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Freestanding PV solar system- -example of Lefke town in Northern Cyprus

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Abstract

Clean energy is the main source to reduce the energy demand, electricity sector's emissions, and global warming. Renewable energy sources are considered more and more due to the existing standard resources being depleted, and the fact that they are harming the environment with CO_2 emissions. Solar and wind energy are the two available forms of renewable energy sources. Solar and wind as the most abundant available energy possess the ability to mitigate change of climate. Various solar and wind technologies have been developed so far and have reached different levels of maturity and applications serving a variety of purposes in many parts of the world. Solar and wind technology is desirable regarding being friendly to the environment and ecology and having positive impacts socially. Due to the intensive competitions in the market of solar-wind-based technologies, technical developments, and support of the public and governments, a gradual reduction in the cost of these technologies has been observed over recent previous decades. Cyprus is an island state whose energy production is almost completely dependent on imported fossil fuels. Its electricity production sector is about 92% dependent on oil products while the remaining 9% is covered by imports of coal (3%) and by renewable energy (5%). Due to favorable geographical attributes, renewable resources such as wind and solar energy provide attractive alternatives to reduce fossil fuels consumption. The study reviewed the literature on renewable resources in Northern Cyprus especially in Lefke town located in the Northern part of Cyprus. Moreover, the study focused on the evaluation of renewable energy system effect on the electricity sector's emissions and fuel consumption. In addition Advantages and disadvantages of such a hybrid system along with a cost analysis will also be presented in this paper. In order to help open novel routes with regard to renewable energy research and practices, a small-scale renewable power system are proposed and studied using RETScreen software.

Keyword: Cyprus; Lefke town; renewable energy; RETScreen software; small-scale renewable power system

1. INTRODUCTION

Energy has been an indispensable need for humankind. This need was met by conventional fossil fuel consumption until the near past. However, fossil fuel use brought many problems. The most important problems associated with fossil fuel consumption are environmental pollution and climate change due to greenhouse gas emission [1,2]. The average temperature of the Earth increases and this increase causes droughts and abnormal climate conditions.

Renewable energy resources increased their importance in the last decades due to these reasons. Additionally, the fact that fossil fuels (such as oil, coal, and natural gas) will be depleted in near future, encourages researchers to make investigations on alternative energy resources [3,4].

Cyprus is situated in the northeastern part of the Mediterranean Sea, 338 East and 358 North of the Equator. It is situated 75 km south of Turkey, 105 km west of Syria, 380 km north of Egypt, and 380 km east of Rhodes (Greece). The third largest Mediterranean island after Sicily and Sardinia, it has an area of 9251 km^2. According to Northern Cyprus Statistical Institute, the total population of Northern Cyprus is estimated to be 306000 people in 2015 [5].

In Northern Cyprus, increasing population, rising life standards, and rapidly growing tourism and industry sectors have led to increased energy demands. Being an isolated energy system, this increase in energy demand is causing a high degree of dependence on imported fuel. Owing to the increasing cost of energy supply, limited oil storage capacity, and the need for environmental preservation (i.e. reduction of greenhouse gas emissions, conservation of the natural and visual beauty of the island), Northern Cyprus is looking into the effective exploitation of renewable sources besides its installed conventional power stations.

The objective of this study has reviewed the literature on energy demand with a focus on generating electricity from renewable energy such as solar and wind energy. Moreover, in order to reduce the dependence on power import, increase the flexibility of power supply and cut down GHG emission, development of renewable energy generation is essential in Northern Cyprus. Finally, this paper recommends some alternatives to generate electricity from solar/wind energy in Lefke town.

2. OVERVIEW OF NORTH CYPRUS POWER SYSTEM

Renewable energy is the energy produced by a natural energy resource such as hydro, solar, wind, biomass, geothermal,

tides and waves, etc. These natural resources are free and continuously replenished. However, renewable energy generation systems are still more expensive than conventional ones and choosing to invest in these systems is a matter of resource availability and cost optimization. Renewable energy currently plays a marginal role in the energy balance of Northern Cyprus. It shares less than 5% of the electricity production as shown in Figure 1.

At present, the electrical energy in Northern Cyprus is currently produced by fossil fuels and photovoltaic power plant, which installed in Serhatköy. The power generation in Northern Cyprus is around 212MW for the diesel generator and 1.27MW for the photovoltaic power plant, i.e., the total power generation in Northern Cyprus is around 300 MW [7, 8]. According to Ozerdem & Biricik, (2011), the total electricity consumption is expected to exceed 1GW in 2020.

