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PRELIMINARY WIND RESOURCE ASSESSMENT

San Cosmo

August 2023

Details

A.1.1 Prepared for:

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Contents

1. FOREWORD

Kosmo Wind S.r.l., a company of Vestas Wind System A/S, (the "**Client**") engaged Vector Renewables Italia S.r.l. as "**Technical Advisor**" (or "**TA**") to perform a preliminary analysis for the definition of the wind resource and energy assessment of the San Cosmo wind farm (the "**Project**") in development in Italy.

The **Project** includes n. 8 turbines with the following configuration:

Turbine model	Rotor Diameter [m]	Hub height [m]	Tip height [m]	Number of turbines	Wind farm capacity [MW]
Vestas V162-6.2 MW	162.0	125.0	206.0	8	49.6

Tab. 1 - Configuration of San Cosmo wind farm

The activity consisted in the preliminary estimation of the expected annual energy production of the wind farm, according to the **Technical Advisor**'s analysis on the long-term wind regime representative of the area at the desired hub height.

Being the assessment based on re-analysis data characterized by a higher level of uncertainty compared to a measurement on site, the presented energy figures shall be considered as preliminary, and they should be updated when a full year measurement campaign onsite is available.

2. LAYOUT AND TURBINE MODEL

The supplied material useful for this preliminary assessment of the wind resource includes:

1. Coordinates of the wind farm layout
2. Wind turbine model for the proposed wind farm.

As requested by the Client, the energy assessment has been performed by adopting the WAsP 12 model propagation as embedded in WindPRO 3.6. The height contours and roughness maps to be included in the wind flow model were not provided and therefore they were downloaded from online sources covering an area of about 30 km x 30 km. In particular, the elevation map was retrieved from the TINITALY 1.1 Model with a 10 m vertical spacing for the wind farm area while the roughness map was downloaded from the Corine Land Cover 2018 database.

The proposed area extends approximately 3.5 km by 3.0 km. The terrain at site is hilly, with turbine elevation ranging from 130 m to 230 m. The orography of the site can be classified as medium complex with medium terrain roughness. On the basis of the information available at this stage, the height of trees was assumed to be less than 10 m and no "displacement height" corrective was applied.

In the figures below, the roughness and the elevation maps imported into the calculation model can be seen; in more detail, for what concerns the roughness map, the white areas represent roughness length equal to 0.056 m, yellow areas roughness length equal to 0.200 m and the orange areas to 0.300 m.

