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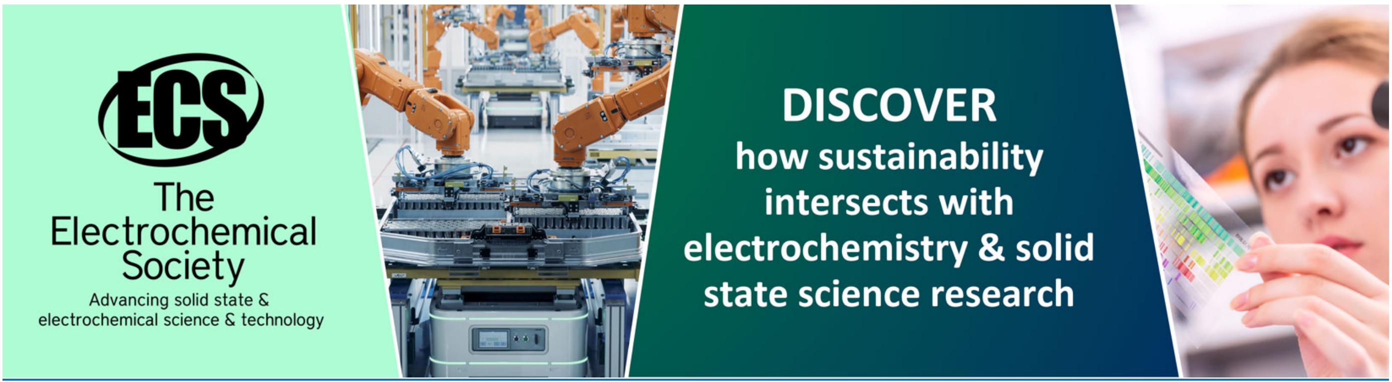

Harnessing wind potential in Covenant University

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Abstract. Energy is one of the major necessities for economic growth and development of any nation. It is one of the most demanded commodities globally, which measures the growth of both government and private settings. Due to the emission of greenhouse gases from burning fossil fuels in electricity generation, greater attention has been directed towards the generation and application of renewable sources of energy that can be used with little or no carbon and/or greenhouse gas emission. It is therefore necessary to explore the applicability of renewable energy resources in our local domains. The purpose of this study is to explore the feasibility of using wind turbines in the generation of electricity in Covenant University. This study reports the wind potential in Covenant University and explores the utility that is attainable from the use of wind turbines in Covenant University and its environs. The wind data profile for Covenant University was collected from World Weather Online from May 2017 to May 2022 and then compared with some models of wind turbines. The wind speed data for Kano state was acquired and analyzed to gain insight into the turbine efficiency in Covenant University. The average wind speed in Covenant University over the 5-year period was found to be 3.75 m/s, while the average wind speed in Kano State over a 3-year period was found to be 4.02 m/s. The available data revealed that the wind potential is not sufficient to substantially drive wind energy conversion in Covenant University, especially with turbines of higher ratings.

Keywords: Wind, Wind Turbine, Energy, Renewable Energy, Capacity Factor.

1. Introduction

Energy as the bedrock for development determines the advancement of any nation. The amount, cost and quality of energy available to a group of people largely dictate the standard of living and quality of life of the individuals in that society. Energy also forms one of the largest economic sectors in the world, and that is because it is necessary for every other sector of any economy [1, 2]. The biggest influencing factor on the future of energy is the transition to cleaner energy sources such as solar, wind, biomass, geothermal, hydroelectric, nuclear etc, rather than the widespread fossil fuel that is deteriorating the earth and its ecosystem. This transition from non-renewable to renewable sources would continue to grow as more investments and research are being made globally into renewables. It is predicted that by the year 2030, the global investment in renewables would be more than five times the amount being invested in the production of fossil fuels reaching an amount of over $1.2 trillion annually [3].

