PROPONENTE: **AME ENERGY S.r.l.**

Via Pietro Cossa, 5 20122 Milano (MI) - ameenergysrl@legalmail.it - PIVA 12779110969

REGIONE CAMPANIA

PROVINCIA DI SALERNO

COMUNI DI BUCCINO E SAN GREGORIO MAGNO

Titolo del Progetto:

REALIZZAZIONE DI UN IMPIANTO EOLICO UBICATO NEI COMUNI DI BUCCINO (SA) E SAN GREGORIO MAGNO (SA) IN LOCALITA' "SERRONE", CON POTENZA NOMINALE PARI A 36 MW

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Consulenza, Progettazione e Sviluppo Impianti ad Energia Rinnovabile

Sede Legale: Via Del Vecchio Politecnico, 9 - 20121 Milano (MI)

P.IVA 11092870960-PEC: I-project@legalmail.it

Sede Opertiva:Via Bisceglie n° 17 - 84044 Albanella (SA)

-mail:a.manco@iprojectsrl.com

Cell: 3384117245

Progettista: Arch. Antonio Manco

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PRELIMINARY WIND RESOURCE ASSESSMENT

Buccino

October 2023

Details

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Client: i-Project S.r.l.
Contact: Antonio Manco
Reference: VRIT230241

A.1.2 Prepared by:

Vector Renewables Italia S.r.l.
Viale Monza, 259, 20126, Milano

Contact details

Contact Name	Position	Email
Marco Guarneroli	Country Manager - Italy	mguarneroli@vectorenewables.com
Chiara Pavani	Head of Technical Advisory – Italy	cpavani@vectorenewables.com
Nell Franchi	Technical Advisory – Italy	nfranchi@vectorenewables.com
Gianmarco Palma	Technical Advisory – Italy	gpalma@vectorenewables.com

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Contents

1. FOREWORD

I-Project S.r.l. (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 of the Buccino wind site (the "**Project**") in development in Italy. In particular, the Project area lies within the administrative boundaries of three town: Buccino, San Gregorio Magno and Romagnano al Monte.

The activity consisted in the preliminary estimation of the expected wind statistics at the site extrapolated from a Virtual Met Mast downscaled to a location deemed as representative of the wind farm, according to the **Technical Advisor**'s analysis on the long-term wind regime representative of the area.

The whole study was carried out with professional approach and instruments, as prescribed by the international methodologies for a trustworthy assessment of expected wind farm production.

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

2. WIND RESOURCE ASSESSMENT

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

1. Area of the wind site
2. Layout of the wind farm and wind turbine model (provided by the client following the release of version V00 of this Report)

As requested by the Client, the wind 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 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 and its values adjusted to the site based on satellite images.

The proposed area extends on a mountain, with an average elevation around 750-850 m. The orography of the site can be classified as complex with medium to low terrain roughness on the top of the ridges.

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 presence of any other obstacle that might affect the **Project**. From public database and aerial pictures publicly available online, it is observed that there are nearby operating turbines at a distance of more than 3.5 km and therefore the interference with the Project is deemed negligible.

The location of the proposed site area is shown in Figure 1.

