Feasibility analysis of repowering a wind park in Galicia

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Chapter One: Introduction

Energy is essential to human development, but the problems mankind facing are: exhaustion of traditional energy resources and a high level of pollution in the environment. It is necessary to find some energy sources that can guarantee sufficient long-term supply and does not create environmental pollution. The development of new energy and renewable energy is the due meaning of sustainable energy development. Insufficient development of new and renewable energy sources has not only caused a series of problems such as environmental pollution, but also seriously restricted the development of energy. Vigorous efforts must be made to push the development of renewable energy forward, optimize the energy structure, enhance energy supply capacity, and alleviate environmental pressures.

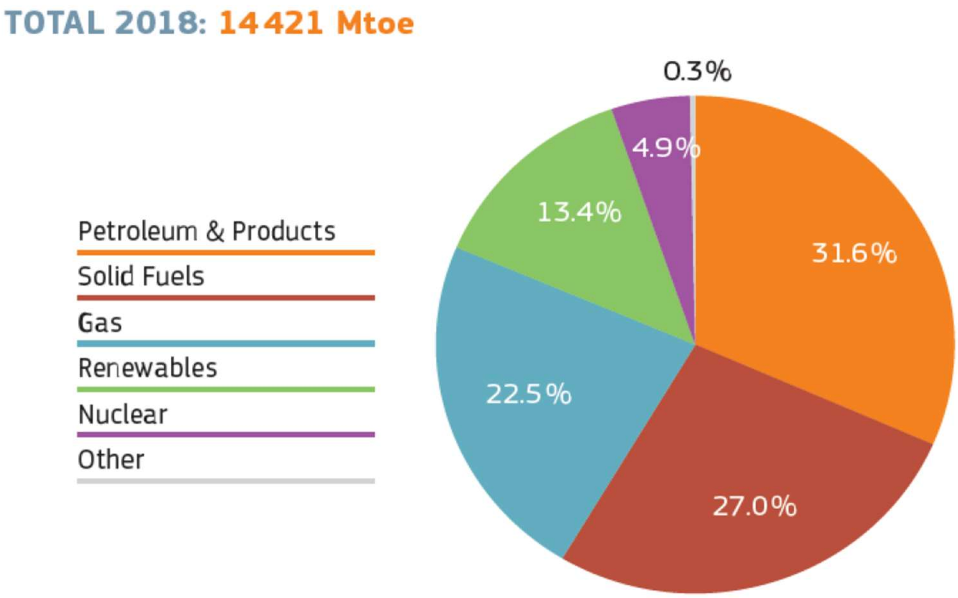

Figure 1: World energy production by Fuel (Mtoe) [1]

Three types of energy sources can be distinguished: (i) Energy from the sun. Including energy directly from the sun (such as solar thermal radiation energy) and energy indirectly from the sun (such as coal, oil and other combustible minerals, wood and other biomass energy, hydropower, and wind energy, etc.). (ii) Energy derived from the earth. Such as geothermal energy, which includes subsurface hot water, underground steam, and dry hot rock mass, and the second is nuclear energy, which is found in nuclear fuels like uranium and thorium beneath the earth's crust. (iii) The energy produced by the gravitation of the moon and from the sun to the earth, such as tidal energy.

Wind power is a renewable energy sourced from the sun. Wind is a natural phenomenon generated by the flow of air, and it is caused by the sun's radiant heat. Sunlight shines on the facade of the earth, which raises the temperature of the surface, and the air on the earth's surface is heated, becoming lighter and rising. The low-temperature cold air moves in parallel with the hot air as it rises, and the rising air cools down and becomes heavier. The higher surface temperature will heat the air and make it rise. This flow of air generates wind [2]. The kinetic energy formed by the flow of air is called wind energy, it is a type of conversion of solar energy. The sun cannot heat the earth's surface completely uniformly, which leads to uneven distribution of ground pressure, and air that flows horizontally as wind. The formation of wind is the result of air movement. Wind energy like other mechanical energy, full of the value of being exploited.

Wind energy has long been used by people, principally through windmills to drive water, grind flour, and so on. The first thing we are interested in now is how to use wind to generate electricity. There are about 10 billion kilowatts of wind resources that can be used to generate electricity on the earth [3], which is almost 10 times the amount of hydropower in the world.

Wind power generation is the process of transforming wind kinetic energy into mechanical kinetic energy and then mechanical energy into electric kinetic energy. The basic principle of wind power generation is to use the wind to propel the blades of a windmill to rotate, then raise the speed of rotation with a speed increaser to drive the generator to generate electricity. Windmill technology allows electricity to be generated at a breeze speed of around 3 m/s. Wind power is forming a worldwide boom because it does not utilize fuel and does not emit radiation or air pollution [4].

A wind turbine is the type of equipment used to generate power from the wind. The wind wheel (including the tail rudder), the generator, and the tower are the three components of this type of wind power generating system. Large wind farms, in general, do not have a tail rudder; often, only small wind farms (even domestic ones) have.

After years of development, wind power technology has matured, and many countries have vigorously developed wind power installed capacity. As shown in Figure 2, in 2019, wind power generation was 1430 TWh, accounting for 5.3% of global power generation. The global installed capacity of wind power exceeded 651 GW, which is an increase of 10% over 2018.

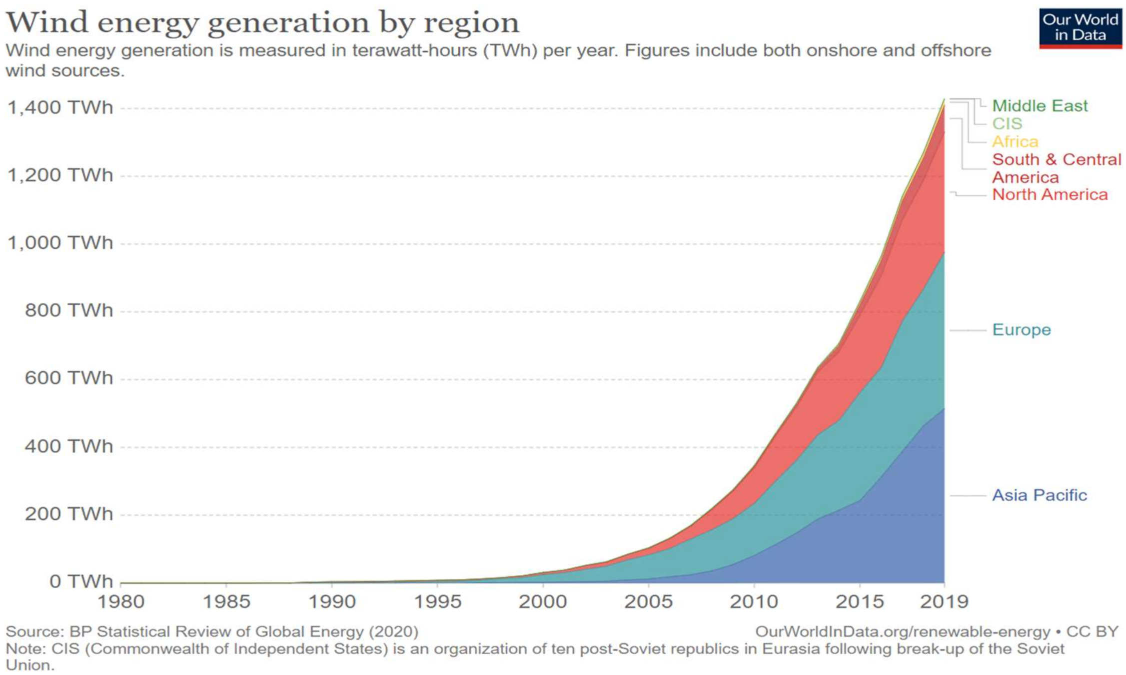

Figure 2: Wind energy generation by region over time [5]

As old wind farms run longer and longer, the efficiency of wind energy utilization continues to decline, so new solutions are needed to boost the efficiency of wind energy utilization.

For example, in the " HOJA DE RUTA DEL SECTOR EÓLICO 2021-2024" of Spain, there is a plan to streamline and facilitate wind farm repowering projects through auctions or other similar mechanisms that facilitate investment in the renewal of the wind farm [6].

From a global perspective, the market for projects with MW and below old units has begun to appear, and customers are also aware of adopting some new technologies to enhance value. Some countries have put forward corresponding policies, such as the Repowering of old wind turbines in the United States. The policies include tax credits and preferential bank loan policies. Europe also pays more attention to inefficient assets, because the European area is relatively small, and if small units are replaced with large units, preferential policies are even greater. In this way, it is meaningful to study the repowering of old wind farms.

This study will take a 20-year wind farm in Galicia as an example to analyze the feasibility of its repowering. The second chapter will introduce the development of wind power technology, the third chapter will introduce the status of the above-mentioned wind farms, the fourth chapter will be the latest wind power technology, the fifth chapter will formulate a repowering plan, and the sixth chapter will analyze the economic benefits. A summary will be made at the end.

Chapter two: Wind power

2.1 Wind power technology

Wind power technology is a technology that uses wind energy to generate electricity, mainly relying on the manufacture of wind energy generators. Because wind energy is a renewable energy source and is environmentally friendly, to promote the advancement of wind power technology is the essential increase action of many countries today [7].

Large-scale wind power technology, as well as medium- and small-scale wind power technology, are the two types of wind energy technology. Although both belong to wind energy technology and have the same working principle, they belong to two completely different industries. The specific manifestations are: different policy orientations, different markets, different application fields, and different application technologies. They all belong to two industries in the same industry.

Large-scale wind power technology originated in some European countries such as Denmark and the Netherlands. Due to the rich local wind energy resources, the wind power industry is boosted by the government, and the development of large-scale wind power technology and equipment is far ahead in the world. Large-scale wind power technology is designed for large-scale wind turbines, and the application area of large-scale wind turbines has very strict environmental requirements. They are all applied to wind farms with abundant wind energy resources and limited resources. They are subjected to various harsh environments all year round. The complexity and variability of the environment has led to a linear increase in the demand for technology.

