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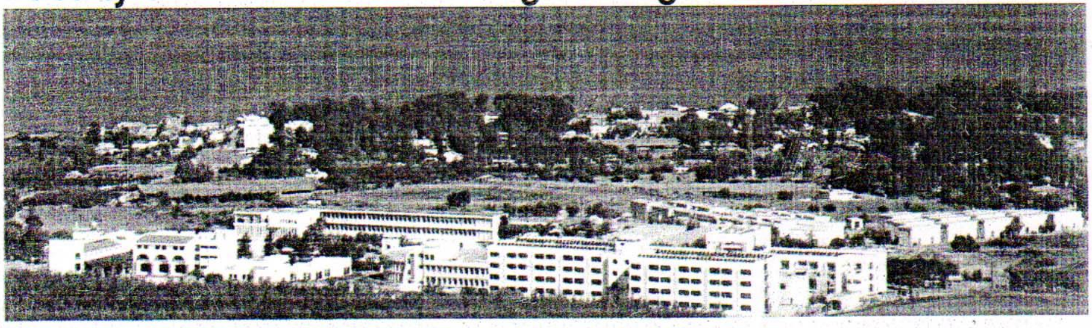

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WIND ENERGY POTENTIAL in N. CYPRUS ECONOMICAL CONSIDERATIONS

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Abstract

Cyprus is an island located in the East of Mediterranean Sea, between 32^0 15' and 34^0 36' East longitude and 34^0 33' and 35^0 43' North latitute. The wind speed differs from 2.5m/s to 7.8 m/s which gives 7.8 W/m2 to 67 W/m2 wind energy potential in N. Cyprus.

Large capacity wind turbines (i.e. 50 kW and over) are getting cheaper as the technology improves and the components are manufactured more economically. At present, the cost of 1 kW installed capacity WEC is less than US$ 1000 for large capacity wind turbines (i.e. less than thermal steam power plant). It is expected to have cheaper wind turbine prices as the international market continuous to explode. The case of small scale wind energy systems is not the same, the high cost of small wind turbines make them economicaly unattractive.

Since wind energy is an environmentally friendly renewable energy resource, it should be integrated into the N. Cyprus energy system as a supplement to base-load generating units. Wind energy systems do not emit CO_2, NO_x, SO_x or any other harmful combustion products as no fuel is consumed in the ind energy systems. Global CO_2 emissions reduction in power generation strongly depends on utilizing renewable energy forms, such as wind, solar, biomass and etc., especially in the developing countries.

1- Introduction

The development of industries and living standarts of the people, brought the energy problem of the countries into discussions of how new energy systems can be integrated into the existing systems. Especially, the developing countries, because of their economical positions, have to find a new way to produce more energy with a cheaper investment and production cost.

The other problem to be considered, is the environmental pollution. Energy production by burning fuel has certain negative impacts on the environment. Whereas utilizing renewable energy technologies in the developing world will help to overcome a major global problem which is CO_2 emission. Remedy of CO_2 reduction is costly. Armour [6] estimated the cost of scrubbing CO_2 from coal fired units to be around $1800/kW.

A wind measurement procedure is carried out by Prof Dr Mustafa Altunç et all.[2] at different wind measurement stations and the data is ready to be usd for application.

A wind atlas for Cyprus will help researchers to design and implement wind energy systems in Cyprus. Wind speeds will be significantly higher at the typical heights, therefore wind turbines are often mounted on towers 100m or higher. From the measurements of wind speed at different points of N. Cyprus, it is estimated that some points are suitable for wind energy

investment and some regions of Cyprus would provide adequate wind resources for wind farm development.

The main objective of this study is to present economic evaluations and possibility to install such energy systems in N. Cyprus.

2- Wind Turbine

Wind turbine is a machine for converting the kinetic energy into mechanical energy. If the mechanical energy is used directly by machinery, such as pump, the machinery is usually called a windmill. If the mechanical energy is than converted to electricity, the machine is called the wind generator.