This paper seeks to investigate the possibility of using wind turbine for electricity generation in Covenant University. It would therefore be necessary to understand the energy source of wind turbines — the wind. Wind is the motion of air and atmospheric particles relative to the earth’s surface. This motion is caused by a gradient in air pressure as result of difference in temperature between two locations on the earth. This pressure difference could either be horizontal or vertical. Typically, air moves from regions of high pressure to regions of low pressure and the resulting wind follow the same pattern. The difference in air pressure on the earth is caused by the uneven absorption of solar radiation on the earth [4]. After uneven absorption of solar radiation by the atmosphere, the second cause of global wind patterns is the Coriolis Effect. This is the deflection of the motion of fluid over a rotating surface. On the earth, the Coriolis effect is observed when wind moving over the earth’s surface is deflected clockwise or counter-clockwise depend on the hemisphere due to the difference in the angular velocity of various latitudes. The earth is a sphere and on the course of its rotation about its axis, the equatorial regions of the earth will spin a lot faster than the polar regions because of their larger circumference. Therefore, objects and structures on the equator would have a greater angular momentum than those of equal mases on higher or lower latitudes. While travelling along the earth’s surface over long distances the fluid angular momentum is conserved, this would result in a deflection either clockwise or counter-clockwise depending on the hemisphere [5-6].

Wind is classified based on several factors like spatial scale, force of causation, duration, speed, direction, location of occurrence, source, the effects etc. There are also various terms used to describe and qualify wind in a particular location like wind velocity, wind density, wind chill, wind power, wind variability etc. These qualities would have to be studied and determined before citing of a wind turbine or wind farm at a particular location. As these parameters would be required to determine the type and specification of wind turbine that should be utilised to maximize power output in that location. Wind patterns are broadly classified into three based on the location and periodicity of occurrence, namely; primary, secondary and tertiary winds. Primary winds are winds that blow all through the year in a particular direction. They are caused by the difference in the absorption of solar radiation by the earth’s atmosphere at different latitudes. Examples are doldrums, trade winds, westerlies and easterlies and horse latitudes. Primary winds are also called prevailing or planetary winds. Secondary winds are winds that change their nature, direction and velocity at different seasons. There are also known as seasonal or periodic winds. Secondary wind and the forces that drive the secondary wind are functions of the unique geographical locations. Some examples of secondary winds are monsoons, hurricanes and cyclones [7]. The time scales of primary and secondary winds are shown in Figure 1.

In light of this, there is a need to examine the various options available to us for generating energy through wind turbines in our local context and how we can optimise and integrate this technology in our society, and in a world class institution like Covenant University, that seeks to meet up with the United Nation’s sustainable development goals. One of which is clean and affordable energy (SDG7) [8-10]. It is therefore necessary to look into the possibility, applicability and profitability of using wind energy systems to generate electricity in Covenant.

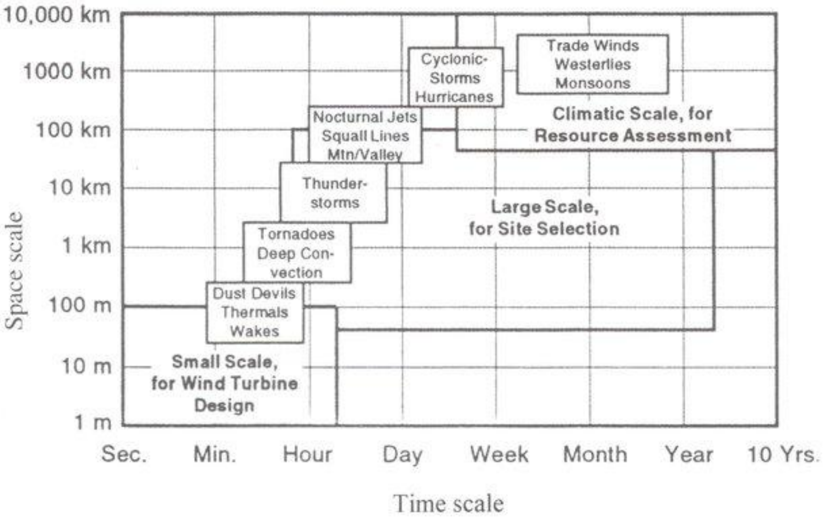

Figure 1: Time and space scale of atmospheric motion [7]

