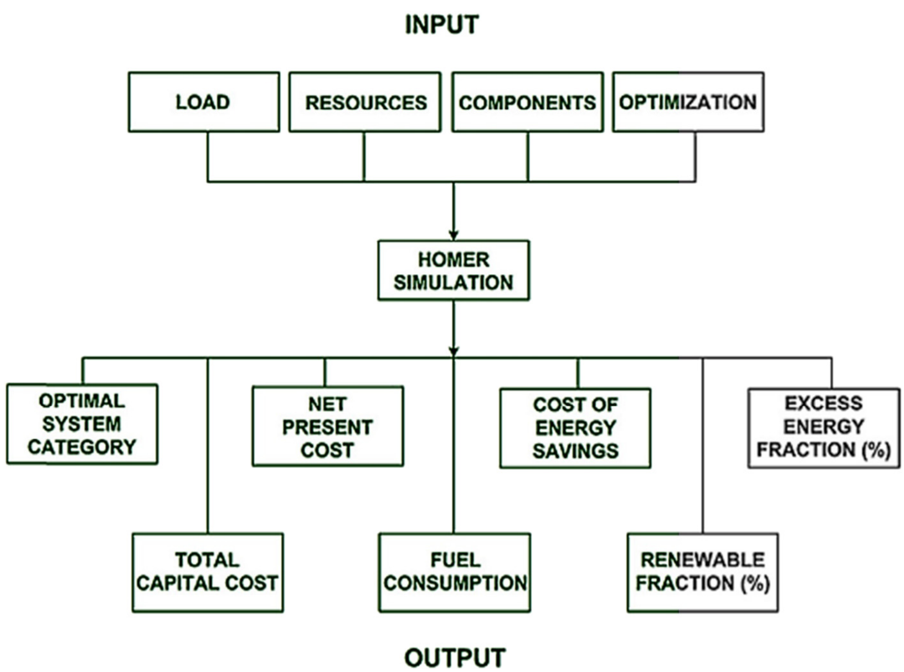

Fig. 6. The architecture of Homer software (Erdinc and Uzunoglu, 2012).

used to calculate important parameters such as electrical production (kWh/yr), hours of operation, fuel consumption (L/yr), losses (kWh/yr) and mean output (kW). In this regard, below results extracted from Homer software that is obvious in Table 5. Table 5 shows the overall breakdown of the technical specifications for PV-Wind turbine and generator.

Also, Table 6 demonstrates overall technical specifications for PV-Wind turbine and generator breakdown for Zahak. As can see and compare with Zabol, two cities are a near potential in Hybrid system.

In this study, the electricity production by the photovoltaic collectors for Zabol 1700 (kWh/yr) and Zahak 1699 (kWh/yr) also obtained electricity production by wind turbine 9.036 (kWh/yr) and 7263 (kWh/yr) obtained for Zabol and Zahak respectively. The generator also produced 927 and 1606 (kWh/yr) electricity for Zabol and Zahak respectively. Figs. 7 and 8 shows the amount of generated energy by PV, Wind turbines and generator in this study.

Also, Fig. 8, shows the monthly average electricity production by the PV collectors and generator 1 for the Zahak. Power generation by the generator has a significant contribution in some months.

In this study for two cities selected 1 PV Array (1 kW), 1 WES 5 Tulipo (1 kW), 1 Generator (1 kW), 6 Surrette and Inverter and converter (1 kW). Total net present cost for Zabol 28,076 $ and Zahak 31,873 calculated by Homer software. Cash flow summary for two mentioned cities showed in Figs. 9 and 10 that has been broken down by component for PV-diesel-battery-converter. The maximum cost after the generator cost belongs to the Surrette 6CS25P cost.

Table 7 shows a total analysis of the detailed breakdown of the NPC for PV-Wind-Diesel-Battery-Converter hybrid system. It also shows the highest and lowest total lifetime cost of the system as belonging to the battery 1 and converter, which have values of US$ 10,549 and US$ 1066, respectively for two cities. Also, this system exhibits a maximum regarding the cost of the system for Zabol which is US$ 28, 06 and for Zahak which is US$ 31,873.

Fig. 11 shows potential wind energy for Zabol and Zahak cities. In this figure, as it can be seen the July and Jun months have the highest rate of wind speed monthly.