The mature technology of small and medium wind power is relatively less restricted by natural resources, and has a significant effect as a distributed independent power generation. Not only can it be connected to the grid, but it can also be combined with photovoltaics to form a more stable and reliable wind-solar complementary technology. Small and medium wind power technology is ultimately to meet the terminal market of distributed independent power supply, rather than the approximate monopoly market that meets power generation and grid connection as large-scale wind power technology, and the speed of technology update must adapt to the broad and rapidly developing market demand.

Wind energy and solar energy are the most sophisticated, sizable and industrialized industries in the world in terms of the new energy application. Both wind energy and solar energy alone have their disadvantages, while wind power and solar power are complementary. The combination of two new energy sources achieves the most reasonable comprehensive utilization of new energy in terms of natural resource allocation, technical solution integration, performance and price comparison, and not only reduces the unit cost of meeting the same demand, but also expanding the application range of the market, but also improving the reliability of the product. Wind-solar integral technology combines small and medium-sized wind power technology and solar energy technology, and accommodates many new technologies in different utilization ranges. The wide range of fields involved, the wide range of applications, and the large technological differentiation are incomparable by just individual technologies.

2.2 Development of wind power

With the continuous expansion of the single unit capacity of wind turbines, the length of the blades has also developed from about 20 meters to more than 60 meters. As the 10 MW wind turbine enters the development stage, its blade length will reach more than 75 meters. The enlargement of wind turbine blades makes the three-dimensional separation and unsteady characteristics of the blade surface flow more complicated, which brings more difficulty to the flow control of the blade surface; at the same time, the aeroelastic problem induces the stability of the wind turbine to decrease, and the three-dimensional wind turbine blade aerodynamic design and structural design have become the primary problem that needs to be solved in the large-scale wind turbine. At present, the three-dimensional shaping methods of forward-bent, backward-swept, and pre-twisted blades have become research hotspots, involving multidisciplinary issues such as aerodynamics, structure, and materials. The optimization of the blade structure is quite challenging, and the topology optimization technology of the blade It is a more realistic research direction. At present, the design system of wind turbine blades is primarily depended on the two-dimensional design method based on the momentum leaf element theory. The trend of the design system from two-dimensional to three-dimensional is gradually beginning to appear. In-depth research on the aeroelastic problems to which it is adapted and the evaluation of aerodynamic noise, the method has begun to be researched, and the establishment and improvement of a three-dimensional aerodynamic-structure-material comprehensive design system will be beneficial to the design of high-level blades and the development of innovative results.

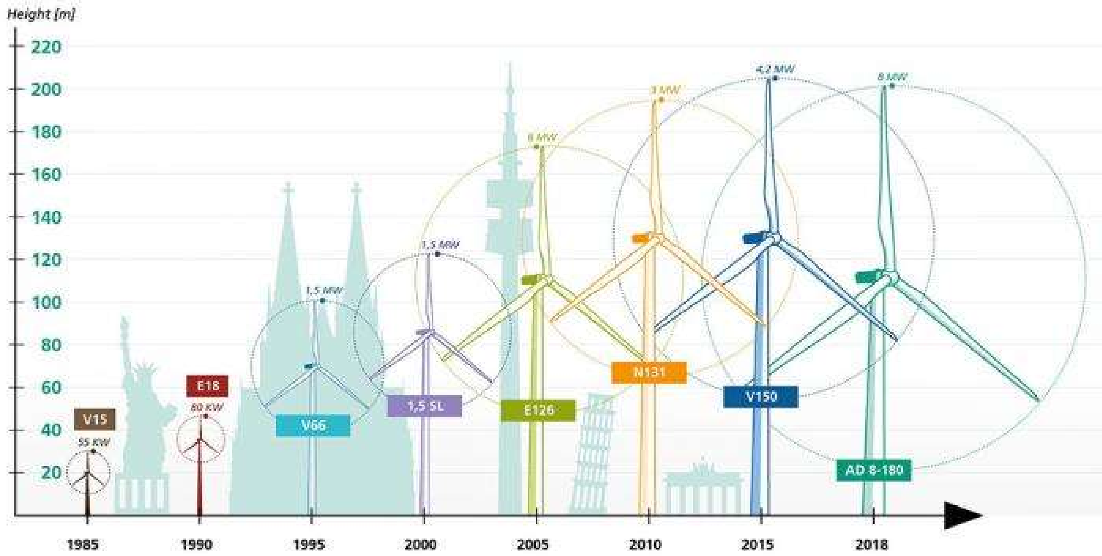

Figure 3: Growth of wind turbine capacity and size [8]

Due to the unstable characteristics of wind energy, as the proportion of wind turbines in the power grid becomes larger and larger, the impact on the power grid becomes more and more obvious. Smart grid is an effective solution to the grid connection of renewable energy power generation. At the same time as the construction of ultra-high-voltage power grids, the R&D and construction of smart grids should be particularly strengthened. This is one of the main trends in the future. At the same time, the continuous increase in the size and weight of the fan blades makes the control of the fan more and more difficult. The use of new load control technology (intelligent blade control technology) can reduce additional blade loads that damage the rotor and other components, reduce blade material requirements, reduce maintenance and improve fan reliability. At the same time, it can also make the transmission system and tower, the load and weight of the engine room and other components have been reduced to a certain extent, which greatly reduces the cost of the wind turbine. The independent pitch system is a new technical means to control the operation of large wind turbines. The development of this system is beneficial to reduce the blade load while increasing the efficiency of wind energy capture. The intelligentization of wind turbines puts forward higher requirements for a series of technologies such as wind turbine load optimization control technology, simulation methods, wind power prediction technology, detection technology, fault diagnosis and early warning system, and is an important direction for the research of the new generation of wind power technology.

With the accelerated advancement of the wind power industry, the cost of wind turbines has dropped rapidly. At present, grid-connected power generation is the main form of wind energy utilization. Ensuring the quality of power from wind farms to the grid is a requirement for stable and safe operation of the grid, as well as an important measure for the sustainable development of wind energy. The uncertainty of wind energy resources and the development on a massive scale and application of wind power have brought more problems to the regulation of power grids. Therefore, the smart grid is one of the effective solutions to the grid-connected wind power generation. In addition, the research and improvement of wind power storage systems has received sufficient attention. Mature large-scale energy storage systems are in the research and experimental stage and will form an important industry in the future. The physical energy storage method is a more effective technical approach in the large-scale energy storage technology research program. In this way, the organic combination of centralized and distributed in wind power can be realized and become a sustainable and correct development model.

At present, onshore wind farm equipment and construction technology are basically mature. With the depletion of onshore wind energy resources in Europe, the main driving force for the growth of wind energy technology in the future will come from the booming offshore wind power. Offshore wind power puts forward higher requirements on the safety, reliability, ease of maintenance and construction cost control of wind turbines. Floating wind turbines have been the focus of research and development in the wind power industry in recent years. This technique is critical for increasing the exploitation of offshore wind resources, to optimize the design and safe operation of wind turbines, and to improve wind energy conversion efficiency.

2.3 Repowering wind farms

As the first batch of wind farms have been running for more than 20 years, their efficiency has declined but they occupy high-quality wind resources, on the other hand, to reach the target of 35% of the demand coverage with renewable energies by the year 2030, more and more wind farms need to be re-powered [3].

Another situation is that some old wind farms have defects at the beginning of the design, and the unreasonable arrangement of the wind turbines leads to the failure to achieve the desired efficiency during operation. Or the environment near the wind farm has changed, for example, there are other new build wind farms running nearby, causing the wind turbines to fail to operate at optimal efficiency. In this case, it is more necessary to redesign and repowering the wind farm.

The repowering scheme for wind farms involves replacing old equipment of lower power and efficiency with new machines with higher power and performance, thereby increasing the ability to use wind resources in the same physical location. Modern wind turbines have much more power and are more reliable than old ones, this will greatly increase the power generation capacity of the retrofitted wind farm.

The already established facilities (roads, substations, power grids, assembly areas, etc.) can be used during construction of repowering. In addition, previous permits can be used to save costs and time, which makes repowering more economically advantageous. At the same time, old wind turbines may be recycled, and other equipment also has some salvage values.

Various evaluations are very important in repowering: First, the terrain complexity assessment, a slight terrain difference will result in a difference of more than one thousand hours of power generation between wind turbines that are close to each other; second, weather data correction requires the wind speed and direction of the wind turbine to be corrected using weather data, in this way, we can better find the matching degree of resources and power generation; third, power generation and reliability, need to clarify the annual failure loss; fourth, evaluation of unit performance, mainly power curve compliance evaluation, control system the performance analysis matches how much room there is for improvement; fifth, the post-design evaluation, the optimization of the arrangement can greatly increase the power generation of the project; sixth, the post-evaluation of the effect of repowering. To know how much power generation has been increased by the technological transformation plan, to conduct a comparative evaluation of the improvement effect in the early and late stages.

In short, wind farm reconstruction is a complex and valuable project that must be carefully considered and evaluated to make the best plan to improve the efficiency of wind energy utilization.

Chapter Three: Status of the old wind farm

In the preceding chapters, we analyzed the advantages and scope of application of rebuilding wind farms. Given that Spain is a pioneer country in the development of wind power and there are many wind farms that have been in operation for more than 20 years, we will take a detailed analysis of an old wind farm located in northwestern Spain as an example.

