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Research Article

Simulation of Biogas Utilization Effect on The Economic Efficiency and Greenhouse Gas Emission: A Case Study in Isfahan, Iran

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ABSTRACT. Biomass is a type of renewable energy that, in despite of its potentials and advantages including simple production technology, decreasing environmental issues, and energy generation capacity at the consumption site, has not been sufficiently utilized in Iran. Since, due to statistics, Isfahan enjoys remarkable prospects in terms of wind, solar and biomass energies, a combined system of indigenous energy sources for powering a cattle farm has been investigated and evaluated in this study. To evaluate the possibility of the optimal system for comparative reasons, the HOMER software was used. The designed hybrid system was a wind-solar-biomass generator that used a battery saver as backup. Although it seems that wind and solar energies have the highest potential for energy generation in Isfahan, the results showed that biomass, by itself, can provide the required power for a cattle farm. In fact, biomass energy was more economically efficient than wind and solar energies. Owing to the low electricity cost, generated from fossil fuels, in Iran, relative to a large number of countries, the findings revealed that using biomass for generating the electricity of a cattle farm will compensate the expenses by the mid-15th year and will generate profit for 9.5 years later. The results also showed that the solar cell-based hybrid system is cheaper than the wind turbine-based one. Regarding the price of per kWh of electricity produced, the results showed that the biomass generator system with the price 0.12 $/kWh is the cheapest, and the solar cell-based and wind turbine-based hybrid systems are 3.33% and 10.83% more expensive, respectively. The results can be used for electricity generation with minimum pollution and expenses in the same regions.

Keywords: Cattle dung; HOMER; Hybrid energy systems; Investment return; Biogas; Isfahan; Greenhouse gas; Economic.

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1. Introduction

Currently, the potential risk of greenhouse gas emission and climate change are clearly indicative of a need to decrease reliance on fossil fuels (Haghighi Bardineh *et al.* 2018; Wang *et al.* 2019). In 2008 it was stated that if the present energy consumption trend continues, the limited coal, petroleum and natural gas resources will be run out in 122, 42 and 60 years, respectively (Lior 2008). Of the overall energy demands, the fossil fuel's share is 80%, while nuclear and renewable energies account for the remaining 20% (Rout, 2007). In 2005, a total of 26.6 billion tons of CO_2 was produced, of which 41% was due to power generation by fossil fuels. Based on research, this amount will reach to 44.8 billion tons by 2030 (IEA 2007). Also, it is estimated that CO_2 emissions according to electricity generation would increase by 46% until 2030 (Mondal and Denich 2010). There are two approaches to energy generation; an unstable approach with a heavy dependence on fossil fuels or nuclear energy leading to serious pollution issues and the disposal of radioactive waste; and a stable approach relying on the utilization of renewable resources (Dabrase and Ramachandra 2000). Environmental risks, reduced fossil fuel resources and never-ending rise in natural gas, petroleum and electricity costs have led to increasing attention to renewable energy consumption as clean, infinite, unlimited and environmentally friendly energy resources (Ahmadi *et al.* 2018a; Ramezanizadeh *et al.* 2018a; Rezaei *et al.* 2018). Researchers suggest that proper energy consumption with reasonable costs is a key

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factor in the advancement of countries (Mondal and Denich 2010; Maherchandani *et al.* 2012; Ahmadi *et al.* 2019). Therefore, clean and affordable energy resources should be paid attention to by countries wishing progress.

Most of Iranian cities, in general, and Isfahan, in particular, have decent solar, wind and biomass energy resources (Jahangiri and Shamsabadi 2017; Jahangiri *et al.* 2019). Isfahan receives 5.34 KWh/m^2.d of solar energy on average (Jahangiri *et al.* 2018b). Moreover, its average wind speed is 2.6 m/s and a daily 250 tons (7500 tons a month) of waste is collected and piled up in Isfahan. In addition, due to studies by the authors of the present paper, an approximate 3510155.25 tons of animal dung is produced in Isfahan Province on a daily basis. Despite its decent potential in renewable energies, no clear-cut methodical research has yet been done in Isfahan to evaluate the degree of this potential for electricity generation. Therefore, this study aims to evaluate electricity generation using renewable energy resources in a cattle farm of 5 hectares with 1000 cattle by HOMER software.

According to their economic importance and environmental effects, many researchers have investigated renewable energies. Some have done a number of studies in different regions and for different applications, using the HOMER software and a combined system. They have considered different combinations, based on regional demands and the availability of energy resources. One study in this field is the evaluation of the potential of renewable energy resources for electricity generation in Bangladesh indicated that a consistent and uniform planning approach is required in the form of energy policies to encounter technological, economic, social and political obstacles (Mondal and Denich 2010). Since transferring power to villages and isolated regions is a recurrent challenge in a lot of countries, Maherchandani *et al.* (2012) evaluated the economic feasibility of the utilization of a combination of biomass, photovoltaic (PV) and wind in these regions. They revealed that, based on the potential of Indian villages, a combinational use of these energies leads to a fall in prices and greenhouse gas emission. They estimated the cost of each Kilowatt hour electricity production at \$0.037. Since only 38% of people in Bangladesh have accessed to electricity, Islam and Mondal (2013) have also evaluated the potential of electricity generation from vegetable biomass in different regions of Bangladesh. In another research done on electricity generation in Ireland, it was shown that the wind energy followed by hydropower (in mountainous regions) has the highest potential for electricity generation in this country in both states of being connected or separated from the electricity network system. In this study, the cost for each Kilowatt hour of electricity was estimated at 0.24 and \$0.074 for combinational independent systems and hybrid systems connected to the network, respectively.

