Implementation of energy sustainability using hybrid Power Systems, a case study

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Abstract:

Without a doubt, many remote areas have a hidden potential of energy, which can be considered for electricity production. Indeed, energy supply for remote areas is one of the most critical targets of SDGs BY the 2030 year. Based on this explanation, this paper presents a techno-economic analysis of hybrid energy systems installable for two capital provinces of Iran, concerning SDGs targets. Firstly, a comprehensive investigation of SDGs and UN-Habitat III targets are described and then, concerning these targets and existing data gathered by the meteorological organization of Iran, a techno-economic analysis is conducted using Homer software. Regarding the high potential of renewable energies in Zahedan and Zanjan cities of Iran, implementing hybrid energy systems could be feasible for producing electrical energy as a correct policy and a good vision by policymakers and energy experts in the future. In this respect, a PV-Wind-Generator system is investigated in this paper for producing electricity in the two mentioned cities. Technical analysis of the solar energy for Zahedan is showing that the total amount of electricity production by the hybrid system is about 40,617 kWh/yr. In addition, the total amount of electricity production by this hybrid system for Zanjan is to equal 41,728 kWh/yr. Therefore, regarding this high potential of energy in these areas, investment on the solar energy for both cities has economic justification, while from the wind energy potential viewpoint, only Zahedan is proper for investment.

Keywords: Renewable energy, Hybrid system, SDGs, Homer software, Energy Sustainability

Nomenclature

CO_2	Carbon Oxide Emission
Mbtoe	Million Barrels Ton Oil Equivalent
NPC	Net Present Cost
PV	Photovoltaic
SDGs	Sustainable Development Goals
Habitat III	Housing and sustainable urban development

1. Introduction

Industrial activity by a human is lead to emission on of greenhouse gases, and it causes the global climate structure (Razmjoo et al. 2019, Bekhrad et al. 2018, Pazhoohesh, Shahmir, and Zhang 2015). These industrial activities by humans will be lead to more production of greenhouse gases during time (Asrari et al. 2012, Davarpanah and Mirshekari 2019, Zarei et al. 2019). Also, with greenhouse gas production, carbon dioxide amount increases and it hurts the environment (Ahmadi et al. 2019). For reducing greenhouse gas emissions amount, It is recommended to move toward energy sustainability, especially using more renewable energy resources (Khorasanizadeh et al. 2014)(Ghasempour et al. 2019, Davarpanah and Mirshekari 2019b, a Lokeswaran and Eswaramoorthy 2013). Renewable energies are most effective in sustainable urban development for entire community (Mohammadi et al. 2016). Nowadays, the utilization of clean energies has been a mandatory law in many countries, and these regard governments are trying to substitute these resources with fossil fuels (Qolipour et al. 2016)(Maleki, Pourfayaz, and Ahmadi 2016). Thus, changing clean energies with fossil fuels could reduce air pollution in the future (Razmjoo et al. 2019). Different types of clean energies are used for providing energy among which solar and wind energy are more known (Sami 2018).

1.1. Literature review

In the field of energy provided by clean energy in different areas, many types of research have been carried out that some of them are mentionable. For example, investigating the performance of the various hybrid systems for installation in Damghan, Iran (Mostafaeipour et al. 2016) and Northern Cyprus(Razmjoo and Davarpanah 2019, Alayat, Kassem, and Çamur 2018). Investigating different challenges of solar energy application in Iran such as energy security, energy access and energy approach for stakeholder(Dehghani Madvar et al. 2018). Analysis of two hybrid renewable energy systems to installation in coastal area(Kasaeian et al.2019).

1.2. Motivation

Since energy sustainability is a significant factor for sustainable development, the main contributions of this study can be briefly stated an investigation of the conditions of energy regarding SDGs and Habitat III to achieve energy sustainability. Thus in this research, the authors investigated the energy status of the two cities in Iran that have the proper potential of renewable energy resources. It has also made significant contributions to their development and proposing a practical approach. To expedite this action, all the worries have been stopped. It is because, unfortunately, many domestic investors, having misunderstood about the real potential of the renewable energy resource and payback time, are in danger of losing their money. In general, this study has three novelties. Firstly, investigates the SDGs and UN-Habitat III that in each of them the role of energy supply and renewable energy resource that is an important goal especially for inhabitants of the residential area. Secondly, it considers the global energy security challenges and energy gaps in developing countries. Finally, a renewable hybrid system is investigated for energy production for the residential area (Razmjoo and Davarpanah 2019).

1.3. The relation between the objective and new findings of this manuscript

Energy sustainability depends upon different factors, making it relevant from a broad range of topics(Razmjoo, Sumper, and Davarpanah 2019). Indeed, sustainable energy has become a significant global goal, and it is now one of the critical goals of the United Nations. Table 1 indicates the 17 targets of SDGs by 2030 towards sustainable development(Armin Razmjoo, Sumper, and Davarpanah 2019).

Table1. Targets of SDGs by 2030 towards the sustainable development

Indicators	**Economy**	**Environment**	**Social**
No poverty	√	x	√
Zero Hunger	√	x	√
Good health and well-being	x	√	√
Quality education	x	x	√
Gender Equality	x	x	√
Clean water and sanitation	x	√	√
Affordable and clean energy	√	√	√
Decent work and economic growth	√	x	√
Industry, Innovation, and Infrastructure	√	x	√
Reduced Inequality	x	x	√
Sustainable Cities and Communities	√	√	√
Responsible Consumption and Production	x	√	√
Climate action	x	√	√
Life Below Water	x	√	x
Life on Land	x	√	√
Peace and Justice Strong Institutions	x	x	√
Partnerships to achieve the Goal	x	x	√

Also, fourteen targets of UN-Habitat III (Alshehry and Belloumi 2015) indicated in Table 2 are the ones more involved with human life. Moreover, these targets are assigned in line with the sustainable development goals by the 2030 year.

