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Technical, economic, and environmental analysis for the installation of a 3MW wind power plant in Libya

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Abstract - *The motivation for the work discussed herein stems from the increasing demand for renewable energy and the declining supply of nonrenewable energy. A growing proportion of global energy production is transitioning to renewable sources. Wind energy is experiencing heightened implementation for power generation owing to its economic advantages. Libya possesses a wealth of renewable energy resources, with an average wind speed of 4.5 m/s at 10 meters and 8 m/s at 50 meters. The economic study of this plant indicates that the wind farm incurs an investment cost of $3,450,000, yielding annual savings of $499,826.70. The payback period was determined to be 7 years, the savings-to-investment ratio was computed at 3.62, the net present value was positive, and the return on investment was 14.4%.*

Key Words: wind plant, economic analysis, turbine, greenhouse gases, renewable energy.

1.INTRODUCTION

Energy needs have significantly expanded as a result of the world economy's rapid development, particularly in emerging nations. Interest in using renewable energy has grown as a result of the understanding that the resources needed to generate energy from fossil fuels are becoming finite and that carbon emissions into the atmosphere are linked to climate change [1]. The development of a pollution-free, renewable wind system is essential. North Africa is home to Libya, which shares borders with Algeria, West Tunisia, South Africa, South Sudan, East Egypt, the Mediterranean, and southern Chad and Niger. The population grew by 1.3% annually in 2019 after reaching roughly 637500 in 2018[2]. Libya is the fourth largest country in Africa with an area of 1.75 million square kilometers, and it ranks 17th as the largest country in the world, and most of its lands are shrubs, desert, and semi-desert [3]. Generally speaking, the average wind speed in Libya is between 5 and 10 meters per second. In Libya, one of the primary benefits of wind energy is that it can meet the demand for electricity in most areas. Therefore, it is essential to create a new and remarkably amazing technical innovation industry in order to reduce global warming and the pollutants linked to energy use. But wind technology is becoming more and more attractive. There are hourly, daily, and yearly variations in wind energy output. Therefore, direct powering loads that need a consistent and continuous input energy supply is not a good fit for wind turbines.

1.1Energy policy of Libya

Libya's energy sector depends more on imported fossil fuel. Increase electricity per capita consumption by an average of 2.7, 5, and 4.7 MWh between 2002 and 2018[2]. Unpredicted costs of this fuel, coupled with an increase in global warming associated with thermal plants, pose a great danger in the energy sector. To complement this, renewable energy sources need to be harnessed for electricity generation.

2.WIND TURBINE PARAMETERS

Quantifying several key features of the wind is necessary to effectively map its resource. Primarily, and most significantly, the velocity,

We must precisely measure the wind over a minimum duration of one full year. Secondly, we must analyze the origin of the wind's direction. Finally, the variation in wind speed as a function of altitude must be examined to understand how wind speed measurements will be adjusted when interpolated with the wind turbine hub height [4].

Wind energy is the second best alternative renewable energy source. The wind speed in some coastal cities is shown in Fig -1. The average wind speed at three different heights in different cities in Libya is shown in Chart -1.

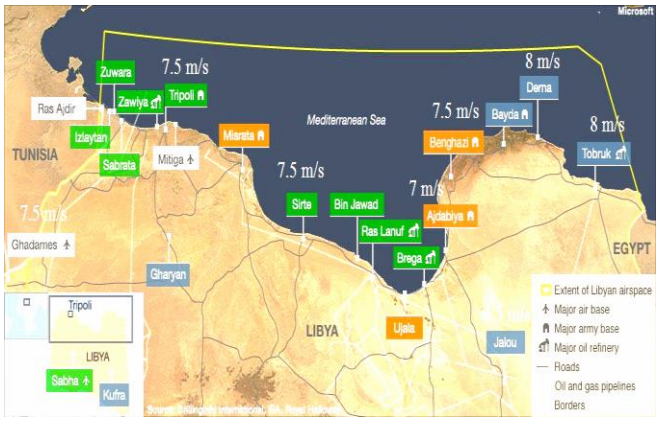

Fig -1: The wind speed in coastal cities in Libya[2]