Some researchers have examined the feasibility of PV and biomass utilization in Australia using the HOMER software. They showed that the combinational use of grid, solar, and biomass is economically efficient with a cost of \$971,377. The estimated price for each Kilowatt-hour of electricity generated by this system was 0.129 dollars (Karimi and Moride 2013). In another study, a combination of biomass energy and PV for generating a house's electricity in an isolated region in India was studied. Results revealed that the utilization of this system could be initially costly, but frequent and wide use of this technology could decrease the costs. Due to the findings of this research, with a 50% state subsidy, capital cost will return in approximately 6 years (Kumar, 2013). Among other studies on the combinational utilization of solar, wind and biomass energies, a study by Pradhan et al in 2013 is worth mentioning. this research, two combinations were examined in both states of connected and non-connected to the electricity network system, demonstrating that the combinational system in a non-connected state costs 17.3 times more than the connected state. Researchers in this study believed that this design could be initially expensive, but costs could be lowered and the system could be transformed to a cost-effective one through wider and industrialized applications. In a study, Nguyen et al. (2014) evaluated the potential of biomass for electricity generation in Vietnam using computer software. Results clearly showed that the use of biomass in place of diesel for electricity generation would have substantial economic benefits according to the availability of biomass in Vietnam. Furthermore, greenhouse gas emission and subsequent destructive effects on the environment would be reduced (Sahu et al. 2013). Since electricity generation is of paramount significance for developing countries, Jahangiri et al. (2015) examined the technical and economic aspects of fuel cell utilization for electricity generation in such countries. Results showed that, due to poor performance and high initial costs, the use of fuel cells for electricity generation does not lead to satisfactory results in Khorramabad or similar cities in developing countries. On the other hand, using a combinational system of wind and solar energies along with a diesel power generator will be cost-effective (Nguyen et al., 2014). In a study, Ahmed et al. (2015) studied a combinational system of solar and biomass energies for generating the electricity of a village (100 families, 10 stores) in Bangladesh. In this study, the optimum approach was a combinational use of solar and biomass energies with an estimated total cost of 159,864.92 dollars (12,469,464 BTD) which will be cost-effective during the system life (25 years). According to this research, the electricity generation costs by renewable energies (0.1370 \$/kWh) will be almost halved compared to conventional electricity generation methods. In 2016, Sarker investigated the feasibility of electricity generation by gas generators and renewable energies (solar and wind) for a house; the results suggested that not only does this system lead to a reduction in CO_2 emissions by 22,626 kilograms annually, it will achieve economic efficiency. Noor et al. (2016) also examined the feasibility of using solar energy for supplying the electricity of telecommunication towers in Malaysia by HOMER software; they demonstrated that the proposed system has better reliability, efficiency, planning flexibility and environmental benefits than the diesel generator systems with fossil fuels. In this study, the proposed system by the software can save 3.5 kilowatts of energy. Electricity generation costs for the tower will be 39911.04 dollars (610639 RM), without the diesel generator, and 27532.28 dollars (421244 RM) with the diesel generator. Nacer *et al.* (2016) evaluated the possibility of using renewable energies (solar and wind) in dairy farms of Algeria and showed that the proposed system is capable of producing an annual 136-Gigawatt hours of electricity and it simultaneously leads to the reduction of greenhouse gas emissions by up to 80 million tons. In one study, Salehin *et al.* (2016) modelled an optimized combinational energy system for the island of Kutubdia Upazila in Bangladesh in which they used solar and wind energies along with a biogas generator. The designed system consisted of 28 Kilowatts of solar panels, 30 Kilowatts of wind turbines, 8 Kilowatts of biogas generator systems and 9 Kilowatts of diesel generators. The electricity and initial costs were estimated at 0.42 dollars per Kilowatt-hour and 199,541 dollars, respectively. In addition, Chauhan and Saini (2016) explored the economic efficiency of renewable energy utilization for isolated regions. Due to their results, the Indian government is rich in renewable energy resources. So, the utilization of these resources, in place of electricity grids, for the distant production of the required electricity for rural families is cost-effective and efficient. Based on another study on electricity generation in an isolated region in India, it was suggested that integrated renewable energies are capable of providing a practical solution (Rajanna and Saini 2016). Since the potential of wind and solar energies is not equal in different regions, Al Busaidi *et al.* (2016) have compared these two resources in Oman and introduced an optimal approach in their study. In addition, Park *et al.* (2016) showed that the utilization of solar and wind energies has the highest potential for reducing costs in South Korea and considerably reduces the greenhouse gas emission. In another study, electricity generation by renewable energies for one of the largest urban counties in South Korea was simulated. In this research, system components (including photovoltaic panels, wind facilities, converter and battery), limitations and practical consequences of this study were examined (Baek *et al.* 2016). In a study, Hosseinalizadeh *et al.* (2016) studied renewable energy systems (wind, solar and fuel cells) for four regions in Iran. Results suggested that the use of combinational systems in these regions, particularly wind-solar systems, is cost effective and the fuel cells are not cost-effective due to initial and replacement costs.