Table 2. Fourteen targets of UN-Habitat III towards sustainable development

Indicators	Economy	Environment	Social
Legislation	x	x	√
Mobility	x	x	√
Housing & slum upgrading	x	x	√
Safety	x	x	√
Climate change	x	√	√
Gender	x	x	√
Planning & Design	x	x	√
Economy	√	x	√
Reconstruction	√	x	√
Resiliency	√	x	√
Human rights	x	x	√
Water & sanitation	x	√	√

Youth	x	x	√
Energy	√	√	√

Having taken into account the above descriptions, Table 3 shows the most essential energy indicators which are proper for urban areas and achieving energy sustainability.

Table 3. Energy sustainability indicators

Indicators	City	Energy
Electrical consumption	√	√
Enough investment	√	√
Energy Burden	√	√
Access energy	√	x
Loss of energy	√	x
New technology	√	√
Total final consumption in residential	√	√
Total renewable energy production	x	√
Reduction of CO_2 and GHG	√	√
Renewable energy potential	x	√
Energy affordable	√	√

2. Energy security (Challenges, obstacles and solutions)

Today, there are still many concerns and barriers to secure energy supply in many countries of the world, especially significant countries at the regional and national levels. Therefore, it is imperative to investigate the needs and problems of the stakeholders in this regard throughout the energy supply chain (Ang et al. 2015)(Bogoviz et al. 2018, Wang et al. 2018). Also, it should be an in-depth and different look at the growing interconnectedness between the local, regional and global levels. On the other hand, it should be tried to solve the existing problems and move towards realistic goals. More attention to the nature of the threats and opportunities in the energy sector mostly faces by the human being will help us to do the necessary measures to achieve the considered goals of securing energy, stabilizing the market, and designing a sustainable future for energy.

2.1. Energy security and energy gaps in developing countries

Without any doubt, the most crucial issue in the 21st century is energy. Since energy is directly related to security and development, examining the problems ahead and developing an appropriate strategy and effective policy could have a remarkable effect in improving energy and reducing a part of the required demands of inhabitants of different areas in developing countries(Porter and Kramer 2019, Azarova et al. 2019). Energy security can be considered as a continuous and reliable supply with reasonable prices in energy carriers. In other words, one of the critical issues in providing consumers with energy in developing countries is a program to identify the best and most appropriate carrier in each region, based on which the energy basket of the country is determined(Kassem, Gökçekuş, and Çamur 2018). Having a more diversified energy basket causes reducing in the country's reliance on a specific energy carrier which in turn increases the energy security and the possibility of maintaining and protecting energy sources. It can be added that the impact of energy correct policies on energy planning, economy and environment is inevitable(Kern, Kivimaa, and Martiskainen 2017, Davarpanah, Mirshekari, and Razmjoo 2019). Different fluctuations in Oil & Gas international marketing and political challenges in the oil exporters' countries have caused many problems for these countries and other dependent countries to energy. Since developing countries need a stable situation and energy security, renewable energies can be good solutions (Bakhtiar, Aslani, and Hosseini 2020, Hosseini and Wahid 2016). Therefore, investigating the mentioned challenges by policymakers can mitigate the problems (Iddrisu and Bhattacharyya 2015; Nie and Yang 2016; Davarpanah and Nassabeh 2017).

Besides, it can be mentioned that policymakers in most countries have a crucial role in moving society towards development. Thus, the type of policy should be considered in line with the priority of society and benefits them(Pfenninger 2017). Proper planning should be with the collaboration of experts that it does not hurt the community, but also help achieve sustainable development more rapidly. Hence, about the global issues, the concept of energy security should be expanded to different parameters such as the protection of the entire energy supply chain, improving the energy infrastructure and also exceptional attention to consumers as an essential duty of governments(Levinson 2019, Zhang, Wang, and Wang 2017).

2.2. Renewable energy and providing energy

Energy supply has high importance for different countries, especially for electricity generation. But now the primary source for electrical production is fossil fuels that it hurts the environment and has too much cost. In this regard, one reliable way for reducing different environmental problems and the supply of electricity is renewable energy utilization(Newbery 2016). Moreover, investment in the solar-wind hybrid systems will have economic justification in the long-term duration (Qolipour et al. 2017). Fortunately, now investing in renewable sources has increased in different areas in the world and it will be increased confidently (Maheshwari and Ramakumar 2017; Razmjoo et al. 2019).