Besides, Fig. 12 demonstrates the diagram of horizontal radiation pertaining for Zabol city. As it is clear, the highest and lowest level of solar radiation with 7.210 kWh/m^2/d and 2.970 kWh/m^2/d, occurred in Jun and December respectively.

Table 5
The technical specifications for each component of system breakdown for Zabol.

PV	Hours of operation (hrs/yr) 4374	Mean output (kW) 4.66	Capacity Factor (%) 19.4	Electrical production (kWh/yr) 1700
Wind turbine	Hours of operation (hrs/yr) 8265	Mean output (kW) 1.03	Total rated capacity (%) 2.5	Electrical production (kWh/yr) 9.036
Generator	Hours of operation (hr/yr) 941	Fuel consumption (L/yr) 420	Fuel energy input (kWh/yr) 7775	Electrical production (kWh/yr) 927

Table 6
The technical specifications for each component of system breakdown for Zahak.

PV	Hours of operation (hrs/yr) 4375	Mean output (kW) 4.57	Capacity Factor (%) 19.1	Electrical production (kWh/yr) 1699
Wind turbine	Hours of operation (hrs/yr) 8181	Mean output (kW) 0.829	Total rated capacity (%) 2.50	Electrical production (kWh/yr) 7263
Generator	Hours of operation (hr/yr) 927	Fuel consumption (L/yr) 725	Fuel energy input (kWh/yr) 2972	Electrical production (kWh/yr) 1606

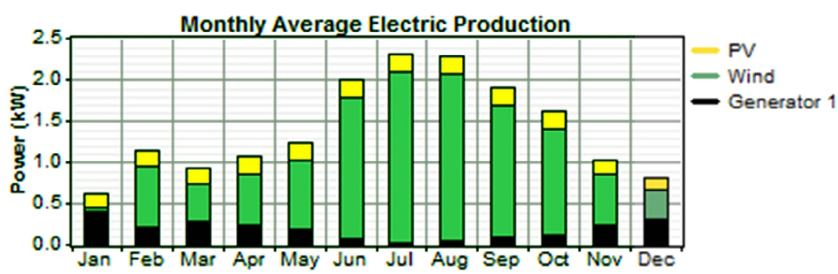

Fig. 7. Monthly average electric production of PV-generator hybrid for Zabol.

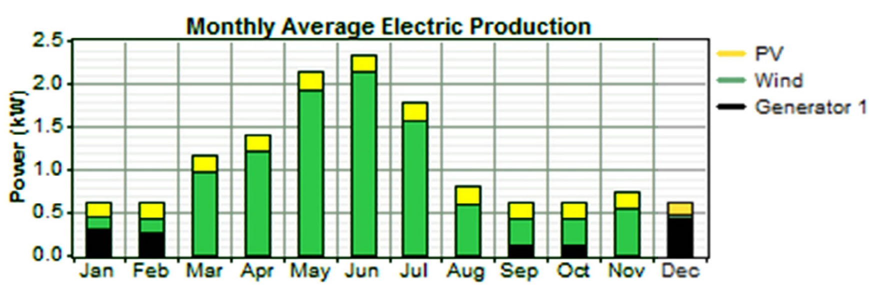

Fig. 8. Monthly average electric production of PV-generator hybrid for Zahak.

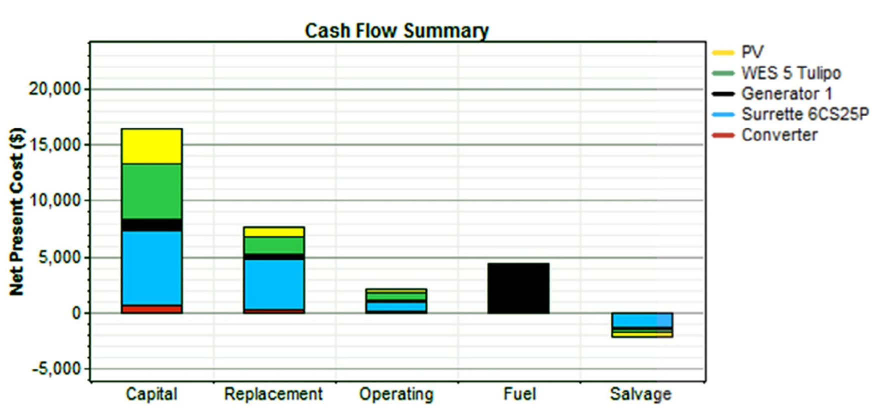

Fig. 9. Annualized cash flow summary by component for PV-diesel battery-converter-Zabol.