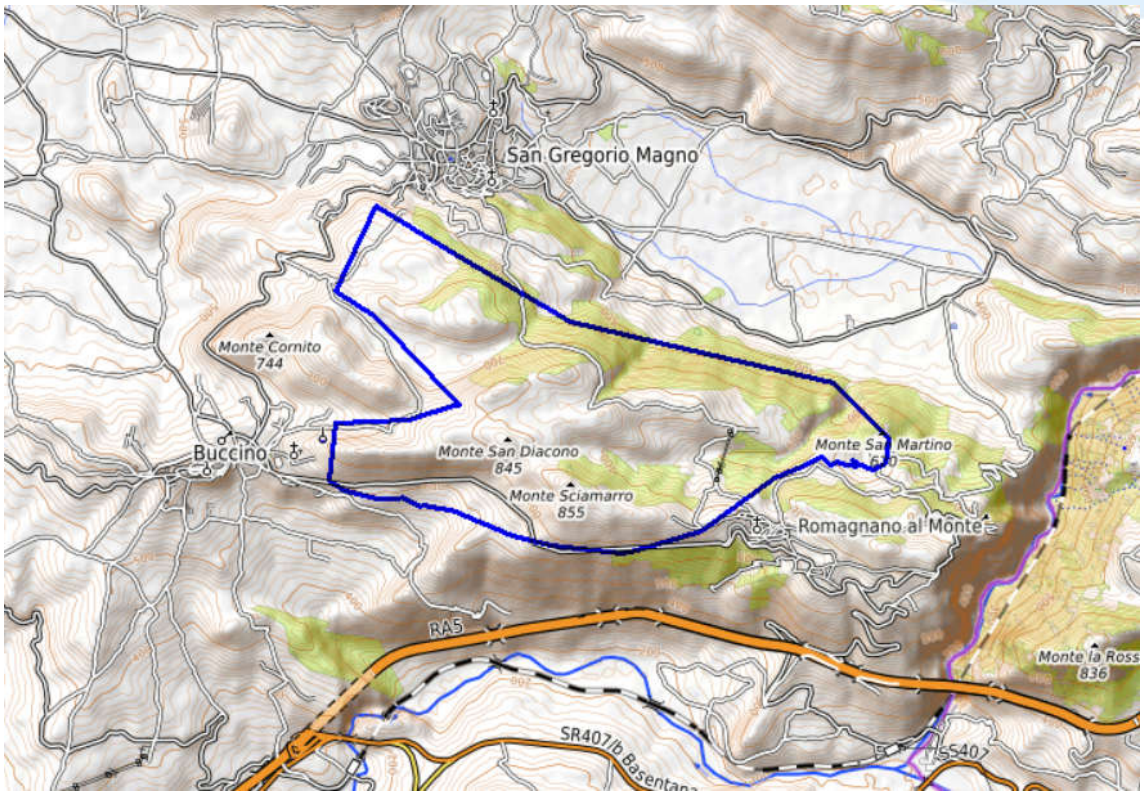


Fig. 1 - Proposed wind site

Considering that a measurement campaign recorded onsite is not yet available, the preliminary estimation of the wind resource of the Project is extrapolated from a Virtual Met Mast downscaled to a representative location of the Postiglione site at 100 m height. 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 Vortex Series ERA-5 hourly time series has been acquired.

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 wind resource 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 planned 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.

The long-term wind regime expected onsite has been assessed using the Virtual Met Mast characterized by a long-term wind speed at 100 m of 5.7 m/s, whose Weibull distribution, energy and wind roses split into five wind speed classes and 12 sectors are reported below. It is observed the prevailing winds are from the West and the NNE sectors.

