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AVAILABLE LANGUAGE: **IT**

IMPIANTO EOLICO MONTEMILONE

COMUNI DI

MONTEMILONE E VENOSA (PZ)

Relazione specialistica - Studio anemologico

File name: SCS.DES.R.CIV.ITA.W.5681.002.00_A.5_Studio Anemologico.docx

REV.	DATE	DESCRIPTION	PREPARED	VERIFIED	APPROVED
00	19/02/2024	EMISSIONE	SCS INGEGNERIA SCS Team	SCS INGEGNERIA F. de Castro	SCS INGEGNERIA A. Sergi

IMPIANTO / Plant	*CODE*																			
IMPIANTO EOLICO MONTEMILONE	*GROUP*	*FUNCION*	*TYPE*	*DISCIPLINE*			*COUNTRY*			*TEC*	*PLANT*				*PROGRESSIVE*				*REVISION*	
	SCS	**DES**	**R**	**C**	**I**	**V**	**I**	**T**	**A**	**W**	**5**	**6**	**8**	**1**	**0**	**0**	**2**	**0**	**0**	

CLASSIFICATION:	***UTILIZATION SCOPE*** : **PROGETTO DEFINITIVO**

PRELIMINARY WIND RESOURCE ASSESSMENT

MONTEMILONE

March 2024

Details

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Version control

Version	Description	Date	Drafted	Reviewed	Approved
V00	Initial version	08/07/2022	NF	IP	AC
V01	Updated layout	07/10/2022	NF	CP	AC
V02	Updated layout	11/08/2023	NF	GP	CP
V03	Updated WTG model	05/03/2024	NF	GP	CP

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Contents

1. FOREWORD

SCS Ingegneria S.r.l. (the "Client") engaged Vector Renewables Italia S.r.l. (formerly Windfor S.r.l.) as "Technical Advisor" to perform a preliminary analysis for the definition of the wind resource of an area located in Italy, municipality of Montemilone, Province of Potenza, in Basilicata to evaluate the potential of the Montemilone wind farm (the "Project").

A first analysis was undertaken in July 2022 resulting in a preliminary layout designed by the Technical Advisor for the Project, whose details are described in the report RVRIT22170 V00. In October 2022 and August 2023 revision V01 and V02 respectively of the report were issued for a new layout provided by the Client.

The current analysis consisted in the update of the former energy assessment, assuming the same wind resource assessment and wind flow model already performed and described in the above-mentioned report, for a new configuration provided by the Client:

Turbine model	Hub height [m]	Number of turbines	Wind farm capacity [MW]
13xSG 7.0-170	115.0	13	91.0

Tab. 1 - Configuration of Montemilone wind farm

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

As requested by the Client, the Energy Assessment has been performed by adopting WAsP 12 model propagation as embedded in WindPRO 4.0. 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 obtained by using the sources available in the area deemed as representative, such as land-based wind data and re-analysis data.

It is necessary to emphasize that the Virtual Met Mast does not replace a traditional on-site measurement mast. Therefore, any assessment of the energy production will have a high uncertainty: the results shall be intended as a **preliminary estimation only** and they should be updated when a full year measurement campaign onsite is available.

2. SUPPLIED MATERIAL

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

1. proposed area and layout for the Project
2. restricted areas
3. n. 1 wind farm configuration for the proposed wind farm.
4. coordinates of n. 1 operational wind farm

No site inspection has been carried out at this stage in order to verify the nearby wind farms or the presence of any other obstacle that might affect the Project.

2.1. Proposed area and layout

The following figure shows the proposed area and restricted areas provided for the Project.