Additionally, one study examined the feasibility of using solar and biomass energies in providing electricity for a farming field in Kerman and it was suggested that the utilization of a combinational system of biogas and solar energies is more cost-effective than single energy systems in this region (Heydari and Askarzadeh 2016). In addition, in a study by Khavari *et al.* (2016) the combinational energy systems for an isolated region in Iran were evaluated. This study revealed that the combinational diesel-wind system is the most efficient system for some of the isolated regions. In another research, Ribeiro *et al.* (2016) focused on the major contributing factors to renewable energy production in two Brazilian cities. Results showed that the characteristics and structure of the site and region are contributing factors to production. In one study, the potential of major renewable energy resources (wind and solar energies) were examined in different locations of 6 geographical and political regions in Nigeria. Moreover, the technical and economic feasibility of utilizing photovoltaic, wind and diesel energies in combination with battery storage systems was examined for a rural medical center in the selected sites. Results indicated that two sites were capable of using wind energy and all sites were capable of using solar energy. Additionally, simulation results by HOMER showed that the hybrid system will be the best option for all the sites under study (Olatomiwa *et al.* 2016). In another research, the electricity generation costs for a rural health center using a system based on fuel cells via the national electricity grid were compared. The results indicated that not only is renewable energy utilization cost-effective, but it may be economically profitable (Munuswamy et al., 2011). The present study analyzed, for the first time, a range of available energies in a cattle farm in Isfahan City in a combinational approach (biomass, wind and solar).

2. Materials and Methods

In this research, indigenous renewable energy sources, their daily and seasonal changes, along with the electricity demand for the cases understudied were identified and subsequently the optimal combinational energy system for a cattle farm in Isfahan was evaluated. Wind and solar energy data in this province were collected from the Renewable Energy Organization of Iran (SUNA) and, additionally, the biomass data were obtained from relevant articles and field observations. In this paper, optimal modeling with a combination of renewable energies was conducted by HOMER software. This software was selected for the comparison of energy sources, feasibility study and presentation of the most optimal approach. HOMER has been designed for meeting such challenges as the periodicity of seasons and unpredictable issues in renewable energies. This software considers the technical and economic capabilities of the combinational system's components and ultimately provides a comparative analysis of the feasible options in economic terms (Lambert *et al.* 2016). HOMER is additionally capable of comparing the input data by the user (Prasad *et al.*, 2012). In case there is a deficiency of electricity generated by these energy sources, the software allows defining a supplementary electricity generation method, such as diesel generators or the national electricity network. In addition, other aspects including durability and annual greenhouse gas emissions are considered in this system (Lambert *et al.* 2016).

3. History of biogas in Iran

The history of biogas production from cattle dung dates back to the early 19th century. In 1808, a person named Humphry Davy produced 0.3 liters of methane by fermentation of cattle dung and distillation (Joshua *et al.* 2014). In Iran, the Sheikh Bahaei hammam (late 16th to 17th centuries) was probably the first hammam warmed by methane. Yet, the first modern methane digester in Iran was built in the village of Niazabad, Lorestan in 1975. In 1982, a 3 m^3 unit was studied at Sharif University of Technology. During 1982-1986, the Research Center for Renewable Energies in the Atomic Energy Organization of Iran conducted a number of studies in this field including the construction of 10 biogas units in the provinces of Sistan and Baluchestan, Ilam and Kurdistan. In 1980s, the Ministry of Construction Jihad also took some measures in this field. In 1984, an experimental unit was initially constructed in Heydarabad, Karaj. Subsequently, a practical unit was constructed in a village in Gorgan in 1985. This ministry constructed 40 more digesters in different regions of the country, of which 18 units reached the gas production stage. Universities and research centers have also taken some steps in this field; including a unit constructed by the Academic Center for Education, Culture and Research of Agricultural University of Karaj during 1984-1986 and a unit constructed in Shahin Dej, West Azerbaijan in 1993. The latest constructed units consist of a biogas unit for sewage digestion in Kish Island and a unit for cattle dung distillation in Mahdasht, Karaj, which both have been designed and constructed by the Atomic Energy Organization of Iran during 1998-1999 (Soufi and Saleh 2015).

4. The studied region (Isfahan Province, Iran)

Iran is a country located in south west Asia in the Middle East. With an area of 1,648,195 square kilometers, Iran has an approximate population of 77,189,669 according to a 2013 national census. Iran borders the republic of Azerbaijan, Armenia and Turkmenistan to the north; Afghanistan and Pakistan to the east; and Turkey and Iraq to the west. It is bordered by the Caspian Sea to the north; and by the Persian Gulf and Gulf of Oman to the south. The temperature difference between the hottest and coldest regions in winter reaches above 50°C on occasion. In 2004 and 2005, the hottest place on earth was a site in Dasht-e Loot in Iran (Jafari *et al.* 2018). Isfahan province is located in the center of Iran at 32° 39' N and 51° 40' E (Figure 1).

Fig. 1 The location of Iran and Isfahan.

Cattle husbandry is a mainstream industry in the central regions of Iran, and the energy of the resultant dung can be utilized for electricity generation (Zareei 2018; Pishkar *et al.* 2017). Due to a number of studies by the Statistical Center of Iran in 2013, there are 1,365,935 adult and young cattle in industrial cattle farms in Iran, of which 7.65 percent were purebred, 6.27 percent were mixed breed and the rest were of indigenous breeds. After Tehran, Isfahan has the largest number of cattle (194,898), of which 131117 are purebred, 62,446 are mixed breed and the rest are of indigenous breeds. According to researchers, different breeds produce different amounts of dung. In fact, purebred, mixed breed and indigenous cattle produce 20.25, 13.5, and 9 tons of annual dung, respectively. Considering the difference in the amounts of dung produced by different cattle, the overall annual cattle dung produced in Isfahan reaches 3510155.25 tons (Table 1).

Fig. 2 Images of the exterior and interior of the cattle farm building.

