Cover page

Title: Implementation of Offshore Wind Farms in Gran Canaria, Spain

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ABSTRACT

Reduce oil dependence of the Canary Islands is a must. Its power generation depends almost entirely (94%) on oil and it is today the only fuel for this purpose. They are only seven islands (Lanzarote, Fuerteventura, Gran Canaria, Tenerife, La Palma, La Gomera and El Hierro) but there are six independent electrical systems due to the great depths that exist among them. Only are electrically connected Lanzarote and Fuerteventura by submarine wire. It has been studied the possibility of constructing pumping hydro plants with the aim of storing energy, reducing consumption and increasing penetration of renewables in the islands. Concretely, the studies were performed in five islands whose height would allow the construction of this type of plants. Lanzarote and Fuerteventura have been left out by environmental reasons and being very flat. Today the *Store* project is been executed by ENDESA electricity company, where three electrical storage systems are analyzed although they are very small and very expensive [5].

The islands are very small, have a high percentage of environmentally protected areas (see Table I), a high population density and a high tourist occupancy. For this reason, it has been tried to find a siting for an offshore wind farm next to Gran Canaria, which would serve for creating an electricity system composed by three electrically interconnected islands. Nowadays Fuerteventura and Lanzarote are connected and Gran Canaria too in a short term.

TABLE I. SURFACES ISLANDS

Island (ha)	Lanzarote	Fuerteventura	Gran Canaria
Total surface	85,494	165,974	156,010
Protected Area	35,029	47,695	66,707.9
	40.97%	28.74%	42.76%

INTRODUCTION

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Gran Canaria has a population of 850,391 people. Lanzarote and Fuerteventura have a population of 246,589 people. These three islands were visited by 7,305,549 tourists in 2011. The Islands are 1.000 km away from mainland Spain, but only 100 km from Morocco. They have good winds, several wind farms with more than 4,000 hours equivalent per year, and high solar radiation due to being further south in Europe. Oil is the only conventional fuel in the islands, no gas neither coal. The rest of the generation is renewable energy (wind and sun).

Spain is the second European country in installed wind power, but does not have any offshore wind farm, because the almost complete lack of continental shelf and

environmental considerations. In order to mitigate this, the Ministry of the Environment, along with other ministries conducted a study to analyze the coastline where offshore wind farms could be constructed. The authorization should be granted by the Ministry as set out in the Real Decreto 1028/2007 [4].

In the planning of the electricity and gas sectors 2012-2020, it is provided the interconnection between Gran Canaria and Fuerteventura. In this way, the three islands (Gran Canaria, Fuerteventura and Lanzarote) would be electrically interconnected forming a single electrical system. In Gran Canaria it was already studied a place for a hydroelectric pumping. It is the most populated island, with greater electricity consumption and could provide space for the renewable generation of the set.

For the creation of a big wind farm for this new electrical system, land has been ruled out because it is limited and the best places are already occupied. Furthermore in the case of Gran Canaria, the airport restricts greatly its wind development. In this paper different options are considered for this purpose, and it is assessed the power and energy that could be got in the areas found.

DESCRIPTION OF THE CURRENT AND PLANNED ELECTRICAL SYSTEMS

Today there are two independent electrical systems. You can see the daily consumption in the web page of Red Eléctrica de España (REE) [8] that is the sole transmission agent and operator of the Spanish electricity system. In its web page you can access demand prediction and groups covering it, in daily curves that are updated in real time.

In Gran Canaria there are installed four technologies: steam turbine, combined cycle, gas turbine and diesel engines. In Fuerteventura and Lanzarote there are only installed the last two technologies mentioned. The electrical system of Gran Canaria has two power stations, and Fuerteventura and Lanzarote have a power station each one. Table II shows the power installed in each island. Table III shows the peak power and annual energy in 2010 and estimated ones for 2020, with the electrical systems existing today.

