Wind power costs in Portugal

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Abstract

In a way to reduce the external energy dependence, increasing also the investments in renewable energy sources and aiming for the concretization of the European renewable objectives, the Portuguese government defined a goal of 5100 MW of installed wind power, up to 2012. If the drawn objectives are accomplished, by 2010 the wind power share may reach values comparable to leading countries like Denmark, Germany or Spain. The Portuguese forecasts also indicate a reinforcement of the natural gas fired generation in particular through the use of the combined cycle technology, following the European tendency.

This analysis sets out to evaluate the total generating cost of wind power and CCGT in Portugal. A life cycle cost analysis was conducted, including investment costs, O&M costs, fuel costs and external costs of emissions, for each type of technology. For the evaluation of the externalities ExternE values were used.

The results show that presently the wind power production cost is higher than the CCGT one, at least from the strictly financial point of view. CCGT costs increase significantly when charges for externalities are included. However, they only reach levels higher than the equivalents for wind power for high externality costs estimations. This partially results from the low load factor of the wind farms in Portugal and also from the low emission levels of the gas fired technology used in the comparison.

A sensitive analysis of the technical and economical parameters was also conducted. Particular attention was given to the natural gas prices due to the possible increase over time. The fuel escalation rate is the parameter that has larger effects on the final costs. It was verified that the total cost of wind plant is more influenced by the load factor than the total cost of CCGT.

Keywords: Wind power, energy costs

1 Introdution

The European Union is committed under the Kyoto Protocol to reduce greenhouse gas emissions (GHG) by 8% from 1990 levels by 2008 – 2012. Portugal, as an EU member state should limit the increase of their GHG emissions to 27% in the same period.

According to the National Climate Change Plan 2006 (NCCP), in 1990 the energy sector contributed with 67% of the total GHG emissions and it is expected to increase to 75% of the national total of emissions by 2010. Still with in the same sector, and in 1990, there are the most contributing activities to this problem - activities related with the electricity and heat industry – 35% (estimates of 30,3% in 2010).

The increase of renewable energy sources (RES) contribution for electricity production is an important element of the package of measures necessary to comply with the Kyoto Protocol, under the United Nations Framework Convention on Climate Change, and it is also fundamental for the achievement of the Directive 2001/77/EC objectives.

Under the Directive on Renewable, Portugal must achieve a target of 39% of its electricity production from RES in terms of gross electricity consumption in 2010. This percentage essentially corresponds to electricity production from RES in 1997, in which the major electricity production was originated from hydroelectric power stations. Portugal assumed that the Electricity System Expansion Plan will proceed with the construction of new hydroelectric power plants with an installed power rating of more than 10 MW, and that another type of renewable capacity will increase at an annual rate eight times higher than the recent developments.

With the Resolution of the Ministers Council n.º 63/2003 the Portuguese Government reinforced the promotion of hydroelectric resources and the support to the development of renewable energy resources, such as wind, mini-hydro, biomass, photovoltaic and waves.

Portugal is strongly dependent on external energy sources, special oil, accounting for almost 85% of the primary energy, higher than the UE average. Although the natural gas sector has grown considerably over the past few years, this is a fossil fuel that also contributed for GHG, in spite of being in a more reduced form. The only national resources came from the renewable sources, specially the hydro sector.

The large hydro is the most important source for electricity production, but it is dependent on the climatic conditions. In a dry year, like 2005, it is necessary another energy source, namely the thermal production. Besides, this sector has been facing serious environmental obstacles (BCG, 2004) and, consequently, showing a lower expansion than expected.

With the marginal contributions of the remaining energy sources and the difficulties foreseen in the hydroelectric sector, it is expected that the wind power sector will be very important for the objectives fulfilment. This source presents a high potential, but its growth depends on several factors namely the enterprising and financial capacity, the long period for the licensing requests or the access to the grid.

2 Portuguese electric power system

2.1 Portuguese electricity system

There are two electricity systems in Portugal, the Public and the Independent. The Public Electricity System (PES) is regulated in order to ensure power supply for the whole national territory. The Independent Electricity System (IES) includes a Non-binding

Electricity System (NES) and the Special Regime Producers (SRP) – cogeneration and renewable plants.