2. Methodology

The inter-annual wind speed data were gotten from World Weather Online which is a meteorological organisation that does weather forecasts and have real-time measurements of weather parameters across the globe. The wind parameters that were gotten are wind speed, wind density and wind temperature. The data gotten were from May 2017 to May 2022 for Covenant University and from July 2019 to June 2022 for Kano state. The data gotten from World Weather Online consisted of large data sets, as the data consisted of measured wind parameters on an hourly basis from May 2017 to May 2022. These large data sets had to be further processed and the monthly and yearly averages were then calculated. The values for wind speed were then compared with the specifications and parameters of some known wind turbines namely, ACSA LMW, Aeolos-H, Aeronautica 47, Acciona AW-77 and Mitsubishi MWT95. The expected power outputs of the wind turbine models were computed using Equation 1 to produce another data set. The graphs of these data sets are then plotted using the Numbers app. The analysis and calculations were also done using the Numbers app. The power output of the wind turbine is given in Equation 1.

$$P_T = \frac{1}{2}\rho A v^3 C_p \qquad 1$$

where C_p is power coefficient, ρ is density of air, $A = \pi r^2$ is Area of rotor, r is radius of turbine rotor, v is velocity of air.Capacity Factor (CF) is the ratio between the average power output of a turbine over a period of time and the maximum possible power output of that turbine. This relationship is shown in Equation 2.

$$\text{CF} = \frac{\text{Average Power Output}}{\text{Maximum Power Output}} \qquad 2$$

3. Results and Discussion

Table 1 gives the values of the average monthly wind speed in Covenant University from May 2017 to May 2022 and Figure 2 is the wind speed curve over that time period. From the data, the minimum average monthly value of wind speed was 2.81 m/s, the maximum average monthly value of wind speed was 4.69 m/s and the average of the average monthly value of wind speed over the 5 years is 3.75 m/s. The average outputs of the various wind turbines were computed. The density of air at the average Ogun state temperature of 29°C is 1.17 kg/m^3. The power coefficient (C_p) varies depending on the wind speed and the efficiency of the turbine, but for a good wind turbine the power coefficient ranges from 0.35 to 0.45. These values would be used to compute for the upper and lower limit of the expected power output. Another major determining factor in the output of a wind turbine is the cut-in and cut-out speed, which indicates the range of wind speed where the wind turbine would produce useful energy.

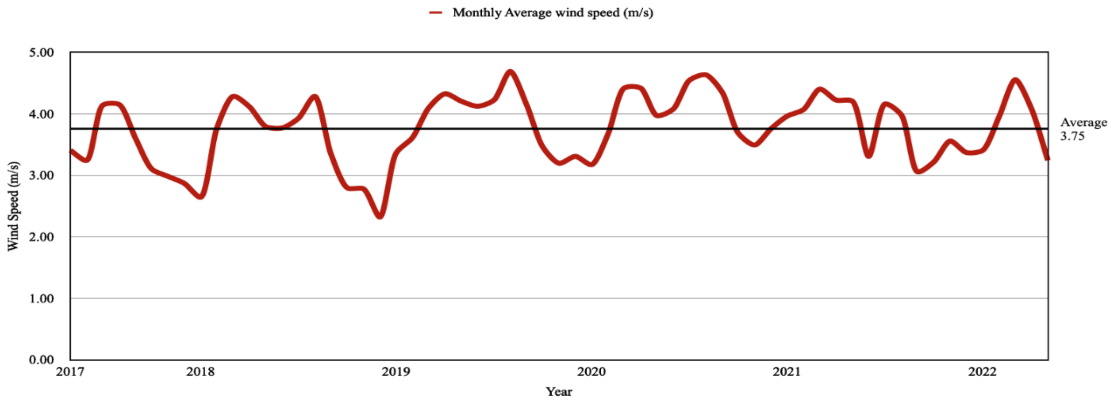

Figure 2: Average wind speed from May 2017 to May 2022

Table 1: Average Monthly wind speed in m/s

MONTH	2017	2018	2019	2020	2021	2022
JANUARY	---	2.64	3.36	3.17	3.96	3.41
FEBRUARY	---	3.77	3.61	3.67	4.07	3.95
MARCH	---	4.28	4.09	4.42	4.40	4.55
APRIL	---	4.11	4.32	4.42	4.22	4.07
MAY	3.41	3.79	4.20	3.97	4.20	3.24
JUNE	3.24	3.77	4.12	4.07	3.31	---
JULY	4.14	3.92	4.22	4.54	4.16	---
AUGUST	4.15	4.28	4.69	4.63	3.98	---
SEPTEMBER	3.60	3.34	4.15	4.35	3.06	---
OCTOBER	3.10	2.80	3.46	3.68	3.22	---
NOVEMBER	2.98	2.78	3.19	3.49	3.56	---
DECEMBER	2.87	2.32	3.31	3.75	3.37	---