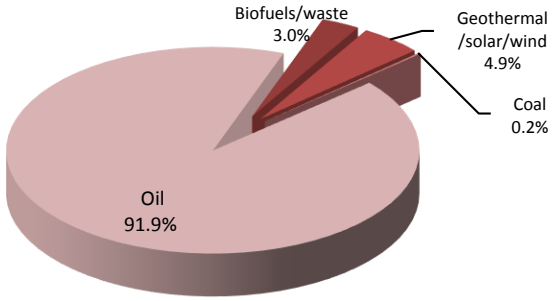

Figure 1. Share of total primary energy supply in 2015 for Cyprus [6]

Therefore, the most important advantages and disadvantage of renewable energy are ubiquitous (found everywhere across the world in contrast to fossil fuels and minerals), and low density and variability, which results in higher initial cost because of the need for large capture area and storage or backup power, respectively [10]. Hence, the need for thorough economic assessment of renewable power generation in Northern Cyprus is necessary as the investor's hope and expect solely on the long-term security of income from the solar/wind energy investments. In this regard, solar and wind potential has been studied in many regions in Northern Cyprus and relevant studies can be found in the recent literature. For an instant, Yenen & Fahrioglu [8] assessed the wind energy potential as a renewable energy resource for Northern Cyprus and based on measured data we provide an energy generation scenario in terms of the blade area of the turbines. Alayat et al. [11] studied techno-economic assessment of the wind power potential for eight locations, namely, Lefkoşa, Ercan, Girne, Güzelyurt, Gazimağusa, Dipkarpaz, Yeni Boğaziçi, and Salamis, distributed over the Northern part of Cyprus. The results showed that small-scale wind turbine use can be suitable for generating electricity in the studied locations. Kassem et al. [12] investigated the economic evaluation of 12 MW grid-connected wind farms and PV power plants at Lefkoşa and Girne in Northern Cyprus for electricity generation. They concluded that the selected regions have a huge solar potential and actual market opportunities for investors to develop grid-connected PV projects compared to wind farm projects. Kassem et al. [13] investigated the wind characteristics the economic evaluation of Salamis site in Northern Cyprus. It is found that the wind power density value in the region is considerable and can be exploited using small-scale wind turbines.

3. LEFKE, NORTHERN CYPRUS

Lefke is a small town whose outer margins encompass a stretch of picturesque coastline in the north west of Cyprus and situated on the northern foot of the Troodos Mountains. It is surrounded by the green covered mountains with its cool climate in summer and rather cold in the winter due to being close to the high range of mountains. Lefke is geographically located at a Latitude: 35.11199 N, Longitude: 32.84997 E and the elevation from the sea level is about 129m. The total area of the lefke town is about 15.9 km² (3928acres). The location of the town is also shown in Figure 2.

Figure 2. The geographic location of the study area

According to global wind atlas map, the average wind speeds in Lefke are ranged from 2.75m/s to 2m/s. Furthermore, global horizontal irradiation in Lefke is ranged from 2000kW/m^2 to 2100kW/m^2 based on global solar atlas map. Photovoltaic system implementation still limited in Cyprus but a huge solar use as sources for generating electricity. Kassem & Gökçekuş [14] evaluated and analyzed the techno-economic of proposing a 1MW grid-connected PV power plant in Lefke town. the analyzing result showed that PV plant could be used as a viable alternative to reduce the GHG emissions in Northern Cyprus and generating electricity from environmentally friendly scours.

4. RENEWABLE ENERGY POTENTIAL IN LEFKE, NORTHERN CYPRUS

As shown in Figure 3, higher wind speeds are mostly seen in the south part of Cyprus and only on the top of the Beşparmak Mountains in the north part of Cyprus. Beşparmak gives its depictive name to the whole mountain range and Selvili-Tepe in the west with the highest peak of 1024m are the most renowned and outstanding mountains in North Cyprus. According to Solyali et al. [4], the mean annual wind speed at

Selvili-Tepe location is about 5m/s at 30m height. In addition, according to Alayat et al. [11], Dipkarpaz has better conditions for developing a wind farm with a wind turbine of 90m hub height, at which the capacity of the wind turbine is 1 MW or above. According to global wind atlas map, the average wind speeds in Lefke are ranged from 2.75m/s to 2m/s as shown in Figure 3. Furthermore, it is noticed that the wind power density at Lefke is classified as poor wind power as shown in Figure 4.