Also, Fig. 13 indicates the diagram of horizontal daily radiation kWh/m^2/d for Zahak city. The highest and lowest level of solar radiation respectively with 7.000 kWh/m^2/d and 2.980 kWh/m^2/d, occurred in Jun and December.

Fig. 14 shows the generator one output for Zabol. Diesel Generator is used to help the hybrid system for electrical production. However, in this system, about the type and specifications of the proposed turbines, generators are not in the acceptable status of

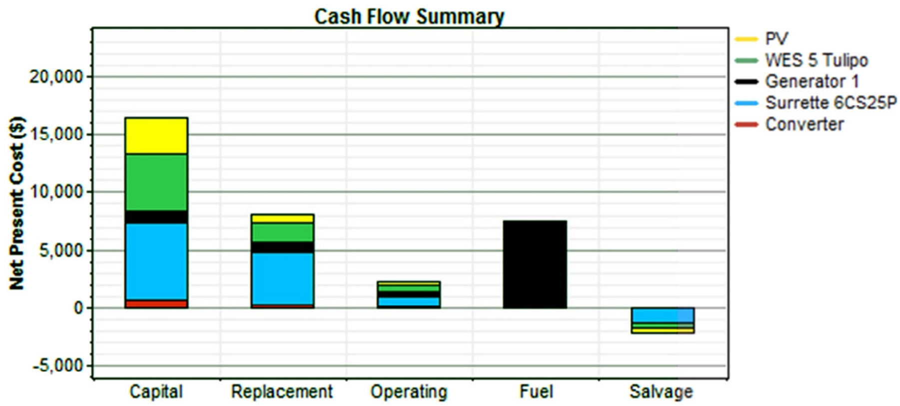

Fig. 10. Annualized cash flow summary by component for PV-diesel battery-converter Zahak.

Table 7
A detailed breakdown of the NPC for PV-Wind-diesel-battery-converter hybrid system.

Cities	Component	Capital ($)	Replacement ($)	O & M ($)	Fuel ($)	Salvage ($)	Total ($)
Zabol	PV	3000	780	320	0	−437	3,622
Zahak	PV	3000	780	320	0	−437	3,622
Zabol	WES 5 Tulipo	5000	1669	639	0	−311	6,998
Zahak	WES 5 Tulipo	5000	1669	639	0	−311	6,998
Zabol	Generator 1	1000	356	241	4296	−91	5,801
Zahak	Generator 1	1000	830	414	7418	−63	9,559
Zabol	Battery 1	6600	4464	767	0	−1281	10,549
Zahak	Battery 1	6600	4464	767	0	−1281	10,549
Zabol	Convertor	700	292	128	0	−54	1,066
Zahak	Convertor	700	292	128	0	−54	1,066

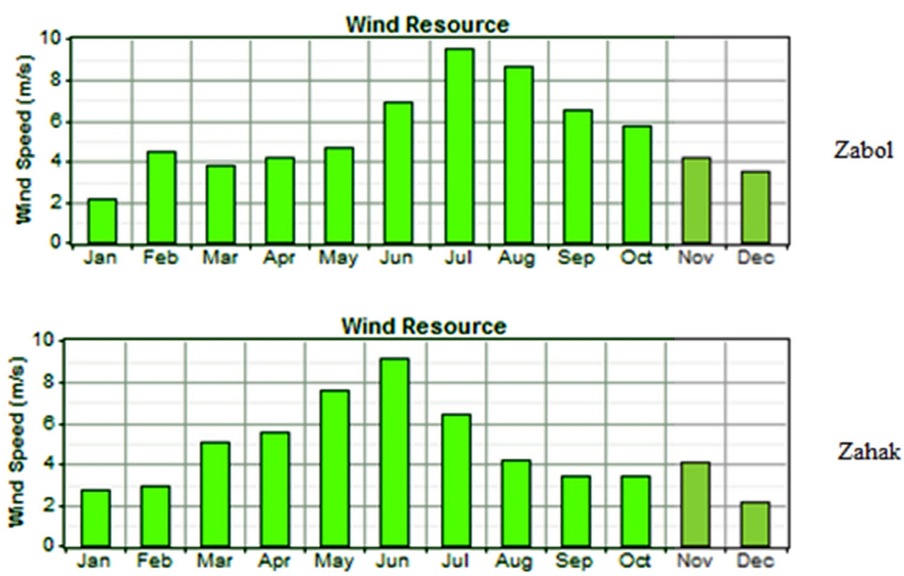

Fig. 11. Wind potential energy for Zabol and Zahak cities.