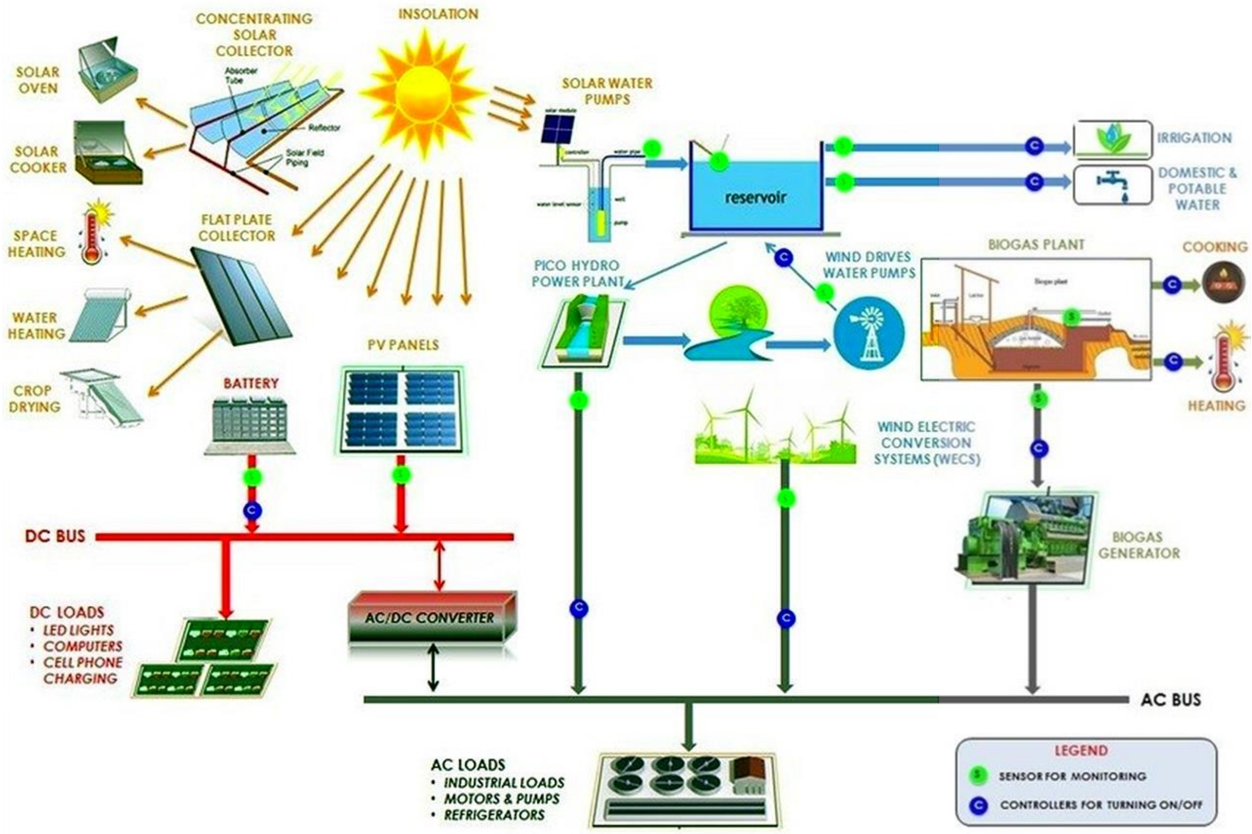

Figure 1.The critical role of renewable energies for achieving energy sustainability with an emphasis on reduction of CO_2 emission (Maheshwari and Ramakumar 2017)

2.3.Energy consumption status in Iran

Iran has a high rate of energy consumption each year. The most consuming sections in this country usually are industrial, transportation, agricultural and residential. The energy supply in this country is highly dependent upon fossil fuels that are the leading causes of air pollution(Jahangiri et al. 2019). Thus, an effective way for minimalizing this dependence is to use renewable energy potential that Iran has to produce a part of its required energy(Vahdatpour et al. 2017, Ebrahimi et al. 2019).

2.4. The renewable potential of Iran (Solar-Wind energy)

Potential of renewable energy of Iran country with about 300 sunny days and 4.5-5.5 kWh average solar irradiation is excellent. With this appropriate energy potential and proper planning by policymakers, this country could increase daily energy to achieve a nominal capacity of around 139,996 MW. Besides, Iran has excellent potential for wind energy. High potential areas such as Manjil, Binalud, Zabul, and Zehak are the appropriate locations for exploiting wind energy. The total amount of wind energy estimation for this country has been estimated by the SUNA organization that in this regard the total capacity of Iran's wind-driven energy is evaluated to be around 6500 MW(Razavieh et al. 2017). Figure 2 demonstrates the solar irradiance and wind speed potential Maps of Iran.