The production of electric energy in Portugal is dominated by hydro and thermal production, with the latter being resourced by coal, natural gas and fuel-oil. According to *Rede Eléctrica Nacional, SA* (REN, 2004, 2005) the total installed power reached in 2005 about 10,4 GW in PES and NES and almost 2,4 GW in the Special Regime Producers.

The SPR reached 18,5% of the total installed power and is expected to increase considering the new goals for the renewable sources of energy - 2000 MW for the cogeneration systems (in 2010) and 5100 MW for wind energy (in 2012).

In 2005 the hydroelectric production was very low, requiring an increase in thermal power production (especially fuel/oil power plants). The deliveries of the Special Regime Producers grew 47%, to which contributed significantly the wind power and cogeneration plants. These producers represent almost 14% of the total electric production.

2.2 Wind power sector

Figure 1 illustrates the evolution of installed and cumulative wind power, in Portugal. Between 1999 and 2005 the average annual rate was 67%, but the great evolution happened in 2004 and 2005, with growth rates of 112% and 94%, approximately.

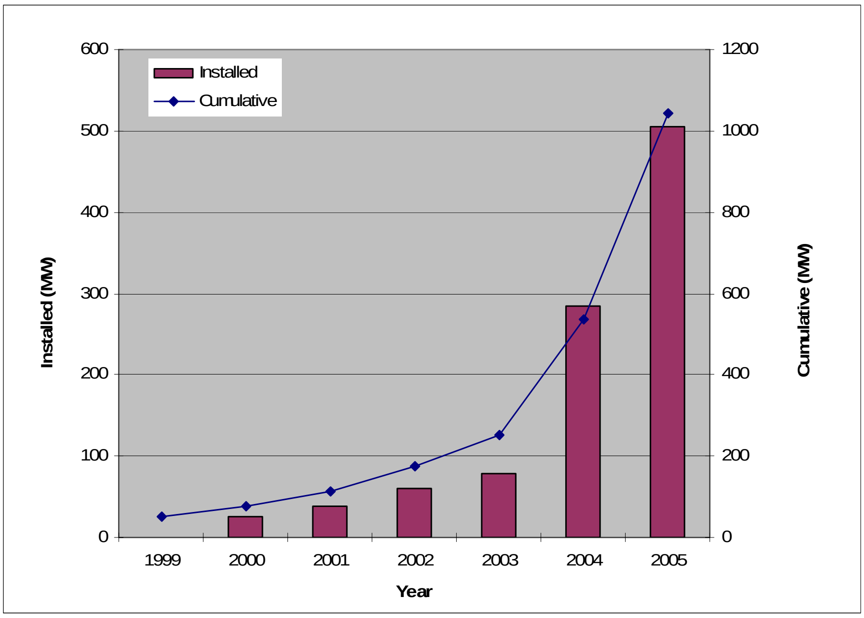

Figure 1. Installed and cumulative wind power, in Portugal (Source: DGGE, 2006).

Although presenting an impressive rising trend, wind power levels for Portugal are still distant of the European leaders, namely from Germany that reached 18 GW of total installed capacity in 2005, from Spain which crossed 10 GW on that year, and even from Denmark, with more than 3 GW.

According to the Energy and Geology Directorate General of (DGGE) data (DGGE, 2006), by the end of 2005 this source of energy represented about 20% of the renewable electricity production, and only 3,3% of the total electricity production. The DGGE forecasts expected that wind energy would contribute for 12,2% of the total electric production by 2010, an ambitious goal when compared with the three European leading countries in wind power capacity.

Considering the wind power capacity in 2005 and the national objectives, an average of 732 MW should be installed per year, 47% more than in 2005, reaching a value of 12% of the total electricity production, higher than the contribution of this source in countries as Spain (6%) and Germany (5%) and close to the contribution in Denmark (19%).

Although the wind sector presents a great potential some barriers exist to its development, namely the delays in the licensing processes (especially associated with the environmental approval) and the difficulties on the access to the grid (BCG, 2004). Particularly important is the improvement of interconnection capacity as a key requirement for ensuring the security of supply and to proceed with the planned hydro schemes in order to avoid possible situations of operational reserve deficit (Ferreira et al, 2007).