TABLE II. POWER GENERATION TECHNOLOGIES

Installed Power MW	Lanzarote	Fuerteventura	Gran Canaria
Power Station	213.9	187	1,138.7
Wind Energy	79.1	8.8	13.1
Photovoltaic Energy	34	6.5	10.7

TABLE III. PRESENT AND FUTURE DEMAND

MW /GWh	Lanzarote- Fuerteventura	Gran Canaria

Peak power 2010	256.5	570.5
Peak power 2020	384	854
demand 2010	1,451.1	3,526.8
demand 2020	2,113	5,209

It is planned to create a pumping station on the island of Gran Canaria with the following features: a jump of 283 m and 2.35 GWh. The jump is not excessive but there is the advantage that dams already exist, and it is possible to duplicate the storage capacity due to the existence of another dam at the same height as the highest dam and with the same volume [1, 3].

The document prepared by the Ministry of Industry collects submarine interconnection between Fuerteventura and Gran Canaria. It would be 120 km long and 1,600 m maximum deep. This would interconnect the three islands.

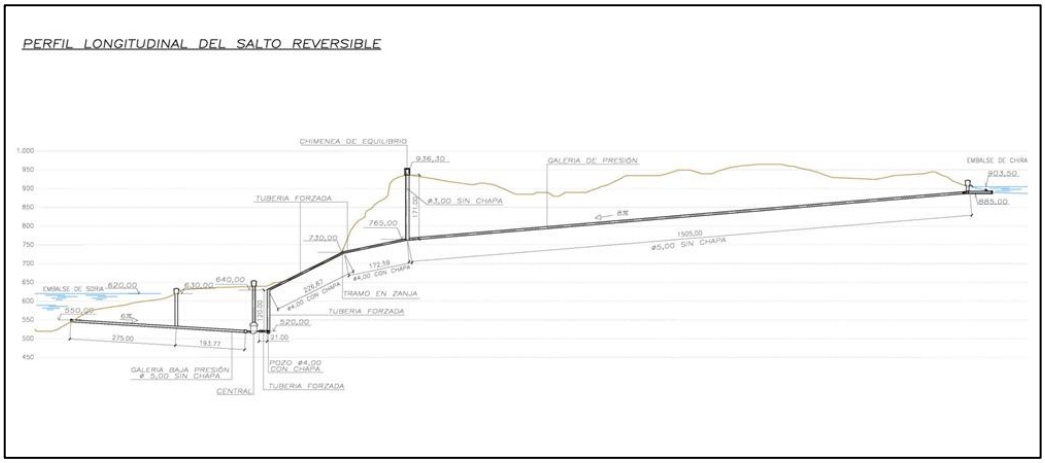

Figure 1. Hydroelectric Power Plant

ANALYSIS OF TECHNICAL OPTIONS

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First the marine wind map of the island is analyzed [2] [6] and later the bathymetry among the islands. Based solely on these two criteria it is established the areas where it is possible to situate offshore wind farms.

