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Techno-Economic Feasibility of Energy Supply Systems from Renewable Sources of Solar and Biomass in Rural Areas Located In Cold and Dry Climate

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ABSTRACT: The present work focuses on the feasibility study of locally available renewable energy production systems for mountainous rural areas with cold and dry climates (including solar systems and biomass resulted from manure dung). The studied rural area consists of three cold and impassable villages of Pichebon, Narmelat, and Dinheroud, located in Eastern Alamut of Qazvin. Three scenarios have been presented and related techno-economic analyses have been done. Firstly, all heating needs and electricity demands have been met solely by the photovoltaic system. In the second scenario, heating and electricity needs have been supplied by biogas and combined heat and power system. Moreover, the heat loss of the motor has been used to warm up the digester. In the last survey, the electricity need has been supplied by the photovoltaic system along with covering heating demand through biogas. In this scenario, the required heat to operate digester is provided using the photovoltaic system. The results show that the second scenario that has a positive Net Present Value in each discount rate (5%, 10% and 15%) and Internal Rate of Return is 24.24% , 23.26% and 38.6% for Pichebon, Narmelat and Dinehroud villages, respectively, is as practical design and economic option.

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1- INTRODUCTION

Energy is a key asset required to reduce poverty, improve the standards of lifestyle, and facilitate socio-economic development. Nowadays, almost 80% of the global energy demand is met by means of fossil fuels, resulting in significant environmental impacts [1]. World reduction of fossil fuel energy resources, increasing the greenhouse gas emissions and global warming along with the increase of energy demand and raising the price of energy have motivated researchers to find renewable and clean energy resources [2]. On the other hand, the supply of fuel and energy to the impassable and remote rural areas lacking the national electrical grid and gas pipeline is highly costly due to long distance and unsuitable geographic conditions. In many studies, hybrid energy systems that consist of different energy resources have been considered for providing energy needs of remote and isolated rural areas.

Singh et al. [3], proposed a hybrid Photo Voltaic (PV)-wind generation system along with biomass and storage to fulfill the electrical load demand of a small area. The results showed that a hybrid energy system is a more reliable, economical and suitable source of electricity, particularly for off grid locations. Ahmad et al. [4], studied the techno-economic feasibility of a grid-tied hybrid microgrid system for local inhabitants of Kallar Kahar near Chakwal city of Punjab province in Pakistan and investigated the potential for electricity generation through hybrid wind, photovoltaic and biomass system. The results of the techno-economic feasibility study showed that the hybrid power system can generate more than 50 MW.

In this study, meeting the energy needs of three cold and impassable villages including Pichebon, Narmelat and Dinehroud locating in eastern Alamut in Qazvin (Iran), has been evaluated. To conduct the studies, three different types of systems, based on existing renewable energy sources, in order to supply electrical and heating needs for the mentioned villages comprising of PV-Battery, Biomass (Anaerobic Digestion (AD) of livestock's dung)-Combined Heat and Power (CHP) engine and PV-Biomass (AD) are investigated. The most economical system is recommended in terms of Net Present Value (NPV) and Internal Rate of Return (IRR).

2- METHODOLOGY

2.1. Description of the selected rural areas

The three studied villages as Pichebon, Narmelat, and Dinehroud, with geographical coordinates as defined: longitude E 50.78, and latitude N are 36.40, 36.36 and 36.35, respectively, as well as altitude 2720 m, 2100 m and 2220 m above sea level respectively, are located in the eastern Alamut in Qazvin, Iran. The number of households living in Pichebon, Narmelat and Dinheroud is 35, 5, and 40, respectively. According to the field studies, it is concluded that only two renewable energy sources namely solar and

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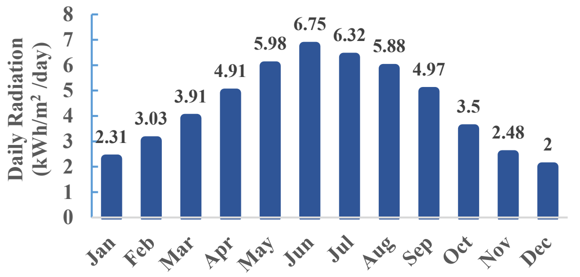
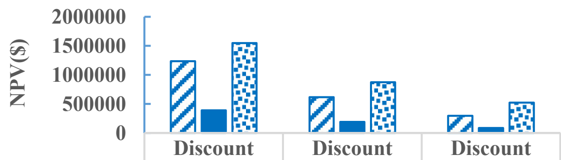