3 Costs analysis of electricity generation systems

Different methods can be used to compare the cost of project alternatives and to determine which provides the best value. The most often used is life cycle cost (LCC), an economic evaluation technique that determines the total cost including all expenses, incurred over the entire life of the system.

Typical costs for a system may include capital, operation, fuel and decommissioning costs. A complete life cycle cost analysis may also include other costs, as well as other financial elements (such as discount rates, interest rates, depreciation, etc).

The equation used to calculate, for each power plant, the levelized electricity generation cost (EGC) is the following (NEA, 2005):

$$EGC = \sum \left[\left(I_t + M_t + F_t + X_t\right) \left(1 + r\right)^{-t} \right] / \sum \left[E_t \left(1 + r\right)^{-t} \right] \qquad \text{(eq. 1)}$$

where: EGC – Average lifetime levelized electricity generation cost

It – Investment expenditure in the year t

Mt – Operations and maintenance expenditure in the year t

Ft – Fuel expenditure in the year t

Et – Electricity generation in the year t

r – Discount rate

The future costs were converted into a present value considering the period of time and the discount rate.

This analysis depends on the values of the investment costs, operation and maintenance costs, fuel costs and external costs. It is sensible to the load factor and thermal efficiency of the system (for natural gas) and is influenced by economic parameters, such as discount rates, growth rates, inflation and interest rates.

3.1 Data sources

In this study the total generating cots of wind power and combined cycle natural gas (CCGT) have been determined. The data and system characteristics necessary for economic evaluation are given in Table 1.

Table 1. Data and system characteristics used in economic evaluation for wind farm and CCGT.

	Wind	CCGT
Installed capacity	20 MW	1200 MW
Load factor	22%	85%
Thermal efficiency	-	57%
Life time	20 years	25 years
Investment costs	1206.20 €/kW	514.19 €/kW
O&M annual costs	15.37 €/kW	23.59 €/kW
Fuel costs	-	22.23 €/MWh

Levelised costs were calculated assuming constant pricing and based on the 2005 value. A discount rate of 5% and 10% was used in the analysis.

The external costs depend on several factors, like the type and age of the central, the fuel, the efficiency of control and treatment emissions systems, etc. In life cycle analysis emissions from materials production (for example materials for the turbines and materials used for the electrical transmission equipment) are also included. In the case of wind fuel cycle, it is in this phase that most emissions are produced.

The estimates for the external costs (from effects of GHG emissions) used in this analysis are derived from the ExternE Program studies for wind and natural gas fuel cycle – emissions from wind parks installed in Denmark, United Kingdom, Germany and Spain and a combined cycle installed in Portugal. Damages have been calculated for a range of different assumptions – four different values of CO_2 emissions – varying with each adopted discount rate (1, 3 and 5%) and within the 95% confidence interval. The estimates to 1% discount rate correspond to a scenario where impacts occur for a longer period.

Table 2. External costs for different damage estimates (Source: European Commission, 1998a).

External costs	Wind (€/MWh)	CCGT (€/MWh)
Low	0.02 – 0.07	1.93
Mid 3%	0.11 – 0.31	9.41
Mid 1%	0.29 – 0.81	24.02
High	0.87 – 2.44	72.54

3.2 Results

With the technical characteristics of the power plants presented in Table 1 and with the economic assumptions, the annual levelized costs - €/MWh of electricity produced - have been calculated for the two technologies. The results are shown in Table 2.

This approach does not incorporate several aspects, like the need of backup capacity to compensate wind intermittency and fluctuations, or the need to reiforce the distribution and transmission systems, or the feed-in tariffs.

Table 3. Annual levelized costs for the two technologies.