In this study we choose a wind power plant “Ameixenda-Filgueira” which located in the west of the Santiago de Compostela city of Galicia, Spain. The plant was built in 1998, the total installed power is 34.8 MW with 58 “Navantia-Siemens Bonus Mk-IV” wind turbines (power 600 kW, diameter 44 m), owned by Acciona Energia. The following is some information about the wind farm:

Table 1: Ameixenda-Filgueira Wind Farm characteristics

Characteristic	Value
Total power (MW)	34.8
Number of wind turbines	58
Turbine manufacturer	Navantia-Siemens
Turbine model	Bonus Mk-IV
Tower total mass (Ton)	94.2

Table 2: Ameixenda-Filgueira Wind Turbine characteristics

Characteristic	Value
Rated power (kW)	600
Rotor diameter (m)	44
Rotor area (m²)	1,521
Power density (m² / kW)	2.54
Number of blades	3
Rated wind speed (m/s)	15
Cut-in wind speed (m/s)	5
Cut-out wind speed (m/s)	25

The diameter of the rotor is 44 m, the height of the tower is 40 m. Both the pitch of the blades and the speed of the generator are fixed parameters in this wind turbine model. The generator type is asynchronous.

The following wind turbine power curve shows how much electrical energy the wind turbine will produce at various wind speeds:

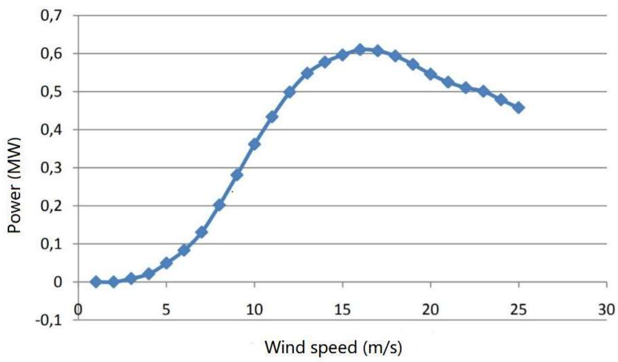

Figure 4: Actual turbine's power curve

The Figure 5 below is a Google satellite photo (In order to facilitate viewing, the wind turbines have been enlarged) shows the distribution of 58 wind turbines in Ameixenda-Filgueira wind farm. According to their location we divide them into five groups: the first group has 14 wind turbines, the second group has 14 wind turbines, the third group has 13 wind turbines, and the fourth group has 4 wind turbines, and in the fifth group there are 13 wind turbines. According to the Google Maps distance measurement tool, the distance between each wind turbine is about 90 meters.

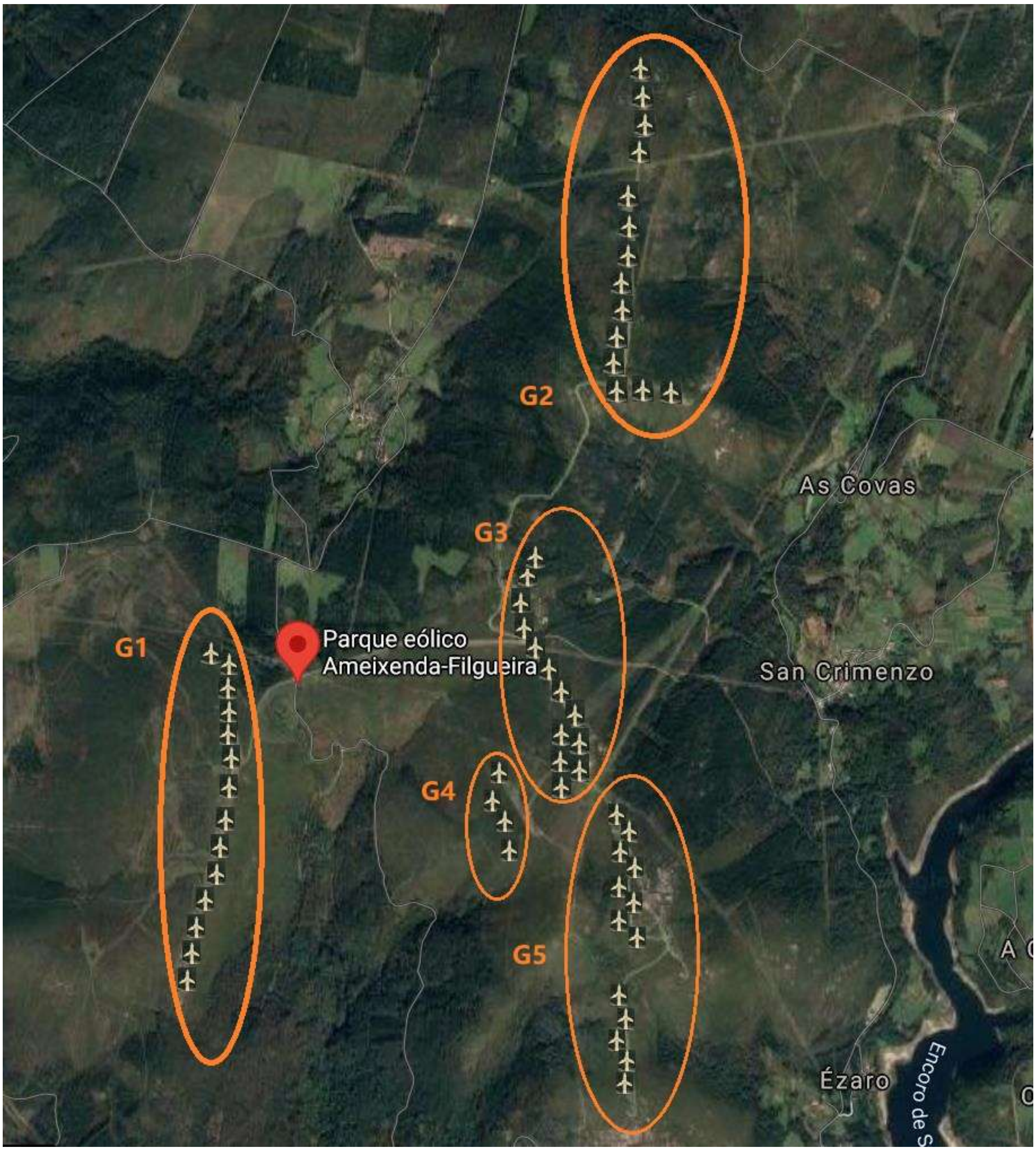

Figure 5: Ameixenda-Filgueira Wind Farm Layout

Chapter Four: Large-scale and intelligent wind turbines

Modern wind turbines are progressively profitable and more reliable in performance, and have been expanded to a power rating of several megawatts. Since 1999, the average power generation capacity of turbines has increased, and the average capacity of turbines installed in 2016 was 2.15 MW [9]. The development of longer and lighter rotor blades, bigger towers, more reliable transmission systems, and performance-optimized control systems helped facilitate this transition.

With the steady increase of the single unit capacity of wind turbines, the use of intelligent control technology, through the deep integration of advanced sensing technology and big data analysis technology, comprehensively analyze the operating status and working conditions of the wind turbine, adjust the operating parameters of the unit in real time, and realize wind power more efficient and highly reliable operation of equipment is the trend of intelligent research on wind power equipment in the future. The technical requirements of large-scale wind turbines mainly include: integrated optimization design and lightweight design technology for high-power wind turbines, integrated load reduction optimization technology for high-power turbine blades, load and advanced sensor control, and electrical of high-power wind turbines intelligent diagnosis of control system, fault self-recovery and maintenance-free system, and green manufacturing technology of high-power onshore wind turbines and essential components.

For example, the following figure 6 depicts a dependable and cost-effective real-time monitoring system based on ZigBee wireless sensor networks; it is a novel method for developing a remote monitoring system for wind turbines [10]. The ZigBee network equipped with various sensors will actively collect dynamic data related to the operating state of the system, including the parameters and operating environment of the mechanical and electrical units. Each wind turbine will have a wireless network, which can send information to a remote monitoring center through a GPRS module to achieve complete and long distances wireless communication. This system is very useful for building a reliable and economical real-time monitoring structure for wind plants (both offshore and onshore) with enhanced security and efficiency.

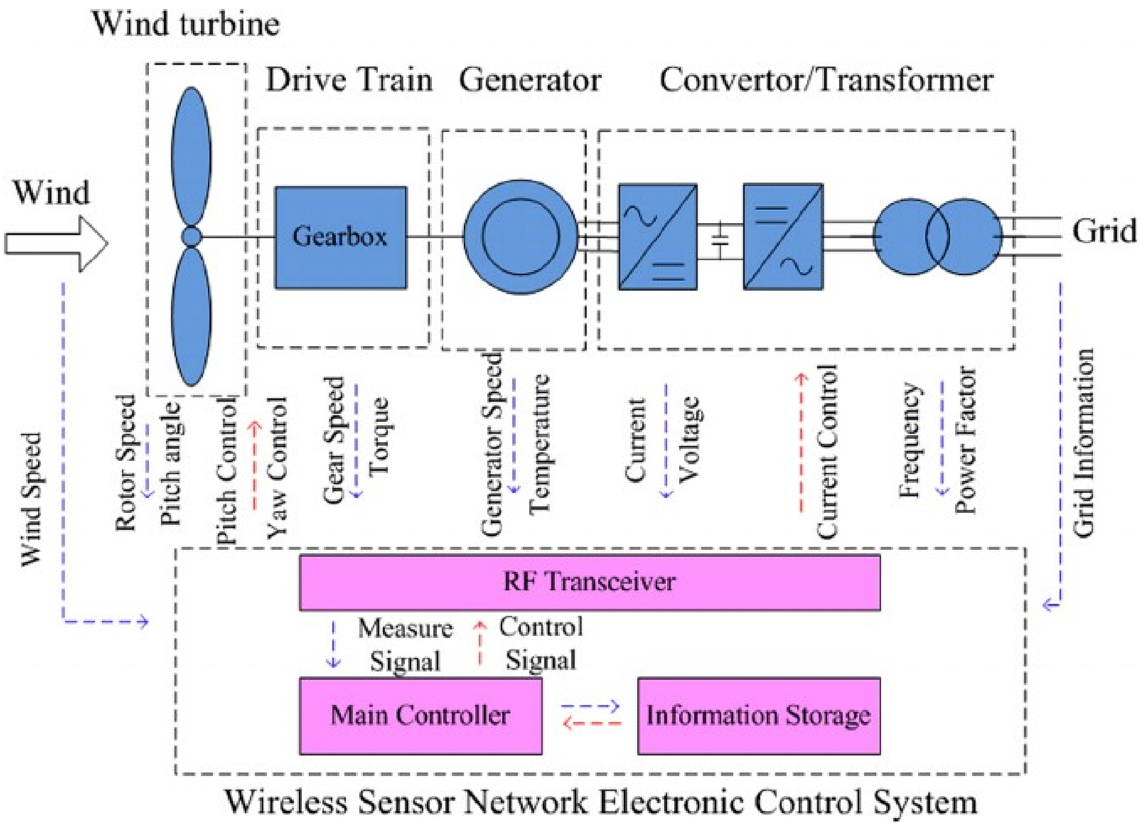

Figure 6: Schematic diagram of single wind turbine WSN

In this case, we can give priority to the replacement of new larger-capacity units to greatly increase the power generation capacity of the wind farm and optimize the intelligent control of the wind farm.

