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RESEARCH ARTICLE OPEN ACCESS

A techno-economic simulation model of wind turbines power plant in AlShegaya and Almutla area in Kuwait using RETScreen program.

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ABSTRACT:
The attempt to achieve sustainability concept of the power generation sector has been the driver for researching energy efficient solutions to supply power. An attractive option is to develop innovative energy systems including renewable sources since this paper clarify the advantage of renewable power plant in terms of greenhouse gases emission. Also, this study investigates the wind power plant in two different location Shagaya and Mutla in Kuwait, these two locations were selected based on wind speed and availability of wind throughout the year which is approximately 5.3 m/s. The aim of the presented work is to develop a simulation model to assess the capacity factor, predict the levelized cost of energy produced from wind turbine, and greenhouse gases emission reduction at the two selected locations mentioned before and keep in mind Kuwait location is considered as an ideal area for wind availability. The techno-economic analysis is conducted through a simulation model by using Ret-screen Expert program which allow us to select specific wind turbine model and capacity. As a result, each run will provide massive result data, nonetheless, the three parameters mentioned above will be the main emphasis of this study. By merging final values of the three factors, the best location and most suitable wind turbine could be defined.
For each site, wind turbines Power plant Comprises of 50 wind turbines each one capacity 2MW with height equal 80 m with wind speed of 7.1m/s. Detailed analysis was conducted using the simulation model to calculate the capacity factor which is 31.3% for AlShagaya and AlMutla sites with 274,374 MWh electricity exported to the Kuwait grid . moreover, gross annual GHG emissions reduction approximately 93% for both locations. The estimated annual saving and revenue for Alshagaya is 175,560,502$ but for Almutla city is 166,855,573$. Additionally, the energy production cost (LCOE) for AlShagaya wind plant is 0.088 $/KWh, but for AlMutla city is 0.097 $/KWh. Finally, according to the simulation of RET screen program the best location based on the analysis obtained is AlShagaya due to significant impact of economic factors.
KEYWORDS
Wind turbine, RETScreen program, Wind speed, Airfoil losses, Electricity export rate, Capacity factor, Rated power, LCOE, IRR, Net present value, GHG reduction.

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I. Introduction

Currently, Kuwait is moving towards using renewable energy to meet the increase in energy demand, due to Various environmental and economic benefits which Includes unlimited renewable resources. Kuwait has a vision of producing 15% of kuwait total production to be from renewable energy by 2030. However, renewable sources are variable and unstable to a certain extent, but Kuwait has a surplus of unused solar and wind energy with high efficiency. Meanwhile wind energy is an essential renewable resource used around the world. In Kuwait, AlShagaya phase 1is the first wind Power Plant with a capacity of 10 MW however, it satisfies less than 1% of energy demand today. Kuwait electrical demand depends mainly on traditional methods which are steam turbine and gas turbine. The characteristics of energy generation changed since the world is going to more green energy and sustainable aspects which was forced by climate change that’s why it become a necessary to study the entry of renewable energy into production to raise the sustainability and capacity of the electrical system.

1.1.Aim of the study

1. Identify the potential sources of two locations in Kuwait (AlShagaya and AlMutla) to install wind power plants by using RETScreen program.

2. Analyze and investigate economical, technical and environmental aspects in two areas (AlShagaya and AlMutla) from simulation models.
3. Compare the results of simulation models of two locations and determine which one is more suitable location.

II. Methodology

2.1. Study Domain:

The map of Kuwait (figure 1) demonstrate that the wind speed is centered in the middle of Kuwait and heading on the western part of the country based on this AlShagaya and AlMutla were selected. This study presents the analysis of simulation models in two areas in Kuwait, which are AlShagaya and AlMutla. The two locations were selected based on Kuwait's year-round wind direction which is northwest through wind rose analysis as in figure 2 with the average wind speed of 8.2 m/s at 100m.