Table 1
Number of cattle in the Iranian provinces

Province	Number	Province	Number
Azerbaijan E	32463	Fars	98497
Azerbaijan W	18317	Qazvin	65925
Ardebil	19460	Qom	60601
Ishahan	194898	Kordestan	4287
Alborz	60081	Kerman	37596
Ilam	3236	Kermanshah	
Boshehr	13647	Kohgiluyeh and Boyer-Ahmad	4973
Tehran	299875	Golestan	23370
Chaharmahal and Bakhtiari	22914	Gilan	4004
Khorasan S	9225	Lorestan	11606
Khorasan Razavi	112909	Markazi	75997
Khorasan N	6623	Mazandaran	23882
Khozestan	18251	Hormozgan	1715
Zanjan	12977	Hamedan	16084
Semnan	37570	Yazd	53764
Sistan and Baluchestan	5738	**Total**	1365935

In the present study, the potential for electricity generation at a cattle farm in south east Isfahan was studied. The cattle farm under study had an area of 5 hectares. It incorporated several buildings including the administrative unit, warehouses, steel warehouses for keeping the cattle, milking facilities, cold storage facilities, refinery and mill (Figure 2).

5. Combinational system

Researchers believe that the independent combinational system is an appropriate approach toward generating the needed electricity (Giraud and Salameh, 2001; Wang and Singh, 2007). Paska et al. (2009) defined a hybrid energy system as one of the electricity generation units with a wide range of renewable and non-renewable initial energy sources. The electricity generation system with renewable energy sources can save electricity for consumer demand and reduce costs (Kaldellis et al., 2010; Pradhan et al., 2013). For instance, in a cloudy day when the solar panels are producing very little levels of electricity, the wind and biomass generators can compensate for the power by generating electricity (Sahu *et al.*, 2013). Using the distributed renewable energy systems can partially decrease related damages (Singh and Goswami, 2010) and negative environmental effects (Banerjee and Islam, 2011) to electricity generation. This system is also appropriate for isolated locations with no access to electricity (Shiroudi *et al.*, 2011).

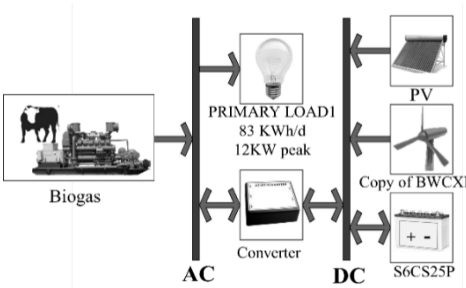


Fig. 3 The intended combinational system.

In the present paper, a combinational system of renewable energies (solar and wind) with a biogas generator was designed. In this examination, photovoltaic solar panels and wind turbines were used to supply the renewable energy source, and biomass sources were utilized for biogas production, which can be observed in the following Figure 3.

5.1 Electrical load

The primary areas of the cattle farm under study included the administrative unit (electrical equipment including compact fluorescent lamps, an evaporative cooler, a computer and a refrigerator), milking section (operating in 3 two-hour periods for 48 cattle in each 24 hours), cold storage facilities, refinery (operating daily with 3 ten-kilowatt motors), mill (operating every day from morning to noon) and steel warehouses for keeping the cattle (with ceiling fans and compact fluorescent lamps). Since the cattle farm being studied used low-power electrical equipment, it had lower electricity consumption levels than peer consumers (Figure 4). The electricity consumption of this complex during 24 hours was collected and inputted into the software. The smart software calculated the consumption levels for different months of the year (Figure 5).

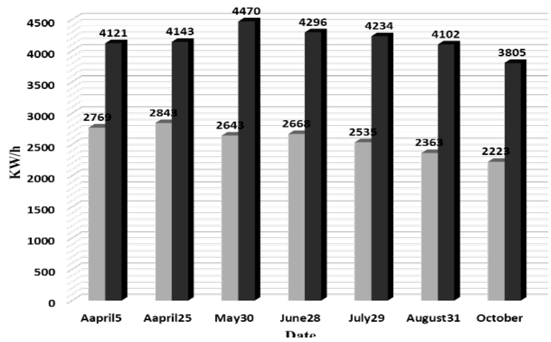


Fig. 4 The average monthly electricity consumption levels of the cattle farm being studied (Gray) and peer consumers (Black) in 2015.

5.2 Renewable energy sources

Renewable energies consist of a wide range of energy sources including solar, wind, water, geothermal and biomass (Nazari *et al.* 2018; Ahmadi *et al.* 2018b; Alizadeh et al. 2018; Ramezanizadeh *et al.* 2018b). In this paper, wind, solar and biomass energies were used based on the available potential in the region. The following sections show the amount of each of the utilized energies (Table 2).