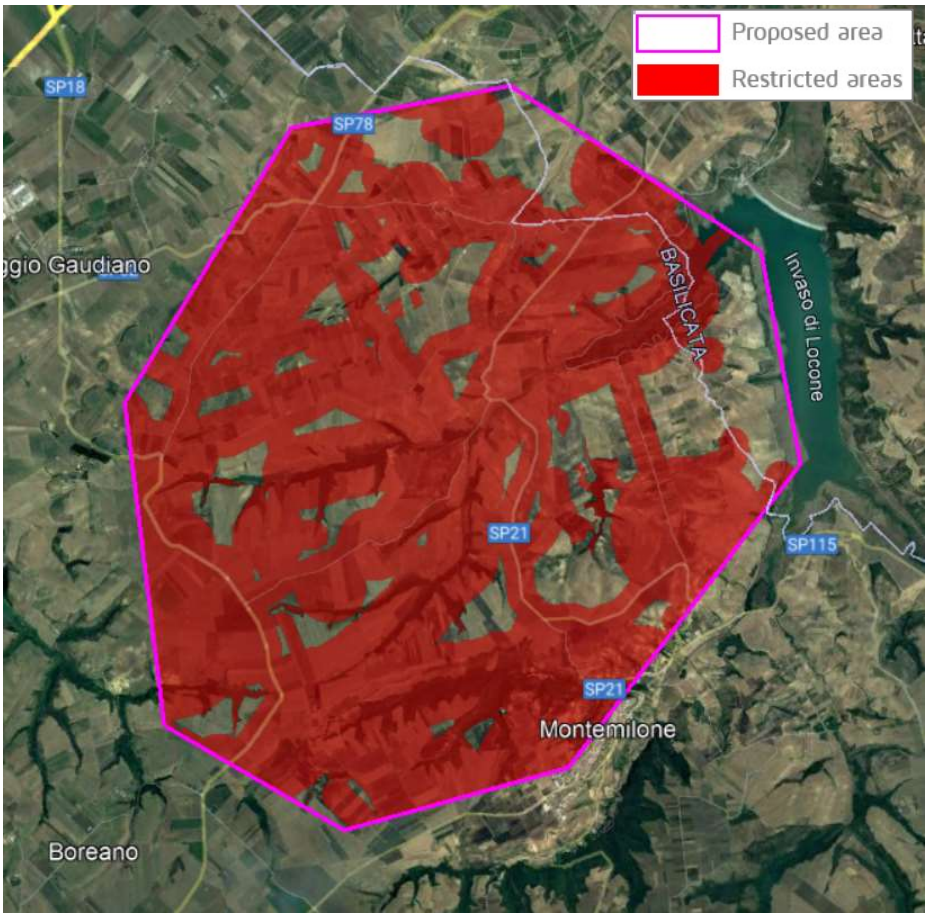


Fig. 1 – Proposed area and restricted areas

The proposed area lies on a hilly and moderately complex terrain at about 300 m a.s.l. with low roughness.

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 20 km x 20 km. In particular, the elevation map was retrieved from the Italian digital elevation model (DEM) Tinitaly, that has been created from individual DEMs from the administrative regions of Italy, with the grid resolution of 10m. The roughness map was downloaded from the Corine Land Cover 2018 database.

The metric coordinates of the provided layout are shown in the following table.

UTM WGS84 Zone 33		
Turbine ID	**Longitude [m]**	**Latitude [m]**
WTG01	575967	4542517
WTG02	576643	4542735
WTG03	578021	4541810
WTG04	579127	4542620
WTG05	579787	4542420
WTG06	579353	4543851
WTG07	579812	4544422
WTG08	580930	4544363
WTG09	580936	4545233
WTG10	581930	4544146
WTG11	582675	4546363
WTG12	582093	4546942
WTG13	582727	4547276

Tab. 2 - Montemilone wind farm coordinates

The layout of the Project is shown in the following figure.