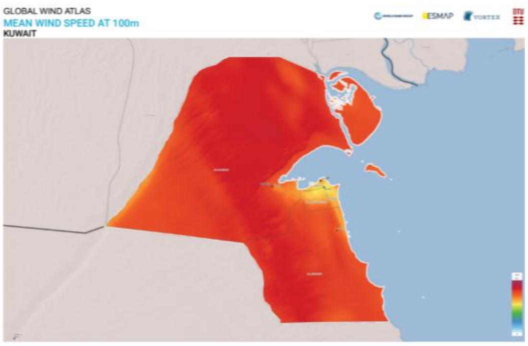

Figure 1: Kuwait Map mean wind speed at 100m

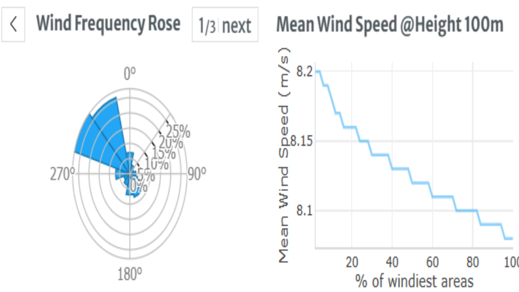

Figure 2: wind rose analysis and mean wind speed

2.2. RETScreen program

The low-carbon planning, implementation, monitoring, and reporting are made possible by the RET Screen Clean Energy Management Software platform. The importance of ret screen is to highlight the data effectively. The advantage of the program is providing useful techniques in renewable energy sciences and many of the techniques are useful for research purposes regulators concerned with operational and economical parameters as well as contains many tools to evaluate the model. Ret screen has different approaches to analyze data in terms of functions that are used to specify the purpose of the program which are study and discover renewable and nonrenewable energy plants.

2.3. Input data

The data of wind turbines plant for both locations (alshagaya and mutla) are same , input data includes wind power plant output of 100 MW , the type of turbines are vestas V90-2MW at 80 m with 90 rotor diameters each turbine installed capacity is 2 MW and the wind turbine hub height is 80 m. We discovered that in our location, 7.1m/s is the average wind speed in Shagaya and al Mutla at height of 80m meanwhile based on average input data from the weather forecast is 5.3m/s at ground level, we can capture as wind speeds typically increase with altitude. In addition, the Airfoil soiling losses which are caused by soiling of the blades from such things as bugs or dust. In Kuwait 25% of the year has dusty weather so in program the Airfoil soiling losses is 2% represented Accumulation of bugs or dust affects the aerodynamic performance of the blades. Miscellaneous losses are 6% represented any Tornadoes. Also, the average availability of all wind turbines in a wind farm is 98% includes downtime losses are the result of scheduled maintenance, wind turbine failures, station outage and utility outage. In RETScreen program we input the data as shows in figure 3. The reason why we decided to have the same input is to compare between the two locations in fairground so the output will be different because of the location only.

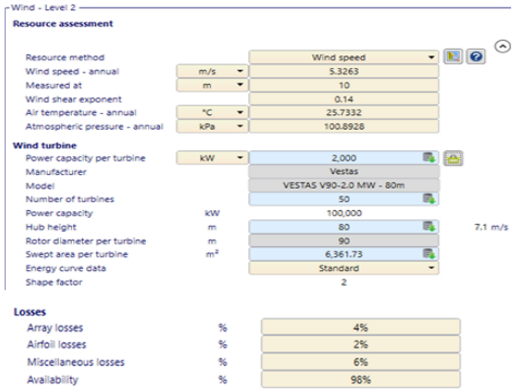

Figure 3: input data for RETScreen program

2.3.1. ALShagaya.

It is one of the areas, which is in Kuwait and the coordinates of the site are 29.195328°, 47.043457°as in figure 4. The RETScreen program calculates average temperatures and average wind speeds during the year at a height of 10 meters from the ground from ground-based meteorological stations the area is considering as very dry area as shown in figure 5.

Figure 4: AlShagaya Location

	Unit	Climate data location	Facility location	Source
Latitude		29.2	29.2	
Longitude		48.0	47.0	
Climate zone		1B - Very hot - Dry		Ground+NASA
Elevation	m	48	246	Ground – Map
Heating design temperature	°C	5.8		Ground
Cooling design temperature	°C	46.9		Ground
Earth temperature amplitude	°C	25.8		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	12.5	65.6%	16.43	3.10	101.8	3.7	12.8	171	78
February	14.8	55.5%	7.56	4.10	101.6	4.1	14.8	90	134
March	19.3	47.1%	10.85	5.50	101.3	4.5	19.4	0	288
April	24.9	36.8%	6.90	6.20	101.0	4.5	25.9	0	447
May	31.5	23.5%	0.62	7.10	100.6	4.7	32.2	0	667
June	36.0	15.1%	0.30	7.90	100.0	5.8	36.0	0	780
July	37.7	15.6%	0.00	7.50	99.7	5.6	37.9	0	859
August	36.8	19.8%	0.00	7.10	99.9	4.8	37.8	0	831
September	33.3	23.8%	0.00	6.20	100.4	3.7	34.1	0	699
October	27.3	38.7%	1.55	4.80	101.1	3.5	28.7	0	536
November	19.9	52.4%	10.20	3.40	101.6	3.5	21.0	0	297
December	14.1	64.2%	10.54	2.90	101.8	3.5	14.9	121	127
Annual	**25.7**	**38.1%**	**64.95**	**5.49**	**100.9**	**4.3**	**26.3**	**381**	**5,743**
Source	Ground	Ground	NASA	Ground	Ground	Ground	NASA	Ground	Ground
Measured at					m	10	0		

Figure 5: climate data analysis

2.3.2. AlMutla.
The second ares of interest is AlMutla, which is in Kuwait and the coordinates are 29.458133°, 47.720833° as figure 6. The RETScreen program calculates average temperatures and average wind speeds during the year at a height of 10 meters from ground-based meteorological stations the area is considering as very dry areas.