2.1. Wind turbine types

Wind turbines are classified based on the axis about which the turbine rotates. Turbines that rotate around a horizontal axis are most common. The names of different types of wind turbine depend on their geometry, and the way wind passess over the blades. The wind turbines are classified into three groups [3];

a-Horizontal axis
b-Vertical axis
c-Concentrators

2.1.1. Horizontal axis machines

Blades on the rotor may be in front (upwind) or behind (downwind) of the tower. Upwind turbines need a tail or some other mechanism to maintain orientation, such as side facing fan tail rotors. Downwind turbines are affeceted by the tower, which produces wind shadow and turbulence in the blade path. Wind may be expected to veer frequently in a horizontal plane and the rotor must turn to follow the wind without oscillation. Two and three-bladed rotors are common for electricity generation. Multiblade rotors, having high starting torque in the light winds, are used for water pumping and other low frequency mechanical power [3].

2.1.2. Vertical axis machines

A vertical axis machine can accept wind from different directions. Gearing and generators can be directly coupled to the axis at the ground level. But failures from many natural resonances, and unwanted power periodicities appear at the output. Because of these disadvantages great majority of working machines are horizontal axis [3].

2.1.3. Concentrators

Turbines draw power from the intecepted wind and it may be advantageous funnel or concentrate wind into the turbine from outside the rotor section.Blade tips are designed such that draw air into the rotor section and hence harness power from a cross section is greater than the rotor area [3].

3. Turbine design and construction

The airflow at the blades is not the same as the airflow far away from the turbine. The air flow about the wind turbine is at atmospheric pressure and if pressure is constant then, only kinetic energy is extracted. Because of conservation of mass, the velocity of air is constant as it passes through the rotor plane. The air that passes through the rotor can`t slow down because it needs to stay out of the way of the air behind it. So at he rotor the energy is extracted by a pressure drop. It is this high pressure in front of the wind turbine that deflects some of the upstream air around the turbine.

The maximum limit to wind turbine performance is called the Betz Limit [1]. Betz limit is determined by looking at the axial momentum of the air passing through the wind turbine.

The degree at which air at the turbine is less than the air far away from the turbine is called the axial induction factor which is defined as [1]

$$a = (U_1 - U_2)/ U_1 \tag{1}$$

where U_1 is the wind speed far away from the rotor and U_2 is the wind speed at the rotor

Axial momentum relates the wake flow to the pressure difference at the rotor. Using Bernoulli equation between field flow and the flow near the turbine Betz managed to solve the velocities of the flow in the far wake and near he wind turbine as [1]

$$U_2 = U_1 (1 - a) \tag{2}$$
$$U_4 = U_1 (1 - 2a)$$

U_4 is the wind velocity in the far wake. U_4 is defined because, power extracted from the turbine is defined by the following equation [1];

$$P = 0.5 \, g \, A \, U_2 (U_1^2 - U_4^2) \tag{3}$$

From equation (3); the formula for the coefficient of power (similar to efficiency but not the same) can be derived as [1]

$$Cp = P /(0.5 \, g \, A \, U_1^2) \tag{4}$$

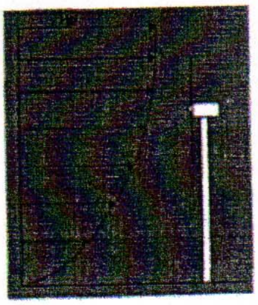
The Betz relationship (1) is given by

$$Cp = 4a (1 - a)^2 \tag{5}$$

The Betz limit is defined by the maximum value that can be given by the above formula. This limit factor is found by taking the derivative with respect to the axial induction factor, setting it to zero and solving for the axial induction factor. This is 16/27.

3.1. Tower height

Doubling the altitite of a turbine increases the expected wind speeds by 10 % and the expected power by 34 %. Doubling the tower height generally requires doubling the diameter as well, increasing the amount of material by a factor of eight.[1]



$$(V_1/V_2) = (H_1/H_2)^{\alpha}$$

H_1: height that speed V_1 is measured

H_2: height that speed V_2 will be calculated

V_1: wind speed that is measured at height H_1

V_2: Wind speed that will be calculated at height H_2

α: Smoothness coefficient (0.10 - 0.40) .

Fig. 2. Wind speed related to tower height [4]

3.2. Number of blades

Vibration intensity decreases with lager number of blades, also, noise and wear are lower and efficiency higher. But the cost increases with number of blades.