Table 2 and Figure 3 to 7 gives the estimated monthly average power output of the various selected models of wind turbines. In the figures, the red line indicates an upper limit to the monthly power output, while the blue line indicates the lower limit. This means that output power of these models of wind turbine would fall somewhere in between the red and blue line. The capacity factors of the wind turbines calculated using the average power output divided by the power rating of the turbine. The capacity factor gives the measure of the effectiveness or productivity of the turbine in that location. It compares how much energy a turbine produces with how much energy it should produce. The capacity factor is calculated using Equation 2. The capacity factor for an effective wind electric system lies between 0.26 to 0.56 (CSS, 2022). Figure 3 gives the power curve for the ASCA LMW model of wind turbine, and it is observed from Table 2 that the average power output over the 5 years would fall between 176.3 and 226.27 W. There was a month where the average monthly speed fell below the turbines cut-in speed and on this month the turbine would produce relatively no usable energy. The measure of the turbine utility which is given by the capacity factor is between 0.18 to 0.23, which is relatively low compared to the standard range. Figure 4 gives the power curve for the Aeolos-H model of wind turbine, and it is observed from Table 2 that the average power output over the 5 years would be between 4,373.05 and 5,622.5 W. There was a month where the average monthly speed fell below the turbines cut-in speed and on this month the turbine would produce relatively no usable energy. The measure of the turbine utility which is given by the capacity factor is between 0.15 to 0.29, which is relatively low compared to the standard range.

Figure 5 gives the power curve for the Aeronautical 47 model of wind turbine, and it is observed from Table 2 that the average power output over the 5 years would be between 31.75 and 40.82 kW. There were 22 months where the average monthly speed fell below the turbines cut-in speed and on these months the turbine would produce relatively no usable energy. The measure of the turbine utility which is given by the capacity factor is between 0.04 to 0.05, which is very low compared to the standard range. Figure 6 gives the power curve for the Acciona AW-77 model of wind turbine, and it is observed from Table 2 that the average power output over the 5 years would be between 84.45 and 108.58 kW. There were 22 months where the average monthly speed fell below the turbines cut-in speed and on these months the turbine would produce relatively no usable energy. The measure of the turbine utility which is given by the capacity factor is between 0.06 to 0.07, which is very low compared to the standard range. Figure 7 gives the power curve for the Mitsubishi MWT95 model of wind turbine, and it is observed from Table 2 that the average power output over the 5 years would be between 156.96 and 201.81 kW. There were 6 months where the average monthly speed fell below the turbines cut-in speed and on these months the turbine would produce relatively no usable energy. The measure of the turbine utility which is given by the capacity factor is between 0.07 to 0.08, which is very low compared to the standard range.