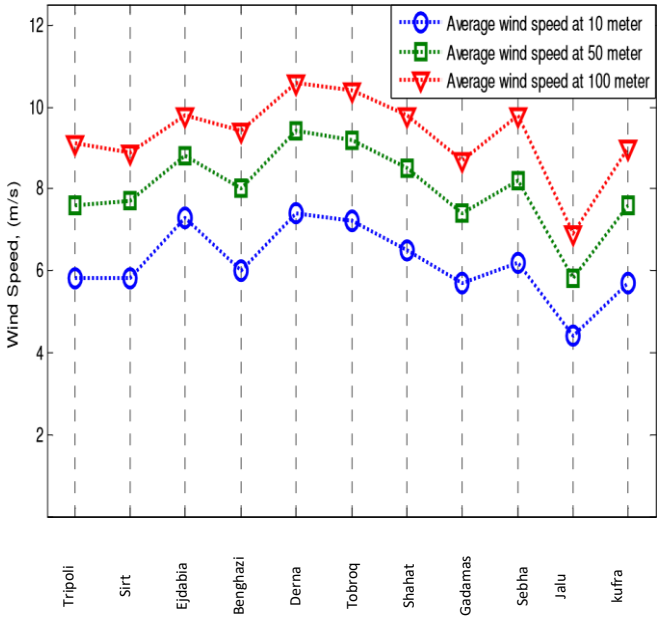

Chart -1: The monthly average wind speed in different cities in Libya [2]

Wind turbines are available in different specifications. We selected Raum wind turbines for this study. The table below displays the specifications of this turbine

Table -1: wind turbine specifications [5]

Type	3 blade, horizontal axix
Cut-in speed	3m/s
Cut-out speed	11m/s
Survival wind speed	45m/s
Rated power output	1.3kW
Swept area	6.8m²
Blade diameter	2.9m

2.1 analysis of the wind farm

Table -2: power output from a single turbine [5]

Month	Power delivered by the wind turbine in watts at 50m, Cp=0.3	Power delivered by the wind turbine (kWh)
January	243.8	181.4
February	287.5	193.2
March	199.3	143.5
April	134.7	96.9
May	102.3	76.1
June	117.8	84.8
July	145	107.9
August	140.7	104.7
September	122.5	88.2
October	102.3	76.1
November	150.4	108.3
December	199.3	148.3

From the results obtained above, each wind turbine can produce an expected total energy of 1409.4kWh. However, fora wind turbine of 3Mw, 2200 wind turbines are required. Land requirement the expected land area for the installation of the wind turbine can be calculated as follows

Power output = 2200 (1408.4) 0.85 = 3098480kWh/year

Pav/m² = power density/320 = 76.43/320 = 0.2388

0.2388×8760 = 2.092kWh/m²/year

Land requirement = 3098480/2.092 = 1481109m

3. ECONOMIC ANALYSIS

The investment cost of a wind farm fluctuates based on turbine size and other project-related expenses. The estimated range is from $900/kW to $1150/kW [4]. Alternative sources indicate that the cost may reach as high as $1308/kW to $1400/kW. We assumed $1100 per kW for this paper. The assumed generation cost is 18 cents per kWh, as the generation cost for an onshore wind farm varies between 14 and 18 cents per kWh [4]. The analysis assumes a discount rate of 12% and a project lifespan of 25 years. The calculation of the investment cost is
3000 * 1150 = $3,450,000. The annual generation cost is calculated to be $499,826.7

3.1 Simple payback

We use this metric to calculate how long it will take to recover the initial investment in a cost-saving initiative.

SPP= investment/saving = 3450000/499,826.7=7 years

3.2 Present value

Of the project after 25 years can be estimated as
P= A × [P/A, I, N], Where
A= Annual savings, P=Present value,
I= Discount rate, N= Number of year.
P=499,826.7× [7.8431] =3920190.8

3.3 Net present value (NPV)

NPV=A × [P/A, I, N] – present value cost
NPV= 3920190.8-3,450,000=470190.8
Saving to investment ratio (SIR): This calculate the present worth of all benefits, then calculate worth of all costs and takes the ratio of the two sums.
SIR= lifetime saving / investment cost
SIR= [499,826.7*25] / 3450000 = 3.62

3.4 Return on investment (ROI)

It is the inverse of the simple payback period given as a percentage. It provides the annual proportion of investment costs that will be recouped through savings.
[saving / investment]*100 = [499,826.7/ 3450000]*100 =14.48%.

4. ENVIRONMENTAL ANALYSIS

The rotation of the wind turbine's propellers generates noise that may disrupt nearby residents. The propeller may also lethally impact birds in the vicinity. Nonetheless, the power plant will diminish greenhouse gas emissions linked to thermal facilities.

5. CONCLUSIONS

This paper describes a 3MW wind farm located in Libya.
The economic study indicates that the wind farm incurs an investment cost of $3,450,000, yielding annual savings of $499,826.70. The payback period was determined to be 7 years, the savings-to-investment ratio was computed at 3.62, the net present value was positive, and the return on investment was 14.48%. The results indicate that a wind farm is viable in Libya, with significant annual savings and a reasonable payback period. Furthermore, it was demonstrated that the facility will diminish the output of greenhouse gases.

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