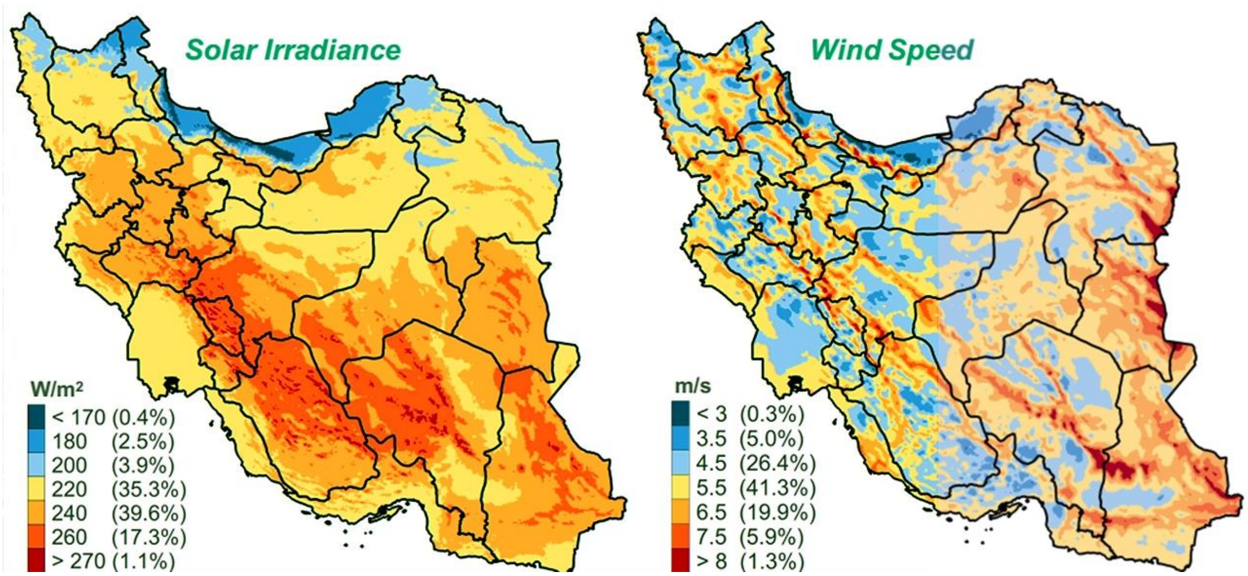

Figure. 2. Solar irradiance and wind speed potential Maps of Iran

3. Case studies

This paper investigates two cities in Iran with the potential of producing renewable power generation and in the line of Energy Sustainability. The two studied cities are located in two different areas. Also, Figure 3 shows the wind speed potential data for studied cites.

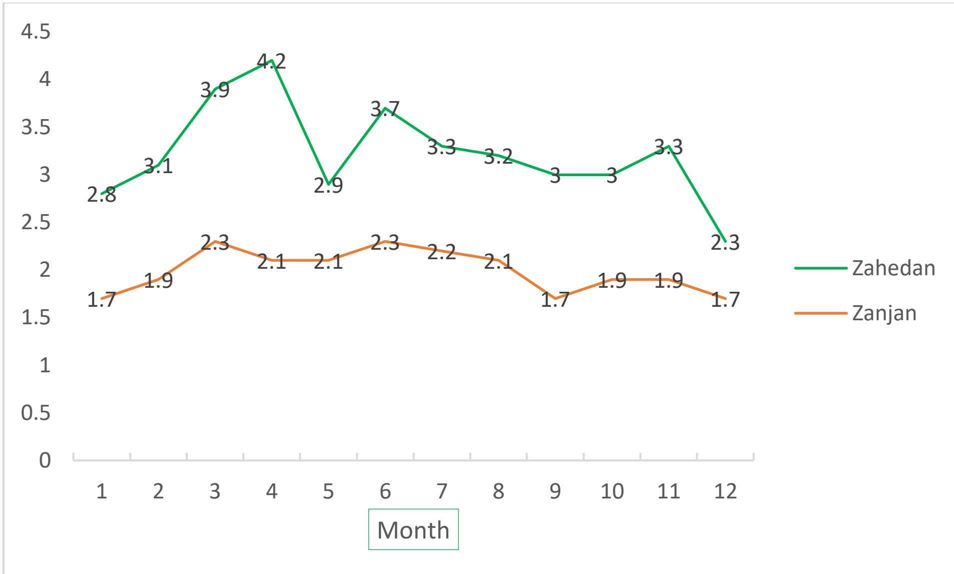

Figure 3. The values of wind speed in different moths of a year for Zahedan and Zanjan cities

Fig 4 shows the horizontal irradiation values in Zahedan city. The highest level of solar irradiation is 6.960 kWh/m^2/d per square meter in June and the lowest level is 3.330 kWh/m^2/d in December.

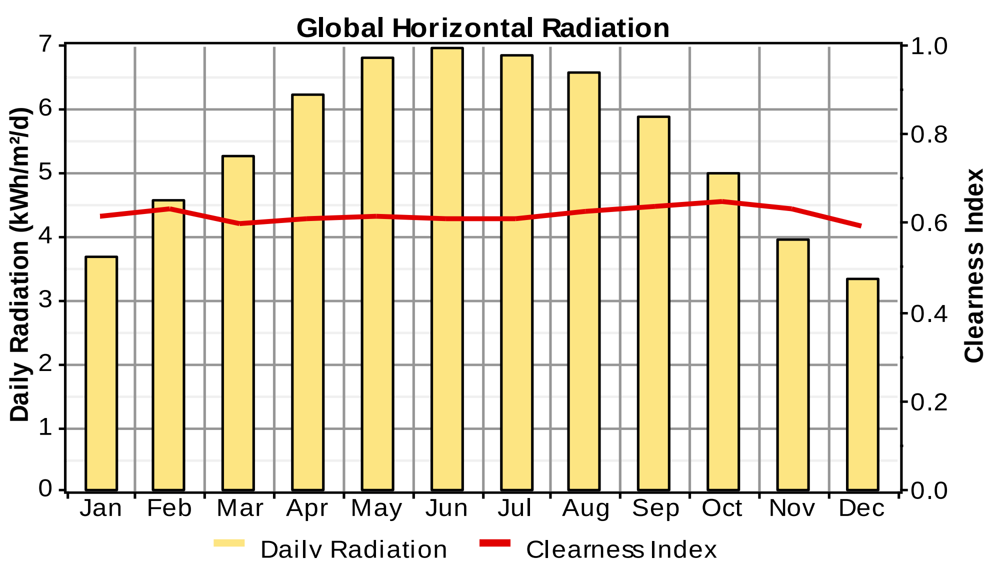

Figure 4. Global horizontal irradiation for Zahedan city

Additionally, the horizontal irradiation values of Zanjan city has been demonstrated in Figure 5. As this Fig shows, the highest amount of solar irradiation is 7.860 kWh/m^2/d in June, and the lowest values are 2.126 kWh/m^2/d, in December.