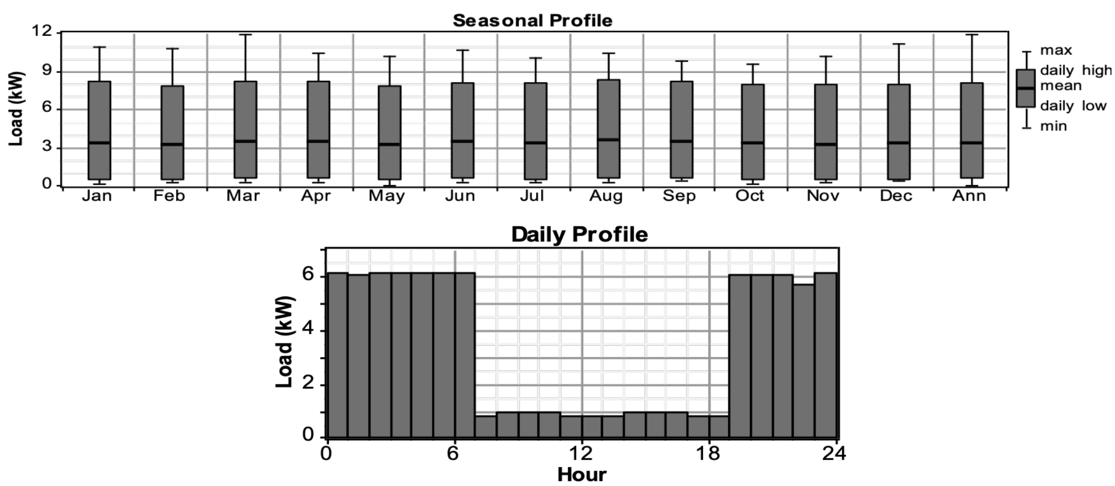


Fig. 5 On the down: daily electricity consumption levels of the cattle farm, on the up: monthly consumption levels of the cattle farm.

5.2.1 Solar energy in Isfahan

The amount of solar radiation in different regions of Iran has been estimated at 1800-2200 KWh, which is above the global average (Yousefi *et al.* 2018). High potential for solar energy in Iran has provided the possibility of using solar energy equipment in many locations of the country (Alamdari *et al*., 2013). In this paper, the amount of solar radiation was obtained from NASA's website and its average was calculated (Ganoe *et al*., 2017). Due to the data, the average amount of solar radiation in Isfahan is 5.34 KWh/m^2 every day. These data along with the geographical coordinates of Isfahan (a longitude of 32 and latitude of 51) were inputted into the HOMER software (Figure 6 and Table 2).

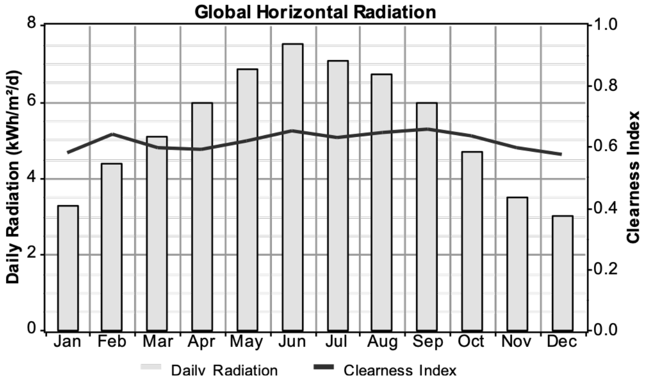


Fig. 6 Daily radiation data for different months during the year in Isfahan Province.

5.2.2 Wind energy in Isfahan

The wind velocity in Isfahan was obtained by the data from Iran meteorological administration website (Ministry of Energy, 2018). Due to the data, Isfahan has the highest wind flow velocity (3.5 m/s) in April and May and the lowest wind flow velocity (1.9 m/s) in January and December (Figure 7, Table 2).

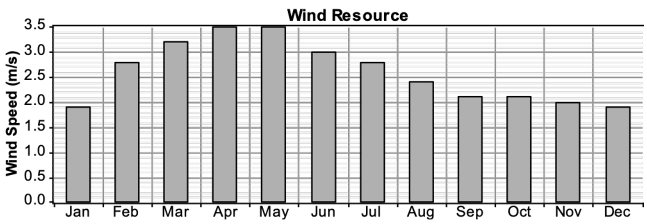


Fig. 7 The wind velocity of different months in Isfahan.

5.2.3 Biomass energy

Biomass incorporates different materials, including woods from different sources, agricultural wastes and animal dung (Alidadi Shamsabadi *et al.* 2016a). They are fermented in the absence of oxygen in certain conditions and are transformed into biogas which primarily comprise 65% methane (CH_4) and 35% carbon dioxide (CO_2) (Mokrane *et al.,* 2018). Currently, the total global demand for this energy is approximately 53EJ, of which 86% are used to meet the industrial heating and cooking demands, which usually include old and traditional systems with low efficiency. The remainder 14% is utilized for electricity generation, cogeneration (combined heat and power) and transportation. While at present final energy from biomass was about 50 EJ of energy or 14% of the world's final energy use, the realistic potential for final energy from biomass worldwide could as much as 150 EJ by 2035 (World Energy council, 2016).

In this paper, the resulting energy from the cattle dung has been intended for electricity generation. The dung from one cow can produce the required electricity for two 100W lamps for 24 hours. The gas of the cattle dung incorporates 55-65% methane, 30-35% carbon dioxide, along with certain amounts of Hydrogen, Nitrogen etc. Its thermal capacity is approximately 600 B.T.U/ft^3. Cattle dung suspension consists of 1.8-2.4% Nitrogen (N_2), 1.0-1.2% phosphorus (P_2O_5), 0.6-0.8% potassium (K_2O), and 50-75% organic humus. Based on the percentages of different cattle breed (67% purebred, 32% mixed breed and 1% native), an average of approximately 17,977.5 tons of cattle dung will be produced annually in the cattle farm being studied which is equivalent to 49.25 tons a day (Figure 8, Table 2).

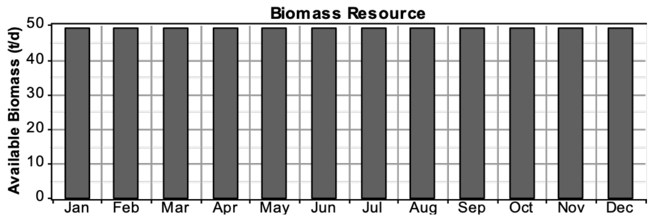


Fig. 8 The amount of available biogas (dung) sources.