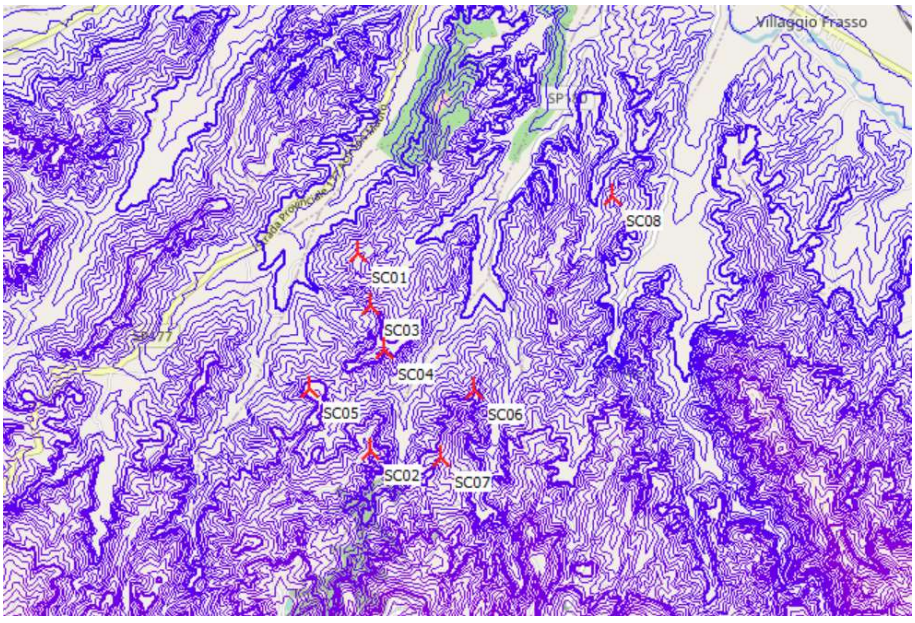


Fig. 1 – Elevation map

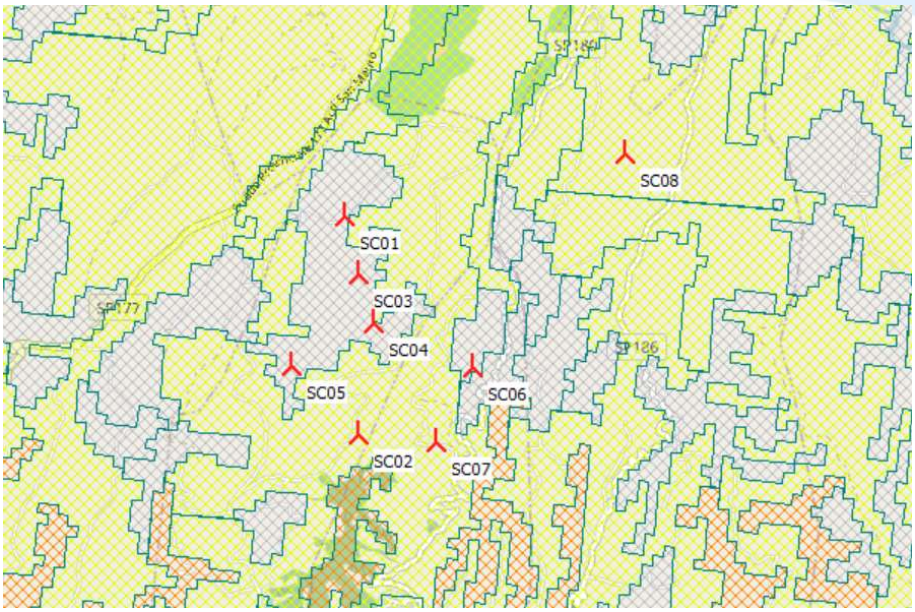


Fig. 2 – Roughness map

No information has been provided regarding other neighbouring turbines in operation or even in development phase and no site inspection has been carried out at this stage in order to verify this or the presence of any other obstacle that might affect the **Project**.

To be noted that from public database and aerial pictures publicly available online no operating turbines in the area within a radius of approximately 20 times the proposed rotor diameter are identified.

2.1. Wind farm layout

The coordinates of the proposed layout are reported in the table below:

UTM WGS84 ZONE 32		
Turbine ID	Longitude [m]	Latitude [m]
SC01	622531	4386715
SC02	622696	4384618
SC03	622679	4386161
SC04	622833	4385691
SC05	622050	4385263
SC06	623798	4385282
SC07	623455	4384550
SC08	625232	4387366

Tab. 2 – San Cosmo wind farm coordinates

The location of the proposed turbines in red is shown in Fig. 3.