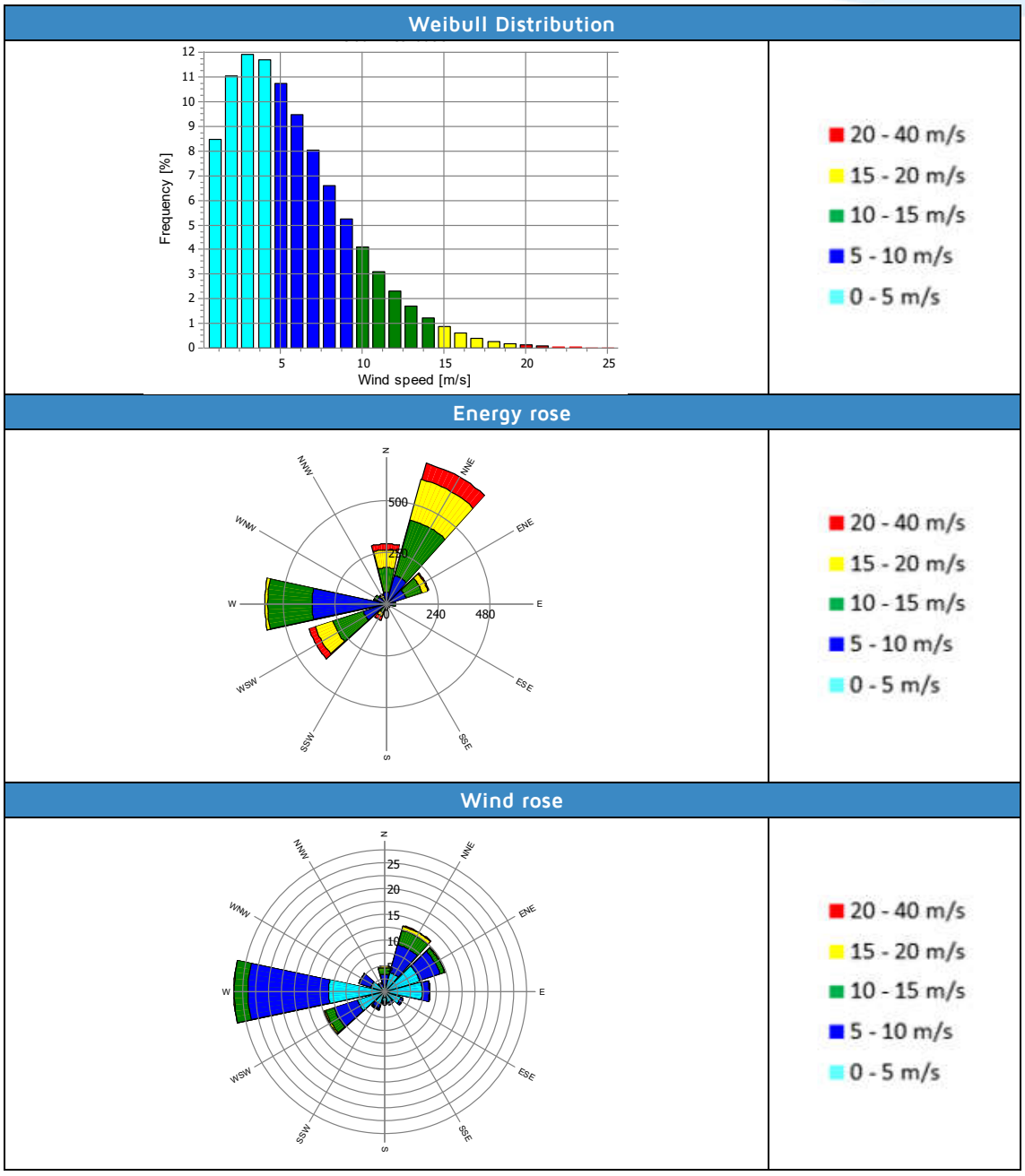


Fig. 2 - Wind conditions at the Virtual Met Mast at 100 m

The following figure shows the estimated wind resource on the site area.

