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Feasibility of utilizing renewable energy systems for a small hotel in Ajloun city, Jordan

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ABSTRACT

This paper presents a feasibility analysis for renewable energy (RE) supply options feeding a small hotel in Ajloun city located in the north part of Jordan. Both technical and economical aspects are investigated for each scenario of the considered supply options. Net present cost (NPC), renewable fraction (RF) and payback time (T_{PB}) are used to asses the potential of each supply option. All required modeling, simulation and evaluation are carried out using the assessment software package HOMER (National Renewable Energy Laboratory, US). The results obtained show that on-grid small wind turbine scheme is the most feasible supply option to feed the electrical loads in the hotel. With hub height of 25 m and zero sell back rate (SBR) the NPC of this configuration is $\$62.7 \times 10^3$, which is even less than that of grid-only supply option. Moreover, it is resulted in 62% RF, a T_{PB} of 10.9 years and a reduction of green house gas emission (GHE) of 8.8 ton per year. When the extra generated energy is sold back to grid with SBR of \$0.06 (0.5 of the purchase price), the assessment parameters NPC, T_{PB} and GHE are reduced to $\$44.3 \times 10^3$, 0.101 ton/year and 6.6 year, respectively. In addition, the results show that the NPC of grid-connected wind energy scheme sharply decreases with the increase in the carbon tax. The authors believe that the implementation of stand-alone configurations, based on wind and hybrid wind/solar energy resources, will increase in the future. This is due to the expectations of the decrease in the costs of the main components constituting these configurations and the increase in the overall efficiencies of these schemes.

1. Introduction

Jordan spends high amount of its hard currency for energy bill [1] where oil is the dominant energy sector for economic and social developments [2]. In addition, the country has a great potential of wind and solar energy resources [1]. These aspects motivated the government and the researchers to pay more attention for the utilization of wind/solar energy resources. The current publication investigates the feasibility and viability of utilizing various RE supply options to supply a small hotel in Ajloun city located 76 km north-west of the Jordan's capital, Amman. Ajloun city is a hilly region, with an elevation of 760 m. It occupies a geographical zone extending between 32°21′0″N, 35°44′0″E latitude and 32°.35″, 35°.73″ longitude. The location has acceptable levels of wind speed and solar insolation [1]. Detailed statistical analysis for wind speed and solar irradiation in the selected site can be found in [3].

In the literature, the authors of this paper could not find an extensive study examining the technical feasibility and economical viability of various RE schemes to supply a small hotel. More specifically, the authors found few publications deal with the use of renewable energy resources to supply hotels. Most of these studies are directed to investigate the feasibility of using one or two configurations, e.g. off-grid PV system, to feed tourist accommodations. Dalton et al. [4] provides feasibility analysis for stand-alone wind/solar RE schemes to feed small to medium tourist accommodations. They concluded that hybrid wind/PV stand alone scheme can feed the needed power at acceptable cost. Their results showed that the NPC ratios of the proposed schemes, with respect to the three corresponding present configurations, are 0.5, 0.7 and 0.77. The authors in [5] demonstrated the viability of implementing their proposed off-grid photovoltaic scheme to supply a small scale tourist accommodation in Greece. Feasibility analysis of stand-alone RE configurations to supply a large hotel in Australia is assessed in [6]. The authors of the paper concluded that wind energy conversion scheme is the most economically viable RE supply option. Feasibility analysis of stand-alone RE configurations and grid-connected schemes to supply a large hotel in Australia is presented in [7]. The study shows that on-grid large wind turbine scheme is the most efficient and economical supply option to feed the load demand in the hotel.

However, an extensive studies investigating the technical feasibility and economical viability of utilizing various renewable energy supply options in Jordan have not achieved yet, a number of