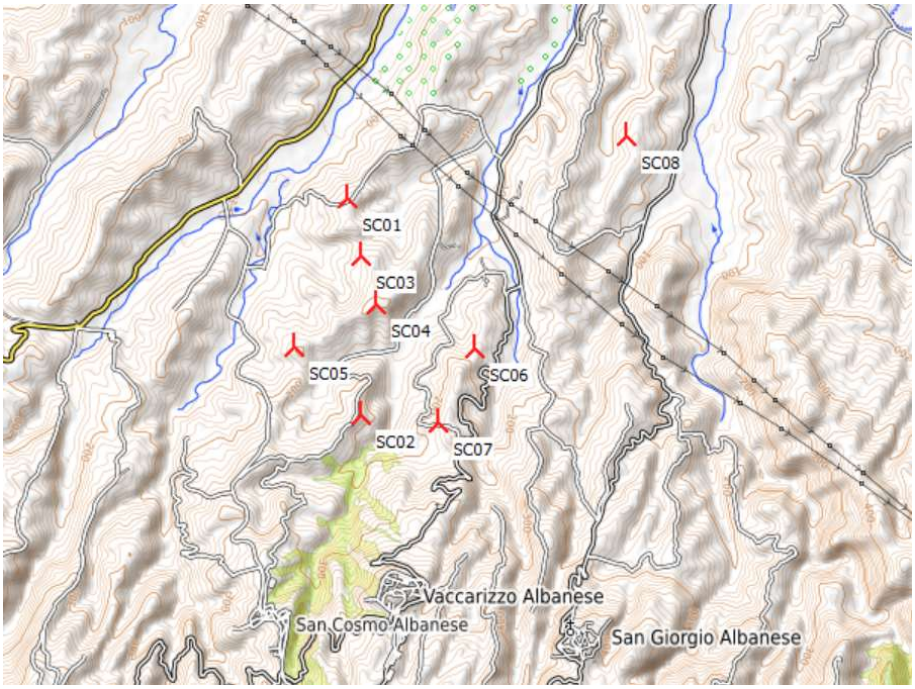


Fig. 3 - Proposed wind turbines

Some buildings are observed at the site, and therefore attention should be taken in assessing their cadastral state and destination use, and in managing any impact assessment in terms of noise and shadow flicker limitations, if any.

Technical Advisor's standard requirements for distances between turbines are five rotor diameters in the prevailing wind direction, and three rotor diameters in

directions perpendicular to the prevailing. The next table shows the distances separating the wind turbines in diameters of 162 m rotor.

RD=162m\Meter	SC01	SC02	SC03	SC04	SC05	SC06	SC07	SC08
SC01	-	2103	573	1068	1530	1913	2354	2778
SC02	12.9	-	1543	1082	913	1287	762	3739
SC03	3.5	9.5	-	495	1096	1423	1788	2823
SC04	6.5	6.6	3.1	-	892	1048	1300	2926
SC05	9.4	5.6	6.7	5.5	-	1748	1576	3814
SC06	11.7	7.9	8.7	6.4	10.7	-	808	2530
SC07	14.4	4.7	11.0	8.0	9.7	5.0	-	3330
SC08	17.0	22.9	17.3	18.0	23.4	15.5	20.4	-

Tab. 3 - Spacings in rotor diameter and meters of San Cosmo wind farm

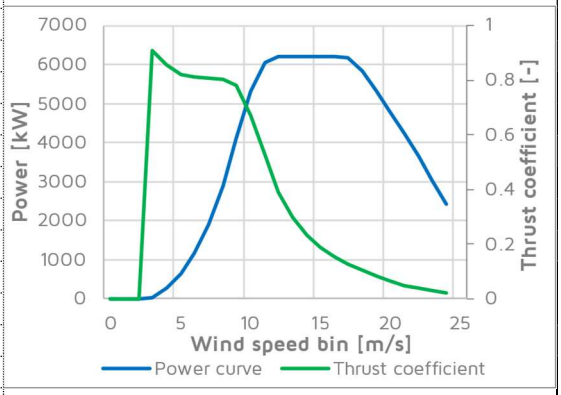
The above requirements are broadly met being the minimum distance of 3.0 rotor diameters between the turbines. In addition, according to the prevailing energy sectors (WSW or 240°), the spacing within turbines is higher than the recommended 5 rotor diameters between turbines.

To be noted that the site suitability analysis is outside of the current scope of work. In spite of the minimum distances between turbines are met, it is recommended to obtain the turbine manufacturer's Mechanical Load assessment and site suitability Analysis (MLA), in order to ensure that the desired wind turbine model and the proposed layout will be suitable for the site according to IEC 61400-1 Standard Ed.3 and that the fatigue loads, resulting from the wind conditions onsite and acting on the turbine main components, are within the design load envelope.

