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WIND ENERGY IN CATALONIA: AN ASSESSMENT OF THE WIND ENERGY POTENTIAL AND THE DEVELOPMENT OF A 15 kW WECS

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The paper is a contribution to the quantification of the wind potential in Catalonia, quantified on a municipal basis. Calculations have not been based on the data of meteorological stations but rather on questionnaires handed out to all 935 catalonian municipalities. The results of the assessment were: 5300 GWh /year, using 12 m. diameter WECs, and 7700 GWh/year, using 24 m. diameter WECs.

The paper also explains some developments on wind technology in Catalonia. Starting with a quantification of small wind machines, most of them erected between 1890 and 1940 and mainly for pumping water, the authors present the first modern medium size wind machine designed and erected in Catalonia on March 1984: 12 m. diameter, three blades, fixed pitch.

1. INTRODUCTION.

It has not been until summer 1981 that the Spanish Government decided to restart the necessary work to know the Spanish Wind Energy Potential. Also during 1981 the Autonomous Government of Catalonia - the Nordeast corner of the Iberian Peninsula - decided to begin the Catalonian Wind Atlas (1).

2. PRELIMINARY WIND STUDIES IN SPAIN.

Those decisions were taken many years after the first world modern studies on wind energy assessments were made (2, 3, 4, 5, 6) and after twenty one (1) years since the former Director of the "Comisión Nacional de Energias Especiales" wrotte:

> "if present problems, that actually poses the wind energy, were solved they could speed up the introduction of wind machines. This subject has a great interest because our energy resources are scarce. This reason makes me to suggest the specialists that they don't refuse theis responsabilities to find adequate solutions to those problems, and thus they will contribute in the use of this natural wealth: the wind" (7).

Few years before, E. W. Golding tought a short wind energy course in Madrid (8), and spanish scientists begun the task to make the first Spanish Wind Energy Map (9). The results of this work were reported at the U. N. Conference on New Sources of Energy (10).

3. THE WIND POWER POTENTIAL OF CATALONIA.

The first and the most important problem encountered during the preliminary work to make the Wind Atlas of Catalonia (1) was the lack of reliability, in the view of wind power, from the data of the meteorological network.

To avoid this problem and to make possible to assess the Wind Energy Potential of Catalonia it was decided to use the results of a questionnaire handed out to all catalonian municipalities.

There are many reasons that suggested not to use the meteorological data. These are:

a) Catalonia is a very mountainous country. The catalonian lands go from 0 to 3400 m. of height,
b) the existent meteorological network don't cover all catalonian territory, but only the coastal part,
c) the present meteorological stations are situated in populated areas, not suitable to erect wind machines.

But one reason had a lot of influence to take this decision:

d) the wind data from the questionnaires was a compilation of people's knowledge, because it came from people who lives and works in rural communities. Moreover the methodology developed to make the wind assessment could be useful to many countries that don't have sufficient and reliable meteorological data to make "scientific" assessments of wind energy potential.

During the preliminary work to make the Wind Atlas of Catalonia all 935 catalonian municipalities were questionned (11). Of these, 511 municipalities answered the questionnaires - 54.65 % -. These responses and the analysis/selection of meteorological data made possible the "provisional" Wind Atlas of Catalonia (12) shown in Figure 1.

The questionnaires submited to the municipalities also allowed the identification of a first series of sites where WECs could be erected: 153 place-names related with the word " "wind" were identified and 716 places considered more windy than the rest of the municipality were located. Also 658 local names - 228 different names - of the "wind" were encountered.

One of the questions posed to the municipalities was:

"Do you find that your municipality
is very windy ?
has a lot of wind ?
has small winds ?
has very slight winds ?
has no wind ?

From a single statistic (from "very windy - 5" to "no wind - 1" in five categories) later equated to average wind speed (because in the comparison of these codes - in m/s - with the existent meteorological data we encountered a good similarity), and assuming that the best places where the wind blows had higher average wind speed, it has been possible to calculate the density probability function of wind speed for the best assumed places of each municipality (13).