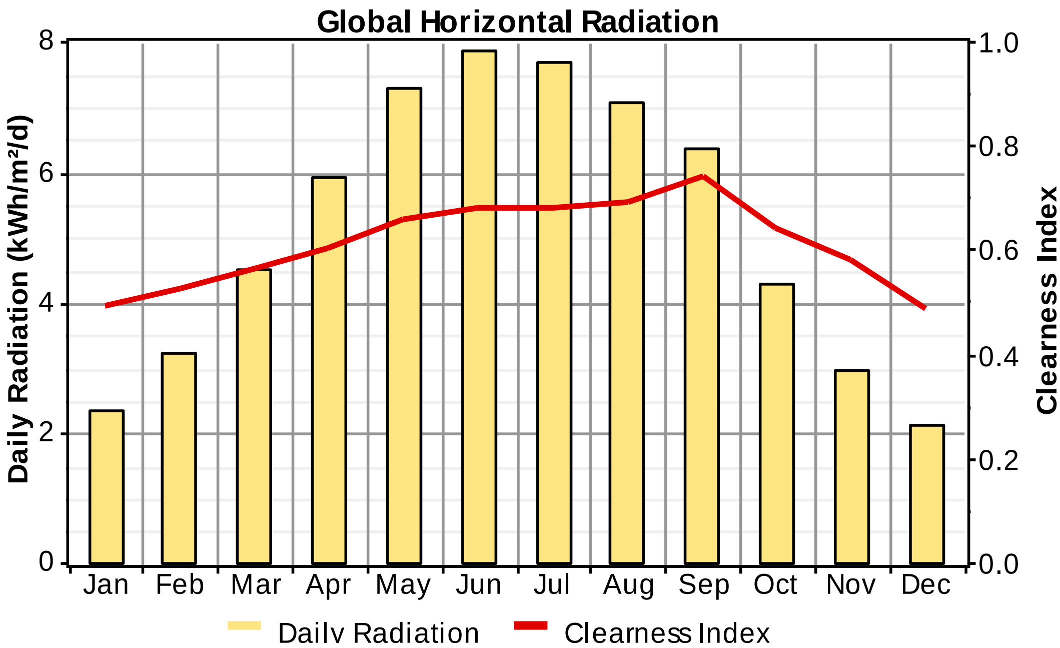

Figure 5. Global horizontal radiation for Zanjan city

4. Methodology

Energy sustainability investigation concerning SDGs has been carried out for two cities in Iran. The Homer software has been used for techno-economic analysis of the study areas. Firstly, the SDGs and energy indicators are considered for the cities, and afterwards, using the related data a hybrid system is analyzed and simulated for the sake of energy production. The associated data was gathered from the Meteorological Organization that presents newly updated data each year. These data are analyzed by Homer software and results are obtained as the output of the Homer and are analyzed technically. This paper emphasizes that renewable energy developing is one of the best actions to achieve energy sustainability.

5. Result and discussions

5.1. Technical analysis

Production of electricity is a crucial factor to develop a country and for do this; renewable energy could be used as a reliable source. Assessing the wind and solar potential by energy-related software is a well-known method that can help the researcher estimate the amount of usable energy in an area. The technical-economic analysis using homer software has been performed for this study. In this regard, Table 4 shows the technical specifications as the breakdown for the PV-

Wind- Generator system. As can be seen, the amount of electrical producing that is the main issue in this paper by the PV system is 12,205 kWh/yr amount, by the Wind turbine 3 kW is 2,769 amount and by the Generator is 25,643 kWh/yr amount. It means that among these systems, Generator has most electrical production percent.

Table 4. The technical specifications for each component of system breakdown for Zahedan

PV	PV penetration (%)	Mean output (kW)	Capacity Factor (%)	Electrical production (kWh/yr)
	39.3	1.39	19.9	12,205
Wind turbine 3kW	Hours of operation (hrs/yr)	Mean output (kW)	Total rated capacity (%)	Electrical production (kWh/yr)
	5,382	0.316	6.00	2,769
Generator	Hours of operation (hr/yr)	Number of starts (starts/yr)	Fuel energy input (kWh/yr)	Electrical production (kWh/yr)
	7,329	383	103,64	25,643

Also, table 5 demonstrates this analysis for Zanjan city. It is clear from Table 5 that, the PV system, Wind turbine, and Generator system has 20,555 kWh/yr, 1,190 kWh/yr and 19,983 kWh/yr has electrical production respectively. Indeed, the PV system producing more amount of electricity than two other systems in this city.

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

PV	PV penetration (%)	Mean output (kW)	Capacity Factor (%)	Electrical production (kWh/yr)
	65.3	2.31	19.3	20,555
Wind turbine 3 kW	Hours of operation (hrs/yr)	Mean output (kW)	Total rated capacity (%)	Electrical production (kWh/yr)
	5,181	0.136	3.00	1,190
Generator	Hours of operation (hr/yr)	Number of starts (starts/yr)	Fuel energy input (kWh/yr)	Electrical production (kWh/yr)
	6,404	404	102	19,983

5.2. Electrical production analysis

Figure 6 shows the electricity production in different months of a year by the PV and generator 1. In this Figure, the generator has a high percentage of electrical power than other sectors. August month from the two aspects of energy production (PV, Generator) then additional months will have more efficiency in the Zahedan city.

