Combined-cycle plants as back-up for wind power

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1. Background

Interest in renewable energy sources has been growing over the last ten years. This is mainly in response to the increased consumption of fossil fuels, the problem of security of supply and also to tackle the environmental problems caused by such consumption.
Alternative power plants such as solar, biomass and wind energy systems are the main trends. In most cases, however, alternative energies cannot by themselves cope with the existing demand, so they need to be combined with other fossil fuels like natural gas, oil, etc.
Natural gas has emerged as the best fuel to be used in partnership with renewables. Its combustion yields low emissions of pollutants, it is ash free, the carbon monoxide content (mostly responsible for acid rain) is practically zero and the amount of NOx formed is a lot less than for any other fossil fuel. Furthermore, CO_2 emissions (responsible for the greenhouse effect) are much lower than with other fuels, and the products of combustion and respiration of the human (CO_2 and H_2O) may even be comparable. Natural gas is therefore the best option to support renewable energy.
Gross electricity generation from renewable energy sources (RES) has grown significantly in Europe since 1990. Of the new renewable energy sources (excluding large-scale hydropower), wind power makes the largest input to renewable energy capacity. One of the main shortcomings of wind power is that wind is very unpredictable. Strength can vary from calm to storm force. Therefore, wind turbines cannot produce a continuous amount of electricity for a sustained period, which creates problems of network stability and uncertainty regarding the availability of energy.
The partnership of natural gas combined-cycle plants and wind power is a good answer to grid stability problems and makes the whole system more secure. Gas is used as a back-up to handle the fluctuation of wind power.
Through the survey and installed power and production of wind power and combined-cycle plant in Spain will be analyzed the relationship between them.
Based on the values found will be made the correlation analysis and estimate development prospects

Keywords: combined cycle plants, natural gas, wind power.

2. Aims

Although wind power has many advantages, including being a renewable source of energy and not emitting greenhouse gases, it also has considerable disadvantages. The most relevant are the visual and noise pollution they cause, but technically speaking the biggest drawback of wind power is the intermittency of production. That is, due to its fluctuating nature wind cannot provide continuous production.
A so-called support system therefore has to be used. The support system supplements the wind power by coming into operation to produce electrical power when the latter fails, and so ensures the demand is met.
The most common support systems used to back up wind power plants are combined-cycle gas turbines. This is because, although they use a fossil fuel, it is one that has great advantages over other one, and, furthermore, the technology they employ is highly efficient. The aim of this paper is to analyze and predict the correlation between the development of installed capacity and production from wind power and combined-cycle plants.

3. Methods

The number of countries that are engaged in renewable energy production has increased exponentially in the last decade, and wind energy has been singled out from other renewable energy sources as a promising and attractive option.
Renewables have a long history of European policies and associated measures. The European Commission has listed the promotion of community renewable energy as one of its goals since 1986 (Official Journal C 241; 1986). In 1997 it set a target of 12% of energy coming from renewable sources by 2010. Recent policies, as contained in the 2007 document "An energy policy for Europe" (Com; 2007) have amended the targets to 20% integration of renewable energy by 2020 and 10% integration of renewable energy in transport.

3.1 European policies for wind power

The 20% target means that more than one-third of the EU's electricity will come from renewable sources in 2020 – up from 16% in 2006. By 2020, wind energy is expected to have overtaken hydropower as the EU's largest renewable source of electricity (Table 1).

Table 1 Contribution of renewable sources to EU electricity consumption in 2020 (European Renewable Technology Roadmap 2008).

Type of energy	2005 TWh	2020 - Target	
		TWh	%
Wind	70.5	477	34.8
Hydro	346.9	384	28
Photovoltaic	1.5	180	13.1
Biomass	80	250	18.3
Geothermal	5.4	31	2.3
Solar thermal elect.	---	43	3.1
Ocean	---	5	0.4

To achieve this objective the EU adopted a new renewable energy Directive in April 2009 to set individual targets for each Member State. In response to Directive 2009/28/EC (European Parliament and the Council; 2009) Member States presented their national renewable energy action plans in 2010. This plan sets national targets for 2020 with respect to the share of energy from renewable sources consumed by transport, power generation and heating and cooling (Figure 1).