Fig. 1. Monthly solar radiation profile in the selected rural area [5]



	Discount rate 5%	Discount rate 10%	Discount rate 15%
Pichebon	1235140	616760	294697
Narmelat	390365	190893	87004
Dinehroud	1548201	873297	521795

Fig. 2: *NPV* of the second scenario for each village

biogas (from anaerobic digestion of animal dung) are available to meet energy needs. The solar radiation data for these regions were obtained from the National Aeronautics and Space Administrative (NASA) surface meteorology and solar energy website [5]. Based on the NASA data, the annual average of solar irradiation is estimated at 4.34 kWh/m^2/day which is more than the standard amount (3.5 kWh/m^2/day) for the use of solar collectors or photovoltaic systems [6]. The monthly solar radiation profile is depicted in Fig. 1.

2.2. Estimation of gas and electricity consumption

The amount of electricity and gas consumption of each household per day has been assessed by considering the electricity and gas bills of other villages with the same climates. Based on the electricity consumption and natural gas bills, the maximum amount of power and gas consumption per household are 3.5 kWh/day and 14 $\frac{m^3}{day}$ respectively.

2.3. Description of sustainable energy production systems

Regarding renewable energy sources existing in these areas, three scenarios are considered to supply required heating and electrical needs. Each scenario is explained in subsequent sections.

2.3.1. The first scenario (PV system)

In this scenario, all heating (cooking is included) and electrical needs have been met solely by the photovoltaic system. Therefore the amount of required NG should be equalized to electrical energy.

2.3.2. The second scenario (Biogas and CHP system)

In the second scenario, heating and electricity have been supplied by biogas as well as the CHP system. Moreover, the heat loss of the CHP has been used to warm up the digester.

2.3.3. The third scenario (Biogas and PV)

In the last scenario, the electricity need has been supplied by the photovoltaic system along with covering heating demand through biogas. The required heat to operate digester is provided using the photovoltaic system.

In each scenario, the volume of the digester, type of CHP engine, gas pipeline, heating need for warming the digester and equipment of solar system have been calculated.

2.4. Economic analysis

The economic analysis has been done by means of *NPV* and *IRR* criteria.

Net present value is the present value of the expected cash inflow from an investment minus the cost of acquiring the investment. In a general form the NPV is calculated as [7]:

$$NPV = \sum_{j=1}^{N} \frac{Q_n}{(1+i)^j} - I \qquad (1)$$

where N is the project lifetime; Q_n is the cash flow in the year n with n =1,…, N; i is the return rate and I is the initial investment. The internal rate of return on an investment or project is the annualized effective compounded return rate or rate of return that sets the net present value of all cash flows (both positive and negative) from the investment equal to zero.

The cost of scenarios contains the expenses relating to the panel, battery, charge controller, inverter, digester, CHP engine and gas piping. The revenue of these projects including to sell power and gas, compost of manure as well as decreasing the emission of carbon dioxide. In this survey, three discount rates of (5%, 10% and 15%) have been taken into account.

3- RESULTS AND DISCUSSION

The results of the calculation revealed that the *NPV* of the first and third scenarios, even at a discount rate of 5%, are negatively representing this fact, these scenarios are not economical to meet the energy needs of studied villages. But the *NPV* of the second scenario is positive at all considered discount rates for each village that can be seen in Fig. 2. In addition, the internal rate of return in this scenario is 24.24% 23.26% and 38.6% for Pichebon, Narmelat and Dinehroud villages, respectively.

4- CONCLUSION

In this study, three scenarios have been considered to supply the energy needs of studied rural areas. Results illustrated the second scenario with positive *NPV* as well as the internal rate of return for each village is greater than discount rates is the best and economical alternative to meet the energy demands of three villages.

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