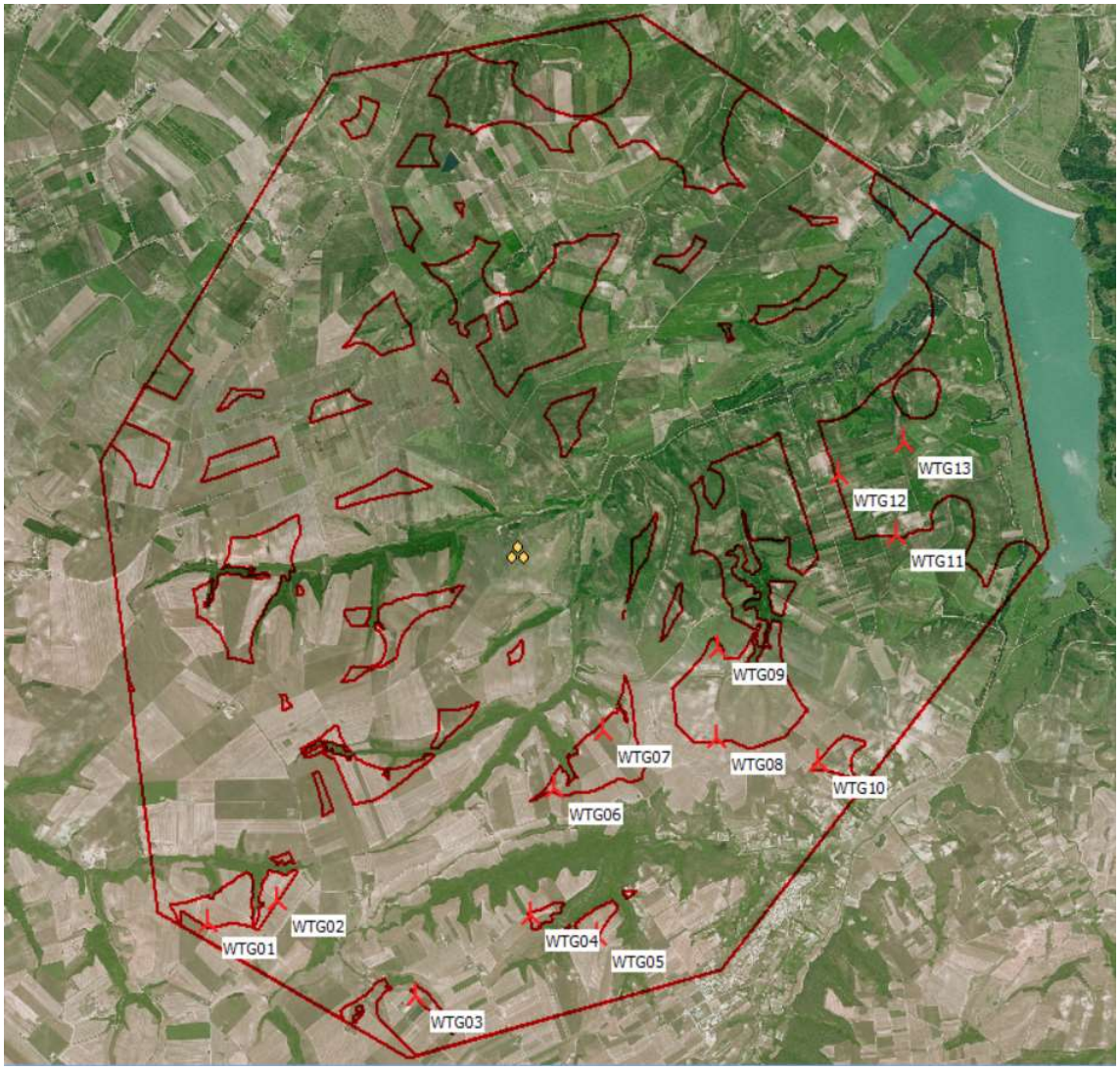


Fig. 2 – Map of the site with proposed Montemilone wind turbines

The next table shows the distances among the closest turbines in meters and in diameters of 170 m rotor for the 13 turbines for the proposed layout.

All turbines are spaced by minimum 4.1 rotor diameters. Nevertheless, it is recommended to obtain the turbine manufacturer's Mechanical Load assessment and site suitability Analysis (MLA), in order to ensure that the fatigue loads, resulting from the wind conditions onsite and acting on the turbine main components, are within the design load envelope.

ID	Nearest WTG	Horizontal distance	Rotor diameters	Distance in rotor diameters
		[m]	[m]	[RD]
WTG01	WTG02	710	170	4.2
WTG02	WTG01	710	170	4.2
WTG03	WTG04	1371	170	8.1
WTG04	WTG05	690	170	4.1
WTG05	WTG04	690	170	4.1
WTG06	WTG07	733	170	4.3
WTG07	WTG06	733	170	4.3
WTG08	WTG09	870	170	5.1
WTG09	WTG08	870	170	5.1
WTG10	WTG08	1023	170	6.0
WTG11	WTG12	821	170	4.8
WTG12	WTG13	717	170	4.2
WTG13	WTG12	717	170	4.2

Tab. 3 – Montemilone wind farm spacings

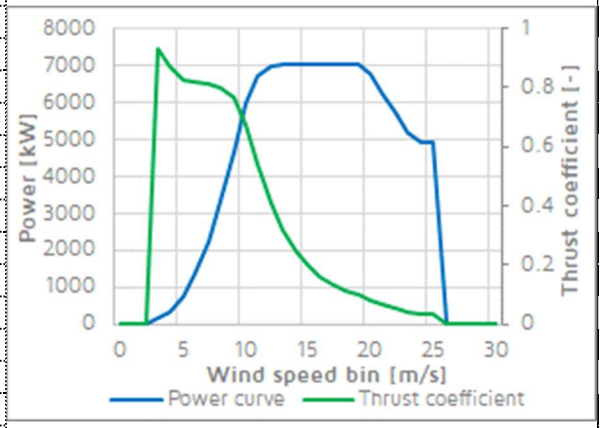
The existing wind farm consists of n. 12 Vestas V126-3.3 MW turbines with a hub height of 94 m, located at a distance of about 20 diameters of a 170 m rotor to the North-West of the Project. These turbines will be included in the wake model to account for the potential interference with the Project. Instead, the evaluation of the impact of the Project on existing wind turbines is outside the current scope of the work.