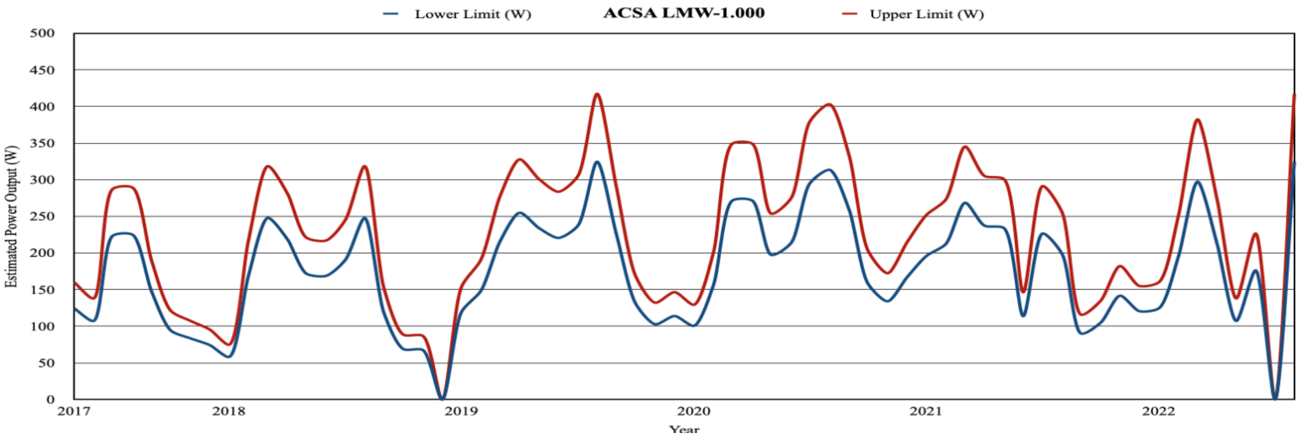

Figure 3: Estimated output curve for ACSA LMW-1000 from May 2017 to May 2022

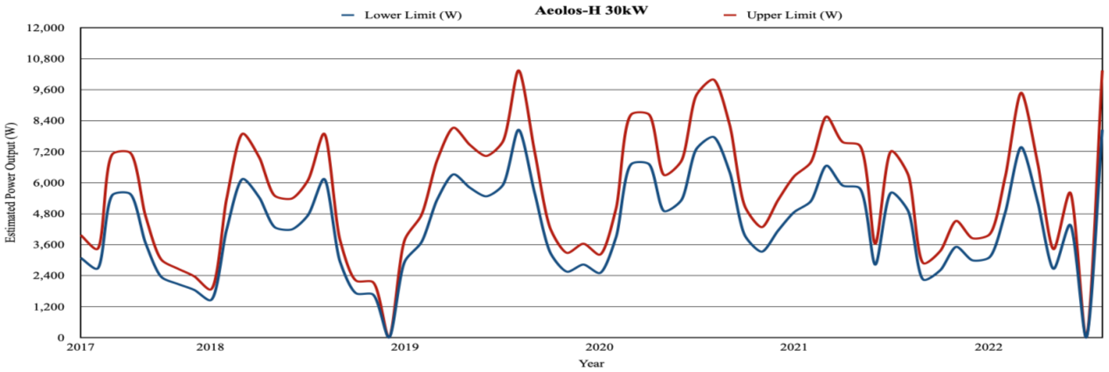

Figure 4: Estimated output curve for Aeolos-H 30kW from May 2017 to May 2022

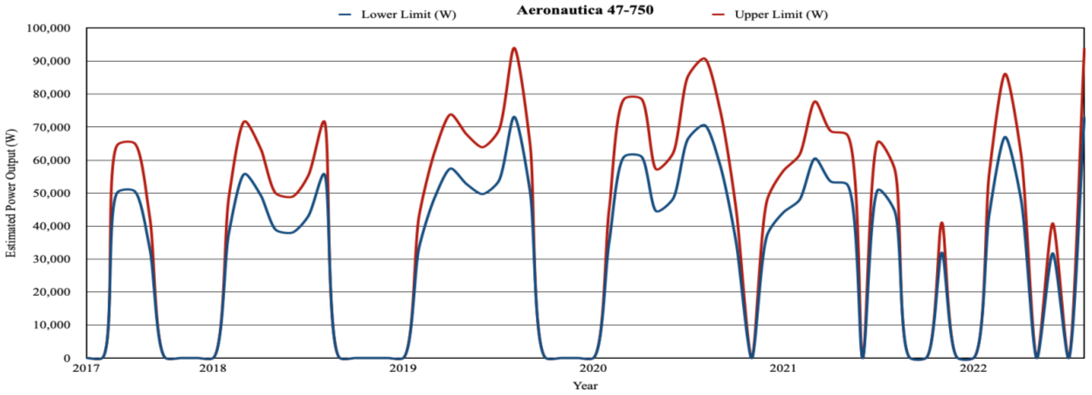

Figure 5: Estimated output curve for Aeronautica 47 750kW from May 2017 to May 2022