Chapter Five: Repowering plan

5.1 Wind resource assessment

A weather station is a set of devices, intended to measure different variables over time. Among the most common measurements collected by meteorological stations are those of Temperature, Relative Humidity, Atmospheric Pressure, Wind Speed, Wind Direction, Precipitation, Hours of Sunlight, etc. [11]. With all these data, numerical models can be studied and fed for prediction and study of climatic and meteorological phenomena.

In order to obtain statistical wind data, we found a weather station located at Padrón which is near the wind farm, and obtained wind data of this station from May 7, 2013 to April 30, 2021, in this way we can get the raw data of wind. The altitude of the weather station is 100 meters, and the average temperature during the measurement period is 14.68 degrees Celsius.

To further quantify the energy contained in the wind, wind resources need to be characterized by a Weibull distribution. The Weibull distribution is a continuous probability distribution, when it is applied to the distribution of wind energy, two parameters are needed for the calculation: the shape parameter, k, and the scale parameter, c [12].

$$p(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^k} \qquad \text{eq. 1}$$

$$k = A \quad ; \quad c = e^{-\left(\frac{B}{A}\right)} \qquad \text{eq. 2}$$

Where the $p(v)$ is Weibull distribution, k is Weibull distribution's shape parameter, c is Weibull distribution's scale parameter.

To calculate the parameters A and B as in the equations below:

$$A = \frac{\sum f_i x_i y_i - (\sum f_i x_i)(\sum f_i y_i)}{\sum f_i x_i^2 - (\sum f_i x_i)^2} ; B = \sum f_i y_i - A \sum f_i x_i \qquad \text{eq. 3}$$

In order to calculate the wind data, we first got the wind speed interval and Weibull distribution table as below.

Table 3: Wind speed data distribution and Weibull distribution calculation

Interval (m/s)	Class frequency (days)	Cumulative freq. (Fi)	Relative frequency (fi=ni/N)	Cumulative freq. (Fi)	xi=Lnv	yi=ln(-ln(1-Fi))	fixi	fixi^2	fiyi	fixiyi
1-2	22	2612	0.008	0.008	0.41	-4.77	0.00	0.00	-0.04	-0.02
2-3	155	2457	0.059	0.068	0.92	-2.66	0.05	0.05	-0.16	-0.14
3-4	445	2012	0.170	0.238	1.25	-1.30	0.21	0.27	-0.22	-0.28
4-5	579	1433	0.222	0.460	1.50	-0.48	0.33	0.50	-0.11	-0.16
5-6	455	978	0.174	0.634	1.70	0.01	0.30	0.51	0.00	0.00
6-7	412	566	0.158	0.792	1.87	0.45	0.30	0.55	0.07	0.13
7-8	213	353	0.082	0.873	2.01	0.73	0.16	0.33	0.06	0.12
8-9	146	207	0.056	0.929	2.14	0.97	0.12	0.26	0.05	0.12
9-10	103	104	0.039	0.969	2.25	1.24	0.09	0.20	0.05	0.11
10-11	39	65	0.015	0.984	2.35	1.41	0.04	0.08	0.02	0.05
11-12	28	37	0.011	0.994	2.44	1.64	0.03	0.06	0.02	0.04
12-13	9	28	0.003	0.998	2.53	1.80	0.01	0.02	0.01	0.02
13-14	4	24	0.002	0.999	2.60	1.97	0.00	0.01	0.00	0.01
14-15	1	23	0.000	1.000	2.67	2.06	0.00	0.00	0.00	0.00
15-16	1	22	0.000	1.000	2.72	-	0.00	0.00	0.00	0.00
Total	2612	-	1.000	-	-	-	1.65	2.85	-0.24	0.00

Through the calculation of the above data and formulas, we get the result:

$k = 2.81 \;\; ; \; c = 5.65 m/s$

Then we can compare the statistical data and Weibull distribution as figure 7 shows, the summary table with detailed digital of calculation is in Annex I.

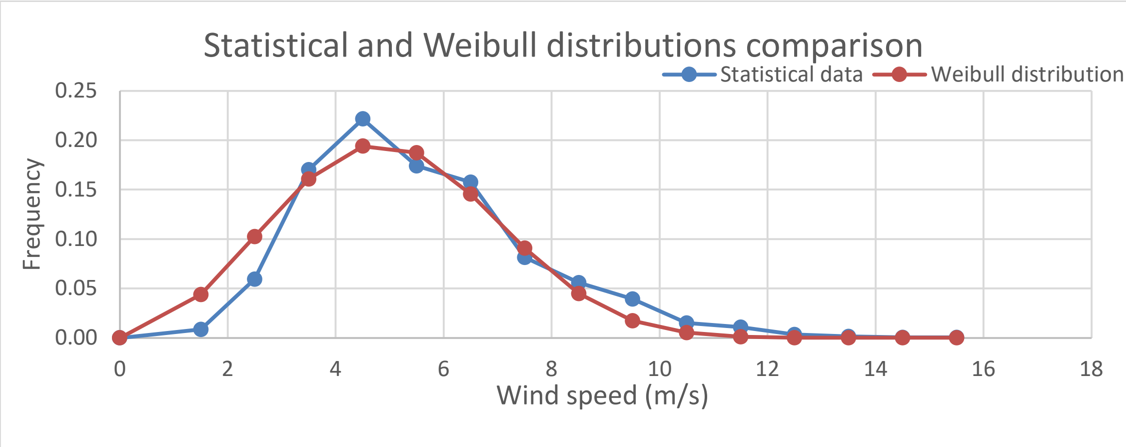

Figure 7: Statistical and Weibull distributions comparison

In view of the different heights of different towers, we need to calculate the Weibull distribution (parameters k and c) at different heights for subsequent tower type selection using equations:

$$k' = k\left(\frac{1-0.088\ln\left(\frac{z}{10}\right)}{1-0.088\ln\left(\frac{z'}{10}\right)}\right) \qquad \text{eq. 4}$$

$$c' = c\left(\frac{z'}{z}\right)^{\beta} \qquad \text{eq. 5}$$

$$\beta = \frac{0.37-0.088\ln\,c}{1-0.088\ln\left(\frac{z}{10}\right)} \qquad \text{eq. 6}$$

Where the z and z' is Altitude of the wind speed measure.

We calculate the height distribution from 60 to 140 meters and showed it in Figure 8, the summary table with detailed digital of calculation is in Annex I. With the Weibull distributions, we can select and the wind turbine model and plan the wind farm next.

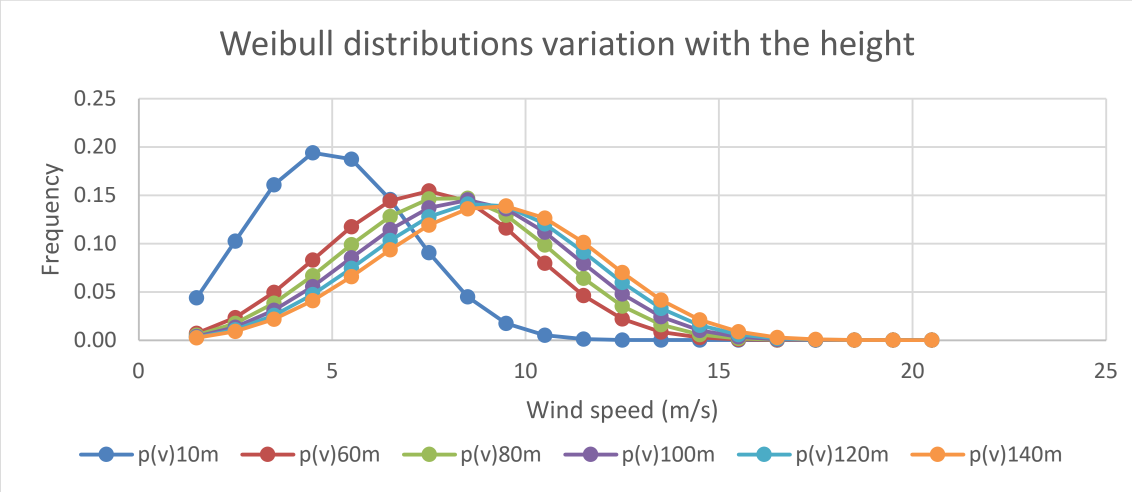

Figure 8: Weibull distributions variation with the height

5.2 Wind Turbine replacement

Since the original wind turbine of this farm has reached the end of its service life, an important part of this repowering plan is the choice of replacing with new wind turbine model and the number of new wind turbines that need to be arranged.

Considering Vestas is the wind turbine manufacturer with the highest market share in the world, with a market share of 14.8% in 2020 [3], and it has a manufacturing base in Spain, so we plan to choose among Vestas models. The following table 4 shows some technical parameters of Vestas' four types of wind turbines.