3.3. Turbine size

Typical turbines are at 40 – 90 meters blade diameter with a few kW to 10 MW. Labor and meintenance costs increases gradually with increasing turbine size.

3.4. Generating electricity

Wind turbines turn at a speed which produces electricity most efficiently. The variable frequency current produced is converted to DC and than back to AC matching the line frequency and voltage. If the turbines are sited offshore' the DC energy is transmitted from turbine to a central station inverter for connection to grid.

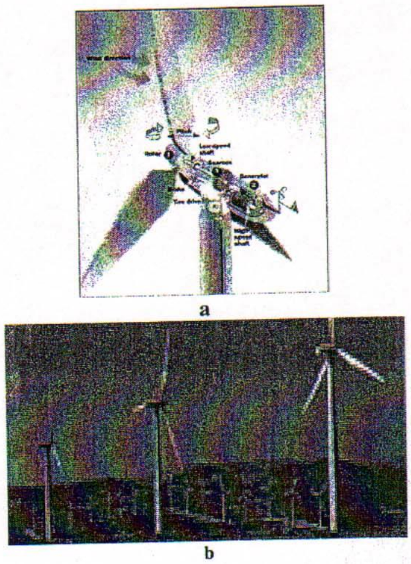


Fig. 3. a-wind turbine b- wind farm[5]

4- Suitable locations in Northern Cyprus for wind energy

According to the measurements made by the TRNC Office of Meteorology (Altunc et all.) [2] Kalecik, Sınırüstü, Yenierenköy, Sadrazamköy, and Taşkent are the most suitable locations in N. Cyprus for wind energy investments. Also the peaks of the Kyrenia Mountains are very suitable for wind farms. The wind speed and energy potential measured at the stations mentioned above are given in Table 1;

le 1. Wind speed and energy potential at ferent measuremet stations [2]

Station	Summer V(m/s)	Power (W/m2)	Autumn V(m/s)	Power(W/m2)	Winter	Power(W/m2)
Kalecik (2000) July/Aug. Sep/Nov	2.6	323	2.7	277		
Sınırüstü (2000) July/Aug. Sep/Nov	3.1	508	3.1	454		
Y Erenköy (2000-02) July/Aug. Sep/Nov	4.6	524	3.7	607	4.1/5.1	1768/3447
Sadrazam köy (2000) July/Aug. Sep/Nov	4.9	455	4.3	1166		
Taşkent (2001/02) July/Aug. Sep/Nov	3.3/3.8	917/1551	3.8	866/1270	4.1/4.1	1482/1690

5. World trends

Utilization of wind energy is one of the fastest growing technologies. Zervos [6] presented European experience in developing wind energy to meet the Kyoto targets in the European Union (EU). Zervos indicated that one of the cheapest option for reducing CO_2 emissions from power generation is using wind turbines. Large capacity wind turbines (i.e. 50 kW and over) are getting cheaper as the technology improves and the components are manufactured more economically. At present, the cost of 1 kW installed capacity wind electric system (WEC) is less than US$ 1000 for large capacity wind turbines [7] whereas this figure is 3000 US$ for small scale WECs. As the international market continues to explode, wind turbine prices will continue to fall. This is not the case for small scale WECs, the cost generally makes small wind turbines unattractive on commercial bases [8]

6. Economical considerations

An economic analysis will be presented here for a WEC systems. Similar to other renewable energy systems, WEC systems are characterized by high capital, low operation and maintenance cost, and zero fuel cost.

In this study, a small scale WECs is considered and the cost of construction is estimated to be US$ 3000 per kW installed capacity. The cost of energy generated by WEC systems depends mainly on technical (i.e. wind speed and nature of turbines) and financial factors such as internal rate of return (IRR) and pay-back period. The power available from wind is a function of the cube of the wind speed. Therefore, the climate and the geographic location are important in choosing the technology. The total investment cost, cost of capital, operation and maintenance costs, capacity factor, tax, inflation rate and debt/equity ratio are the factors affecting the power generation costs [9].

