Economic-Technical feasibility study of the "Sierra de Tineo" wind farm expansion. Tineo – Principality of Asturias (Spain).

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Abstract. The aim of this work is to explore the possibilities of extending the Sierra de Tineo wind farm. We study the location chosen, the wind resource in the area and simulate the wind regime with computer tools. The economic and sensitivity study of the investment, as well as the new Legislation of the Principality of Asturias is also considered.

Key words.

Wind Energy, legislation, wind resource, economic study, feasibility study.

1. Introduction.

Energy is an essential factor in the forecast for the global economic development. Given the current economic crisis, the energy market presents some problems due to various reasons such as the increasing demand or the fluctuation of energy prices. This has led to the development of energy policies where the prime objectives have focused on energy saving, efficient use and source diversification.

During the last year, the worldwide markets have been characterized by a huge volatility because of the high impact of the financial crisis. This has lead to a substantial modification of the sector perspectives, especially in the near future.

According to the World Energy Outlook (WEO-2009), published by the AIE, the global energy demand fell by 1,3% in 2009. This fact, with the low demand forecasts and the liquidity restrictions in the main markets, has lead to a sudden decrease of the energetic sector investments.

According to data from Red Eléctrica de España (Spanish Electric Net), the energy consumption during 2009 in Spain decreased by 4,5%. The ordinary regime covered the 70% of the demand, while the special regime the remaining 30%, a 6% higher than the previous year.

The energy strategy of the Spanish Government is summarized in the Plan de Acción Nacional de Energías Renovables (PANER – Renewable Energy National Action Plan), where it is established, as an aim for 2020, that the renewable sources will represent, at least, the 20% of the final energy consumption. In addition, the Royal Decree 661/2007, of 25th May, regulating the activity of electricity production in the special regime, envisages the development of a Plan de Energías Renovables (PER), for application in the period 2011-2020. This PER will replace the PER 2005-2010 with which Spain has successfully transformed its energy model and also developed a leading industry in some fields.

2. Wind Energy in Spain. "Sierra de Tineo" wind farm.

The development of renewable energies is a priority in the Spanish policy because of its many positive effects on the society as a whole. Spain, with an eolic power close to 20 GW, ranks fourth in installed wind energy behind the United States, Germany and China.

The Spanish region of Asturias ranks tenth and has the 1.9% of the national installed wind power.

Sierra de Tineo wind farm (Figure 1) is composed by 22 turbines of 2 MW of unitary power, which means 44 MW of total power. The expansion of this wind farm is justified as long as a suitable location is found. This location must comply with local legislation, have a good wind resource and be profitable from an economic point of view. The place that we will study is "La Peña los Ourales", a prolongation to the northeast of the original wind farm.

Sierra de Tineo's wind farm expansion is in a very advanced stage of processing right now. After the initial report and the urbanistic consultations to the City Council involved, the Department of Industry and Employment of Asturias resolved favorably, allowing the promoter company continue with the process.

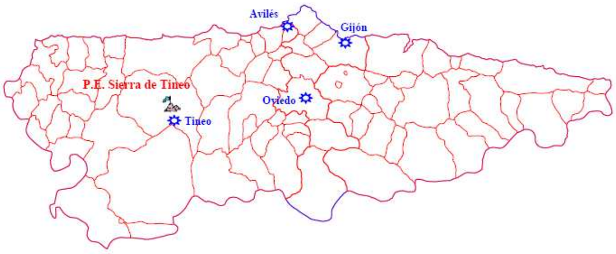

Figure 1. Wind farm site and its expansion.

3. Operating Method.

A. Matching the legislation.

The legal standards in Asturias are given by the following laws:

1) *Decree 42/2008*, of 15th May, approving the Sectorial Directives of Territory Arrangement for the wind energy use.
2) *Decree 43/2008*, of 15th May, about wind farm authorization procedures by the Principality of Asturias.

These Decrees form the legislation currently in force in Asturias, and include, for the first time, articles relating to wind farm expansions

According with the legislation, the wind farm expansion must be placed in a *High Capacity Area* (Decree 42/2008), and agree with the expansion criteria established in the *22th Directive* (Decree 42/2008.

B. Studying the Wind Resource..

The wind resource is analyzed and studied through the wind data recorded in two meteorological towers. The first one, located in the Sierra de Tineo's wind farm expansion zone (Tower 1), has been recording data since 2005 at three different heights: 80, 60 and 45 m, respectively. The second one is set in the surroundings (Tower 2), and has been recording wind data since 2004 at 45 m high. The measurement period is long enough to consider it representative of the site (Tower 1: 34 months; Tower 2: 56 months). The longer the measuring campaign is, the better the results are.