Table 2
The amount of solar, wind and biomass in the region being studied

Month	Solar: Clearness Index	Solar: Average Radiation (KWh/m^2-day)	Wind: Wind Speed (m/s)	Biomass: Available Biomass (tonnes/day)
Jan	0.582	3.250	1.9	49.2
Feb	0.639	4.380	2.8	49.2
Mar	0.595	5.090	3.2	49.2
Apr	0.591	5.980	3.5	49.2
May	0.616	6.850	3.5	49.2
Jun	0.654	7.500	3.0	49.2
Jul	0.628	7.070	2.8	49.2
Aug	0.645	6.740	2.4	49.2
Sep	0.660	5.980	2.1	49.2
Oct	0.636	4.670	2.1	49.2
Nov	0.597	3.500	2.0	49.2
Dec	0.577	2.990	1.9	49.2

6. System components

To analyse the present paper economically, the data concerning wind and solar energies, biogas quantity and certain issues including the type, quantity, initial costs, operating & maintenance costs of facilities (generator, battery, turbine, converter and solar panels) were defined for the system for simulation purposes.

6.1 Photovoltaic panel

Solar system costs include cable and charge controller costs which were obtained by the analysis of today's market. Panel costs for 1KW of power have been estimated at 6,900 dollars. Panel replacement costs have also been estimated at 6,900 dollars for 1KW of power. According to the manufacturer, the panels had 25 years of life-span (Jahangiri et al. 2015) (Table 2).

If the effect of temperature on the PV array is not significant, HOMER uses the following equation to calculate the output of the PV array (Jahangiri *et al.* 2018a):

$$P_{pv} = Y_{pv} f_{pv} \left(\frac{\overline{G_T}}{\overline{G_{T.STC}}} \right) \quad (1)$$

Where Y_{PV} is the rated capacity of the PV array, meaning its power output under standard test conditions [kW], f_{PV} is the PV derating factor [%], $\overline{G_T}$ is the solar radiation incident on the PV array in the current time step [kW/m^2] and $\overline{G_{T.STC}}$ is the incident radiation at standard test conditions [1 kW/m^2].

6.2 Wind turbines

Wind energy is capable of considerably reducing fuel costs, greenhouse gas emissions and environmental issues. Wind turbines are an optimal choice for providing public electricity in developing countries (Mostafaeipour and Abesi 2010; Qolipour *et al.* 2016; Al-Shammari *et al.* 2016). Using the wind turbines, the kinetic energy of the wind flow can be transformed into mechanical and subsequently electrical energy. The wind turbine used in this study was a BWC XL12 direct current turbine with a power of 1.24 KW. The initial velocity and the velocity of the maximum power were approximately 3.5 m/s and 13 m/s, respectively. The initial and replacement costs were 3,900 dollars annually and the operating & maintenance costs were 100 dollars annually. The turbine had a life-span of 25 years and was located at 10 meters above the earth's surface (Jahangiri et al. 2015) (Table 4).

Power curves typically specify wind turbine performance under conditions of standard temperature and pressure (STP). To adjust to actual conditions, HOMER multiplies the power value predicted by the power curve by the air density ratio, according to following equation (Jahangiri *et al.* 2018a):

$$P_{WTG} = \frac{\rho}{\rho_0} \times P_{WTG.STP} \quad (2)$$

where P_{WTG} is the wind turbine power output [kW], $P_{WTG,STP}$ is the wind turbine power output at standard temperature and pressure [kW], ρ is the actual air density [kg/m^3] and ρ_0 is the air density at standard temperature and pressure (1.225 kg/m^3).

6.3 The generator

The generator in this study was an 800 dollar biogas generator. Replacement costs were 700 dollars and maintenance costs were considered at 0.001 dollar per hour. It had a life-span of 15,000 hours (Table 4). HOMER uses the following equation to calculate the average electrical efficiency of generator (Jahangiri et al. 2018a):

$$\eta_{gen} = \frac{3.6\, P_{gen}}{\dot{m}_{fuel} LHV_{fuel}} \quad (3)$$

where E_{gen} is the generator's total annual electrical production [kWh/yr], m_{fuel} is the generator's total annual fuel consumption [kg/yr] and LHV_{fuel} is the lower heating value of the fuel [MJ/kg].

6.4 Battery

The power generated from renewable sources can be saved in a battery bank for urgent circumstances. The consumers can even sell the surplus to local water and electricity companies and it may even generate an income for the consumer (Sahu *et al.* 2013). In this paper, the battery system was utilized to store the wind turbine and photovoltaic outputs. The primary goal was to store the energy so that it could be discharged in urgent cases. In this system, Surrette 6CS25P rechargeable batteries were used with a voltage and power of 6V and 1,156Ah, respectively. The initial, replacement, and annual operating & maintenance costs of the batteries were 1,200, 1,100 and 50 dollars, respectively (Jahangiri *et al.* 2015) (Table 4).

HOMER also plots the lifetime throughput, which it calculates for each point in the lifetime curve using the following equation(Jahangiri *et al.* 2018a):

$$Q_{Lifetime.i} = f_i d_i \left(\frac{q_{max} V_{nom}}{1000W/kW}\right) \quad (4)$$

Where $Q_{lifetime,i}$ is the lifetime throughput [kWh], f_i is the number of cycles to failure, d_i is the depth of discharge [%], q_{max} is the maximum capacity of the battery [Ah] and V_{nom} is the nominal voltage of the battery [V].

6.5 The converter

The converter changes the direct current (DC) to the alternating current (AC) and vice versa. According to the manufacturer's data, the suggested converter system had an initial cost of 800 dollars, replacement costs of 700 dollars and annual operating & maintenance costs of 100 dollars. Moreover, the life-span of the converter was estimated at 15 years (Jahangiri *et al.* 2015) (Table 4).