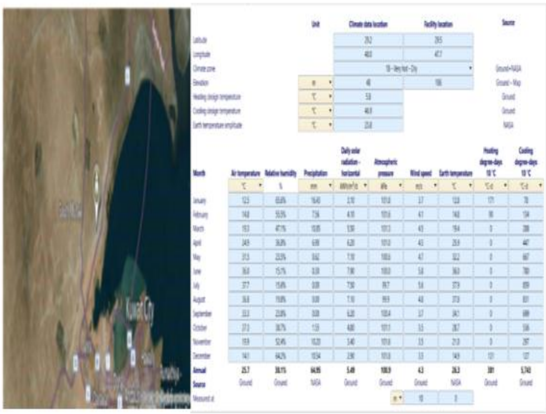

Figure 6: AlMutla location and climate data analysis

III. Results and discussions:

3.1. AlShagaya simulation analysis model.

The simulation of wind speed at tAl-Shagaya site, in figure 7, is high in summer due to the seasonal winds blowing from the Pacific and Indian Oceans to Kuwait when temperatures rise as the pressure in the region decreases the wind speed increases. Which is ideal since our peak power demand is in summer.

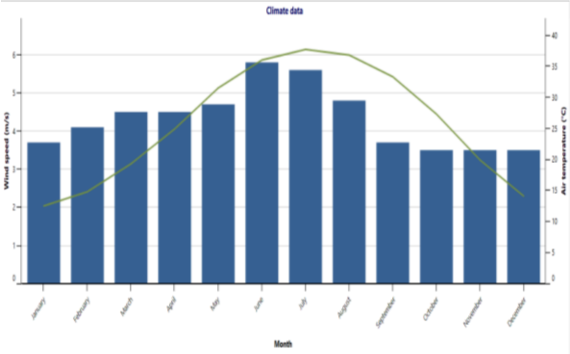

Figure 7: wind speed analysis in kuwait

Based on our input data the power energy curve shows ,in figure 8, the cut in point which is the point turbine start to generate electricity at 4 m/s. The rated power which is the highest point of turbine to reach installed capacity at 14 m/s, also the cutout point which the turbine will stop operating to preserve turbine components when wind speeds rise for long periods at 15 m/s. Also, the area between energy and power curve increases which means there is reliability on this type of turbine.

Wind speed m/s	Power curve data kW	Energy curve data MWh
0	0	
1	0	
2	0	
3	0	517
4	56	1,526
5	165	3,013
6	339	4,719
7	570	6,402
8	863	7,926
9	1,215	9,243
10	1,606	10,351
11	1,878	11,258
12	1,974	11,975
13	1,995	12,510
14	2,000	12,874
15	2,000	13,082
16	2,000	
17	2,000	
18	2,000	
19	2,000	
20	2,000	
21	2,000	
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26	2,000	
27	2,000	
28	2,000	

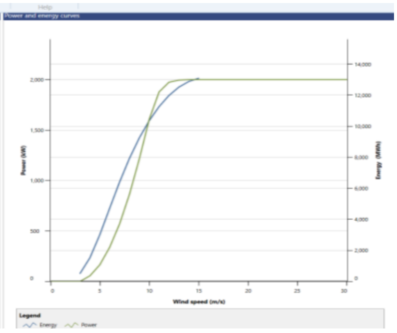

Figure 8: power energy curve

And the parameter discovered from program run is shown in figure 9.

Summary		
Capacity factor	%	31.3%
Initial costs	$/kW	1,000
	$	100,000,000
O&M costs (savings)	$/kW-year	36
	$	3,600,000
Electricity export rate		Electricity export rate - annual
	$/kWh	0.10
Electricity exported to grid	MWh	274,374
Electricity export revenue	$	27,437,364
Other information		**Per turbine**
Unadjusted energy production	MWh	6,594
Pressure coefficient		0.996
Temperature coefficient		0.964
Gross energy production	MWh	6,332
Losses coefficient		0.87
Specific yield	kWh/m²	863

Figure 9: operation parameter of AlShagaya

The capacity factor is, the average power output divided by its maximum power capability of wind turbines plant, 31.3% which emphasizes on that AlShagaya is perfect location for wind turbine and the electricity export rate is 0.10 $/kwh. Moreover, the temperature coefficient is 0.964 which mean the temperature is very high and the air density low however with higher pressure coefficient 0.996 increase the air density so that the power availability from the wind turbine is suitable.