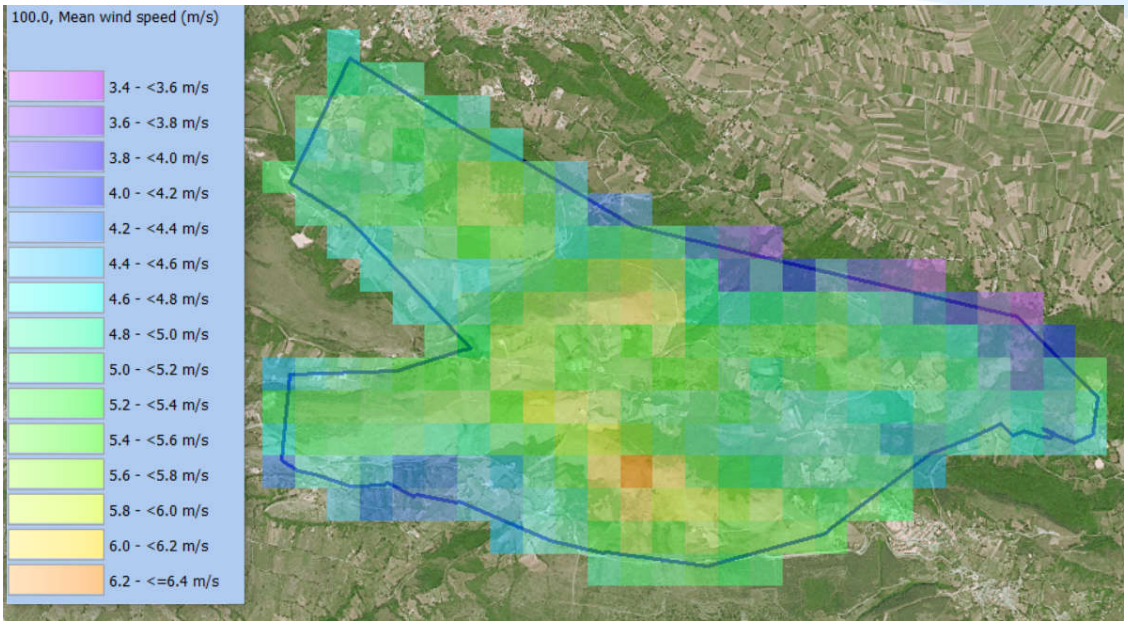


Fig. 3 - Wind resource map

3. LAYOUT

Based on the wind map provided in SECTION 2, the Client has designed and supplied a layout for the Project consisting in n. 6 wind turbines. The coordinates of the proposed layout are reported in the table below:

UTM WGS84 ZONE 33			
Turbine ID	Longitude [m]	Latitude [m]	Elevation [m a.s.l.]
1	533691	4499412	710
2	534155	4499395	750
3	534344	4498513	805
4	535111	4498750	778
5	536081	4498770	700
6	535272	4497745	802

Tab. 1 – Buccino wind farm coordinates

The location of the proposed turbines in red is shown in Fig. 4.

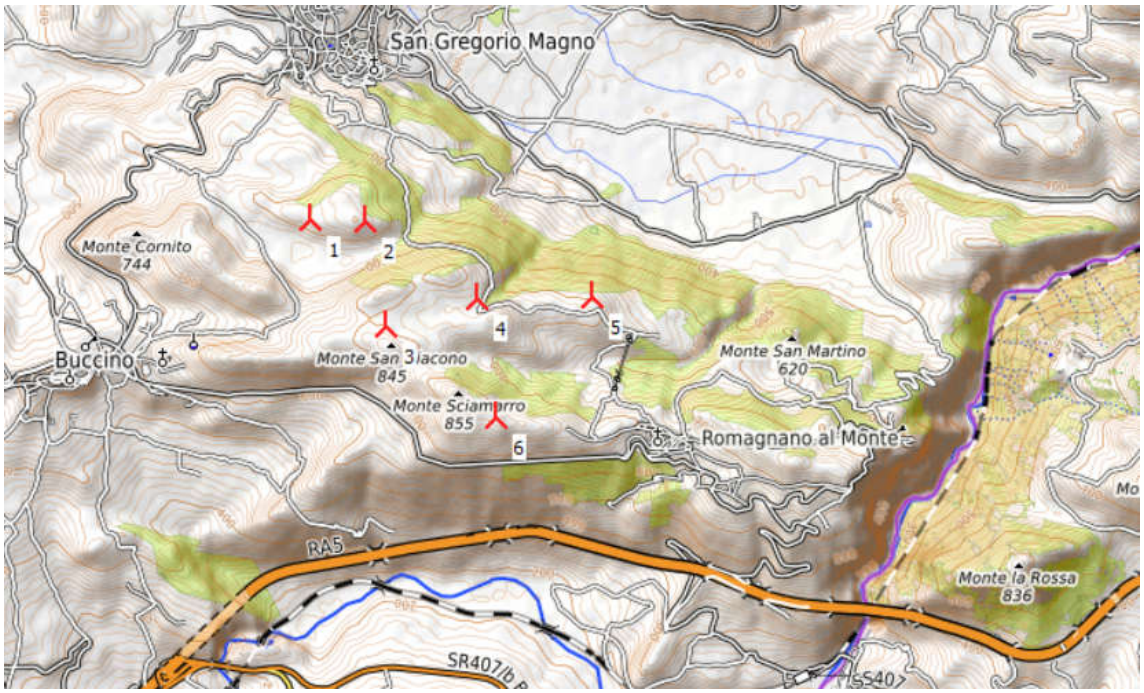


Fig. 4 - Proposed wind turbines

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 170 m rotor.