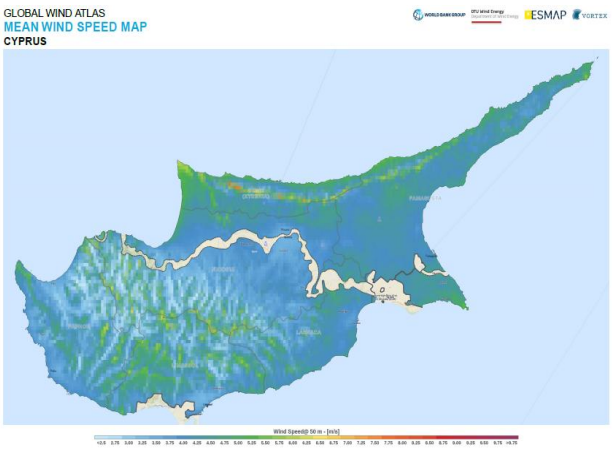

Figure 3. Wind atlas map for Cyprus at 50m height

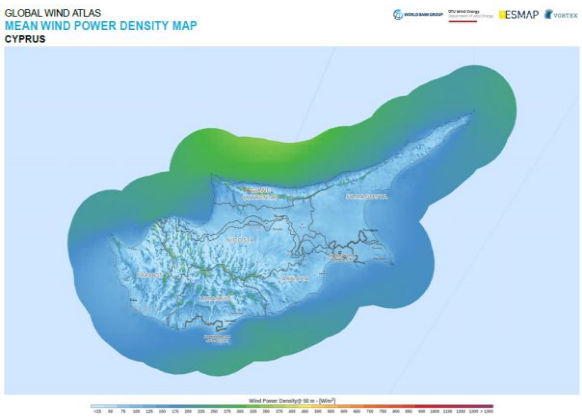

Figure 4. Mean wind power density map at 50m height

Furthermore, global horizontal irradiation in Lefke is ranged from 2000kW/m^2 to 2100kW/m^2 based on global solar atlas map. Figures 5-8 show the GeoModel long-term averages of solar resource: Global Horizontal Irradiation (GHI), Global Tilted Irradiation (GTI), Diffuse Horizontal Irradiation (DIF) and Direct Normal Irradiation (DNI) generated by Global Solar Atlas, the principal climate phenomena that determines solar power generation.

Figure 5. Long-term averages of solar resource (Global Horizontal Irradiation)

Figure 6. Long-term averages of solar resource (Direct Normal Irradiation)

Figure 7. Long-term averages of solar resource (Global Tilted Irradiation)

Figure 8. Long-term averages of solar resource (Diffuse Horizontal Irradiation)

5. SMALL-SCALE ROOFTOP BUILDING RENEWABLE POWER SYSTEM

Based on previous Figures 5-7 Cyprus has huge solar potential and actual market opportunities for investors to develop grid-connected PV projects compared to wind farm projects. Thus, the economic evaluation of a small-scale rooftop-building grid-connected PV power system is discussed in this section.

The slope angle and azimuth angle of open rack or free stand mounting position plant are considered as the optimized value from the simulation study carried out in PVGIS software tool, which are 31° and -11°, respectively.

In order to evaluate the technical, economic, and environmental effect of renewable energy projects, RETScreen software was used in this study. RETScreen software is a useful tool for analyzing and evaluating the feasibility of grid-connected renewable power system [15]. Although their installation costs are high at the beginning, PV generators are cost-effective in terms of operation and maintenance. The systems become more and more efficient thanks to technological developments, and costs are gradually reduced. In this study, the economic analysis of 45kW grid-connect PV power plants is done according to the technical economic parameters (Table 1), which assumed based on previous scientific research.

Table 1. Parametric cost-benefit analysis data, assumptions, and cost analysis of the system

Parameters	Value
Technical data	
Plant capacity	45kW
PV module type	mono-Si - CS6X-300M
Losses	15%
Capital Cost	
CS6X-300M	250-300$
Inverter (50kW)	4000-7000$
Total capital cost	40000$
O&M cost	
Open surface	1.5 c$/kWh
Other parameters	
Inflation rate	7.2%
Discount rate	12%
Project life	25 year
Electricity export escalation rate	5%

The annual produced electricity exported to grid and CF values of 45kW PV plant are presented in Table 2. In addition, Table 2 summarized the results of the economic performance of the 45kW PV plant. The results showed that the proposed 45kW rooftop-building PV power system is very promising in the selected location due to the obtained results of economic performance. Moreover, it is noticed that this system is the more economical option for generating electricity than the producing electricity by diesel generating because of lower value s of levelized cost of energy (0.056$/kW) compared to the energy cost of diesel generating which is about 0.15$/kW.

Table 2. Performance of 45kW PV power plant

Parameters	Value
Capacity factor	19
Generated electricity [MWh/year]	74.7
Net present value [$]	56789
Levelized cost of energy[$/kW]	0.056
Internal rate of return [%]	47.5
payback period [year]	2.4
Annual life cycle savings [$]	7241
Net GHG reduction [tCO_2/year]	75
GHG reduction cost [$/$tCO_2$]	132

6. CONCLUSIONS

The main goal of the present paper was to give a conscious analysis of the performance of 45kW rooftop-building grid-connected PV power system for Lefke town in Northern Cyprus. It is found that Lefke town has a very good solar potential i.e. the mean daily solar radiation-horizontal 5.96 kWh/m^2/day. This significant renewable energy source bears utmost importance in today's world where the need for and cost of energy is considerably high. In addition to its cost-efficiency, the system is also environmentally friendly. It does not lead to gas emission or contributes to global warming. Furthermore, PV generators may be a potential energy source for Northern Cyprus, which is dependent on foreign countries in terms of energy. In conclusion, it is observed that PV generators are significantly useful when climatic conditions are taken into account.

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