2.2. Wind turbine models

The expected energy production of the wind farm is estimated considering the following turbine model requested by the Client, whose power curve has been adjusted at the site air density of 1.17 kg/m^3 according to the IEC 61400-12 method correction. The temperature recorded by the nearest climate station available in the WindPro database has been considered in order to evaluate site proper air density; the average temperature recorded by the station Calopezzati V3 (1952-2078) at 215 m. a.s.l. is 17.1 °C and the respective one on the VMM position at the hub height (113 m) is 16.4°C.

Turbine type		V162-6.2 MW	Diameter [m]	162.0
Rated power [MW]		6.2	Hub height [m]	125.0
Rated wind speed [m/s]		13.0	IEC class	S
Cut-in/Cut-out wind speed [m/s]		3.0/24.0	Air density [kg/m^3]	1.175
Bin wind speed [m/s]	Power [kW]	Thrust coefficient [-]		
0	0	0		
1	0	0		
2	0	0		
3	29	0.909		
4	277	0.854		
5	645	0.819		
6	1176	0.812		
7	1916	0.808		
8	2893	0.801		
9	4117	0.781		
10	5325	0.672		
11	6062	0.527		
12	6191	0.389		
13	6200	0.296		
14	6200	0.233		
15	6200	0.188		
16	6200	0.154		
17	6180	0.129		
18	5826	0.104		
19	5325	0.081		
20	4802	0.064		
21	4231	0.050		
22	3649	0.038		
23	3049	0.029		
24	2437	0.022		
25	0	0		



Tab. 4 – Vestas V162-6.2 MW, power and C_t curves

3. WIND RESOURCE ASSESSMENT

Considering that a measurement campaign recorded onsite is not yet available, the preliminary estimation of the expected annual energy production of the Project is extrapolated from a Virtual Met Mast downscaled to a representative location of the San Cosmo wind farm at a height representative of the desired hub heights. The Virtual Met Mast statistics are usually obtained by using the sources available in the area deemed as representative, such as land-based wind data and mesoscale data. For the Project, 10-year hourly Vortex Series ERA-5 time series has been acquired and a pragmatical adjustment was applied to the wind data on the basis of the TA analysis of the wind regime of the area.

It is necessary to emphasize that the Virtual Met Mast does not replace a traditional on-site measurement mast and therefore any assessment of the energy production will have a high uncertainty**. The results shall be intended as a preliminary estimation only.** It is recommended to install at least one met mast onsite, in a position representative of the wind farm and characterized by a good exposure, whose structure should be high at least 2/3 of the proposed hub height, in order to reduce the vertical extrapolation uncertainties, and to update the analysis accordingly. Considering the proposed hub heights, a Lidar measurement should also be taken into account.

The long-term wind regime expected onsite has been assessed using the Virtual Met Mast characterized by a long-term wind speed at 125 m of 6.26 m/s, whose Weibull distribution, energy and wind roses split into five wind speed classes and 12 sectors are reported below.

It is observed that the prevailing winds, for both frequency and energy point of views, are from the west-southwestern sector – 240°.