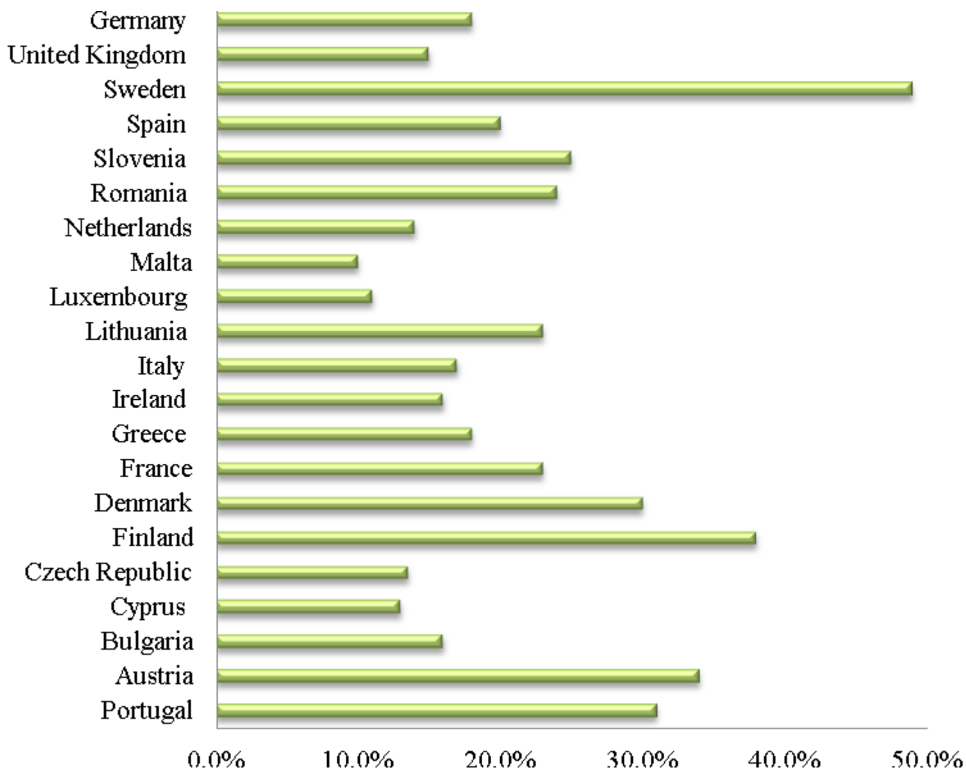

Figure 1 – Targets for renewable energy inclusion in final energy consumption in 2020.

With few exceptions, electricity production is the sector which foresees a greater share of energy being generated by renewable energy sources. Wind energy is conspicuous as a major renewable energy source (figure 2) and excluding countries that do not calculate wind power production (e.g. the Czech Republic, Finland), the average integration of wind power by European countries in 2020, as estimated targets, is approximately 42.3%.

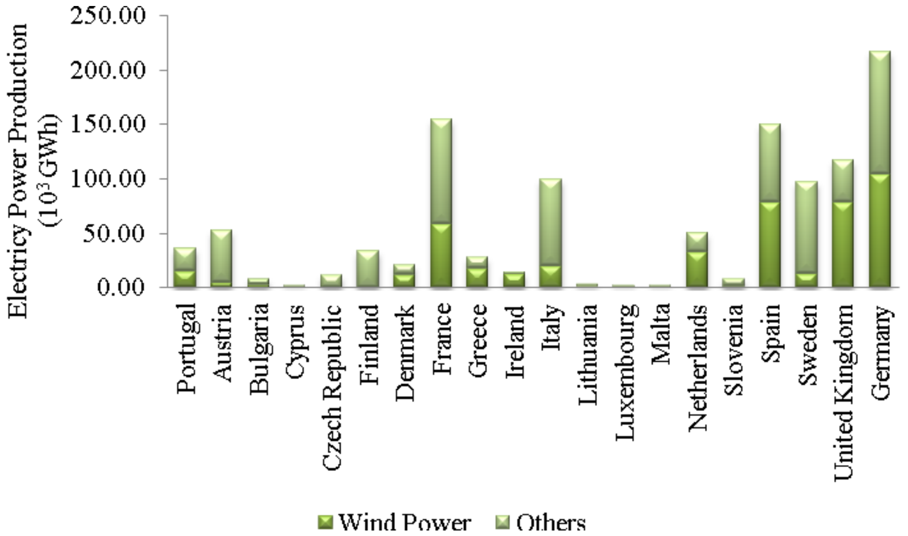

Figure 2 – for wind power and other renewables in electricity power production.