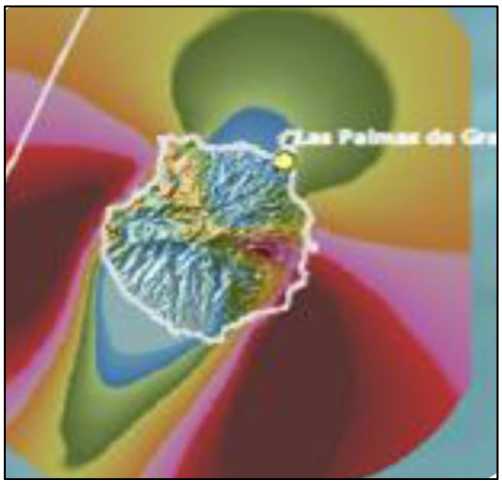

Figure 2. Wind Resource

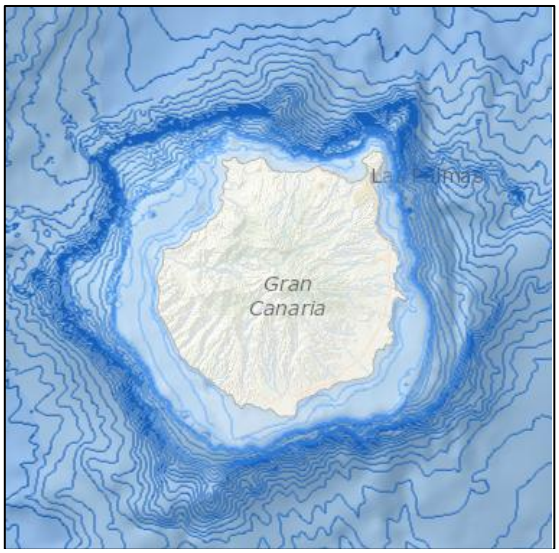

Figure 3. Bathymetry

Presently, existing wind farms driven into the seabed, reach at fifty meters in depth, what is named low deep. But there is already some experimental wind farm based on new technologies, such as innovative foundations and floating wind turbines (see Fig. 4), that will permit the location of wind farms towards deeper waters. It will allow consider a second option that includes deeper areas, up to two hundred meters in depth.

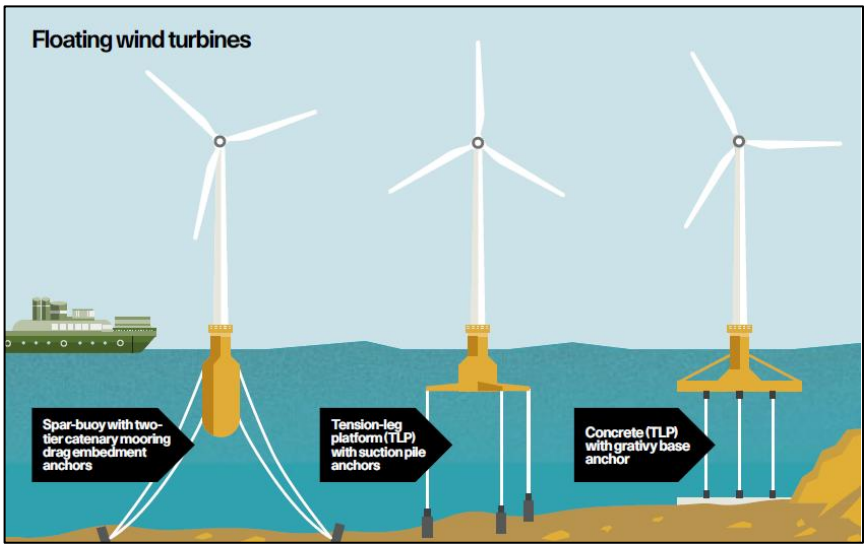

Figure 4.Turbines for more than 50m in deep

ENVIRONMENTAL ANALYSIS

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It has been made environmental considerations but we must not forget that probably the Ministry, in his study of the coast, has already considered them [7].

It has been studied the spaces belonging to the European network Natura 2000, that categorizes two kinds of spaces: SACs (Special Areas of Conservation) and SPAs (Special Protection Areas of Conservation of Wild Birds). The other protected areas of the Canary Islands do not have marine area. Moreover, none of the three marine reserves of the Canary Islands lies on this island. We also analyzed the part of the island classified as Biosphere Reserve, but it does not add any additional protected marine area, because it protects the south-west coast, already designated as SACs. It is also considered the recent cataloging of marine IBAs (Important Bird Areas) that are determined by Seo Bird Life, an NGO that studies and catalogs the relevant spaces to protect due to the existence of marine birds and it coincides again with the south-west coast. Fig. 5 only shows SAC areas in Gran Canaria, because the most of the protected marine areas are included.