RD=170m\Meter	1	2	3	4	5	6
1	-	464	1111	1567	2475	2297
2	2.7	-	902	1153	2025	1993
3	6.5	5.3	-	803	1756	1205
4	9.2	6.8	4.7	-	970	1018
5	14.6	11.9	10.3	5.7	-	1306
6	13.5	11.7	7.1	6.0	7.7	-

Tab. 2 - Spacings in rotor diameter and meters of Buccino wind farm

Considering the most energetic sectors from West and North-North-East, all turbines fully meet the above requirements, except for turbines 1 and 2 spaced by less than 3 rotor diameters.

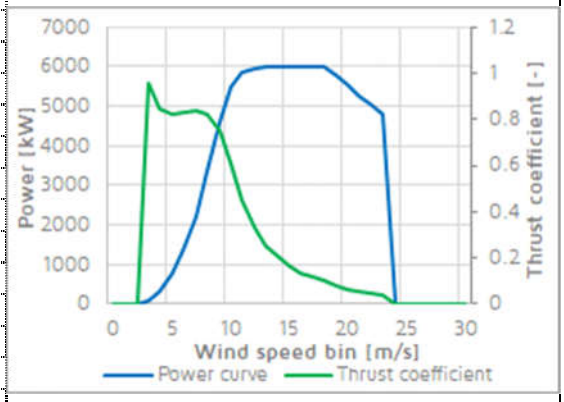
It is recommended to obtain the turbine manufacturer's Mechanical Load assessment and site suitability Analysis (MLA), in order to ensure that the desired wind turbine model and the proposed layout will be suitable for the site according to IEC 61400-1 Standard Ed.3 and that the fatigue loads, resulting from the wind conditions onsite and acting on the turbine main components, are within the design load envelope.

To be noted that no information on nearby wind farm in operation or under development has been provided. Based on the knowledge of the Technical Advisor, no other wind farms are in operation within 20 times the proposed rotor diameter and therefore no external wind farms have been included in the wind flow modelling. In case additional information is available, the assessment shall be updated accordingly.

4. WIND TURBINE MODEL

The expected energy production of the wind farm is estimated considering the following wind turbine model requested by the Client, whose power and thrust curves have been derived from the WindPRO database and adjusted at the site air density of 1.13 kg/m^3 according to the IEC 61400-12 method correction.

Turbine type		SG 6.6-170 AM-6	Diameter [m]	170.0
Rated power [MW]		6.0	Hub height [m]	115.0
Rated wind speed [m/s]		14.5	IEC class	S
Cut-in/Cut-out wind speed [m/s]		3.0/23.0	Air density [kg/m^3]	1.225
Bin wind speed [m/s]	Power [kW]	Thrust coefficient [-]		
0	0	0		
1	0	0		
2	0	0		
3	89	0.953		
4	328	0.847		
5	758	0.824		
6	1376	0.833		
7	2230	0.837		
8	3350	0.825		
9	4590	0.754		
10	5484	0.607		
11	5864	0.451		
12	5971	0.335		
13	5994	0.256		
14	5999	0.202		
15	6000	0.164		
16	6000	0.137		
17	6000	0.117		
18	6000	0.102		
19	5760	0.077		
20	5520	0.064		
21	5280	0.054		
22	5040	0.045		
23	4800	0.038		