3.2 European wind energy tariffs

In most EU member states electricity utilities now buy electricity generated from renewable sources, produced by both individuals and companies. The price paid for 'self-produced' electricity is called a feed-in tariff.

TABLE II Feed-in tariffs per Member State in 2010 (€/kWh) (European Renewable Energies Federation; 2009).

Member state	Windpower 'On-shore'	Wind power 'Off-shore'	Solar PV	Biomass	Hydro
Austria	0.073	0.073	0.29 - 0.46	0.06 -0.16	n/a
Belgium	n/a	n/a	n/a	n/a	n/a
Bulgaria	0.07 - 0.09	0.07 - 0.09	0.34 - 0.38	0.08 - 0.10	0.045
Cyprus	0.166	0.166	0.34	0.135	n/a
Czech Republic	0.108	0.108	0.455	0.077 - 0.103	0.081
Denmark	0.078	0.078	n/a	0.039	n/a
Estonia	0.051	0.051	0.051	0.051	0.051
Finland	n/a	n/a	n/a	n/a	n/a
France	0.082	0.31 - 0.58	n/a	0.125	0.06
Germany	0.05 - 0.09	0.13 - 0.15	0.29 - 0.55	0.08 - 0.12	0.04 - 0.13

Greece	0.073	0.073	0.29 - 0.46	0.06 -0.16	n/a
Hungary	n/a	n/a	n/a	n/a	n/a
Ireland	0.07 - 0.09	0.07 - 0.09	0.34 - 0.38	0.08 - 0.10	0.045
Italy	0.166	0.166	0.34	0.135	n/a
Latvia	0.108	0.108	0.455	0.077 - 0.103	0.081
Lithuania	0.078	0.078	n/a	0.039	n/a
Luxembourg	0.051	0.051	0.051	0.051	0.051
Malta	n/a	n/a	n/a	n/a	n/a

The rates of remuneration for wind energy are generally among the lowest rates paid for electric energy produced by renewable sources in EU countries. The exceptions are Estonia, Latvia and Lithuania who apply the same tariffs for electricity produced from renewable energy sources, and Denmark, where the remuneration of the energy produced by wind is greater than that produced from biomass.

4. Results

In 2009, 10.526 MW of wind power was installed across Europe, 10.163 MW of this being in EU countries. This represents approximately 15.5% growth in the EU, compared with the figures for installed power in 2008 (figure 3).

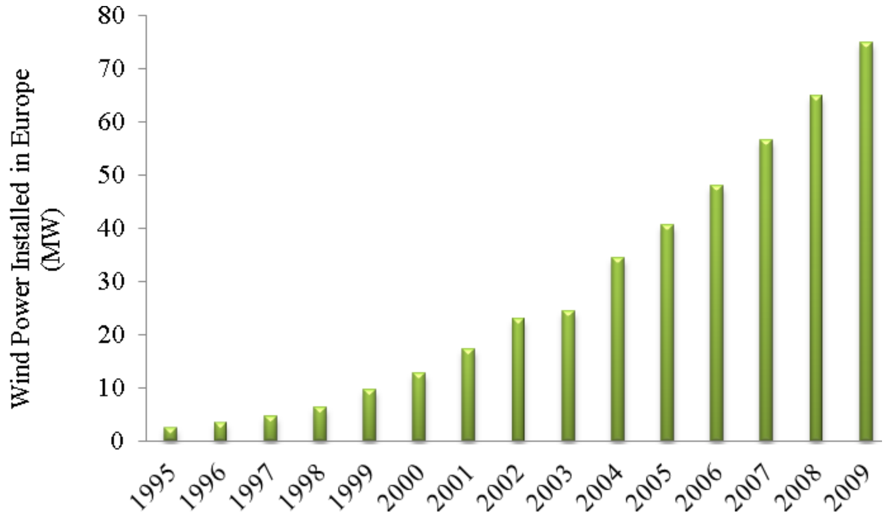

Figure 3 – Wind power installed in Europe (The European Wind Energy Association; February 2010).

