PROJECT DEVELOPMENT REPORT

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1.1 Design Changes

Last year, the municipality of Yabucoa was selected to develop a wind farm with a production of 100MW. For this year the same analysis was made to study different locations and identify the best one. Yabucoa was analyzed as well as three other different locations (As shown in Figure 1) including Vieques Island, Isabela and Culebra Island. A new location was identified to have the highest wind resource and maximum potential for power generation places in the island. The original site at Yabucoa have good wind speeds and wind power generation but had some disadvantages being the potetial of flooding the biggest drawback, after a rigourous analysis the team decided to move on the other three locations to study the most relevant wind parameters and the area characteristics.

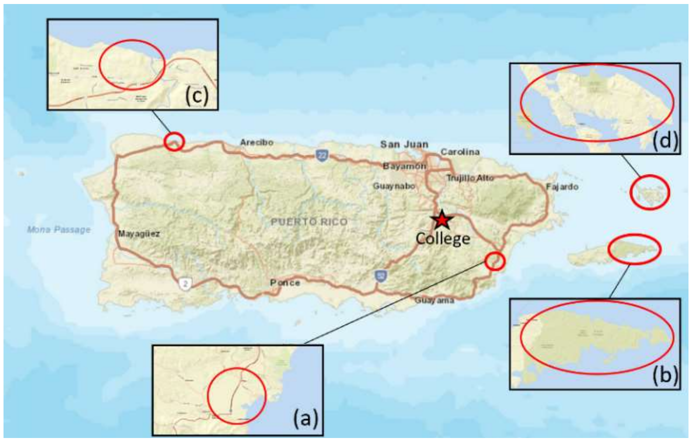

Figure 1: Locations studied for the implementation of a 100MW wind farm (a) Yabucoa (b) Vieques Island (c) Isabela (d) Culebra Island.

Considering the three possible options for the development of a wind farm, Culebra Island demonstrates to have a better location, wind speeds, wind power generation and the necessity to improve its power grid. Culebra Island have an area of approximately 30.1km^2 and it's located approximately 27 km (17 miles) east of the Puerto Rican mainland. Being more specific the location selected for the proposed wind farm it's approximately 78.34 km from José Domingo Pérez School of Engineering at the University Ana G. Mendez. The average wind speeds per year of this location at 100m are approximately 7.25m/s (As shown in Figure 2). Since the average magnitude of the wind speeds in this area are considered to have a Capacity Factor IEC Class III with a value of 0.46 it was used this capacity factor in consideration as well as the design of the wind farm to produce 100MW, also it was identified different models of turbines to produce this amount of power. With the Vestas V150-5.6MW wind turbine and a Capacity Factor of 0.46, the power generated by the turbine will be the product of the Capacity Factor and the Wind turbine Capacity (5.6MW*0.46) as a result 2.576MW will be produced per turbine. If the desirable output is 100MW that means that the quantity of the necessary wind turbines will be the desired output divided by the actual power generation (100MW/2.576MW), as a result 39 wind turbines will be necessary to produce 100MW.