Tab. 3 – SGRE SG 6.6-170 AM-6, power and C_t curves

5. PRELIMINARY EXPECTED ENERGY YIELD ASSESSMENT

The expected energy production of the Buccino 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		
1	533691	4499412	710	115.0	5.29	12.96	12.84	0.94	2140
2	534155	4499395	750	115.0	5.82	15.47	12.63	18.39	2104
3	534344	4498513	805	115.0	5.86	15.50	15.26	1.54	2543
4	535111	4498750	778	115.0	5.87	15.53	14.77	4.86	2462
5	536081	4498770	700	115.0	5.49	13.64	11.93	12.49	1989
6	535272	4497745	802	115.0	6.14	16.23	15.84	2.43	2640
				Average	**5.75**	**14.89**	**13.88**	**6.78**	**2313**
					Total	**89.33**	**83.27**		

Tab. 4 – Buccino energy production – SGRE SG 6.6-170 AM-6

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.

To be highlighted that the wake loss of turbine 2 is deemed as critical since above the threshold of 15%. Beyond the loss in the turbine performance, it is stressed that high wakes may lead to high turbulence level and therefore critical loads on the turbine main components. The other losses are acceptable even if a maximum wake loss of 12.5% is detected at turbine 5.

It is suggested to verify the margins of a layout optimization in order to reduce wake losses and improve the overall wind farm performance. It is again recommended to obtain the turbine manufacturer's Mechanical Load assessment and site suitability Analysis (MLA).

The next step in the analysis is to assess the energy losses to determine the energy that will be available for input into the power grid. At this preliminary phase a reasonable assumption of additional loss of the plant **for a period of 10 years is equal to 10%**, including losses relating to the availability of the plant (wind turbines, B.O.P. and grid), the performance of wind turbines, electrical and environmental losses and excluding potential limitations. A more detailed assessment can be made at a more advanced design stage and once all supply and O&M contracts for the project have been signed or under discussion.

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]
SGRE SG 6.6-170 AM-6	36.0	83.27	2313	**74.94**	**2082**

Tab. 5 – Gross and Net energy production

The expected net production estimates (deliverable to grid) shown in the table above, represent the so-called P50%, 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, 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 for a 10-year period.

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 1.7 has been estimated to convert the uncertainty related to the wind speed into energy uncertainty.

Under these assumptions, and considering such sensitivity factor, the assessment of an indicative uncertainty for the 10-year period provides a value of about 28%.

6. CONCLUSIONS

The activity of the current study consisted in the preliminary wind resource assessment of the Buccino wind site and the subsequently preliminary energy yield assessment of the layout provided by the Client. The study was based on the analysis of the long-term wind regime representative of the area at the desired hub height, according to the expected wind statistics at the site extrapolated from a Virtual Met Mast downscaled to a location deemed as representative of the wind farm. The following conclusions are made concerning the preliminary wind regime and energy production assessment:

1. 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 wind resource will have a high uncertainty. Therefore, the results shall be intended **as a preliminary estimation only.**
2. **In order to reduce the uncertainties and to achieve a bankable project, at least one met mast shall be installed onsite and update the analysis accordingly.** The location of the mast should be selected to be well exposed with respect to the prevailing wind direction and well representative of the turbine locations. The structure of such mast should be sufficiently high to reduce uncertainty related to the vertical extrapolation: a height of at least 2/3 of the proposed hub height is recommended. After the measurement period, a detailed wind and energy assessment, comprehensive of a site suitability analysis of the planned wind turbine model and layout, should be undertaken.
3. No site visit has been undertaken at this stage to verify information regarding the territory (orography, roughness, obstacles etc.) assumed in the assessment or other issues. No information on nearby wind farms in operation or under development has been provided. Based on the knowledge of the Technical Advisor, no other wind farms are in operation within 20 times the proposed rotor diameter and therefore no external wind farms have been included in the wind flow modelling. In case additional information is available, the assessment shall be updated accordingly.
4. At this preliminary stage, a reasonable assumption of the additional losses related to turbine, B.O.P. and grid availability, electrical plant, environment, turbine performance and excluding any potential curtailment consists of about **10% for a 10-year period**. A more detailed evaluation could be performed when supply or O&M agreement are in place or even at a discussion phase.
5. 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.

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