The facilities in Europe are characterized by a continuous development in the mature markets of Spain and Germany, followed by Italy, France and the UK. In 2007, production of electricity from wind power amounted to 104.3 GWh in the European Union (European Environment Agency; 2008).

Spain has the second highest installed wind power capacity in the European Union. In 2009 it had an installed capacity of 18 GW, twice the amount in 2005 (figure 4).

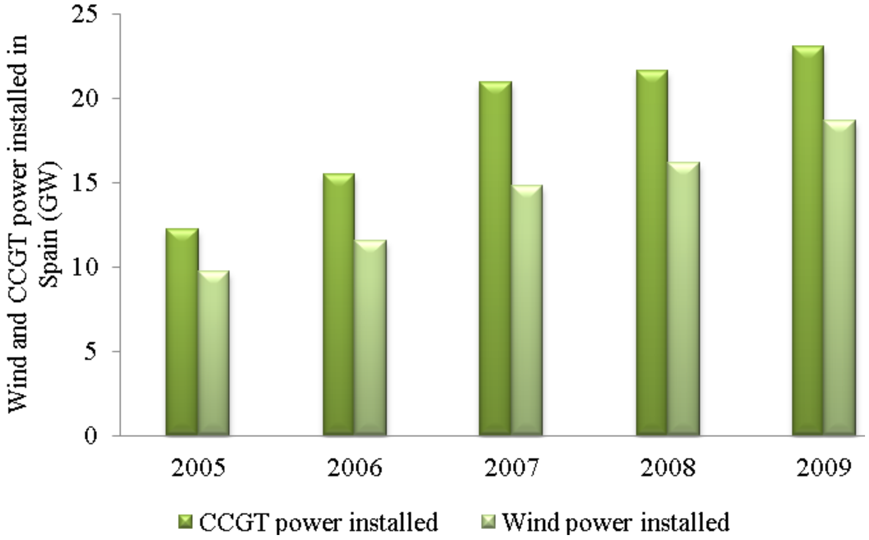

Figure 4 – CCGT and wind power installed in Spain (RED ELÉCTRICA DE ESPANÃ; 2010).

Many of the world`s electricity utilities and independent power producers are turning to gas turbine combined-cycle power technology for new capacity. The main reasons for the predominance of this technology are its high efficiency, moderate capital cost, low environmental impact, favourable natural gas prices and short construction schedules. Recent advances in gas turbine technology permit a combined-cycle efficiency of almost 60 percent. The turbines used in combined cycle plants are usually fuelled by natural gas, of which there are abundant reserves in several countries. Natural gas is becoming the fuel of choice for private investors and consumers because it is more versatile than coal or oil and can be used in 90% of energy applications.
In the last decade most countries concentrated their power generation investments in gas-fired power plants, especially combined-cycle gas turbines (CCGT). The document "European Energy and Transport - Trends to 2030" (European Commission; 2007), indicates that CCGT plants accounted for about 51% of total investment in combined power plants between 2005 and 2010. Also according to the estimates presented in this document, in 2030 the total installed capacity of CCGT plants in Europe will be 145 GW.
A country that epitomises the growing interest and investment in CCGT plants is Spain. In 2005 Spain had a total installed capacity of 12 GW from CCGT; in 2009 the figure was 23 GW, which is an increase of 88% (figure 4).

5. Summary/Conclusions

Although wind power has many advantages, including being a renewable source of energy and not emitting greenhouse gases, it also has considerable disadvantages. The most relevant are the visual and noise pollution they cause, but technically speaking the biggest drawback of wind power is the intermittency of production. That is, due to its fluctuating nature wind cannot provide continuous production.

A so-called support system therefore has to be used. The support system supplements the wind power by coming into operation to produce electrical power when the latter fails, and so ensures the demand is met.