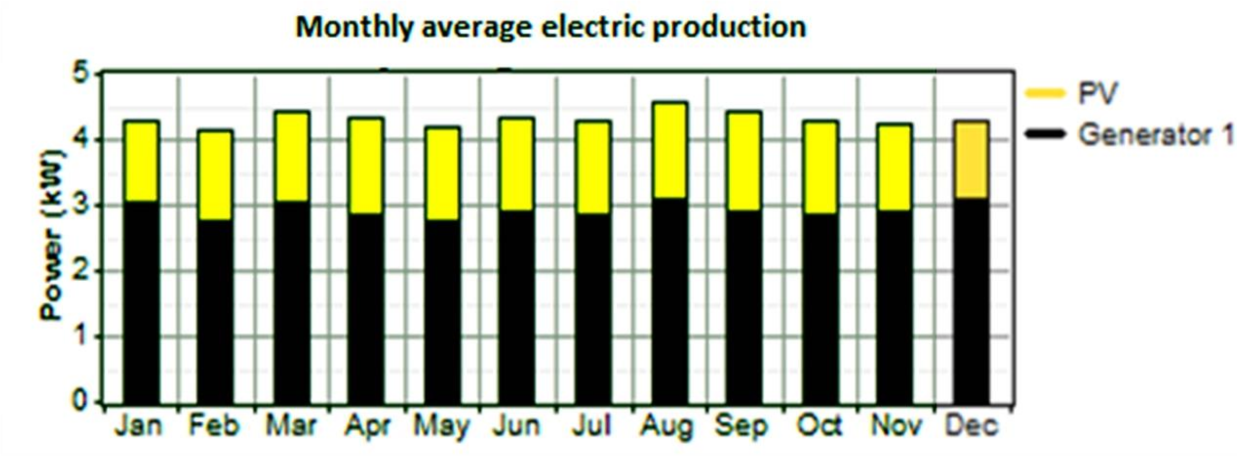

Figure 6. Electric production by PV-Generator system in different months for Zahedan city.

Figure 7 indicates the electricity production in different months of a year by the PV and generator 1. As can be seen, September month from the two aspects of energy production (PV, Generator) for the Zanjan city than other months will have more efficiency generally.

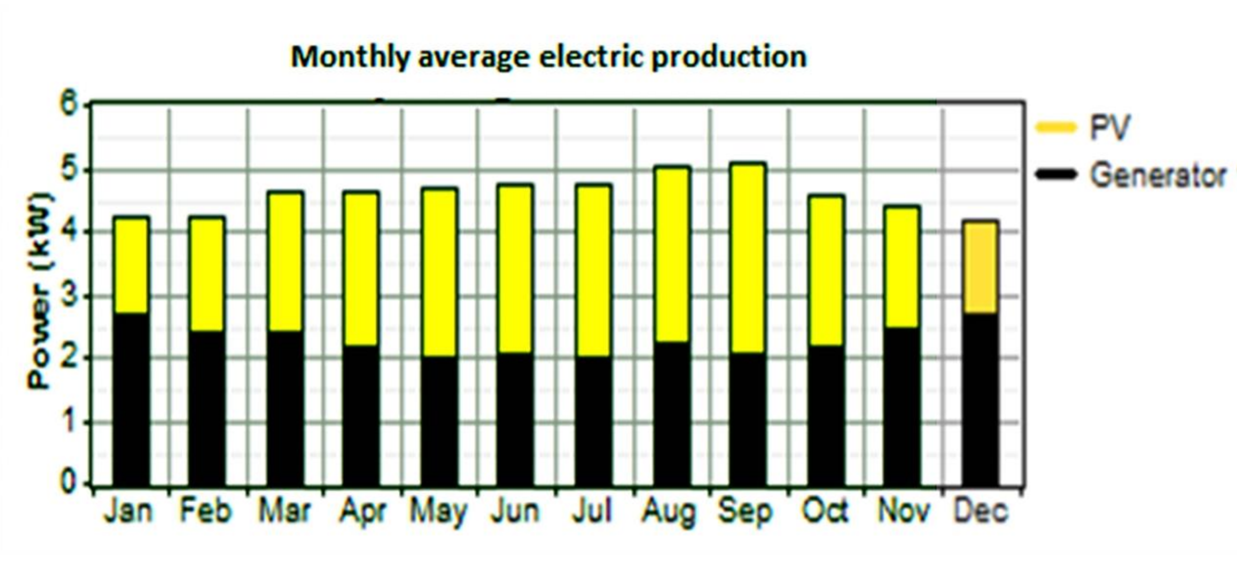

Figure 7. Electric production by PV-Generator system in different months for Zanjan

The electricity production in different months by Wind-Generator is shown in Figure 8 in Zahedan city. It is evident from figure 8 that in August month, energy production performance via Wind turbine and Generator systems is higher than in other months.