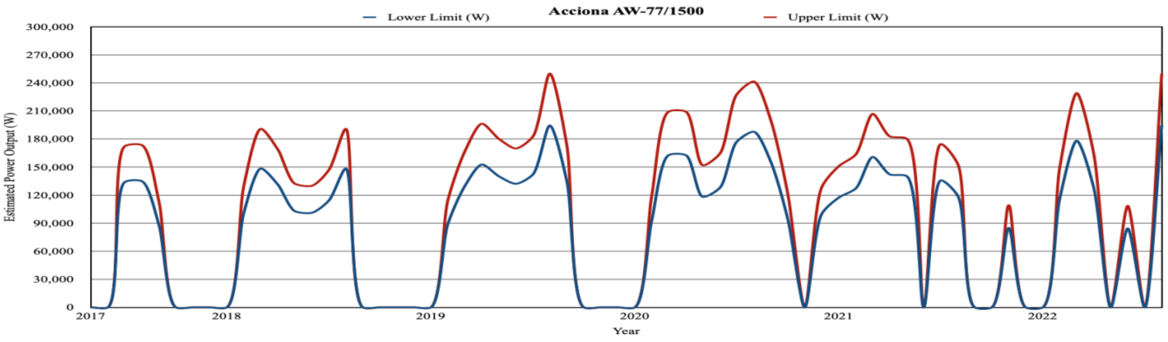

Figure 6: Estimated output curve for Acciona AW-77/1500 from May 2017 to May 2022

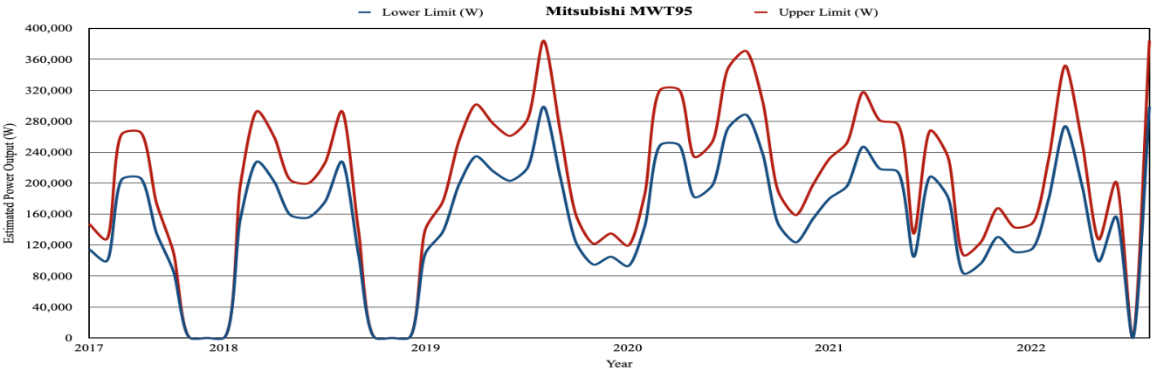

Figure 7: Estimated output curve for Mitsubishi MWT95 from May 2017 to May 2022

Table 2: Estimated power output for the model wind turbines in Covenant University