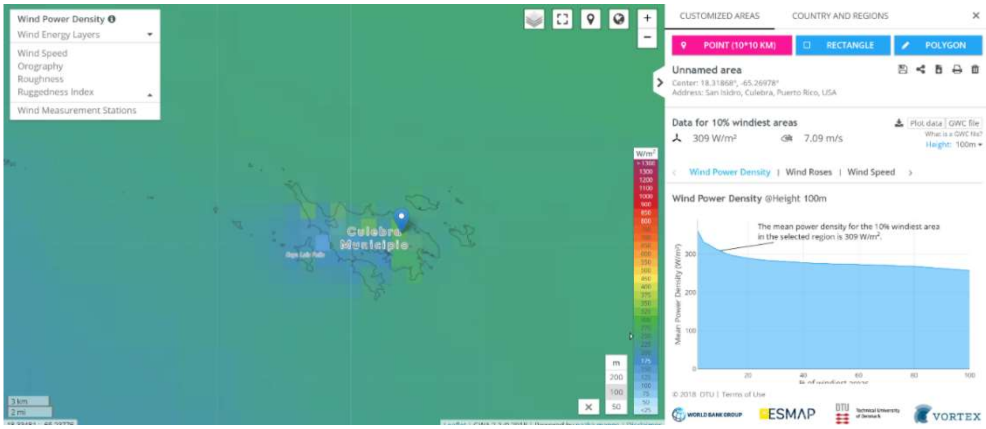

Figure 2: Wind Atlas Power Density (W/m^2) Culebra Island, Puerto Rico.

1.2 Site Description

The location for the proposed wind farm it's classified as an empty "pastures" area and its property of the Puerto Rico Government. The permits and local ordinances required for the use of this location are based under the Puerto Rico Government such as Super SIP, OGP (state and municipal permiting offices) and some JP (Planning Board) regulations may apply. As an advantage, this location is not classified with any demarcation such as Natural Forest or Conservation Protected Area or Archeological/Cultural interest area. Following this and taking in consideration possible environmental risks, the selected location doesn't present any flood, earthquake, landslides, or tsunamis as direct significant risks. This provides more confidence for the developing of the wind farm since the investment in the project is safer because of the natural cover provided by the location. Since Puerto Rico is an island located at the Caribbean Sea, it's exposed to hurricanes. The record of winds for the located selection is 41.13 m/s.

Figure 3: Proposed 100MW wind farm wind turbines ubications.

Figure 3 displays the distribution of the wind turbines at the selected location. An important point to discuss is the Culebra Island airport Benjamín Rivera Noriega (IATA: CPX, ICAO: TJCP, FAA LID: CPX). Since this airport is located near some selected areas for placing wind turbines, the wind turbines were positioned outside the approaching route of the planes and it was considerate to place the turbines so the turbulence radius will be out of reach from the planes (As shown in Figure 4).

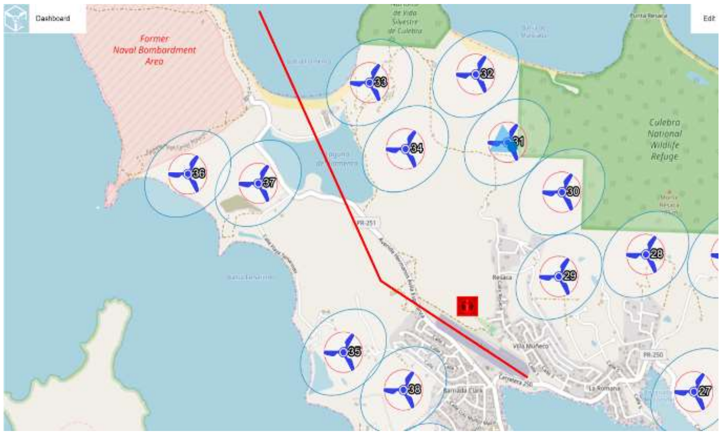

Figure 4: Approaching route to Benjamín Rivera Noriega Airport.

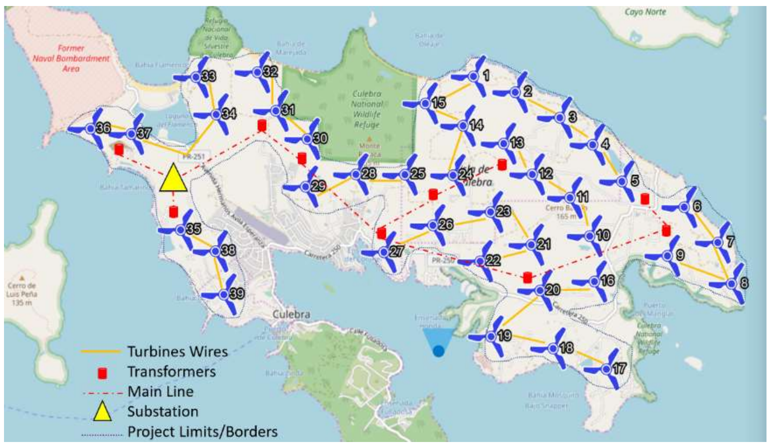

Figure 5: Electrical Plan for the wind farm.