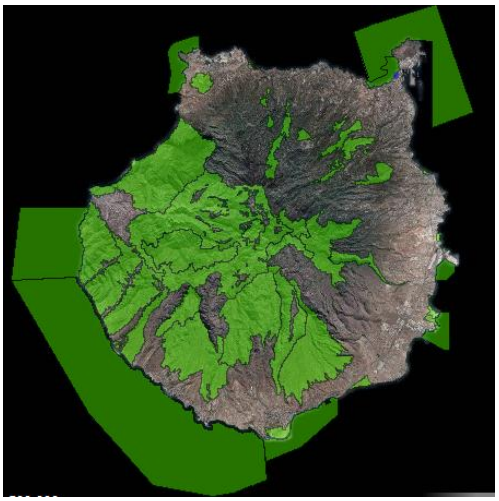

Figure 5. SACs in Gran Canaria

TERRITORIAL ANALYSIS

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Waters from the Canary Islands have been declared Particularly Sensitive Sea Area (PSSA) [9], but they are located in an area crossed by several international maritime brokers frequented by large ships carrying oil and a variety of potential contaminants. Two of them go running parallel, in north-south direction, and leaving Gran Canaria between them. For this reason, in Fig. 6, that show a shoreline survey of the potential areas to situate offshore wind farms, the two sides of Gran Canaria are in red that means its total exclusion as siting of wind farms. Green color means an acceptable area and yellow one an area with restrictions. This map was constructed taking into account the environmental study of the Ministry [7] and our own considerations.

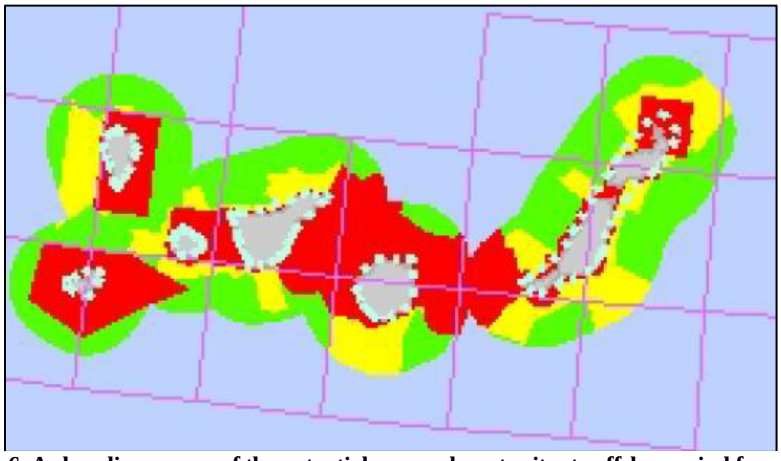

Figure 6. A shoreline survey of the potential areas where to situate offshore wind farms

POTENTIAL OF THE STUDY AREA

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After excluding all invalid areas, we obtained an area of study that is a good option from the point of view territorial, for being close to a relevant port, the port of Arinaga, facing one of the power station of the island, the Tirajana power station, in front of the other two islands, and relatively close to the Chira-Soria pumping station.