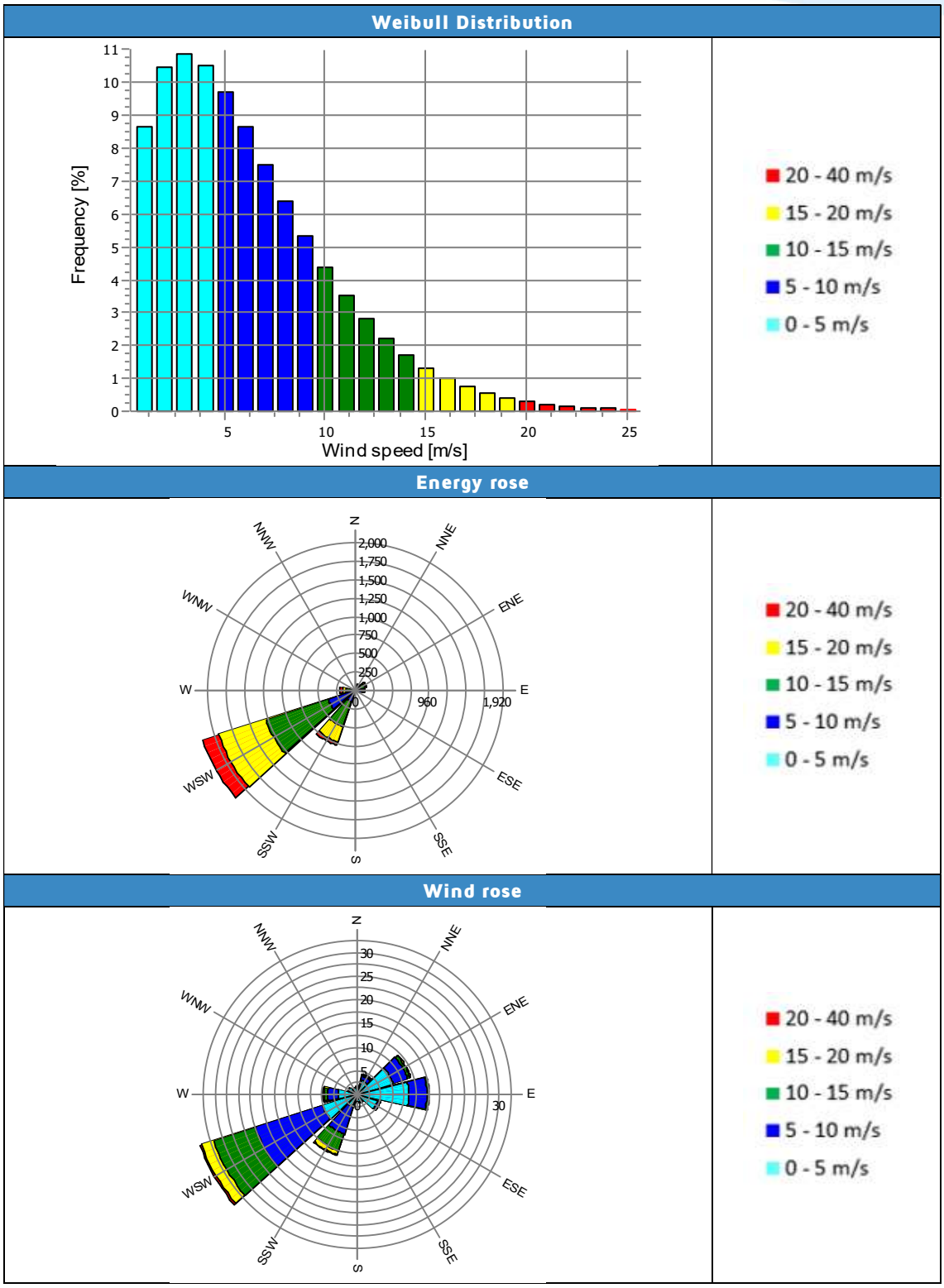


Fig. 4 - Wind conditions at the Virtual Met Mast at 125 m

4. PRELIMINARY EXPECTED ENERGY YIELD ASSESSMENT

The expected energy production of the San Cosmo wind farm has been estimated with the wind turbine configuration requested, using the long-term wind statistics of the Virtual Met Mast and adopting the WAsP 12 model propagation as embedded in WindPRO 3.6. The wake model implemented in the analysis is the N.O. Jensen (RISO/EMD) Park2 2018 wake model with DTU default onshore wake decay constant of 0.090.

The energy production accounts for the losses due to wake effects and to the site air density.

The tables hereunder contain the following information for each wind turbine:

Site ID: ID number of the wind turbine in the table

X [m]: longitude in **UTM WGS84 ZONE 33** coordinates

Y [m]: latitude in **UTM WGS84 ZONE 33** coordinates

Elev. [m]: elevation above sea level (ASL)

HH [m]: hub height

V [m/s]: average wind speed estimated by the model at hub height

Gross Production [GWh]: expected gross output, gross and net of wake losses

Loss [%]: percent of production lost due to wake losses

Equivalent Hours [h]: equivalent annual hours of gross production, net of wake losses