Table 4: Characteristics of Vestas' wind turbine models

Characteristic	V90/2000	V112/3000	V117/3450	V117/3600
Nominal power (kW)	2000	3000	3450	3600
Rotor diameter (m)	90	112	117	117
Rotor area (㎡)	6362	9852	10752	10752
Height min (m)	80	84	91.5	91.5
Height max (m)	125	119	141.5	141.5
Cut-in wind speed (m/s)	3	3.5	4	3
Rated wind speed (m/s)	13.5	15,5	11.5	13
Cut-out wind speed (m/s)	25	25	25	25

The power curves of the above four wind turbines can be obtained through the product website introduction, specific data can be found in Annex I and we summarize the four power curves as shown in the figure 9 below:

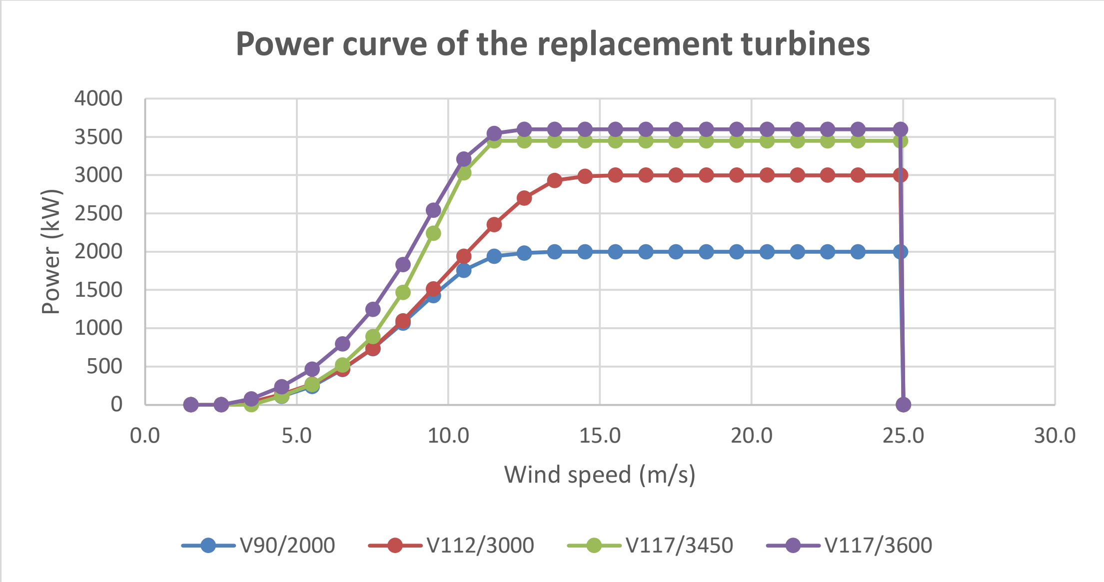

Figure 9: Power curve of the replacement turbines

Considering the height ranges of the four turbines' hubs, we can assume that the installation height of the wind turbine' hubs is 110 meters. Use the following formulas to calculate the available power of each wind at that altitude:

$$\frac{\langle P_d \rangle}{A} = \frac{1}{2}\rho\langle v^3 \rangle \qquad \text{eq. 7}$$

Where the $\langle P_d \rangle$ is Wind's power available, ρ is Air density, $\langle v^3 \rangle$ is Average of the cube of the wind speed.

Then to calculate the efficiency ratio η of each wind turbine,

$$\eta = \frac{\langle P \rangle}{\langle P_d \rangle} \qquad \text{eq. 8}$$

Where the $\langle P \rangle$ is Average power.

With the power curves and wind distributions already had, we can calculate the energy produced by each wind turbine using the following equation,

$$\langle P \rangle = \sum_{v=1}^{25} p(v) * P(v) \qquad \text{eq. 9}$$

Where the $P(v)$ is the Wind turbine's power curve.

To describe the gap between nominal and realistic power production, we can calculate the Capacity factor (CF) of wind turbines,

$$CF = \frac{\langle P \rangle}{P_N} \qquad \text{eq. 10}$$

Where the P_N is the nominal power.

The total energy output of wind turbines produced in a period T is:

$$E = k_t * \langle P \rangle * T \qquad \text{eq. 11}$$

Where the k_t is total correction factor.

In the end, with the planned height of 110 meters, we obtained the following calculation results for the four new wind turbines and the original ones:

Table 5: Turbines' production comparison

Model data	V90/2000	V112/3000	V117/3450	V117/3600	Bonus Mk-IV
Nominal power (kW)	2000	3000	3450	3600	600
Average power(kW)	1094	1257	1720	1958	222
Efficiency ratio η	0.35	0.26	0.33	0.37	0.30
Capacity factor (CF)	0.55	0.42	0.50	0.54	0.37
Energy output annual (MWh)	9587	11015	15064	17156	1946

From table 5 we can see that model V90/2000 and V117/3600 have the highest Capacity factor of 0.55, 0.54 respectively, the following factors should be considered for the selection of wind turbines:

1) According to Spanish law "Real Decreto 661/2007", if the total power increases by more than 40%, which means 48.72 MW, we need to request the System Operator for access again.

2) The port of Brens is 3 kilometers away from the wind farm. There are convenient roads to the wind farm and the location of the tower, so there is no problem when transporting large equipment of turbine model V90/2000 or V117/3600.

3) The use of high-power models can effectively reduce the number of units installed and save the initial investment cost of the project.

4) The 3.6 MW model is easier to optimize the design of the wind farm than the 2 MW model, which can reduce the impact of the wake by 2% to 3% and effectively improve the overall power generation capacity of the wind farm.

In conclusion, without new permission, the V117/3600 wind turbine with a single power of 3600 kW is the best choice. With 13 Vestas V117/3600 wind turbines deployed at a distance of 360 meters each, and the total power can reach to 46.8 MW, energy output annual will be 223,028 MWh, and the energy output annual of the original wind farm with Bonus Mk-IV turbine is 112,868 MWh. The energy output annual almost doubled.

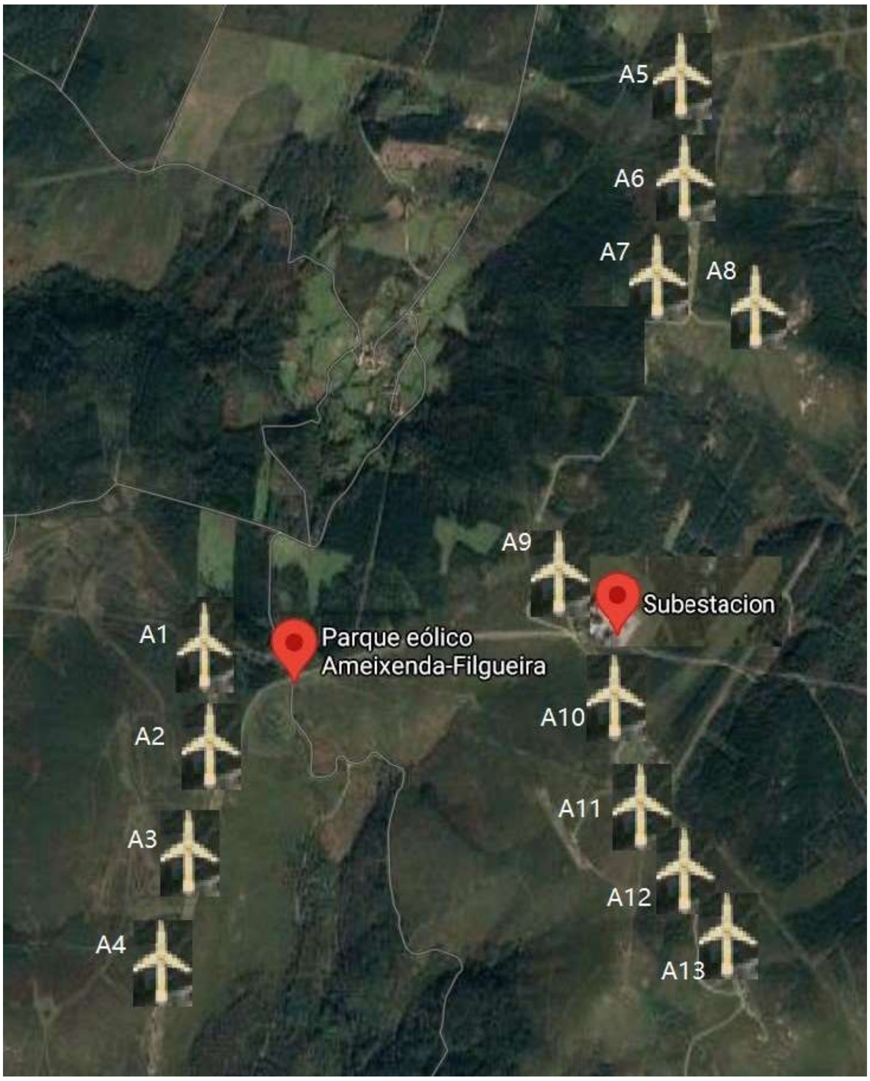

Figure 10: New Ameixenda-Filgueira Wind Farm Layout

5.3 Foundation evaluation

Since the height of the tower is 40 m, obviously it can no longer afford the new wind turbine which weighs 70 tons and the diameter of the rotor reaches 117 meters, new foundations and tower type need to be deployed for the V117/3600 wind turbine.

The foundation is the fixed end of the wind turbine. Together with the tower, the wind turbine is erected at an altitude of 60 to 120 meters, which is an important part of ensuring the normal power generation of the wind turbine. In terms of design, the wind turbine should belong to a high-rise structure. For the general high-rise structure design, a simple structure is adopted to minimize wind load. However, the power source of the wind turbine is mainly wind. To generate power normally, it is necessary to capture enough wind power, which makes the foundation inevitably bear huge horizontal load, and it is quite different from the traditional high-rise structure design. Geological conditions and wind direction influence should be considered when designing. In addition, the wind turbine foundation is also one of the main factors that cause the high cost of wind power generation. The foundation cost accounts for about 10% to 30% of the total cost.