power generation, performance and efficiency. When the wind speed is not suitable (low), and turbine rotates with a smaller acceleration, generators only can produce the electrical power by all its powers. Therefore, about Figs. 14 and 15, the generators could not be working at the maximum power that it means the generators have specific fluctuations in on or off in working hours of the turbine.

Also, Fig. 15 shows the generator one output for Zahak city. As above mentioned, the generators could not work with maximum power in this system.

7.2. Analyses of emission issues

Greenhouse gases emissions from fossil fuels are the most important causes of air pollution and a serious threat to human's health. As before mentioned, the renewable energy hybrid system is one of the best solutions to prevent and reduce this problem in the future. CO_2 calculation has different methods that can be used and one of them is Homer software. To calculate the CO_2 emissions, of course, there are different ways, but from the hybrid energy system the following supporting equations have been introduced (Shezan et al., 2016):

$$tCO_2 = 3:667 \times m_f \times HV_f \times CEF_f \times X_C \quad (15)$$

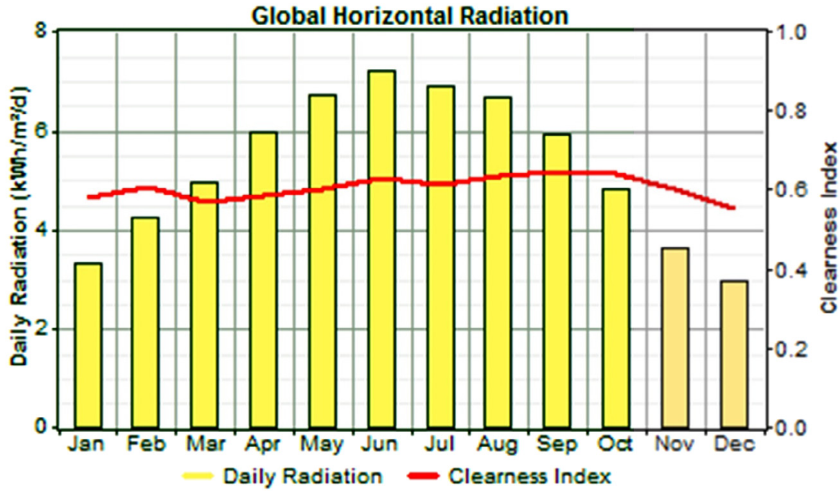

Fig. 12. Global horizontal radiation for Zabol.

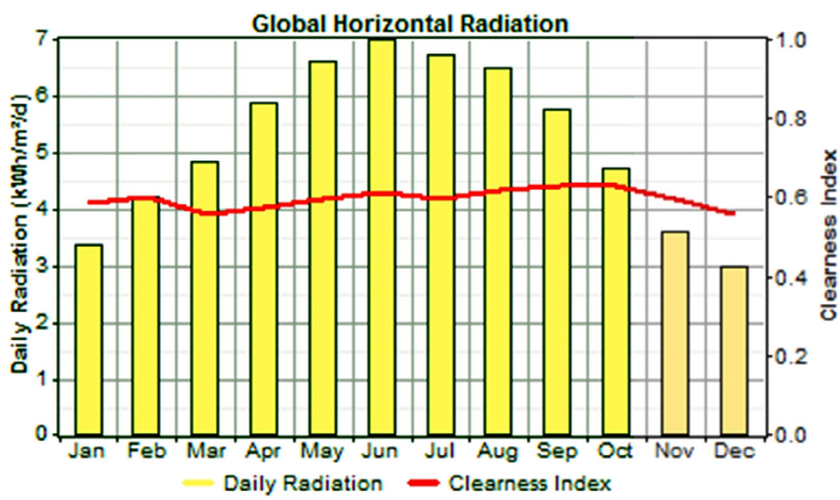

Fig. 13. Global horizontal radiation for Zahak.