For the wind resource analysis, we will use the Measure-Correlate-Predict method (MCP), supported by computer tools such as WAsP (Wind Atlas Analysis and Application Program). This program processes the data (Table 1), and shows the site's compass rose and the Weibull distribution.

Table1.- Wind data obtained in Tower 1 and analyzed with WAsP.

Number of measures		146,088		
Site average speed		7.02 m/s		
Weibull Parameters	A	7.8 m/s		
	K	1.56		
	U	7.11 m/s		
Turbulence Intensity		0.10 (10%)		
Prevailing directions (16 sectors)		E	20%	7.5 m/s
		SW	12,7%	10.8 m/s

Once the data has been summarized, a correlation can be made. In this case, correlation is set at 45 m high. Figure 2 shows the data overlay of both towers in the common measuring time. In Figure 3, a lineal regression is made in order to verify the existence of a real correlation between them.

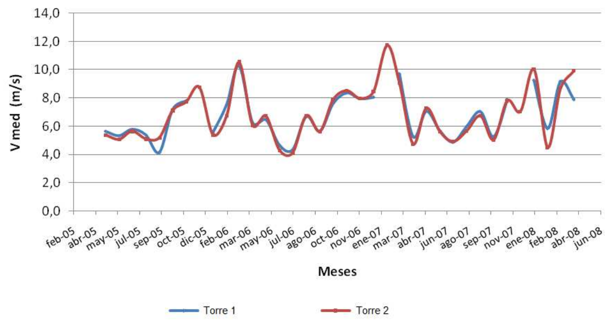

Figure 2. Data overlay.

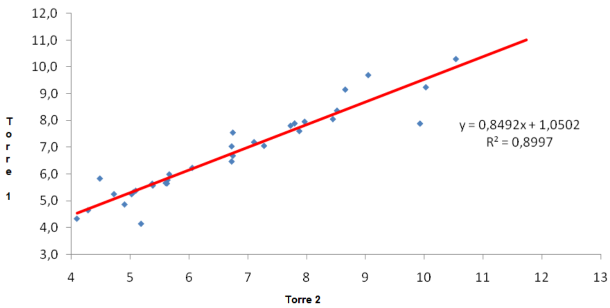

Figure 3. Correlation between two towers.

For the long term prediction part, a comparison between average speeds has been made. Firstly in the common measuring time and then, comparing the results with the average speed in Tower 2 for the long term period (since 2004).

Data in Table 2 shows that average speed in Tower 2 for the common measuring time is representative of the long term average speed, so the average speed in our site for the long term might be supposed as **7.02 m/s** (These two towers are separated about 2.7 km).

Table 2. Average Speed Comparison.

	Period	
	May 05 – Aug 08 (Short term)	Jan 04 – Aug 08 (Long term)
Tower 2 (45 m)	6.63 m/s	6.65 m/s
Tower 1 (45 m)	6.93 m/s	-
Tower 1 (80 m)	7.02 m/s	-

Once this calculation has been made, WAsP permits us to modify the previously calculated distribution to adjust the average speed obtained to the long term. We obtain Figures 4 and 5.

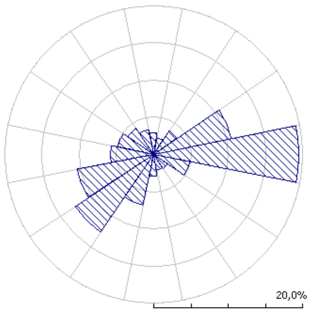

Figure 4. Tower 1: Wind rose adjusted.

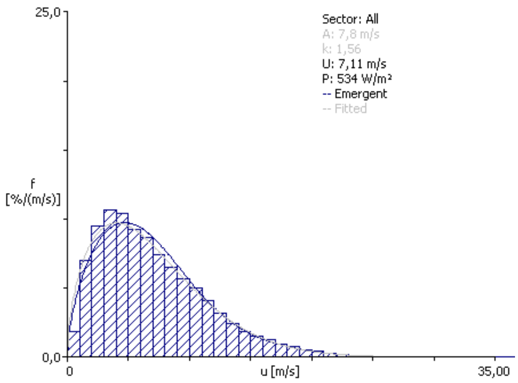

Figure 5. Tower 1: Weibull distribution adjusted.