The foundation forms of onshore wind turbines mainly include pile foundation and spread foundation.

Single pile foundations and multi-pile foundations are the two types of pile foundations. The single concrete pile foundation is composed of a large-diameter concrete cylinder, and the force is similar to that of horizontal piles; the multi-pile foundation consists of pile groups and caps to resist the overturning moment. Pile foundations are widely used in areas with poor geological conditions.

Gravity foundation is one of the spread foundation types, the gravity foundation is a reinforced concrete structure, which relies on gravity to balance the horizontal load and bending moment on the wind turbine. The structure is simple with low cost, and it is suitable for onshore wind farms. In this case, the foundation of the wind farm was constructed using gravity foundation.

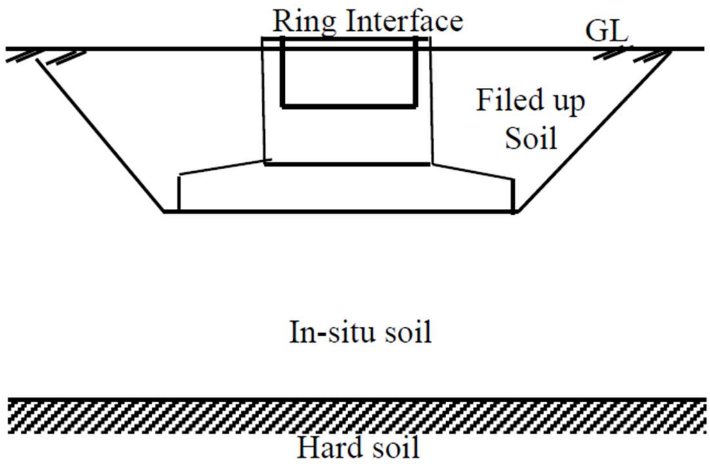

Figure 11: Gravity type foundation [13]

Since the Ameixenda-Filgueira wind farm is located in the "galicia tras os montes" area [14]where the geological conditions are stable, we plan to adopt a gravity foundation with a simple structure and a low cost.

The design of the wind turbine foundation needs to consider the mutual influence of the upper structure of the wind turbine on the foundation and the foundation on the upper structure. In addition to the strength, stiffness and stability encountered in the general foundation structure design, the calculations involved also include dynamic analysis. In this example do not study the detailed foundation design.

5.4 Substation evaluation

The wind turbines have a 650 V to 30 kV step-up transformer to transport energy to the substation through an underground medium voltage network. Since the original substation is for the power service of 36.8 MW, its capacity is small and it has been in service for more than 20 years, so it is necessary to plan a new substation. The two medium-voltage lines will reach the substation, where a transformer will raise the voltage to 220 kV and dump the energy into the transmission lines.

This installation is essential in any type of generation system, since it always seeks to minimize the losses due to the Joule effect, which occur due to the heating of the conductors when a certain current circulates. The greater the current, the greater the losses. It is for this reason that, by increasing the voltage to 220 kV, the current is drastically reduced and, as a consequence, losses are reduced, obtaining greater efficiency when transporting energy.

The transformer is the most important part of the substation, this substation will house a 60 MVA transformer with a transformation ratio of 30/220 kV. Where 30 kV is the voltage that we will have to work in medium voltage and 220 kV corresponds to the voltage of the REE transmission network.

Table 6: Main characteristics of the transformer [15]

Nominal power	60 MVA
Transformation ratio	30/220 kV
Nominal frequency	50 Hz
Medium Voltage side current	987.91 A
High voltage side current	134.71 A
Short circuit impedance	10%

This transformer is in charge of raising the voltage of the medium voltage network to which the wind turbines are connected, to the voltage of the transmission network provided by “Red Eléctrica de España”. The power of this transformer must be greater than the power of the entire wind farm, and even more in case extensions are made in the future. The total power of the park is 46.8 MW, so with a 60 MVA transformer there would be a certain margin in case of installing more power.

In addition, the equipment that needs to be replaced in the substation includes medium voltage cubicles, Power switch, Autovalves, Rotary disconnector, Measurement and protection transformers, etc.

5.5 Conclusion of the repowering plan

According to the Weibull distribution data, we selected 13 Vestas V117/3600 wind turbines for repowering the Ameixenda-Filgueira Wind farm, correspondingly, we also need to carry out the construction of new tower foundation and substation. These works will increase the total power of the wind farm by about 40% to reach 46.8 MW. At the same time, the utilization efficiency of wind energy is improved, and the annual power generation of the wind farm can be almost doubled, reaching 223,028 MWh. Next, we will conduct economic calculations to determine whether this plan can be profitable for the repowering wind farm.

Chapter Six: Economic calculation

The repowering cost includes decommissioning cost of old wind turbines and reconstruction cost of new wind turbines. Also financing cost and operation and maintenance costs shall be considered.

6.1 Old farm decommission cost

As a growing number of first-generation wind turbines reach the end of their useful lives, WindEurope has established a Task Force on dismantling and decommissioning, including the entire wind energy supply chain. The members of the Task Force work together to solve the problem of wind turbine decommissioning in a more sustainable and cyclical manner. Therefore, we need to pay attention to the residual value of the old wind turbine based on the principles of the circular economy.

If the old wind farm is decommissioned, the following facilities will need to be dismantled and related disposal of materials and equipment: such as wind turbines, foundations and Interconnections and substations. Its dismantling requires cost but at the same time the old equipment has some salvage value. Access roads and some O&M building and facilities can be reused by subsequent new power plants.

The main components of a wind turbine (tower, nacelle, hub and blades) are modular components that are easy to disassemble during decommissioning. The tower consists of approximately 94.2 tons of painted steel structure, in which the tower is 57.5 tons, the hub is 22.5 tons, they are made of a combination of steel, copper and different other materials. Some parts in the nacelle and generator may be recycled, both the tower and the hub could have the possibility to be salvaged and recycled for scrap value. The rotor weights 14.2 tons, since the structure of the rotor/blade is mainly non-metallic materials (glass fiber reinforced epoxy resin and carbon fiber), the recoverable value of the rotor/blade is not used in the following cost estimation.

Salvage values can be estimated. Scrap metal prices have always fluctuated with actual market situations. The current salvage value for scrap heavy melt steel (HMS) is approximately € 140.00 per ton. Salvage values for copper materials currently average € 3,450 per ton. It is assumed that the tower and hub will produce approximately 80% of the recyclable materials. By assuming that 5% of the total weight of the hub is composed of copper bearing material, an estimate of copper recovery is obtained [16].

Through the above analysis, we calculated the salvage values of old wind turbines in Ameixenda-Filgueira Wind Farm shown in table 7 below, a total salvage value of approximately € 865,577.50 can be obtained from the decommission. The next step is to calculate the cost of dismantling the equipment of the old wind farm.

Table 7: Salvage values of old wind turbines in Ameixenda-Filgueira Farm

Component	Weight (T)	Steel weight (T)	Copper weight (T)	Steel Value (€)	Copper Value (€)
Tower	57.50	57.50	-	8,050.00	-
Hub	22.50	21.38	1.13	2,992.50	3,881.25
Total (1 Turbine)	80.00	58.50	1.13	11,042.50	3,881.25
Total (58 Turbines)	4,640.00	3,393.00	65.25	640,465.00	225,112.50
Steel price (140€/T), Copper price (3,450€/T)				Total value (€)	865,577.50

Based on the estimated total cost of labor and machinery in Spain, including the work of mobilization and demobilization, and the estimated cost of the work for turbine removal is summarized below in table 8. The cost estimate is based on two days of demolition work for each turbine, including a lift crane, secondary crane, mobilization, demobilization, Petroleum, oils and/or lubricants (POL) contained in the wind turbine nacelle removal and some associated labor costs. This estimate includes the costs associated with transporting turbine components salvaged from the site to the recycling plant.

The estimated cost of demolition of each foundation includes costs for mobilization and demolition of labor and machinery, backfilling and material disposal, and final site restoration [16]. The cost of renovation of the substation needs to include the removal of the replacement equipment.

Table 8: Wind farm decommissioning cost

Turbine Decommissioning	Unit Cost (€)	Unit
Mobilization of Equipment	20,000.00	For Farm
Removal Substation	60,000.00	Substation
Turbine Removal	10,000.00	Per Turbine
Tower Removal	2,500.00	Per Tower
Transport Turbine Parts	5,000.00	Per Turbine
Removal/Disposal of POL	500.00	Per Turbine
Removal of foundation	4,000.00	Per Tower
Subtotal	22,000.00	Per Turbine
Total	1,356,000.00	Total Farm

Taking into account the salvage value of old equipment recycling in table 7, the cost of dismantling the old wind farm can be regarded as € 490,422.50.

6.2 Reconstruction cost

The investment required to reconstruct a wind farm and all the structures associated with it are the basis for determining its economic viability. Approximately 75% of the total cost of the investment is associated with the wind turbine installation, that is, wind turbines, foundations, electrical infrastructure and others. And 10% to civil works, 15% to the electrical installation (10%) that includes the substation (5%).

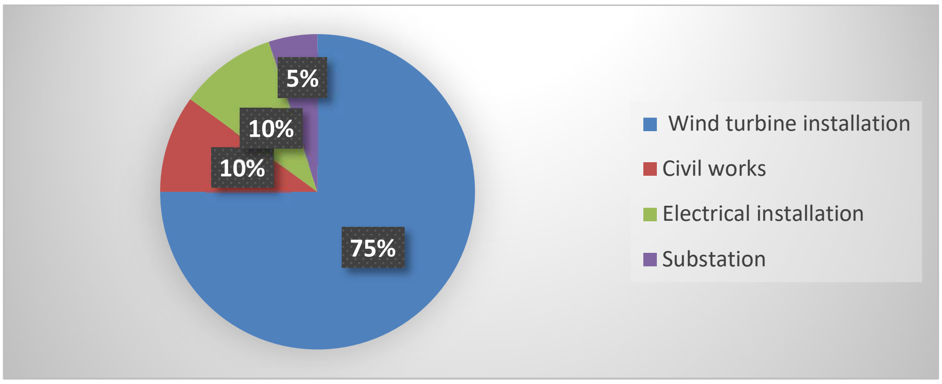

Figure 12: Wind farm cost breakdown

According to El PER 2011-2020, we estimate that the unit cost of installing a 110-meter-high 3.6 MW wind turbine is 1,200,000 Euros per MW including foundations and other ancillary facilities. Therefore, the price of a V117/3600 wind turbine installation is about 4.32 million euros, in the case of the aforementioned unit cost and installation cost ratio of 75:10, the factory cost of a V117/3600 wind turbine is 3.81 million euros.