7. Results

Economically efficient systems were shown, due to the analysis of the HOMER software. In the several analyses presented, various systems with different levels of renewable energy sources were obtained. The optimal result was introduced as the utilization of 9 bio-generators, 5 batteries and 2 converters, which will cost over 46,773 dollars. The second system suggested was a combination of 9 bio-generators, 3 batteries, 2 converters and one solar panel which will cost over 48,097 dollars (Table 4). The results suggest that if a hybrid system, consisting of all the intended renewable energies, is used, a solar panel, a wind turbine, 9 bio-generators, 3 batteries and 2 converters are required, which will cost a total of 53,106 dollar (4th suggestion). Additionally, if only 11 bio-generators are utilized for electricity generation, the total cost will be 64,541 dollars (5th suggestion) (Table 3). According to the results, exclusive use of biomass energies for electricity generation is sufficient. Furthermore, the solar energy has a good potential in Isfahan. Using 3 solar, wind and biomass energies will cost 6,373 dollars more than the exclusive utilization of biomass. The results of this paper will be useful for economic progress and decreasing the consumption of non-renewable energies. In Figure 9, the initial and operating & maintenance costs of the first suggested system have been presented for 25 years, based on the equipment type and prices. As the results of Figure 9 show, the most annual cost over a 25-year-old period, with about $2150, was related to the equipment's replacement cost. Also, the most cost paid for equipment with about $29000 was related to the biomass generator. In a comparison between the initial 5 systems presented by the software, the amounts of the pollutants including carbon dioxide, carbon monoxide, unburned hydrocarbons, particles, sulphur dioxide and nitrogen dioxide can be evaluated in addition to the costs. The first optimal system produces an approximate 23.5 kilograms of carbon dioxide annually. In general, the amount of all the emitted pollutants is the least in the 4th system (Table 5). The reason why the 4th proposed system has the least amount of pollutant production is that using rate of the non-polluting energies (wind and solar) is higher in this system. The reason why the 5th system has the highest rate of pollutant production is it does not use any wind and solar energies and is not supported by a battery saver.

7.1 Comparison of renewable energy utilization costs and domestic electricity costs

To evaluate the costs of the suggested system by the software for electricity generation through the electricity grid, annual electricity consumption costs in the intended unit have been obtained from the data by the electrical distribution company. The costs have subsequently been estimated for 25 years, with an inflation rate of 15%., It is worth noting that, since the state dollar exchange rates will be half for clean energy utilization, one dollar has been considered as equivalent to 17350 Iranian Rials, in the analysis of this section. Considering the calculations, the costs of domestic electricity utilization in the intended unit will be 193,833.16 dollars, while biogas energy utilization costs will be 46,733 dollars. Therefore, biomass energy utilization will not only decrease the negative environmental effects, but will also return the investments in the mid-15th year and generate a profit of 147,100.16 dollars until the 25th year (Table 6). It should be mentioned that electricity costs in Iran are far lower than the global electricity costs (a maximum of 595 Iranian Rials per Kilowatt-hour); on average, electricity costs in Iran are 0.9 times of those in many other countries. In addition, Isfahan produces its electricity by water, and since water resources are reducing considerably, it would be visionary to use other resources for electricity generation.

Table 3
Optimal results by the HOMER software for diesel.

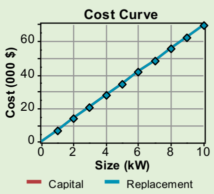
Components	PV	WT	Biog. (kW)	Batt. S6CS25P	Conv. (kW)	Initial Capital ($)	Operating Cost ($/yr)	Total NPC ($)	COE ($/kWh)	Ren. Frac.	Biomass (t)	Biog (hrs)
	0	0	9	5	2	14800	2498	46733	0.120	1.00	136	4567
	1	0	9	3	2	19300	2253	48097	0.124	1.00	129	4557
	0	1	9	5	2	18700	2578	51653	0.133	1.00	135	4574
	1	1	9	3	2	23200	2339	53106	0.137	1.00	128	4554
	0	0	11	0	0	8800	4360	64541	0.166	1.00	222	8759
	0	1	11	0	1	13500	4579	72035	0.185	1.00	222	8759
	1	0	11	0	1	16500	4435	73192	0.188	1.00	220	8677
	1	1	11	0	1	20400	4526	78253	0.201	1.00	220	8660

Table 4
A summary of the different factors of the intended solar panel, wind turbine, generator, battery and converter.

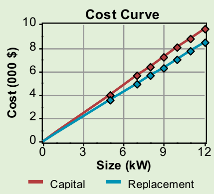
HOMER Input Summary						
	Size (KW)	Capital ($)	Replacement ($)	O&M	Lifetime	Slope
PV	1.000	6,900	6,900	0 ($/yr.)	25 yr.	33 deg.
AC Generator	1.000	800	700	0.001($/h)	15,000 hrs.	Fuel used Biomass
Converter	1.000	800	700	100 ($/yr.)	25 yr.	Inverter efficiency 90%
DC Wind Turbine	Quantity 1	3,900	3,900	100 ($/yr.)	25 yr.	Anemometer height 10 m
Battery	1.000	1,200	1,100	50.00 ($/yr.)	Lifetime throughput 9,645 KWh	Voltage 6 V