Year	**Month**	**Wind Speed**	**ACSA LMW-1000**		**Aeolos-H 30kW**		**Aeronautica 47-750**		**Acciona AW-77/1500**		**Mitsubishi MWT95**	
		(m/s)	**Lower Limit (W)**	**Upper Limit (W)**	**Lower Limit (W)**	**Upper Limit (W)**	**Lower Limit (W)**	**Upper Limit (W)**	**Lower Limit (W)**	**Upper Limit (W)**	**Lower Limit (W)**	**Upper Limit (W)**
2017	**May**	3.41	124.48	160.05	3,087.77	3,969.99	0	0	0	0	114,587.12	147,326.30
	June	3.24	107.32	137.98	2,662.07	3,422.67	0	0	0	0	98,789.43	127,014.98
	July	4.14	223.71	287.62	5,549.08	7,134.53	50,406.52	64,808.38	134,078.44	172,386.57	205,925.89	264,761.86
	August	4.15	225.16	289.49	5,585.19	7,180.95	50,734.55	65,230.13	134,950.97	173,508.39	207,265.97	266,484.82
	September	3.60	147.34	189.44	3,654.81	4,699.04	33,199.45	42,685.01	88,308.63	113,539.67	135,629.81	174,381.18
	October	3.10	93.97	120.82	2,330.90	2,996.87	0	0	0	0	86,499.45	111,213.57
	November	2.98	83.57	107.44	2,072.93	2,665.19	0	0	0	0	0	0
	December	2.87	74.34	95.58	1,843.93	2,370.77	0	0	0	0	0	0
2018	**January**	2.64	58.24	74.88	1,444.64	1,857.40	0	0	0	0	0	0
	February	3.77	168.93	217.20	4,190.41	5,387.67	38,064.71	48,940.35	101,249.95	130,178.50	155,505.88	199,936.13
	March	4.28	247.76	318.55	6,145.80	7,901.74	55,827.03	71,777.60	148,496.67	190,924.29	228,070.29	293,233.23
	April	4.11	219.09	281.69	5,434.57	6,987.30	49,366.35	63,471.02	131,311.65	168,829.26	201,676.48	259,298.34
	May	3.79	171.70	220.76	4,259.08	5,475.96	38,688.50	49,742.36	102,909.18	132,311.81	158,054.23	203,212.59
	June	3.77	168.75	216.97	4,186.00	5,382.00	38,024.66	48,888.85	101,143.41	130,041.52	155,342.24	199,725.74
	July	3.92	190.62	245.09	4,728.43	6,079.41	42,951.97	55,223.97	114,249.78	146,892.57	175,471.81	225,606.62
	August	4.28	247.76	318.55	6,145.80	7,901.74	55,827.03	71,777.60	148,496.67	190,924.29	228,070.29	293,233.23
	September	3.34	117.76	151.40	2,921.04	3,755.62	0	0	0	0	108,399.67	139,371.00
	October	2.80	68.90	88.59	1,709.06	2,197.37	0	0	0	0	0	0
	November	2.78	67.58	86.89	1,676.41	2,155.38	0	0	0	0	0	0
	December	2.32	0	0	0	0	0	0	0	0	0	0
2019	**January**	3.36	119.63	153.81	2,967.48	3,815.34	0	0	0	0	110,123.20	141,586.98
	February	3.61	148.48	190.90	3,683.07	4,735.37	33,456.15	43,015.05	88,991.43	114,417.55	136,678.49	175,729.49
	March	4.09	216.52	278.38	5,370.85	6,905.38	48,787.59	62,726.91	129,772.19	166,849.96	199,312.08	256,258.39
	April	4.32	254.93	327.77	6,323.63	8,130.39	57,442.42	73,854.55	152,793.54	196,448.83	234,669.68	301,718.17
	May	4.20	234.03	300.90	5,805.15	7,463.76	52,732.62	67,799.08	140,265.72	180,341.64	215,428.70	276,979.76
	June	4.12	220.57	283.59	5,471.37	7,034.62	49,700.66	63,900.85	132,200.89	169,972.57	203,042.23	261,054.30
	July	4.22	237.04	304.76	5,879.73	7,559.65	53,410.12	68,670.15	142,067.83	182,658.64	218,196.49	280,538.34
	August	4.69	324.53	417.26	8,050.07	10,350.09	73,125.00	94,017.85	194,508.28	250,082.07	298,737.74	384,091.39
	September	4.15	225.06	289.37	5,582.77	7,177.85	50,712.63	65,201.96	134,892.68	173,433.45	207,176.45	266,369.72
	October	3.46	130.47	167.75	3,236.36	4,161.03	0	0	0	0	120,101.09	154,415.69
	November	3.19	102.79	132.15	2,549.61	3,278.07	0	0	0	0	94,615.79	121,648.88
	December	3.31	113.98	146.55	2,827.31	3,635.12	0	0	0	0	104,921.41	134,898.96
2020	**January**	3.17	100.64	129.39	2,496.34	3,209.59	0	0	0	0	92,639.20	119,107.55
	February	3.67	155.68	200.16	3,861.73	4,965.08	35,079.08	45,101.68	93,308.33	119,967.86	143,308.66	184,253.99
	March	4.42	271.83	349.49	6,742.72	8,669.22	61,249.36	78,749.18	162,919.77	209,468.27	250,222.17	321,714.22