Figure 5 displays the proposed 100MW wind Farm in Culebra Island. As mention before it's composed of 39 Vestas V150-5.6MW turbines with a hub height of 100m and a blade diameter of 90m arranged in subgroups with each group connected in parallel to a step-up transformer for power transmission. The access points for these turbines are basically the main rods of the island since the turbines were positioned strategically. By increasing the voltage in the transmission line from the turbine groups to the substations, the loss of power is reduced in the lines. This wind farm is expected to support Culebra Island electrical grid as well as supply energy to the main island. The main substation will be connected to the main 115kV line and to the Culebra Island main power grid. It's expected to help with high demand of energy and lack of power generation in the norther part of Puerto Rico. Once, the turbines were positioned a simulation was prepared to study the actual parameters of the wind farm. For this case the roughness was simulated (As shown in Figure 6).

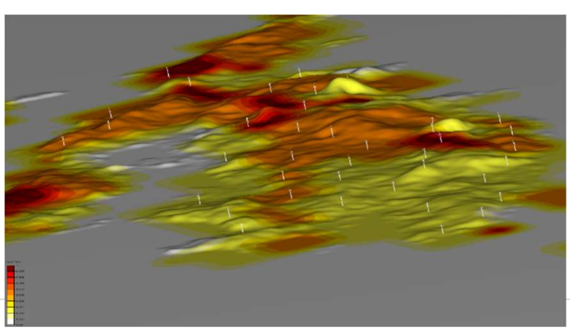

Figure 6: Roughness simulation for the Culebra Island wind farm.

Since Culebra is separated from the mainland, the power services that supports the island depends on under-sea cables from Vieques and the mainland. The implementation of the proposed wind farm at the location of Culebra Island (As shown in Figure 7), will provide power independence of the island and a possible supply for the system allowing for the Vieques power grid to be supplied by Culebra’s wind farm and the northeastern part of the mainland. During an emergency, such as the hurricanes that strike the island, there will be an available wind farm to produce the island power demand and possibly also supply additional demands such as the Vieques power grid.

Figure 7: Culebra Island proposed 100MW wind farm 3D view.

1.3 Social Impact: Survey

A survey was conducted to know how the population of Culebra Island feels about this concept. Culebra Island have a population of approximately 1,800 (2010). Only 27 individuals completed the survey. The people who completed the survey can be classified as residents of Culebra Island that are present through the week in the island and are near their homes between 8:00am and 12:00pm. It was very important to identify the team as students from Universidad Ana G. Mendez and explain the purpose of this survey. It was explained and emphasizde that this survey was only for analytical purposes as part of a project for a collegiate competition and there was be no real plan of developing a wind farm. It was found that 59.26% thought that the development of a wind farm would be very positive in terms of the power grid and the island development too. Other 14.81% of the people thought that it will be positive. This gives a 74.04% of people that said it would be positive. The percentage of people that are open to depend on wind energy was 85.19%. This can be significant since people really want to use renewable energy and a significant quantity of customers that are open to new resources that improve the power grid and use the renewable energy . Finally, 59.26% expressed that the system it’s needed, while another 18.52% said that it’s probably needed. This gave a result of 77.78% that thought it is necessary to rely on wind energy and develop a wind farm. The population of Culebra Island demonstrated to desire the improvement of the power grid system and want to use on different energy systems such as a wind farm. Overall, the wind farm development concept it’s a possible idea that the population are willing to develop and are open to depend on this type of energy.

Chapter 2: Project Development

2.1 Financial Analysis

This section focuses on the production and sales performance of Juracan Energy as a business. Moreover, a Cash Flow Analysis for the 20-year life of the project was developed in order to better understand the way it would behave during said period, and if it was feasible. JE established the wind farm in Culebra, P.R. with the objective of generating renewable energy to sell it to the principal electric distributor in the island Puerto Rico Energy Power Authority (PREPA).