Cartography must be added to the wind simulation so that we can obtain very interesting graphics that helps to determine the best wind areas within the site (Figure 6). We can also add some parameters such the *Rugosity Length* or define obstacles in the surroundings in order to get more reliable results.

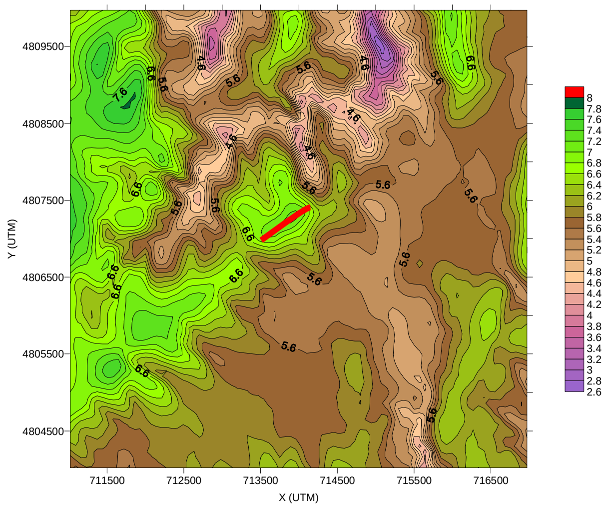

Figure 6. 2D-80 m high wind-lines map.

C. Installed power forecast. Energy generated..

Once the main parameters were analyzed, we simulate the behavior of the wind generator. A generic 2 MW power wind generator is chosen and his main characteristics are given in Table 3. Figure 7 shows a generic 2 MW power curve.

Table 3. Main parameters of the 2 MW wind generator.

Rotor diameter	90 m
Rated power	2,000 kW
Blade length	44 m
Swept area	6,362 m2
Hub height	80 m
Control	Variable pitch
Orientation	Upwind
Rotation speed	9/14.9 rpm
Starting speed	2.5 m/s
Rated speed	13 m/s
Cut speed	21 m/s

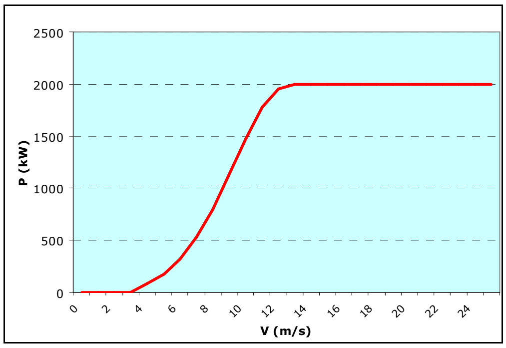

Figure 7. 2 MW Wind turbine power curve.

With those data, it is possible to start deciding the number of wind turbines and its positions on the site. A second look must be given to the mentioned Decrees to identify any other restrictions or recommendations we should comply. Some other technical criteria must also be considered such as the distance among wind turbines or main orientations. Finally, three machines will be installed and their coordinates are given in Table 4.

Table 4.New Wind turbines coordinates

Wind generator	X (UTM)	Y (UTM)
A1	714,039	4,807,344
A2	713,761	4,807,175
A3	713,481	4,807,010

WAsP can simulate and calculate a *Gross Energy Production*. To get the *Free Energy Production* we should substract the wake effect. That means 17.296 GWh per year. That energy must be corrected through the application of some factors the program does not include: wind turbine availability, dirt and ice on blades, electrical losses, maintenance, etc… Once they are applied, the net production is *16.06 GWh per year* or *2,677* equivalent hours.

D. Economic Study.

Sierra de Tineo's wind farm expansion is justified by the existence of sufficient wind resource.

The estimated total investment is about 6,8 million Euros (Table 5). The wind turbines are a high percentage of the total investment.

Table 5. Investment Costs.

Concept	Thousands €
Wind turbines	6,190
Civil Works	453
Electrical infrastructure	129
Restoration Plan Costs	34
Material Execution Budget	**6,806**
Overhead and Industrial Profit	1,293
Contractual Execution Budget	**8,1**

Other costs are: O&M (equipment repairs and replacements), land leasing, insurance, local taxes and fees, administration and management. Among all of them, the O&M costs are the higher (0.01 €/kWh). The rest are estimated as a percentage over the energy sales (Table 6).

The parameters used in this study are shown in Table 7. No inflation is considered in the operating costs, nor on earnings, although it is taken into account when updating the cash flows. No income is considered for the residual value of the facility at the end of its useful life.

Table 6. Other Costs.