With this information a municipal data base has been constructed. The information that it contents is:

- the municipal code, that identifies each municipality,
- the municipal surface in km^2 (from 0.5 to 424 km^2),
- the municipal wind code from the questionnaires answered by 511 catalonian municipalities The wind code for the municipalities that didn't answer the questionnaire always has been selected lower than the average wind code of all the municipalities of each "comarca" (14),
- the wind lulls of each municipality.

To assess the catalonian wind energy potential a mathematical model has been implemented. It is based on:

- the estimation of the density probability function (Weibull distribution) of the wind speed for the best places of each municipality,
- the power function (power versus wind speed) of a predetermined WEC (15). Two WECs - one 12 m. diameter, and other 24 m. - were selected, and they were adapted at the wind regime of each municipality,
- the placement of the WECs into the limits of each municipality with a fixed spatial occupation. The assessment was made with a 10 % of the area of each municipality dedicated to capture of wind power,
- the determination of the spatial distribution of the WECs into the municipal area. A triangular distribution (ten diameter spacing) was selected,
- the assumption taht each municipality had a 40 % of lulls. This value introduces into the mathematical model a conservative element. The existent meteorological data in Catalonia presents from 1 % to 44 % of lulls (12),
- the density probability function has been corrected with lulls (16).

The implementation of the mathematical model has been made with a DEC/VAX 11-780 computer system of the Autonomous University of Barcelona.

With the basic information from each municipality and with the WEC selected, the model determines:

- the density probability function: the Weibull parameters at the heigh of the hub of the used WEC and the more significant wind speeds,
- the power function of the WEC: cut-in, rated and cut-out wind speeds; rated power; operating time at each specific regime; energy that can be produced at each regime; annual energy taht can be produced; hours of annual operation; hours with no production,
- the municipal-"comarcal"-national wind energy potential: number of WECs, total annual energy that can be produced, total power that can be installed.

Results of the model: the Wind Energy Potential of Catalonia would be 5300 GWh/year using 12 m. diameter WECs (rated power from 10 to 70 kW.) and 7700GWh/year using 24 m. diameter WECs (rated power from 40 to 400 kW.). See Figure 2.

4. A QUANTIFICATION OF OLD WIND MACHINES IN CATALONIA.

Another question that was posed to the municipalities was about the number of existing "windmills" (for water pumping or electrical generation) and whether they were in operation or not (in this case if they would be recoverable or not). The responses to this question together with another historical study (17) made possible to determine the number of ancient and recent small wind machines in Catalonia. The Table I shows the results. The answers to that question also permited to know what areas of Catalonia had a reasonable good wind regime. See Figure 3.

5. THE FIRST MODERN WEC IN CATALONIA.

On the late forties an artisan near Barcelona begun to manufacture small DC wind generators. This courageous man makes himself the special DC generator, the variable pitch wood blades, the reticular tower and the rest of the machine. The rotor is downwind, four blades. Since the begining he has been constantly improving his machine, but he has not been able to make machines larger than 4 m. diameter.

On 1981 a group of catalonian engineers created a cooperative (organised in a non-hierarchical form) to develop alternative technology, starting with wind energy projects mostly. Those engineers contacted the artisan proposing him to improve his machine and to jointly develop a larger one. The differences in background, methodology, age and probably others were too large, and because of that, the proposals could not be carried out. Today we remain friends but we work separately.

The cooperative choose to develop a 12 m. diameter, 15 kW. WEC. Following our initial contacts with the Spanish Administration trying to get financed this project, the CDTI - the Agency of Technological Innovation of the Ministery of Industry of the Spanish Government - had stablished a grant for three 7 to 10 kW. WECs and one 25 kW. Our cooperative was one of the four winners of the official resolution. After a few months, some problems - apparently administrative - prevented all the winners to receive the promised grant. Finally, instead of a grant we got a finance on the project.

Our WEC has been entirely designed and developed by our cooperative, using some times the suppliers and university facilities such as computers and laboratories. Construction of the parts has been done on local shops mostly around Barcelona.