Costs	Wind		CCGT	
	(€/kW)	(€/MWh)	(€/kW)	(€/MWh)
1. Investment				
r = 5%	1206.20	50.23	514.19	4.90
r = 10%		73.52		7.61
2. O&M				
r = 5%	15.37	7.98	23.59	3.17
r = 10%		7.98		3.17
3. Fuel				
r = 5%	--	--	22.23 €/MWh	38.98
r = 10%		--		38.98
4. External				
low		0.02 – 0.07		1.93
mid 3%		0.11 – 0.31		9.41
mid 1%		0.29 – 0.81		24.02
high		0.87 – 2.44		72.54
Total cost (no external)				
r = 5%		**58.21**		**47.05**
r = 10%		**81.50**		**49.76**
Total cost (with external)				
r = 5%				
low		58.23 – 58.28		48.98
mid 3%		58.32 – 58.52		56.46
mid 1%		58.50 – 59.02		71.07
high		59.08 – 60.65		119.59
r = 10%				
low		81.52 – 81.57		51.69
mid 3%		81.61 – 81.81		59.17
mid 1%		81.79 – 82.31		73.78
high		82.37 – 83.94		122.30

From de LCCA, the obtained total production costs for wind technology were 58.21 €/MWh and 81.50 €/MWh, for 5% and 10% discount rates, respectively. In the first case, investment costs represented about 86% of the total cost, and in the second case, this share was near 90%. The remaining costs correspond to O&M values. Including external costs, the total costs are expected to be in the range of 58.23 – 60.65 €/MWh, for the lowest discount rate, and 81.52 – 83.94 €/MWh, for the highest discount rate. The environmental costs represent about 0.03 – 4.02%, for the 5% discount rate and 0.02 – 2.91%, for the 10% discount rate.

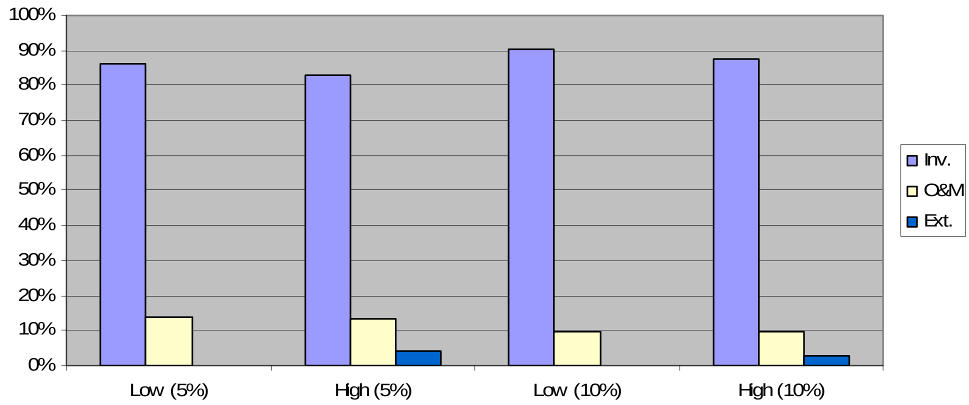

Figure 4. Estimated cost structure for wind plant (5% and 10% discount rate).

For the CCGT system the annual levelized costs, without the environmental costs, reach 47.05 €/MWh, for the 5% discount rate and 49.76 €/MWh, for the 10% discount rate. About 10% and 15% of these costs represent investment costs, respectively. For this technology the major share of costs results from the gas consumption - close to 83% and 78%. The range of values obtained, including the environmental costs, is 48.98 – 119.59 €/MWh and 51.69 – 122.30 €/MWh, respectively for 5% and 10% discount rates. For the low external cost estimations, fuel cost represents the predominant share of the total costs. However, for high external cost estimations environmental costs overcomes fuel cost values.

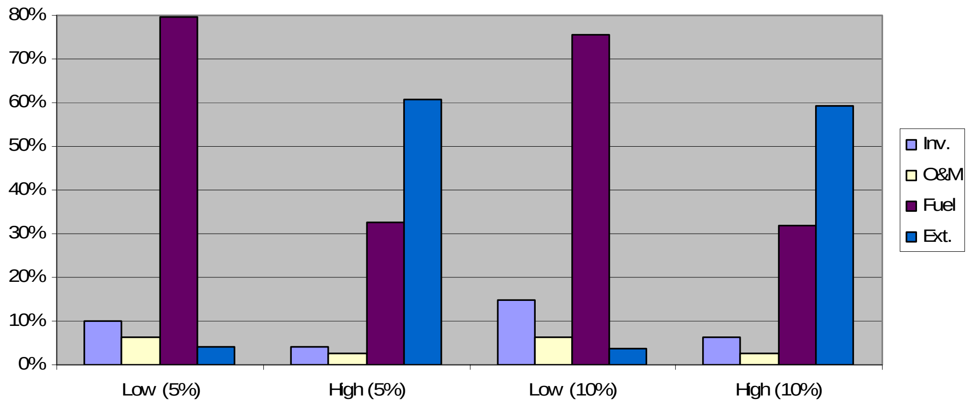

Figure 5. Estimated cost structure for CCGT (5% and 10% discount rate).