Also, as a result from the program GHG analysis as shown in figure(10), The results show gross annual greenhouse gases reduction is 93% which is 642,940 tCO2 of the wind turbine plant compared with natural gas where the tCO2/MWh factor equal to 0.505. GHG reduction credit rate as $/tCO2 is 75$ which will increase the revenue of the plant based on world bank.

Figure 10: AlShagaya GHG reduction analysis

As our financial analysis shows that the total initial cost 900million $, the total annual cost includes operation and maintenance cost approximately 87million$ and total annual saving and revenue is 175,560,502$ with 75 $/tCO2 as a GHG reduction credit rate. Meanwhile net yearly cash flow for year 1 is 88,389,889$ this just presenting few of the data that RETScreen program can generate as shown in figure (11). And the most important output is levelized cost of energy which is 0.08$/kwh and with this project the payback period is 5.7years and net present value (NPV) is 343,247,525$.

Figure 11: AlShagaya financial anaylsis

All this financial analysis comes to one idea that this project is feasible in terms of location , cost and weather data.

3.2. AlMutla simulation analysis model.

Now if we consider the climate data as shown in figure (7) that wind speed at the ALMutla site are the same as AlShagaya site.

Figure (12) shows the energy power curve indicates that Mutla area has potential on operation wind turbine. The cut in point which is the point where turbine start to generate electricity at 4 m/s and the rated power which is the highest point of turbine to reach installed capacity at 14 m/s, also the cutout points the turbine will stop operate to preserve turbine components when wind speeds rise for long periods at 15 m/s.

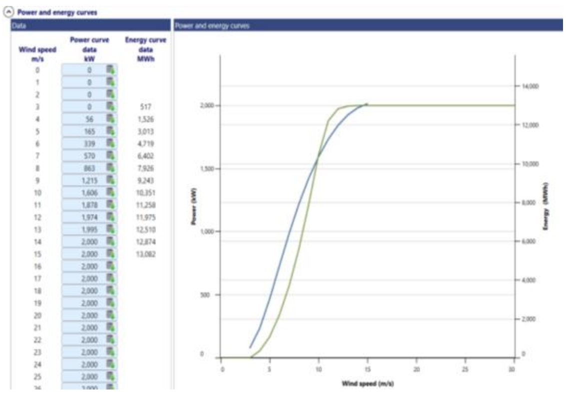

Figure 12: AlMutla power energy curve

As shown in figure(13), The data of the project will show 31.3% capacity factor and electricity export rate as 0.1$/kwh so total electricity exported to the grid is 274,274 MWh. To be more specific AlMutla area has same capacity factor as alshagaya. Moreover, the temperature coefficient is 0.964 which means the temperature is very high and the air density low however with higher pressure coefficient 0.996 increase the air density so that the power availability from the wind farm is suitable.

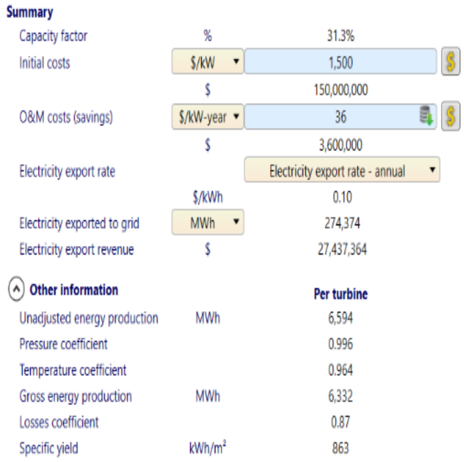

Figure13: AlMutla operation parameter

The effect that wind turbine has on green house gas emissions is observed in figure (14) which compare it to natural gas emissions with 93% of reduction. The tCO_2/MWh factor equal to 0.505 with gross annual GHG emission reduction 611,060 tCO_2.