Based on the actual construction cost of substations in Spain, and considering the available parts of the old substation, we estimate that the cost of rebuilding the 30/220 kV substation is 2.4 million euros.

In summary, the cost of reconstruction is 58.56 million euros. Together with the demolition costs calculated in Section 6.1, the initial investment is 59 million euros.

Table 9: Wind farm initial investment

Cost per unit (€)	4,320,000.00
Cost of substation(€)	2,400,000.00
Cost 13 units (€)	56,160,000.00
Cost demolition (€)	490,422.50
Initial investment (€)	59,050,422.50
Per kW investment (€)	1,261.76

6.3 Financing cost

The financing cost can be expressed by WACC, which is the weighted average cost of capital, it is the rate that a company or organization is expected to pay on average to all its credit investors to finance its assets. Usually, the WACC can be expressed with the following formula [17]:

$$WACC=Ke*E/(E+D)+Kd(1-T)D/(E+D) \qquad \text{eq. 12}$$

Where Ke is cost of equity, E is own funds, D is external funds financed, Kd is cost of debt, T is the tax rate.

We will assume that 80% of the initial investment is financed with external funds and, therefore, the remaining 20% with own funds. Similarly, based on the hypotheses made, the cost of equity is 15%, the tax rate of 30%, and the cost of debt 5.5%, obtaining a minimum required return of:

$$WACC=15\%*20\%/(20\%+80\%)+5.5\%(1-30\%)80\%/(20\%+80\%)=6.08\%$$

We assume that financing costs will be paid within ten years.

6.4 O&M cost

We have already obtained the initial investment in the previous sections, and we also need to calculate the operation and maintenance costs and operating income. The only variable costs that represent a significant percentage of total costs are operation and maintenance.

According to 2020 Wind Energy Technology Data Update, Average operations and maintenance (O&M) costs per unit of capacity is 15 Euro/kW-year [18]. Therefore, the O&M cost of the repowering wind farm is 702,000 euros per year, O&M costs here do not include all operating costs.

Generally, the service life of a wind turbine is about 20 years, and the warranty period provided by the wind turbine manufacturer is 3-5 years. During the warranty period, the manufacturer will be responsible for the entire repair service, and the maintenance cost of the new unit is lower. After the warranty period expires, equipment maintenance becomes a paid service. In addition, the equipment failure rate increases with the increase in service life, and the demand for wind power operation and maintenance increases. We assume here that the warranty period is 4 years, operating materials and some spare parts, if not within the warranty period, have a cost of 0.8% of the factory cost of the wind turbine. The maintenance cost of spare parts for the entire wind farm unit during the 20-year operation period is 396,423.53 euros. Because there is no need to pay for the first four years, for the convenience of calculation, we divide it into 16 years evenly which is about 24,776.47 euros per year.

Maintenance contracts generally do not cover the most serious repairs and the contracted insurance is not valid for any type of failure, so the owner of the wind farm must have a certain amount of spare parts available for the most important repairs. The estimates made in fix this amount, according to data from different wind farms, at 0.5% per year of the factory cost of the wind turbine. That is about 247,764.71 euros per year.

Table 10: Wind farm O&M cost per year

Factory cost of 13 units (€)	49,552,941.18
O&M cost (€/year)	702,000.00
Maintenance cost (€/year)	24,776.47
Important repairs (€/year)	247,764.71
Total O&M cost (€/year)	974,541.18

To sum up, the total O&M cost of the repowering wind farm will be 969,585.88 euros per year as showed in table 10. Taking into account the impact of consumer price index (CPI) on prices, we assume that this cost will increase by 1% during the operation period based on the changes in Spain's CPI in recent years.

6.5 Production income

To understand the production income system of a wind farm in Spain, it is necessary to describe and understand the current legislation and policy. Currently it is not easy to make an estimate of the income that a wind farm can receive, mainly due to the uncertainty created by the future legislative changes that are foreseen, after the publication of RD 2/2009 and RD-Law 9/2013.

Affected by the sovereign debt crisis, Spain had to cut spending to reduce its fiscal deficit, and the renewable energy industry was also greatly affected. In January 2012, the Spanish government announced the cancellation of subsidies for new renewable energy power generation installations.

On July 13, 2013, RD-Law 9/2013 was published, taking emergency measures to ensure the financial stability of the power system, which affects the remuneration system of production facilities with the right to a primary economic regime, among they wind. The RD that regulated the premiums for renewables are repealed and the government will approve a new RD regulating the legal and economic regime for installations for producing electricity from renewable energy sources, cogeneration and waste with premium remuneration. As described in RD-Law 9/2013, a new model will be established based on obtaining a "reasonable profitability" [19].

OMIE is the electricity market operator designated to manage the daily and intraday electricity market in the Iberian Peninsula. In order to estimate the price of electricity sold by wind farms in the future, we will refer to the average final price published by OMIE in the past years as showed in figure 12, hence we can calculate that the average final price of OMIE in the past 12 years is 54.17 euros/MWh.

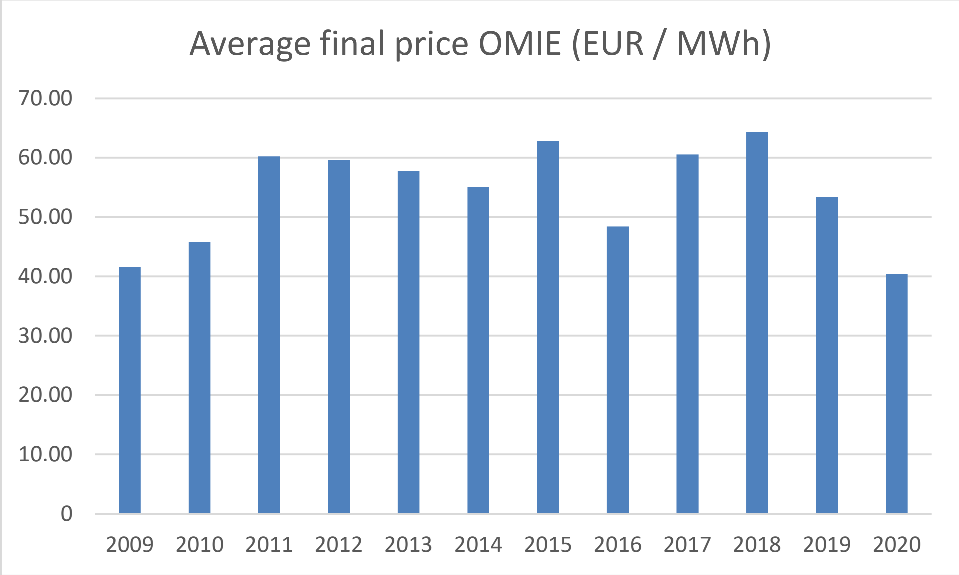

Figure 13: OMIE Average final price [20]

From table 5, we already know that the annual power generation of a single V117/3600 wind turbine is 17,156 MWh, so the theoretical annual power generation of the entire wind farm is 223,028 MWh. To this production we must apply the losses of turbine performance, the losses due to unavailability of the turbines and the network and those due to transformation and transport, both of which will be estimated at 3%. The yield considered will be 88%: 196,265 MWh. Although electricity prices may gradually increase, the efficiency of wind turbines will gradually decrease. Under comprehensive consideration, we calculated at the fixed rate, the annual electricity generation revenue is 10,631,675 euros.

6.6 Expected revenue

The purpose of this section is to calculate whether this program can bring profit and the amount of expected revenue during the operation period. The most known profitability indicators are: the Net Present Value (NPV) and the Payback Period.

The Net Present Value is the current financial value of the future cash flows generated by the investment. NPV introduces the concept of the time value of money, can be expressed as:

$$\text{NPV}= -I_0 - C_d - V_s + \sum_{t=1}^{n} \frac{P_i - C_{OM}}{(1+k)^t} \qquad \text{eq. 13}$$

Where I_0 is Initial investment of reconstruction, C_d is cost of demolition, V_s is value of salvage, P_i is Production income, C_{OM} is O&M cost, the discount rate k is the WACC.

Payback indicates the time period from when the investment is made until it is recovered through the cash flows generated by the facility. This variable becomes important when you want to generate more funds or resources, since shorter profitability periods give the possibility of reinvesting the profits obtained. Through the calculations with above data, we have obtained the main investment and income data of wind farm repowering, and through these data we can get the cash flow during the 20-year operation period. The detailed calculation data is in Annex II, and we get the cumulative cash flow in figure 13, setting the payback of the project in approximately 6.45 years, in the fifth year of operation of the wind farm, the cumulative cash flow started to be positive. The net cash value at the end of the operating period can reach 124,972,925 euros.