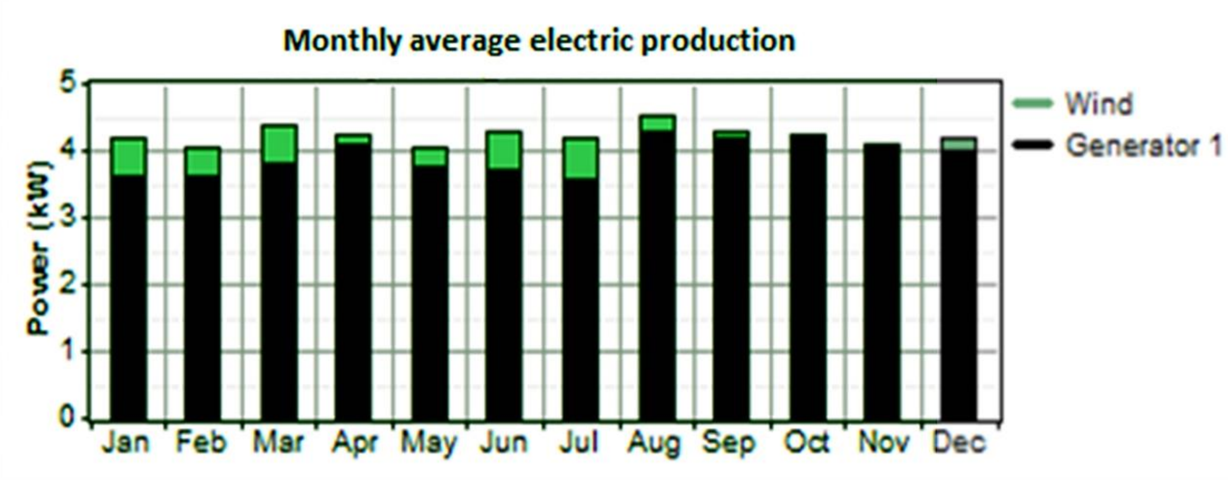

Figure 8. Electric production by Wind-Generator systems in Zahedan city

Also, Figure 9 shows electricity production by the Wind-Generator system in Zanjan city. In this figure, August month from the aspect of energy production has more efficiency than other months generally.

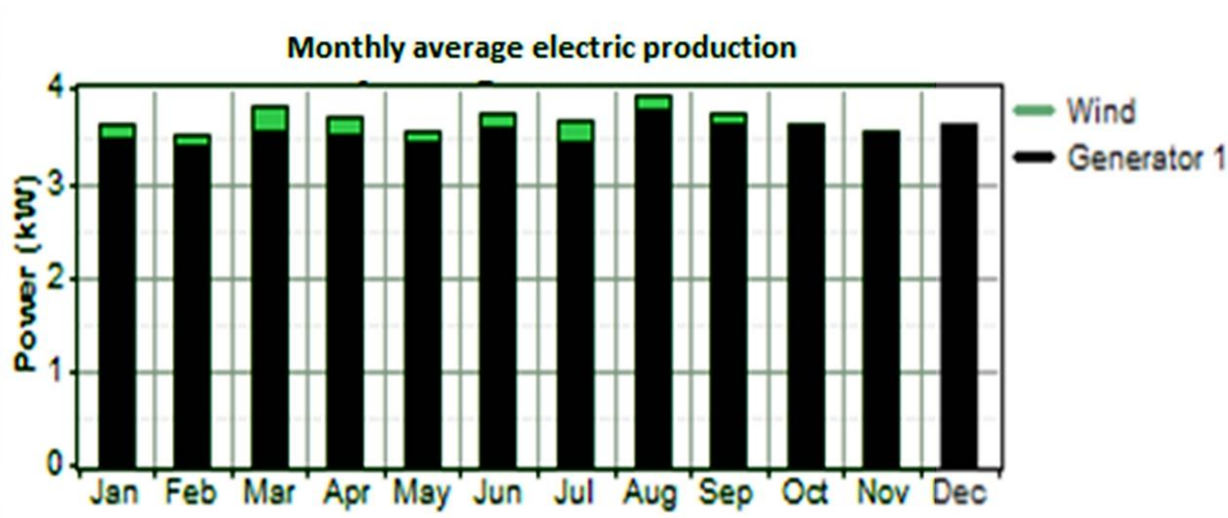

Figure 9. Electric production by Wind-Generator systems in Zanjan city

Figure 10 shows the power output of generator one ranging from 0.0 to 12 kW h/d in Zahedan city. As can see, the performance of the Generator is not 100 %, and it is due to fluctuations that there is in this system.

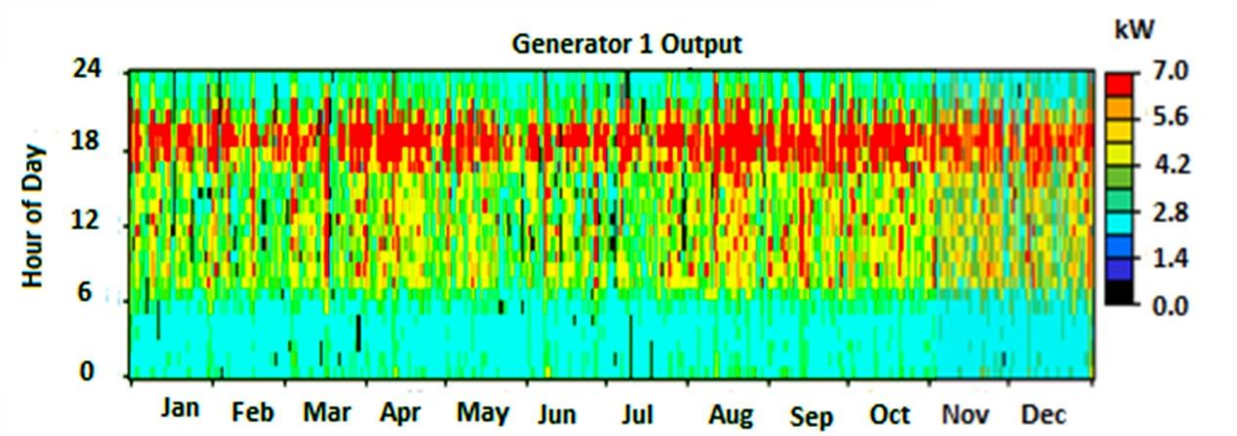

Figure 10. The power output of generator 1 in Zahedan city in different months

Figure 11 indicates the power output of generator one ranging from 0.0 to 12 kW h/d in Zanjan city. As usually in each system, there are especially fluctuations due to different problems; thus, the performance of the Generator Output is not 100 % in this system for Zanjan city.