There are various methods for economic evaluation of an investment project. The most commonly used methods are investment profitability analysis, annual cost method, present worth method and capitalized cost method. In this study, an investment profitability analysis method, IRR is used to evaluate the profitability of a WEC system. By definition, the IRR is the rate of discount that reduces the net present value of a project to zero

$$\sum_{l=0}^{n}(CI-CO)_l a_l = 0 \qquad (6)$$

where $\sum_{t=0}^{n}$ is the summed total for the whole lifetime of the project from year '0' to year '*n*', 'CI' is the cash inflow, 'CO' is the cash outflow, respectively, 'a_t' is the discount factor in the year '*t*' corresponding to the selected rate of discount.

Most conservative investments would yield annual rates of return in the range of 6–9%; a higher percentage is sought to make PV and WEC systems investment worthy of consideration.

For illustrative purposes, assume a WEC system rated at 10 kW. Table 2 summarizes major economic and technical factors of the system.

Table 2. Economic and technical parameters of a small scale WEC system

Economic and technical factors	**WEC system**
System rating (kW)	10
Total investment (US$)	30,000
Project life (years)	30
Capacity factor (%)	30
Operation and maintenance costs (US$/kWh)	0.02
Insurance (% of capital cost/year)	0.5
General inflation rate (% per year)	8
Sales price inflation rate (% per year)	8
Debt/equity ratio (%/%)	45/55
Debt term (years)	10
Interest rate (%)	6

Microsoft Excel is used to calculate the IRR of the investment projects. The IRR is calculated to be 14.1% for the small scale WEC. A large scale WEC system will definitely yield higher IRR. And we can conclude that WECs are economically suitable energy systems for supplementing the base load units (i.e. Teknecik steam power plants). The Excel program allows the user to make changes in any of the input parameters such as, general inflation rate, selling price of electricity, capacity factor, etc. Certainly, some parameters such as inflation rate, capacity factor, electricity selling price are uncontrollable but, good estimates of future values of those parameters enable the project developer to experiment with a variety of system choices and design selection criteria for the range of expected economic and financial conditions. In practice, there is always uncertainty about the future. Therefore, 'what if' scenarios are useful evaluating the impact of key economic decisions the overall performance of projects.

7-Discussions and conclusions

In recent years, N. Cyprus electricity system h been stretched to its limits by winter and summ peaks in demand. Energy statistics showed th serious considerations are required regarding t uncertain load growth, rising cost of fuel, high co of new capacity and environmental constraints. It thought that, the renewable energy resources cou be utilized to help reduce the level of peak dema from the grid.

Presently, wind energy resources available in N Cyprus are found not conducive to constructin renewable base-load electrical power station However, construction of WEC systems for fu and capacity saving and emission reduction ar recommended.

Most of the mature renewable energy technologie are used for power generation on islands. Samsoe Aeroe, Pellworm, Gotland and Dominica are some of the small islands that have taken a decision to become a renewable energy islands (i.e. islands that are 100% self sufficient from renewable energies). The public awareness with respect to utilizing renewable resources in Crete, an island in Mediterranean, is strong. Implementation plan for large-scale development of renewable energy resources is in progress with an aim to produce 45.4% of the total annual electricity demand by 2010 [10]. Most small islands are entities in terms of power generation. Therefore, promoting renewable energy technologies in small islands is going to demonstrate globally the success of large-scale renewable energy technologies.

Profitability analysis method (i.e. IRR method) is used to find the profitability of a 10 kW rated WEC system installed in N. Cyprus. The program developed for IRR calculations took into account such things as: capital expenditure, construction cost, equity and loan amounts, debt interest rate, operation and maintenance costs, inflation rate, capacity factor and the electricity selling price in order to evaluate the profitability of the WEC system. There are several technical and financial variables interacting with the design of a WEC system. Every technical and financial parameter affects the optimal solution of any particular project. Relying on technical optimization only or using any single parameter for the system optimization is not an appropriate approach. In practice, there is always uncertainty about the future. Therefore, 'what if' scenarios are important for evaluating the impacts of key design decisions on the overall project performance. Although, the IRR of the WEC system is found be at an acceptable level (i.e. more than 14%) there are only few locations where the WEC system will be economically viable.

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