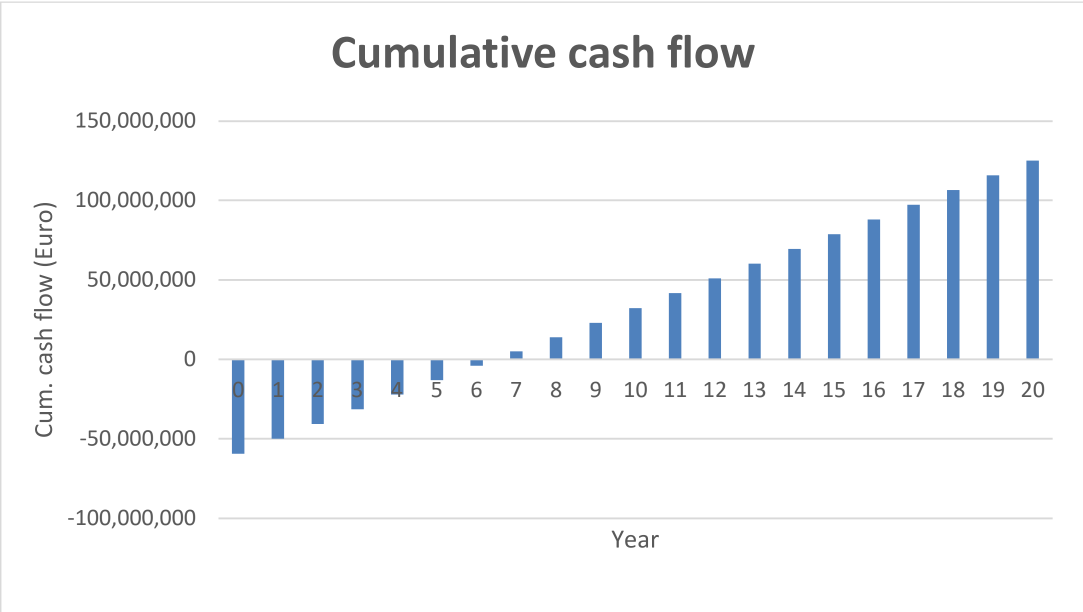

Figure 14: Cumulative cash flow

Through the calculation results, we can know that this repowering plan is economically feasible, the initial investment can be recovered in approximately 6.45 years and the Net Present Value of the investment is about 125 million euros at the end of operation period.

Chapter Seven: Conclusion

The great technological progress in recent years has meant that many renewable energy facilities in Spain have become obsolete, with the decision to repower them increasingly frequent. This work chooses a wind farm in Galicia that has been operating for more than 20 years as an example, and explores the possibility of repowering it.

Based on the assessment of wind energy resources in the region and the calculation of the corresponding Weibull distribution, we proposed a plan to replace the original Siemens Bonus Mk-IV wind turbines with Vestas V117/3600 wind turbines which have higher efficiency and greater power. Through this replacement, the energy output annual of the wind farm has risen from 112,868 MWh to 223,028 MWh, which is nearly doubled.

Similarly, we conducted an economic analysis of the repowering plan, calculated the required investment and expected income. The initial investment requires 59 million euros, the annual revenue from power generation is approximately 10.6 million Euros. Taking into account other costs such as operations, it will take about 6.45 years to recover the required investment and begin to gradually profit.

It should be noted that due to the complexity of operating wind farms and the variability of the market, the income calculation here can never be equal to the true value. For example, price fluctuations caused by relevant laws and policies, and the decline in electricity demand caused by unpredictable events like Covid-19 will make it difficult to accurately predict the actual business situation.

But as a feasibility analysis, based on the calculations of this work, it can be clearly seen that this repowering plan is feasible. This also indicates that the development of sustainable energy in the future can be continuously improved by repowering power plants expired in service.

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Annex

Annex I: Weibull distributions variation with the height calculation

Table 11: Statistical and Weibull distributions comparison

Centro de la clase(m/s)	Statistical data	Weibull distribution
0	0.00	0.00
1.5	0.01	0.04
2.5	0.06	0.10
3.5	0.17	0.16
4.5	0.22	0.19
5.5	0.17	0.19
6.5	0.16	0.15
7.5	0.08	0.09
8.5	0.06	0.04
9.5	0.04	0.02
10.5	0.01	0.01
11.5	0.01	0.00
12.5	0.00	0.00
13.5	0.00	0.00
14.5	0.00	0.00
15.5	0.00	0.00

Table 12: k, c parameters change although the height

Altura (m)	k	c
10	2.81	5.65
60	3.33	8.35
65	3.36	8.50
70	3.39	8.63
75	3.41	8.77
80	3.44	8.89
85	3.46	9.01
90	3.48	9.12
95	3.50	9.23
100	3.52	9.33
105	3.54	9.43
110	3.56	9.53
115	3.58	9.62

120	3.59	9.71
125	3.61	9.80
130	3.63	9.88
135	3.64	9.96
140	3.66	10.04

Table 13: Weibull distributions variation with the height

v(m/s)	$p(v)_{10m}$	$p(v)_{60m}$	$p(v)_{80m}$	$p(v)_{100m}$	$p(v)_{120m}$	$p(v)_{140m}$
1.5	0.04	0.01	0.01	0.00	0.00	0.00
2.5	0.10	0.02	0.02	0.01	0.01	0.01
3.5	0.16	0.05	0.04	0.03	0.03	0.02
4.5	0.19	0.08	0.07	0.06	0.05	0.04
5.5	0.19	0.12	0.10	0.09	0.07	0.07
6.5	0.15	0.14	0.13	0.11	0.10	0.09
7.5	0.09	0.15	0.15	0.14	0.13	0.12
8.5	0.04	0.14	0.15	0.15	0.14	0.14
9.5	0.02	0.12	0.13	0.14	0.14	0.14
10.5	0.01	0.08	0.10	0.11	0.12	0.13
11.5	0.00	0.05	0.06	0.08	0.09	0.10
12.5	0.00	0.02	0.04	0.05	0.06	0.07
13.5	0.00	0.01	0.02	0.02	0.03	0.04
14.5	0.00	0.00	0.01	0.01	0.02	0.02
15.5	0.00	0.00	0.00	0.00	0.01	0.01
16.5	0.00	0.00	0.00	0.00	0.00	0.00
17.5	0.00	0.00	0.00	0.00	0.00	0.00
18.5	0.00	0.00	0.00	0.00	0.00	0.00
19.5	0.00	0.00	0.00	0.00	0.00	0.00
20.5	0.00	0.00	0.00	0.00	0.00	0.00

Table 14: Power curve of the replacement turbines

Wind speed (m/s)	Power (kW)			
	V90/2000	V112/3000	V117/3450	V117/3600
1.5	0	0	0	0
2.5	0	0	0	0
3.5	20	36	0	78
4.5	110	134	113	237
5.5	240	269	265	466
6.5	460	465	520	796
7.5	732	737	890	1247
8.5	1065	1098	1470	1830
9.5	1428	1514	2240	2541
10.5	1756	1942	3030	3209

11.5	1940	2352	3450	3543
12.5	1980	2701	3450	3599
13.5	2000	2930	3450	3600
14.5	2000	2983	3450	3600
15.5	2000	3000	3450	3600
16.5	2000	3000	3450	3600
17.5	2000	3000	3450	3600
18.5	2000	3000	3450	3600
19.5	2000	3000	3450	3600
20.5	2000	3000	3450	3600
21.5	2000	3000	3450	3600
22.5	2000	3000	3450	3600
23.5	2000	3000	3450	3600
24.9	2000	3000	3450	3600
25.0	0	0	0	0

Annex II: Cash flow calculation

Table 15: Cash flow calculation (In Euros)

Year	Initial investment	Financing cost	O&M cost	Production income	Cum. cash flow
0	59,050,423	359,027	0	0	-59,409,449
1	0	359,027	949,765	10,631,675	-50,086,565
2	0	359,027	959,262	10,631,675	-40,773,179
3	0	359,027	968,855	10,631,675	-31,469,386
4	0	359,027	978,544	10,631,675	-22,175,281
5	0	359,027	1,226,308	10,631,675	-13,128,941
6	0	359,027	1,238,571	10,631,675	-4,094,864
7	0	359,027	1,250,957	10,631,675	4,926,828
8	0	359,027	1,263,467	10,631,675	13,936,010
9	0	359,027	1,276,101	10,631,675	22,932,557
10	0	0	1,288,862	10,631,675	32,275,369
11	0	0	1,301,751	10,631,675	41,605,294
12	0	0	1,314,768	10,631,675	50,922,200
13	0	0	1,327,916	10,631,675	60,225,959
14	0	0	1,341,195	10,631,675	69,516,439
15	0	0	1,354,607	10,631,675	78,793,507
16	0	0	1,368,153	10,631,675	88,057,028
17	0	0	1,381,835	10,631,675	97,306,868
18	0	0	1,395,653	10,631,675	106,542,890
19	0	0	1,409,610	10,631,675	115,764,956
20	0	0	1,423,706	10,631,675	124,972,925

Resumen

El objetivo de este trabajo es evaluar la viabilidad de la repotenciación de un antiguo parque eólico en Galicia, España.

Con base en la evaluación de los recursos eólicos en la región y el cálculo de la distribución de Weibull correspondiente, propusimos un plan para reemplazar los aerogeneradores originales Siemens Bonus Mk-IV por aerogeneradores Vestas V117/ 3600 que tienen mayor eficiencia y mayor potencia. Con esta sustitución, la producción de energía anual del parque eólico ha pasado de 112.868 MWh a 223.028 MWh, lo que casi se duplica. Este plan no requiere nuevos permisos porque no aumentará la potencia del parque eólico instalada en más de un 40%, por lo que cumple con las leyes y regulaciones vigentes y.

Se estableció un modelo de financiamiento del plan de repotenciación para calcular el valor actual neto, tomando como ingresos de la producción de electricidad por el nuevo tipo de turbina, su costo de capital estimado y otros parámetros relevantes. La inversión inicial requiere 59 millones de euros, los ingresos anuales por generación de energía son de aproximadamente 10,6 millones de euros. Teniendo en cuenta otros costos como las operaciones, se necesitarán alrededor de 6,45 años para recuperar la inversión requerida y luego comenzar a lucrar gradualmente. Se puede ver claramente que este plan de repotenciación es factible. Esto también indica que el desarrollo de la energía sostenible en el futuro se puede mejorar continuamente mediante la repotenciación de las centrales eléctricas caducadas en servicio.