4 Discussion of the results

Although being a renewable energy source without fuel consumption costs, the investment costs of wind power plants are considerably higher than the gas technology investment values. This results in higher production costs (€/MWh) for wind plants (when external costs are not included).

From the analysis, it was possible to verify that, in order for the total uniform costs of the two technologies (without environmental costs) become similar, the investment cost of the wind system would have to reduce almost by a 22% factor (for a 5% discount rate) or by half (for a 10% discount rate), of the current value.

Other aspects can significantly affect the results obtained. For instance, the increase of the natural gas price (as verified in recent years) or the reduction of the wind farms' O&M costs.

Given the current concerns about GHG emissions, their effects and the European emissions trading schemes, it is also important to analyse the emissions market effects on the total costs of the two technologies.

The total costs, of the two technologies when including the environmental costs, are similar for high and 1% medium estimates of the external costs. For this scenario, the total costs of the gas technology increase significantly and its production costs become twice as high as the wind electricity production costs.

5 Conclusions

In this study, the total generating costs of wind power and CCGT, in Portugal were analysed. A life cycle analysis for each system was performed. Grid costs associated with the distribution and transport systems and the compensation costs in the case of the wind energy (with the storage or backup units) were not included.

From the results for the Portuguese case, it can be concluded that the CCGT is still more attractive than the wind energy when only financial aspects are accounted for. Wind energy presents higher investment and O&M costs than the CCGT that are not yet compensated by the inexistence of fuel costs. In addition the wind energy load factor in Portugal (22%) is low when compared with the adopted for CCGT (85%)

When external costs are considered, the electricity generation costs for the two technologies are similar. However, for high estimates (of GHG emissions) the wind system reaches more attractive values. For this case, environmental costs dominate the cost structure of the CCGT.

The results were obtained assuming constant values. However, an increase on conventional systems costs may be expected, in result of the resources depletion, as well as of the environmental politics (when considered environmental costs). The price of the natural gas has been presenting a significant growth between 2003 and 2005 (almost 84%) and, therefore, in a short time the inversion of the obtained results may be verified, creating a competitive advantage for wind power.

At the same time, the costs of the renewable systems should decrease due to the development and diffusion of these technologies. The analysis showed that the uniform costs of the two technologies (without environmental costs) would be similar if the investment costs of wind energy were reduced by almost 22% (for 5% discount rate) or by half of the current value (for 10% discount rate).

For the expansion of the renewable technologies a strong support from governmental institutions is fundamental. The reduction of the atmospheric emissions must be a priority and the inclusion of the external costs in the economic analysis, should be generally implemented for the evaluation of energy projects.

The sensitivity analysis showed that the increase of the discount rate causes an increase of the investment costs and consequently an increase of the total costs. As the combined cycle has lower investment costs the effects of this parameter in this technology is less significant.

The increasing of fuel escalation rates is the parameter that originates larger effects in the final costs. Even when considered this escalation rate the CCGT system presents lower levelized costs (without environmental costs) than the renewable system for the discount rates and load factors adopted (only exceed for fuel escalation rates superior to 5%).

The total costs (without environmental costs) of a wind farm are more influenced by the load factor than the CCGT system.

The expectations and incentives around the wind energy are comprehensible. Besides, being a renewable energy source, the expected development and the consequent reduction of the costs will turn this technology even economically attractive to the investors. If the life cycle is analysed and the external costs for the wind energy are included it can become more advantageous than the conventional systems.

The expansion of the wind technology in Portugal will influence significantly the energy system costs, but it is fundamental for the execution of the European and national goals in the renewable electricity production, and to contribute for the GHG reduction. Wind power presents the obvious advantage of having operational costs invulnerable to fuel and emissions markets volatility. This represents a clear advantage in an electricity system highly dependent of external energy sources as it is the case of Portugal.

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