2.2 Risk Assessment

A risk analysis was performed to assess and prepare for any possible situation that might affect the development of the project (Table 1). Additionally, the team identified possible solutions to the aforementioned problems/risks

Table 1: Risk and Mitigation strategies

Project Risk	Mitigation Strategy
Non-renewable electricity continues to lead the Market	Any Wind Farm developed by Juracán Energy would compete with the price of Fossil Fuel Derived Energy. Any power generated will be sold to PREPA (with sale prices being determined through Power Purchase Agreements), which means the cost of energy has to be lower than the typical kWh sold to the public in order to gain a profit. This cost would be invisible to the users since the team would be providing service through a third party and economically the clients would not be affected at all (they will be paying the same rate).
Wind farms often endure opposition from local communities debating, they disrupt sights	Surveys were performed in order to understand how the citizens of Culebra would feel about the project, and the results were mostly in favor of it. However, if any opposition were to appear, JE would develop several initiatives, becoming ambassadors of renewable energy by proving that alternative ways of generating electricity are viable and should be pursued. Provide educational talks to raise awareness about the benefits and aids proposed by renewable energy, and in that way involving the habitants of the municipality in the process so that they would feel safe knowing that the project would only affect them positively.
Funding difficulties	The team would continuously look to the stakeholders and potential investors for advice and aid in designing feasible projects that present more funding opportunities.

Natural Disasters	In case of natural disaster, a collaboration with the government and the city hall would take place in order to facilitate the reestablishment of the wind farm, in addition, funds have been assigned for maintenance to make sure the turbines maintain a high level of quality and performance.

2.3 Cash Flow Statement:

Figures 1 & 2: Cash Flow Statement from year 2019 to 2028

Juracan Wind Energy Team

Cash Flow Statement

[USD $]

		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Upfront Costs and Inputs Cash Flow												
Development Costs		30,341,587										
Build Costs		136,500,000										
Construction Financing (input)		100,000										
Cash from Costs and Inputs		**166,741,587**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Operating Cash Flow												
Earnings			29,200,000	29,200,000	29,200,000	29,200,000	29,200,000	29,200,000	29,200,000	29,200,000	29,200,000	29,200,000
Plus: PTCs			5,548,000	5,548,000	5,548,000	5,548,000	5,548,000	5,548,000	5,548,000	5,548,000	5,548,000	5,548,000
Less: Depreciation			3,850,000	3,572,030	3,333,418	3,127,413	2,948,838	2,792,844	2,656,274	2,536,211	2,423,096	2,315,026
Less: Changes in Working Capital			50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Less: Property & Income Taxes			1,011,556	1,022,674	1,032,219	1,040,459	1,047,602	1,053,842	1,059,305	1,064,107	1,068,632	1,072,955
Less: Construction Financing (output)			11,111	11,111	11,111	11,111	11,111	11,111	11,111	11,111	11,111	11,111
Cash from Operations (Net Earnings)		**-**	**29,825,333.33**	**30,092,184.53**	**30,321,251.67**	**30,519,016.72**	**30,690,449.00**	**30,840,202.78**	**30,971,310.06**	**31,086,571.12**	**31,195,161.51**	**31,298,908.77**
Net Increase (decrease) in Cash		(166,741,587)	29,825,333	30,092,185	30,321,252	30,519,017	30,690,449	30,840,203	30,971,310	31,086,571	31,195,162	31,298,909
Opening Cash Balance		-	(166,741,587)	(136,916,254)	(106,824,069)	(76,502,817)	(45,983,801)	(15,293,352)	15,546,851	46,518,161	77,604,732	108,799,894
Closing Cash Balance	**-**	**166,741,587.00**	**(136,916,254)**	**(106,824,069)**	**(76,502,817)**	**(45,983,801)**	**(15,293,352)**	**15,546,851**	**46,518,161**	**77,604,732**	**108,799,894**	**140,098,803**