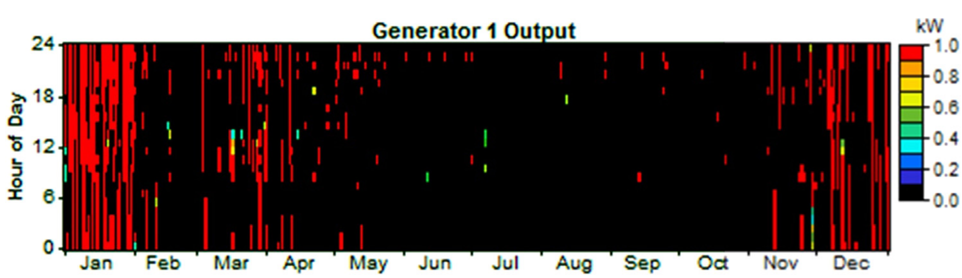

Fig. 14. Generator 1 output for Zabol.

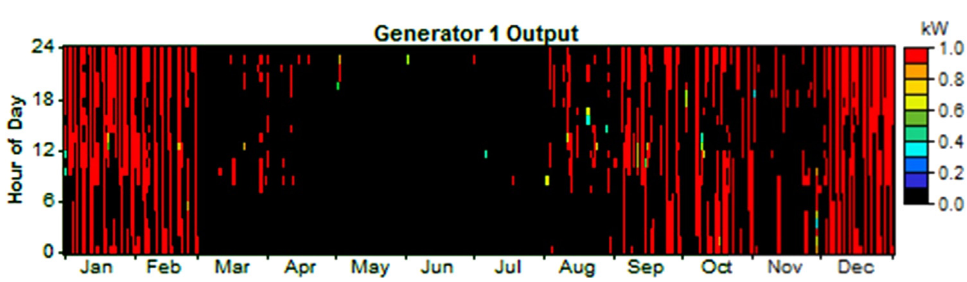

Fig. 15. Generator 1 output for Zahak.

Table 8
Emissions issued produced in this study for two cities.

Zabol		Zahak	
Pollutant	Emissions (kg/yr)	Pollutant	Emissions (kg/yr)
Carbon dioxide	1106	Carbon dioxide	1910
Carbon monoxide	2.73	Carbon monoxide	4.71
Unburned hydrocarbons	0.302	Unburned hydrocarbons	0.522
Particulate matter	0.206	Particulate matter	0.355
Sulfur dioxide	2.22	Sulfur dioxide	3.84
Nitrogen oxides	24.4	Nitrogen oxides	42.1

where in this formula tCO_2 is Amount of CO2 emissions, m_f is Fuel quantity (Liter), HV_f is Fuel heating value (MJ/L), CEF_f is Carbon emission factor (ton carbon/TJ) and X_C is Oxidized carbon fraction. A comparison for two cities from the point of view of pollutions amount by the Hybrid system has been shown in Table 8.

8. Conclusion

A comprehensive consideration associated with UN goals, Urban Themes habitat, and a techno-economic analysis to apply of solar and wind power in two cities of Zabol and Zahak presented in this study. Concerning suitable wind speed and high level of solar radiation in Zabol and Zahak cities, thus, 1 kW PV array, WES 5 Tulipo Turbine, Generator 1 kW and Surrette 6CS25P battery were chosen. From the electricity generation point of view, the amount of electricity production by PV array for Zabol and Zahak was obtained equal to 1700 (kWh/yr) and 1669 (kWh/yr), respectively. Also, the amount of electricity production by wind turbine for Zabol and Zahak was calculated to equal to 9036 (kWh/yr) and 7263 (kWh/yr), respectively. Also, generator produced 927 (kWh/yr) for Zabol and 1606 (kWh/yr) for the Zahak. From the economic point of view, the total net present cost for Zabol and Zahak were calculated equal to 28,076 $ and 31,873, respectively. Therefore, since significant parameters such as energy security and global warming are important for future, the long-term planning for investing in renewable energies and the creation of renewable power plants in these areas are suitable and will have a good economic justification.

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