Our WEC had to be able to operate at low winds, say 4 m/s. average, typical of our region, as well as to resist gusty winds up to 40 m/s. and quite variable on speed and direction. This type of wind, called "tramuntana", is typical of the Empordà, the North East county of Catalonia. The results of those specifications have been a quite sophisticated fixed pitch blade, a strong tower and a difficult to choose yaw system. Some people have told us our machine seems too strong, but up to now, some trees have been pulled out by the "tramuntana" and our WEC is still up and running. The prototype has been erected at Vilopriu (Empordà) and inaugurated on March 10th. 1984. Local newspapers and TV have covered the event. The prototype has been very well accepted by the local community.

The Generalitat - the Autonomous Government of Catalonia - has given us a grant to test the blades and the machine. One blade was tested and broken after a life cycle test. The results were better than calculated, and the blade broke exactly as and where we expected.

The relevant minor problems we have had with our WEC are the change of the gearbox oil to improve the rotational resistive torque, the change of the speed of the mechanical yaw system, and the change of the control to switch the small and large generators.

See in Figure 4 the 12/15 WEC and in Table II the 12/15 Wind Turbine specifications.

6. REFERENCES.

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PRESENT CONDITION		Not Recoverable	Recoverable	In Operation		TOTAL
PRESENT UTILISATION		No Operating		Water Pumping	Electrical Generation	
PAST UTILISATION	Water Pumping	295	216	65	-	576
	Electrical Generation	53	15	-	43	111
	Milling	1	-	-	-	1
	WP + EG	1	-	1	-	1
TOTAL	PRESENT CONDITION	350	231	109		690
	PRESENT UTILISATION	381		66	43	690

TABLE I: Number of old Wind Machines in Catalonia.

TABLE II. ECOTECNIA 12/15 WIND TURBINE SPECIFICATIONS

GENERAL DESCRIPTION: Horizontal axis, fixed pitch, propeller type, up-wind.

Rotor.	
number of blades	3
diameter, m.	12
speed, rpm.	65 - 42
rotation direction	clockwise
location	upwind
type of hub	rigid
conning angle	0
tilt angle	10
Transmission.	
type	two stages
ratio	1:23.6
input speed, rpm.	65
output speed, rpm.	1534
Main generator.	
type	induction
rating, kW.	20
power factor	0.85
voltage, V.	220/380
speed, rpm.	1500
frequency, Hz.	50
Secodary generator.	
type	induction
rating, kW.	3.5
power factor	0.83
voltage, V.	220/380
speed, rpm.	1000
frequency, Hz.	50
Tower.	
type	tubular steel tripod
tower size	
at the base, m,	2.60
at the hub, m.	0.50
tower material	steel
height, m.	14
weight, kg.	800

Blade.	
total length, m.	5.75
root, m.	0.25
blade, m.	5.50
material	fiberglass reinforced polyester
weight, kg.	70
airfoil section	NACA 44 series
twist	30
tip chord, m.	0.35
root chord, m.	0.85
tip speed, m/s.	41
solidity	0.086
swept area, m^2.	113
Orientation Drive.	
type	passive yaw
yaw rate, °/sec.	3
yaw drive	auxiliary propeler and mechanical transmission
Control system.	
rotor speed control	stall-regulated
overspeed control	fail safe hydraulic disc brake on main shaft
overspeed control	spoilers with manual reset
Performance.	
rated power, kW.	15
maximum power, kW.	20
wind speed at centerline of hub:	
start-up, m/s.	4
cut-in, m/s.	3.5
rated, m/s.	9.5
max.prod.,m/s.	14
cut-out, m/s.	30
max. design, m/s.	60
Annual power output	
5.7 m/s. at 18 m.:	48000 kWh.
6.7 m/s. at 18 m.:	67000 kWh.
7.8 m/s. at 18 m.:	86000 kWh.

TABLE II: Ecotècnia 12/15 Wind Turbine Specifications.