Figures 3 & 4: Cash Flow for years 2029 - 2039

2030	**2031**	**2032**	**2033**	**2034**	**2035**
-	-	-	-	-	-
29,200,000	29,200,000	29,200,000	29,200,000	29,200,000	29,200,000
2,211,775	2,113,130	2,018,885	1,928,842	1,842,816	1,760,626
50,000	50,000	50,000	50,000	50,000	50,000
1,077,085	1,081,030	1,084,800	1,088,402	1,091,843	1,095,130
11,111	11,111	11,111	11,111	11,111	11,111
25,850,028.91	**25,944,728.29**	**26,035,204.07**	**26,121,644.64**	**26,204,229.95**	**26,283,131.96**
25,850,029	25,944,728	26,035,204	26,121,645	26,204,230	26,283,132
140,098,803	165,948,831	191,893,560	217,928,764	244,050,408	270,254,638
165,948,831	**191,893,560**	**217,928,764**	**244,050,408**	**270,254,638**	**296,537,770**

2036	**2037**	**2038**	**2039**
-	-	-	-
29,200,000	29,200,000	29,200,000	29,200,000
1,682,102	1,607,081	1,535,405	1,466,926
50,000	50,000	50,000	50,000
1,098,271	1,101,272	1,104,139	1,106,879
11,111	11,111	11,111	11,111
26,358,514.95	**26,430,535.85**	**26,499,344.61**	**26,565,084.51**
26,358,515	26,430,536	26,499,345	26,565,085
296,537,770	322,896,285	349,326,821	375,826,166
322,896,285	**349,326,821**	**375,826,166**	**402,391,250**

The Cash Flow Statement presented above shows an initial investment in year zero (2019) of \$166,741,587.00. Through the projected duration, the project takes in approximately \$28.5 million per year in cash flow income, this is by selling at a price of 10 cent kWh, which the PREPA sells to the public at a price of 22 cents kWh (which is the current cost of energy in the island). The payback period for the investment is of 5.86 years. After the 20 years of project duration, the final earnings (closing Cash Balance for the Project) are of \$402,391,250, which leaves the project doubling its initial investment. After finishing the cash flow, the IRR was calculated:

IRR = 17.07%

This means that when the discount rate is 17.07% for 20 years, the Net Present Value (NPV) is \$0.

After this, the Levelized Cost of Energy (LCOE) was calculated for the wind farm. The formula used was the following:

$$LCOE = \frac{sum\ of\ project\ costs\ over\ lifetime}{sum\ of\ electrical\ energy\ produced\ over\ lifetime}$$

This gave us a total LCOE of \$44.36 for MWh, or \$0.04 for kWh. For a PPA with a sales price of \$0.10 to the PREPA, that gives a net earning of 6 cents per kWh, which for a 100MW wind farm equals a \$48,000 revenue per day for the system.

Comparison with other similar projects:

When comparing the Juracán Energy Wind Farm, to other wind energy projects in Puerto Rico, only two cases can be mentioned; the Naguabo Wind Farm and the Santa Isabel Wind Farm.

Table 2: Wind Farm Comparison for Total Power generated

Wind Farm Comparison			
	Santa Isabel	Naguabo	Juracán Energy (Culebra)
Total number of turbines	44	13	39
Total Power	101 MW	23 MW	100 MW
Power per turbine	2.30 MW	1.8 MW	2.56 MW

As it can be seen on Table 2, the new proposed wind farm would possess the highest count of Power per turbine, therefore, the highest energy production per turbine of the three projects. PPAs were not available to perform an energy price comparison.

2.4 Suggestions for higher project feasibility:

Even if though the proposed project doesn’t currently allow much flexibility in PPA price for the time being, if a reduction of the input costs of the Development and construction process was possible, it would allow the Juracán Energy team to have more control of the PPA rice range, increasing also the profit margin for the production of energy

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