ID	X [m]	Y [m]	Elev. [m]	HH [m]	V [m/s]	Gross Production [GWh]		Loss [%]	Net Hours [h]
						Gross of wakes	Net of wakes		
SC01	622531	4386715	177	125.0	6.39	18.43	18.37	0.29	2963
SC02	622696	4384618	230	125.0	6.10	17.26	16.94	1.88	2732
SC03	622679	4386161	177	125.0	6.38	18.41	17.90	2.80	2887
SC04	622833	4385691	215	125.0	6.26	17.86	16.94	5.12	2732
SC05	622050	4385263	204	125.0	6.23	17.81	17.38	2.41	2803
SC06	623798	4385282	192	125.0	5.90	16.38	15.69	4.21	2530
SC07	623455	4384550	226	125.0	5.96	16.68	16.61	0.42	2679
SC08	625232	4387366	130	125.0	6.10	17.36	16.66	4.07	2687
				Average	**6.17**	**17.52**	**17.06**	**2.65**	**2752**
					Total	**140.18**	**136.48**		

Tab. 5 – San Cosmo energy production – Vestas V162-6.2 MW

It should be noted that the energy production presented above accounts only for the losses due to wake effects and air density and no other losses are included.

Overall, the wake losses are quite low (less than 3.0%), due to the good exposition to the prevalent wind directions for all turbines that are not affected by the mutual wake effects, except for turbines SC04, SC06 and SC08, which show wake losses greater than 4%.

The next step in the analysis is to assess the energy losses (electrical, production and power losses) to determine the energy that will be available for input into the power grid. The following is a list of the loss factors considered for a **10-year period**: at this stage no supply or O&M agreement are in place or even at a discussion phase, hence standard assumptions have been taken into account.

Each loss factor shall be reviewed as soon as the corresponding calculated or contractually agreed values are available.

Loss Factor	Losses [%]
Turbine Availability	-3.0%
Non-contractual turbine availability	-0.5%
B.O.P. availability	-1.0%
Electrical grid availability	-0.3%
Electrical losses	-3.0%
Environment	-0.4%
Turbine Performance	-2.3%
Curtailment	-
Total losses	**-10.1**

Tab. 6 – Wind farm energy losses

The following table summarizes the results obtained for the Project:

Configuration	Wind farm capacity [MW]	Gross production (net of wakes)		Net production (deliverable to grid)	
		[GWh/year]	[h/year]	[GWh/year]	[h/year]
Vestas V162-6.2 MW	49.6	136.48	2752	122.72	2474

Tab. 7 – Gross and Net energy production

The expected net production estimates (deliverable to grid) shown in the table above, represent the so-called $P_{50\%}$, i.e. the production calculated with the average wind conditions, also called central estimate.

Without measurements on site, it is not possible to provide an accurate evaluation of the uncertainty of the wind and energy assessment.

In any case, following the Client request, an exercise has been undertaken evaluating the main uncertainty sources according as far as possible to IEC WG15 outcoming standards in order to provide an indicative average uncertainty value was carried out. In this context, the uncertainty of a parameter is defined as the estimate of the standard deviation of the corresponding statistical distribution.

A sensitivity factor of 1.30 has been estimated to convert the uncertainty related to the wind speed into energy uncertainty. Based on the uncertainty estimation, it is possible to compute the values of $P_{75\%}(1)$, $P_{90\%}(1)$ and $P_{75\%}(10)$, $P_{90\%}(10)$. Specifically, the $P_{75\%}$ and $P_{90\%}$ values represent, respectively, the average energy production that has a 75% and 90% probability of being exceeded in a given period. In this case, the average value of a 10-year period or of 1 year within 10 years.

Under these assumptions, considering such sensitivity factor, the assessment of an indicative uncertainty for the 1-year and 10-year period provides values of about

20.6% and **20.0%** respectively. The results of the sensitivity analysis are shown in the table below.

Configuration	Expected annual production in any period of 1 year (GWh/year)			Expected annual production in any period of 10 year (GWh/year)		
	P50%	P75%	P90%	P50%	P75%	P90%
Vestas V162-6.2 MW	122.72	105.70	90.38	122.72	106.19	91.32

Tab. 8 - Confidence interval for net energy production

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