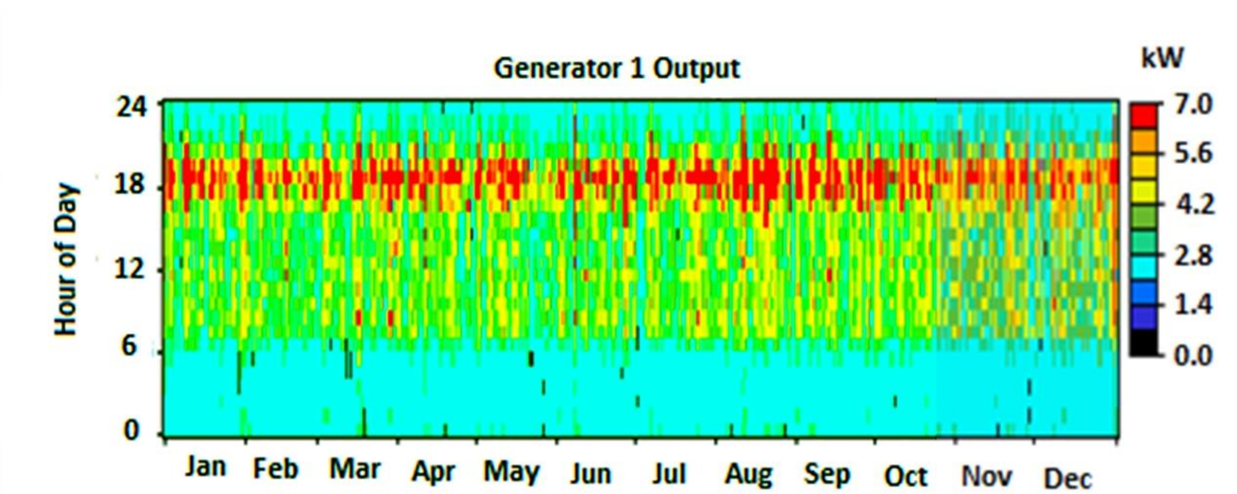

Fig 11. The power output of generator 1 in Zanjan in different months

Table 6 represents the specifications of the battery system. As can see, the amount of nominal capacity of Zahedan with 15,8 kWh is more than the amount of nominal capacity of Zanjan that is 9,24 kWh and.

On the other hand, the amount of losses of the battery for Zahedan is 174 (kWh/yr) and for Zanjan 84.4 (kWh/yr). It shows, for Zanjan city the amount of losses of battery is lower than Zahedan city in Homer simulation. Also, Zahedan city with 780 kWh/yr annual throughput by the battery will have a better situation than Zanjan city with 378 kWh/yr.

Table 6. Specifications of the battery system.

City	Strings in parallel	Bus voltage (V)	Nominal capacity (kWh)	Losses (kWh/yr)	Annual throughput (kWh/yr)
Zahedan	24	12	15,8	174	780
Zanjan	14	12	9,24	84.4	378

Table 7 shows the specifications of generator 1 with the number of hours of operation, the number of starts, the operational life, the capacity factor, the electricity production, and the mean electrical output. The total electricity production by generator for two cities is remarkable and about 65,000 kWh/yr.

Table 7. Specifications of generator 1 system

Zahedan	Hours of operation (hr/yr)	Number of starts (starts/yr)	Capacity Factor (%)	Electrical production (kWh/yr)
	8,625	76	55.9	34,262
Zanjan	Hours of operation (hr/yr)	Number of starts (starts/yr)	Capacity Factor (%)	Electrical production (kWh/yr)
	8,725	28	50.5	30,983

5.3. Economic analysis

The overall analysis of the NPC for this hybrid system demonstrates that the significant part of the expenses among these components belongs to the generator with values of $37,126 for Zahedan and $61,807,126 for Zanjan. Also, the lowest total lifetime expense in this system is related to the converter with $743 for Zahedan and $1,188 for Zanjan. Moreover, the maximum cost to implement this system is equal to $65,237 for Zahedan and equal to $79,624 for Zanjan(Mall, Srivastava, and Agarwal 2006)(Mall et al. 2006).

6. Conclusion

Electrical production by hybrid systems can be investigated and ran in many remote areas, and it is one of the most critical targets of SDGs by the 2030 year because it increases access of energy of inhabitants in these areas. Thus, discovering high potential areas should be considered by policymakers and energy experts that have more concern of energy supply in the future than others. Since Zahedan and Zanjan cities have high solar radiation average about 6.960 and 7.860 kWh/m2/d respectively and an average proper of wind speed, thus a technical analysis for electrical production by a hybrid system was carried out for these cities in this study and the line of Energy Sustainability. In this regard, technical analysis of the solar energy For Zahedan showed, the total amount of electricity production by this hybrid system was obtained 40,617 kWh/yr that 12,205 kWh/yr has belonged to the PV system, 2,769 kWh/yr amount of this was from wind turbine and 25,643 kWh/yr was from the generator. Among these, Generator has the highest production amount than other producers. Also, the total amount of electricity production by this hybrid system was obtained to equal 41,728 kWh/yr for Zanjan that 20,555 kWh/yr belonged to the PV system, 1,190 kWh/yr was from Wind turbine, and 19,983 (kWh/yr) was from the generator. It means that among these producers, the PV system has the highest production amount. In general, with this analysis, it can be expressed that hybrid systems can provide a part of the required energy for residential areas especially in remote areas. Therefore investment on it will be lead to achieving energy sustainability and has economic justification in the future.

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