Cost curve

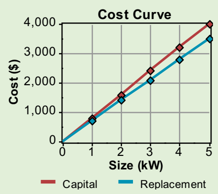
PV



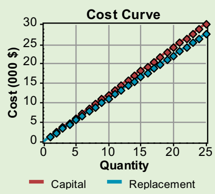
AC Generator



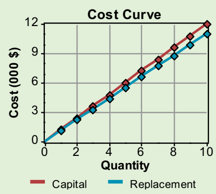
Converter



DC Wind Turbine



Battery



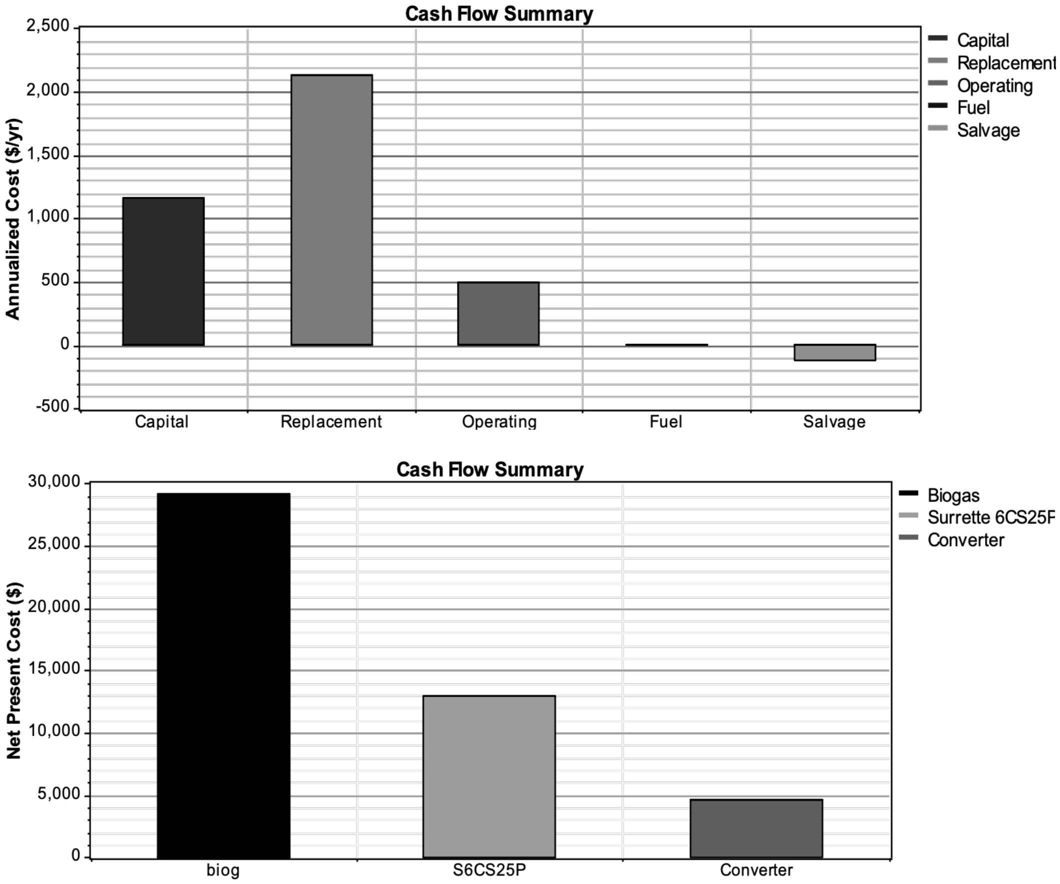


Fig. 9 Initial and maintenance costs of the equipment in 25 years (up): based on the type of costs (down): based on the equipment type.

Table 5
A comparison of domestic electricity costs and the costs of electricity generation by the first suggested system (in dollars).

Optimization result	System 1	System 2	System 3	System 4	System 5
PV.(KW)	0	1	0	1	0
XL1	0	0	1	1	0
BIO.(KW)	9	9	9	9	11
S6CS25P	5	3	5	3	0
CONV.(KW)	2	2	2	2	0
Pollutant	**Emissions (kg/yr.)**				
Carbon dioxide	23.5	22.2	23.4	22.1	38.4
Carbon monoxide	0.884	0.835	0.878	0.83	1.44
Unburned hydrocarbons	0.0979	0.0925	0.0973	0.0919	0.16
Particulate matter	0.0666	0.063	0.0662	0.0626	0.109
Sulfur dioxide	0	0	0	0	0
Nitrogen oxides	7.88	7.46	7.84	7.41	12.9

Table 6
A comparison of domestic electricity costs and the costs of electricity generation by the first suggested system (in dollars).

Domestic electricity costs				Electricity generated from biogas
The annual total	15% of the annual costs	In the 25th year	The total in 25 years	Suggested costs
910.9	136.635	26074.67	193833.16	46733

8. Conclusions

The issue of consuming non-renewable energies is a new topic of discussion in different societies. Scholars believe that clean energy utilization can be a solution to this problem. This research was done to analyse the potential of solar, wind and biomass energies for generating the required electricity of a cattle farm in Isfahan. The best option has been presented according to the region's potential, environmental issues, production costs and efficiency. The price of the electricity unit by the presented model is 46,733 dollars, which is approximately one fourth of the domestic electricity costs in 25 years and thus will be cost-effective according to the system's life-span. In fact, Isfahan enjoys huge potential for electricity generation from biomass energy. The initial results suggest that this system is capable of reducing operational costs and greenhouse emissions into the atmosphere. The designed system suggested in this paper can be used by similar populations, considering the statistical population and available resources. Renewable energy utilization for other locations and cattle farms in particular is recommended for future research. Also, it is recommended that, using the results of the present study, a general comparison be made between the final costs of the electricity supplied by different renewable energies in Iran.

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