	April	4.42	271.66	349.28	6,738.62	8,663.94	61,212.10	78,701.27	162,820.65	209,340.83	250,069.94	321,518.49
	May	3.97	197.23	253.58	4,892.22	6,290.00	44,439.79	57,136.87	118,207.28	151,980.78	181,549.98	233,421.41
	June	4.07	213.22	274.14	5,289.01	6,800.15	48,044.11	61,771.00	127,794.56	164,307.29	196,274.73	252,353.22
	July	4.54	295.65	380.12	7,333.62	9,428.94	66,616.94	85,650.35	177,197.22	227,825.00	272,150.36	349,907.60
	August	4.63	313.49	403.06	7,776.18	9,997.95	70,637.03	90,819.04	187,890.43	241,573.41	288,573.64	371,023.25
	September	4.35	259.88	334.13	6,446.29	8,288.08	58,556.58	75,287.03	155,757.12	200,259.16	239,221.34	307,570.30
	October	3.68	157.50	202.50	3,906.79	5,023.02	35,488.39	45,627.93	94,397.07	121,367.66	144,980.80	186,403.89
	November	3.49	134.12	172.44	3,326.90	4,277.45	0	0	0	0	123,461.17	158,735.79
	December	3.75	166.88	214.55	4,139.39	5,322.08	37,601.30	48,344.53	100,017.29	128,593.66	153,612.69	197,502.03
2021	**January**	3.96	195.89	251.86	4,859.16	6,247.50	44,139.52	56,750.81	117,408.58	150,953.89	180,323.30	231,844.24
	February	4.07	212.18	272.81	5,263.29	6,767.09	47,810.51	61,470.65	127,173.20	163,508.39	195,320.39	251,126.22
	March	4.40	268.53	345.26	6,661.00	8,564.14	60,506.95	77,794.65	160,945.01	206,929.29	247,189.21	317,814.70
	April	4.22	237.34	305.15	5,887.22	7,569.29	53,478.18	68,757.66	142,248.89	182,891.42	218,474.56	280,895.86
	May	4.20	234.03	300.90	5,805.15	7,463.76	52,732.62	67,799.08	140,265.72	180,341.64	215,428.70	276,979.76
	June	3.31	113.89	146.43	2,825.01	3,632.16	0	0	0	0	104,836.13	134,789.32
	July	4.16	226.62	291.37	5,621.45	7,227.58	51,063.99	65,653.70	135,827.27	174,635.06	208,611.85	268,215.23
	August	3.98	199.01	255.87	4,936.53	6,346.96	44,842.26	57,654.33	119,277.83	153,357.20	183,194.20	235,535.40
	September	3.06	89.95	115.65	2,231.30	2,868.81	0	0	0	0	82,803.40	106,461.51
	October	3.22	104.96	134.95	2,603.62	3,347.51	0	0	0	0	96,620.30	124,226.10
	November	3.56	141.73	182.23	3,515.68	4,520.16	31,935.65	41,060.12	84,946.99	109,217.56	130,466.80	167,743.03
	December	3.37	120.59	155.05	2,991.29	3,845.94	0	0	0	0	111,006.54	142,722.69
2022	**January**	3.41	124.48	160.05	3,087.77	3,969.99	0	0	0	0	114,587.12	147,326.30
	February	3.95	194.09	249.55	4,814.54	6,190.12	43,734.18	56,229.66	116,330.40	149,567.66	178,667.37	229,715.18
	March	4.55	297.40	382.37	7,377.10	9,484.85	67,011.90	86,158.16	178,247.79	229,175.74	273,763.89	351,982.15
	April	4.07	213.22	274.14	5,289.01	6,800.15	48,044.11	61,771.00	127,794.56	164,307.29	196,274.73	252,353.22

May	3.24	107.32	137.98	2,662.07	3,422.67	0	0	0	0	98,789.43	127,014.98
Average	**3.75**	**176.30**	**226.67**	**4,373.05**	**5,622.50**	**31,748.89**	**40,820.01**	**84,450.23**	**108,578.86**	**156,962.53**	**201,808.97**
Capacity Factor		**0.18**	**0.23**	**0.15**	**0.19**	**0.04**	**0.05**	**0.06**	**0.07**	**0.07**	**0.08**
Max	**4.69**	**324.53**	**417.26**	**8,050.07**	**10,350.09**	**73,125.00**	**94,017.85**	**194,508.28**	**250,082.07**	**298,737.74**	**384,091.39**

4. Conclusion and Recommendation

From the results of the investigation of wind potential in Covenant University, it can be concluded that the utility gotten from all the wind turbines models are low, and whereas larger utility scale models of wind turbine are usually more efficient than the small-scale wind turbines, that was not the case in this context as the capacity factor continued to drop from the 1 kW to the 2400 kW turbine. The drop in expected output was largely due to the months where monthly wind speed was not up to the cut-in speeds of the turbine.

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