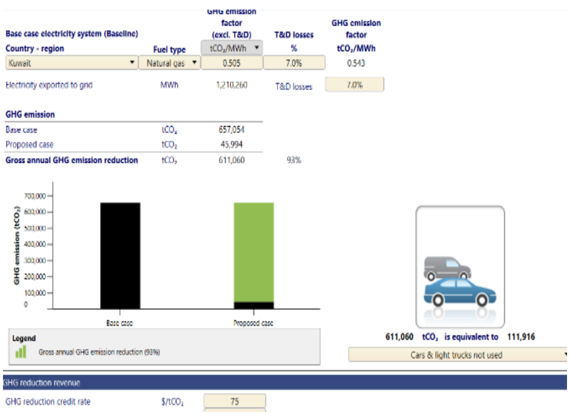

Figure 14: AlMutla GHG reduction

From Financial aspect the figure (15) describes the economical result of the project at Mutla city as the total initial cost 950million$, the total annual cost includes operation and maintenance cost approximately 91million$ and the total annual savings and revenue 166.85 million$ with 75 $/tCO2 as a GHG reduction credit rate. The most significant factor output from the run is LCOE equal 0.097 $/KWh with 6.4 years payback period. Furthermore, the inflation rate is 2% , project life 20 years and the NPV which is to equal 229,611,851$ that indicate that the investment is expected to generate a net gain in value and the future cash flows of the project are greater than the initial cost.

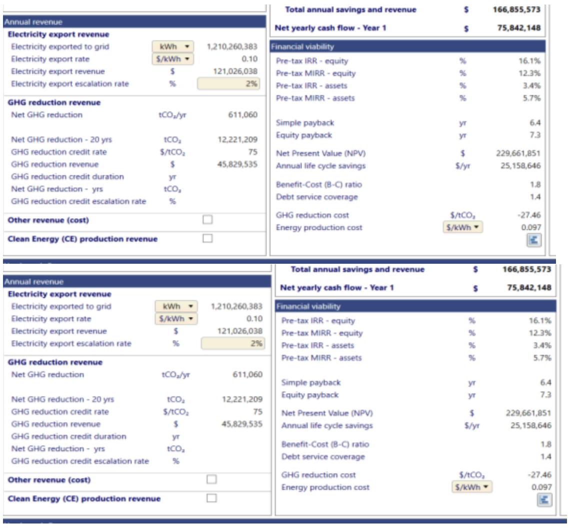

Figure 15: AlMutla financial analysis

3.3.Main finding :

The two proposed location in RETScreen program were evaluated in detailed but we will present summary of main parameter in this section.

Table 1:comparison between AlShagaya and AlMutla site

Wind turbine power plant 100MW		
Parameter	**ALShagaya**	**AlMutla**
Electricity export to the grid MWh	**274,374**	**274,374**
Capacity factor,%	**31.3%**	**31.3%**
Gross annual GHG emission reduction, (tCO_2/yr)*& %	**642,940 93%**	**611,060 93%**
LCOE, (nominal& real)), $/kWh	**0.088**	**0.097**
NPV, $	**343,247,525$**	**229,611,851$**
Total annual saving and revenue	**175,560,502$**	**166,855,573$**
Total initial cost $	**900,000,000$**	**950,000,000$**

IRR assets/ equity	5.2% / 20.1%	3.4% /16.1%

IV. Conclusion

This study presented detailed analysis of generating 100MW by wind turbine power using RETScreen simulation models to Compare two sites ALShagaya and ALMutla. The results showed that based on weather conditions from ground measurement stations and the proposed result from the program is predicting wind turbine capacity factor, wind speed, temperature and pressure coefficients. The main parameters to compare the two locations in terms of feasibility is conducted from the main findings' summary.

First, annual energy production is equal in both locations corresponding to the capacity factor which is 31.3% in both locations. Second, the greenhouse gas emissions reduction is higher in Alshagaya as 642,940 tCO2/yr, in contrast ALMutla is lower due to population density. Third, the net present value of alshagaya is higher than almutla by approximately 113.6milion$. In addition, the IRR for equity and assets of ALshagaya 5.2% and 20.1 % respectively is higher than AlMutla which means that the profitability of an investment over life project period achievable.

The Levelized Cost of Energy (LCOE) is an important measurement of an energy-generating asset can be thought of as the average total cost of building and operating the asset per unit of total electricity generated over an assumed lifetime. Our result shows that LCOE is lower in Alshagaya location which mean as a project evaluator we would recommend alshagaya location to build wind farm with 100MW capacity. The initial cost of AlMutla location is higher than ALShagaya due to the topography variation of the area, also leveling the land, will cost more because of the higher altitudes, and windings to decrease the array losses in wind farm and maximizes the land's potential.

Finally, the analysis demonstrate that AlShagaya area is more suitable than ALMutla area to install wind power plant from an economic, technical and environmental aspects .

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