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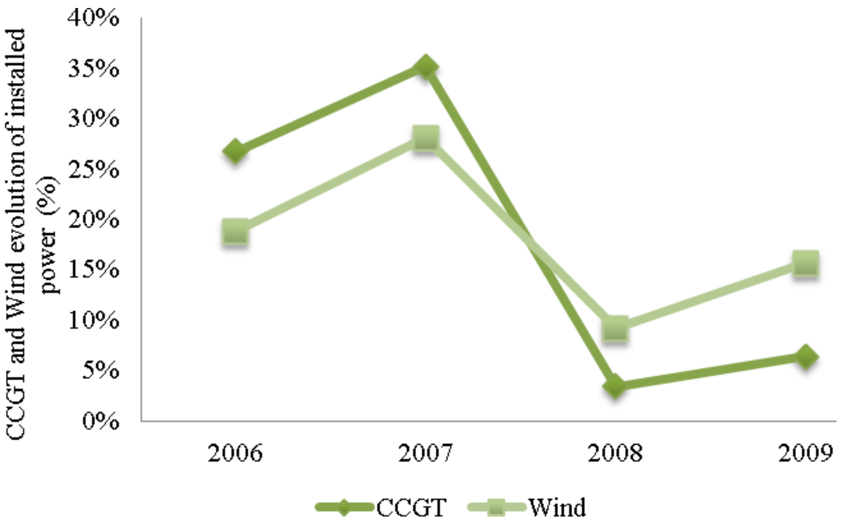

Figure 5 – CCGT and wind installed power in Spain (RED ELÉCTRICA DE ESPANÃ; 2010).

As we can see from figure 5, installed power from CCGT and wind power have a very similar trend. Both forms of energy show a significant increase of installed power between 2006/07 and 2008/09, and both show a decrease in the growth of installed capacity in 2008.

In 2007, which was when there was a greater increase of installed power, CCGT reached a total installed capacity of 20 GW, an increase of 5.5 GW compared with the previous period, and wind power energy grew by 3.2 GW, reaching a total of 14.8 GW.

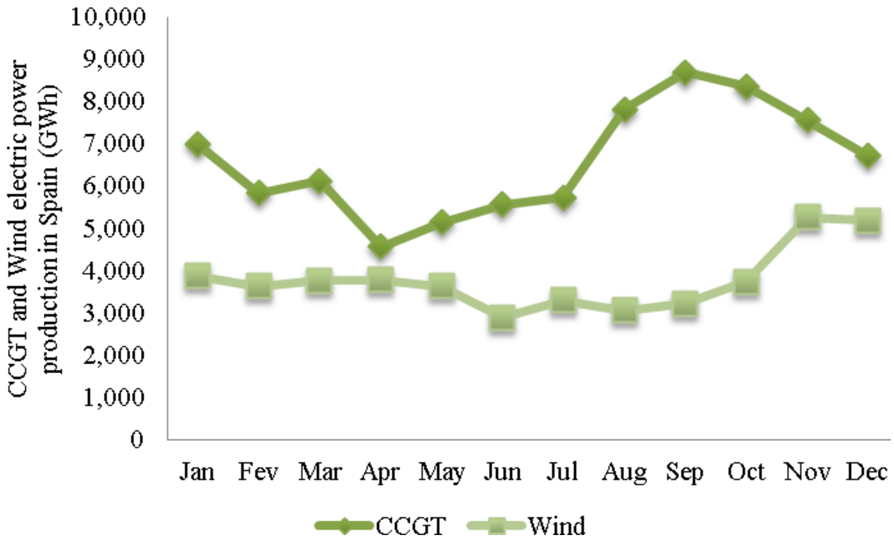

Figure 6 – CCGT and wind electric power production in Spain (RED ELÉCTRICA DE ESPANÃ; 2010).

As figure 6 shows, CCGT electricity production follows the production trend of wind power electricity generation. That is, whenever there is a decrease in wind power generation, the CCGT starts working to remedy this failure. When electricity generation by wind increases, CCGT production decreases.
Thus the intermittent electricity generation by wind power does not lead to failures in the availability of energy and does not jeopardize network integrity.
According to estimates the installed capacity of wind power will tend to continue to increase. The figures for Europe indicate that the production of electricity by wind power will reach 477 TWH in 2020.
Assuming these trends are maintained, the increase in installed capacity of CCGT will continue to grow, too, and it is also expected that the development of CCGT technology will lead to this increase being even higher than anticipated. With current technology, CCGTs are already the best option for supporting the production of other renewable energy sources, especially the production of wind energy.

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