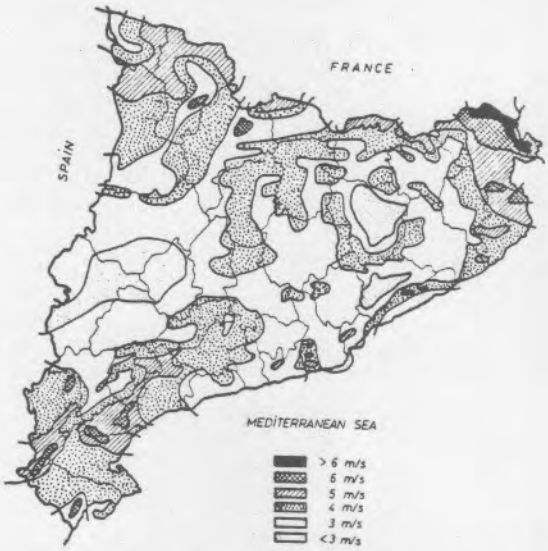

FIGURE 1: Provisional Wind Map of Catalonia.

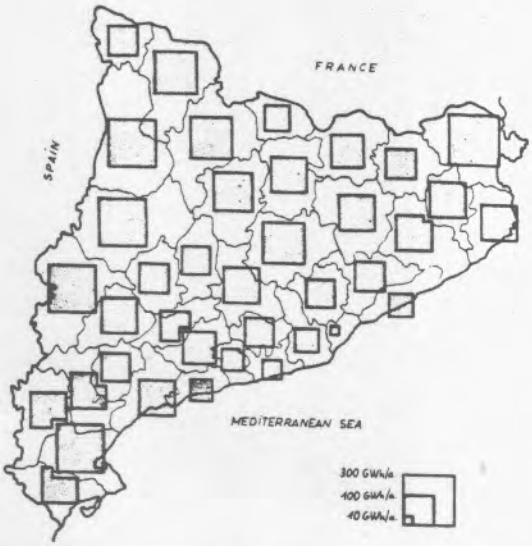

FIGURE 2: Wind Energy Potential of Catalonia.

FIGURE 3: Distribution of old Wind Machines in Catalonia.

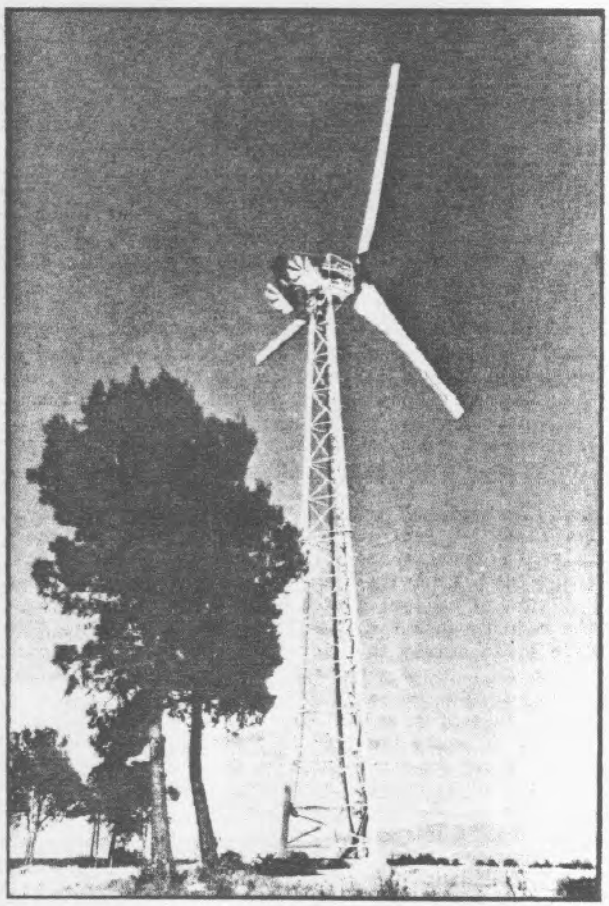

FIGURE 4: Ecotècnia 12/15 WEC.