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Nomenclature

GHE	green house emission, ton/year
H_h	hub height of wind turbine, m
IC	initial cost, $
MO	maintenance and operation, $
NPC	net present cost, $
RC	replacement cost, $
RE	renewable energy
RF	renewable factor, percentage
T_{PB}	payback time, year
WT	wind turbine
RES	renewable energy supply option
SBR	sell back rate
PV	photovoltiac
CSF	capacity shortage fraction
WECS	wind energy conversion system
i	interest rate
CF_j	net cash flow for the year, j

publications deal with the use of RE resources is found in the literature. Badran [8] introduced a survey for the implementation of wind energy in Jordan to drive water pumps; even directly through mechanical means or indirectly through wind-driven electric generator. The author concluded that wind energy pumping systems are preferable over diesel ones because they are more reliable, require less maintenance, safer and they do not pollute the environment. Jaber et al. in [2] have studied the use of conventional energy sources as well as renewable energy resources for space heating system. They showed that a space heating system based on renewable energy resource is the favorable option due to its low cost-to-benefit ratio. Al-Salaymeh et al. have investigated in publication [9] the technical and economical assessment for the implementation of PV systems to feed residential buildings in Jordan. They concluded that the implementation of stand-alone PV system to supply the residential flat in Jordan is not economical due to the high cost of installing this system compared with the electricity cost of conventional grid. The use of grid-connected 5 MW PV-generator system was assessed in [10]. Hrayshat and Al-Soud investigated the potential of solar energy development for water pumping application in Jordan [11], where ten different locations in the country are chosen for this assessment. They concluded that four of the ten selected sites are considered "adequate" for solar pumping, other three sites are "promising" and the rest three sites are considered "poor". Hrayshat [12] investigated the potential of wind energy for electrification of Tafila city in Jordan. The results showed that the available wind power in the selected site is not economical to install stand-alone wind scheme to supply the load demand. However, on-grid small wind turbines can be utilized to support the deficiency of electricity during the peak time.

Different aspects have motivated the authors to carry out the research work in the present publication. As far as the authors concern, the literature lacks to an extensive study dealing with the utilization of various RE supply options to supply a small hotel, and therefore the current investigation will enhance the literature in this area. Such deep investigation is also important to provide a full picture about the possibility of implementing renewable energy resources to supply similar applications in Jordan. This is because a lot of money is spends for oil bill every year and at the same time Jordan has acceptable level of wind speed and solar irradiation. In addition, the advantages of using renewable energy resources to produce electricity, such as free fuel cost and no pollution, motivated the authors for the current study.

In the present work, the technical feasibility and economical viability of various schemes to supply the load demand in a small hotel have been investigated. These configurations can be categorized into grid-connected schemes (grid-only, on-grid wind, on-grid PV, on-grid hybrid wind/PV) and off-grid schemes (wind-only, PV-only, hybrid wind/PV). Stand-alone (off-grid) configurations are attractive supply options, since they are clean, free fuel cost and require less maintenance. In the current publication, the economical viability of these configurations is investigated. The cost of a PV panel and wind turbine is expected to decrease in the future, and consequently off-grid schemes become competitive supply options to feed the load demand. The following research aims are examined in the present study:

- The technical feasibility of a RES to feed the required power demand.
- The economical viability of a RES based on the net present cost (NPC).
- The part of the total annual electrical energy demanded that is produced by renewable resources. Renewable fraction (RF) is used for this assessment.
- The payback time of a RES based power supply.
- The effect of electricity price, SBR and the carbon tax on the NPC of both grid-only and on-grid small WT configurations.

The rest of the paper is organized as follows: Section 2 describes HOMER software, presents the required data inputs and explains the assessment criteria. Results and discussion are presented in Section 3. The last part of the publication drives the conclusions of the present work.

2. Assessment and analysis

2.1. HOMER software

HOMER is a software package developed by the National Renewable Energy Laboratory (NREL) at department of energy in USA [13]. As the user provides the software with the required input data for different power system schemes, it carries out simulations to estimate the technical feasibility and economical viability of each system [13,14]. HOMER considers that the system is technically feasible if it can appropriately serve the load demand and matches any other needed constraints. The economical viability of a system is determined through its NPC, which includes the initial capital cost of the system components, the cost of component replacement during the project lifecycle, the operating and maintenance cost of the system components and fuel cost. The optimal possible system is the configuration which satisfies the user specified constraint at the lowest total net present cost.

2.2. Data inputs

The first step to perform the feasibility analysis for a RE scheme is the insertion of hourly load and environmental data. The load data was obtained by Irbid District Electricity Company LTD. (IDECO) which has computerized data loggers to record the electric energy consumption by the customers. The daily load profile of the hotel under study is shown in Fig. 1 that can be divided into three