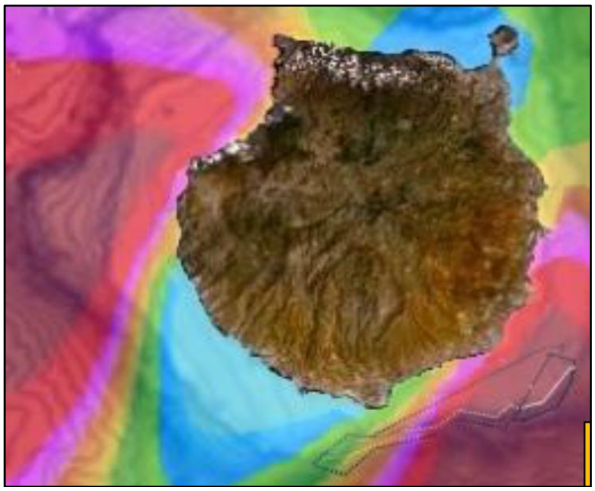

Figure 7. Location of the area of study

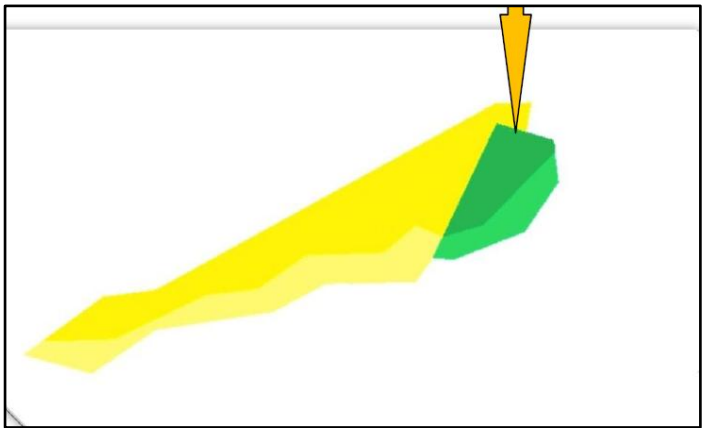

Figure 8. Area of study

Now we will determine how much power could it be produced in this area, how much wind energy production could it be obtained, and how much does it represent with respect to the power and consumption of the islands. A commercial wind turbine

was selected and its power curve was observed in order to make estimates. The model Enercon E-126 7,5 MW, 127m rotor diameter and 135 m high tower was chosen.

Wind characteristics at the site are determined following the link online of the Instituto Tecnológico de Canarias (ITC) [6]. There you can access to wind data at different heights by selecting Weibull parameters. Although data at 135m above the sea surface is offered, we considered data at 100m for production estimates. By placing the turbines in rows perpendicular to the prevailing wind direction and separating the turbines of a row in 4 times the rotor diameter and 12 times the diameter in the wind direction, the distribution shown in Fig. 9 was obtained.

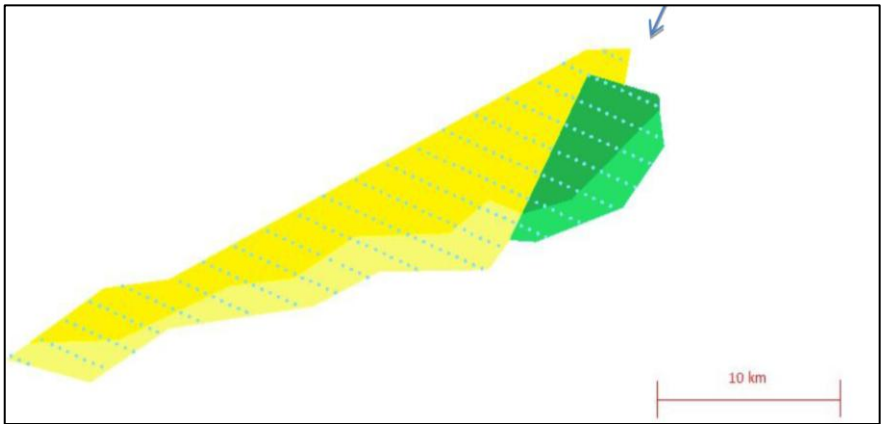

Figure 9. Turbines in the area of study

To determine the production potential of a possible wind farm, it was calculated the production of one machine in the four corners of the area, the result was multiplied by the number of turbines, and it was considered a wind farm coefficient of 80%.

Fig. 9 shows four zones: a green zone without constraints where to locate the offshore wind, a yellow zone with possible environmental constraints, and zones with depths lower than 50m, and greater than 50m but lower than 200m. The number of turbines and estimated production in each area are shown in Table IV.

TABLE IV. TURBINES AND POWER GENERATION

nº of wind turbines	P< 50 m	50m <P< 200 m
Suitable area	36	23
Conditional area	153	62
Energy GWh/year	P < 50m	50 m <P< 200m
Suitable area	1,221	782
Conditional area	5,184	2,106

The equivalent number of hours per year of the selected area is 4,520 hours/year. A little more than what you get today in some of the existing wind farms in Gran Canaria (4,400 hours/year). We are in the windiest zone of the island and in the sea, so it is no wonder the result.

CONCLUSIONS

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We have a production of 9,230 GWh if we use all the obtained area. That is equivalent to 127% of the total planned demand for 2020 and for the whole three islands. In the beginning it could be constructing a litter offshore wind farm and go increasing over the time.

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