Concept	% over sales
Administration & Management	2.00
Land leasing	2.00
Local taxes and fees	4.00
Miscellaneous	2.00
Other variable costs	2.00
Insurance	1.00

The price of energy is **7,8183 c€/kWh** (*Order ITC-3801-2008*, 26th December, which revises the electricity fees from January 1 2009, published in the BOE (Boletín Oficial del Estado – Official State Bulletin) of 31st December of 2008).

Main investment parameters are calculated: NPV, $IRR_{project}$ and $IRR_{investor}$. As a result:

$$NPV = 3{,}230{,}097\ €$$
$$IRR_{project} = 7{,}38\%$$
$$IRR_{investor} = 22\%$$

Partners' investment is recovered after 8 years.

Table 7. Starting parameters.

Installed Power	6,000 kW
Investment	1.35 Million €/MW installed
	Total: 8.1 Million €
Capital Distribution	20% Partners
	80% Bank Credit
Credit Conditions	Capital: 6.48 Million €
	Recovery period: 14 years
	Annual payment: 462,857 €
Interest Rates	Euribor (to 10 years): 2%
	Passive: 3.90%
	Active: 3.50%
	Update Rate: 4%
Useful Life	20 years
Electricity Production	Equivalent hours: 2,677
	Energy output: 16.06 GWh
Income review	1%
Cost review	2%

E. Brief Sensitivity Analysis.

The sensitivity analysis for the NPV and IRR are made by modifying the next parameters:

1) Initial investment.
2) Wind speed .
3) Euribor.
4) Energy price.

Because they have the higher impact over the financial results.

Initial Investment.

Considering a Price range from 1,100 to 1,500 €/kW, the values for NPV and IRR are shown in Table 8. The initial investment has a big impact over those parameters because it represents a fundamental part of the project costs.

Table 8. NPV and IRR according to Initial Investment.

€/kW	IRR (%)	NPV (€)
1,100	32	4,595,956
1,200	28	4,049,612
1,250	26	3,776,440
1,300	24	3,503,269
1,350	2	3,230,097
1,400	21	2,956,925
1,500	18	2,410,582

Wind speed.

Equivalent annual hours are calculated for every average speed value, using the power curve previously shown (see Figure 7).

Results are in Table 9 and, as a conclusion, we can say that wind speed is a very important factor, although the less controllable.

Table 9. NPV and IRR according to equivalent hours.

Eq. Hours.	IRR (%)	NPV (€)
2,500	19	2,528,859
2,600	21	2,925,038
2,677	22	3,230,097
2,700	24	3,312,218
2,800	24	3,717,398

Euribor.

Euribor variations significantly affect the loan conditions and, as a result, the project profitability.

Table 10 shows the results: the higher the Euribor is, the lower NPV and IRR are, because of increasing interests and decreasing cash flows.

Table 10. NPV and IRR according to Euribor.

Euribor.	IRR (%)	NPV (€)
2	22	3,230,097
2.5	21	3,070,526
3	21	2,908,245
3.5	20	2,743,285
4	19	2,575,680

Energy price.

It could be considered as constant for the short term, although little variations may occur at medium term (Table 11). A political change in the treatment of this kind of electricity generation may vary the payment the promoters receive for the energy.

It is an important problem when feasibility studies are made, because the sale price is unknown. The new economic environment has not been considered for this study.

Table 11. NPV and IRR according energy price.

Price (€/kWh)	IRR (%)	NPV (€)
0.05500	8	-416,643
0.06500	14	1,177,371
0.07000	17	1,955,921
0.07818	22	3,230,097
0.08000	23	3,513,022
0.08500	26	4,910,572
0.09000	29	5,070,123

4. Conclusions.

Achieving sustainable development at all levels requires Energy Policies that promote the use of clean and efficient energy, as well as its self-sufficiency.

Wind energy will always be justified from an environmental point of view, because it is a clean, efficient and competitive source of energy. On the other hand, wind projects should not be considered if the environment conditions are not the best. A low wind resource (near 6 m/s or lower), and the presence of sensitive elements in the surroundings (environmental, historical, cultural ones), should be sufficient for not to consider developing such installations.

Sierra de Tineo's wind farm expansion is justified by all the reasons exposed previously. The impact of this new installation will be lower than the one generated by a new wind farm in a new location, because it is an expansion of an existing wind farm.

Nowadays, the growing of these installations is about to collapse in the short-medium term in Spain. The impossibility to know when the installation will get the pre-register and, as a result, to know how much money the promoter will get by selling the energy, makes these infrastructures difficult to assess from an economic point of view.

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