It is noted that several wind farms are under development in the area but have not been included in the assessment since not yet authorized. In case new information is available on the wind farms under development, it is recommended to update the study accordingly.

2.2. Wind turbine model

The expected energy production of the wind farm is estimated considering the following wind turbine model, as requested by the Client, whose power curve has been provided at the air density of 1.225 kg/m^3 and then adjusted to the site air density of 1.17 kg/m^3, according to the IEC 61400-12 method correction within the WindPRO 4.0 software.

Turbine type		SG 7.0-170	Diameter [m]	170.0
Rated power [MW]		7.0	Hub height [m]	115.0
Rated wind speed [m/s]		14.0	IEC class	S
Cut-in/Cut-out [m/s]		3.5/25.0	Air density [kg/m^3]	1.225
Bin wind speed [m/s]	**Power [kW]**	**Thrust coefficient [-]**		
0.0	0	0		
1.0	0	0		
2.0	0	0		
3.5	148	0.929		
4.0	310	0.870		
5.0	751	0.826		
6.0	1374	0.821		
7.0	2221	0.814		
8.0	3318	0.798		
9.0	4659	0.762		
10.0	5950	0.672		
11.0	6728	0.540		
12.0	6962	0.412		
13.0	6997	0.314		
14.0	7000	0.246		
15.0	7000	0.198		
16.0	7000	0.162		
17.0	7000	0.135		
18.0	7000	0.114		
19.0	7000	0.098		
20.0	6737	0.081		
21.0	6212	0.065		
22.0	5687	0.053		
23.0	5162	0.043		
24.0	4900	0.037		
25.0	4900	0.034		



Tab. 4 – SGRE SG 7.0-170, 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 wind farm at the desired hub heights. The Virtual Met Mast statistics is obtained by using the sources available in the area deemed as representative, such as land-based wind data and re-analysis data.

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. Therefore, the results shall be intended as a **preliminary estimation only**. It is recommended to install at least one met mast onsite, whose structure should be high at least 2/3 of the proposed hub height in order to reduce the vertical extrapolation and update the analysis accordingly.

The Virtual Met Mast has been aligned to the long-term wind regime expected onsite by correlation with 20-year ERA5T re-analysis data and has been interpolated to the hub height of 115 m. In the figures below, the following wind conditions modelled at the Virtual Met Mast location, are reported in Fig. 3:

- Energy rose split into five wind speed classes and 12 sectors
- Wind rose split into five wind speed classes and 12 sectors

Investigating concurrent wind roses of different locations in the area, significant disagreements are detected, both among land-based and re-analysis data. It is again strongly recommended to plan a thorough measurement campaign at site.

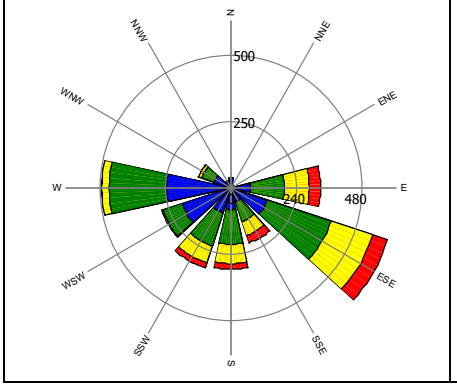
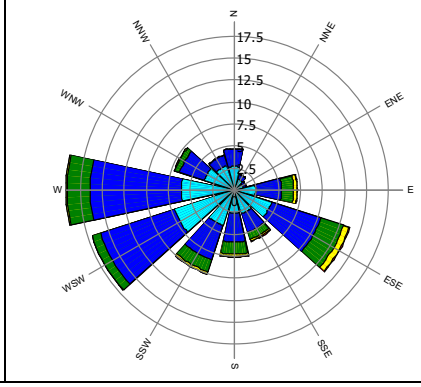
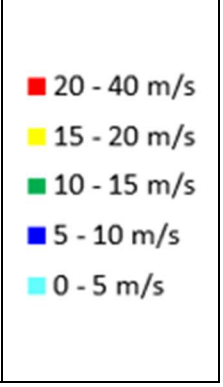
Energy rose [%]	Wind rose [%]	Legend
		

Fig. 3 - Wind conditions at the Virtual Met Mast

4. PRELIMINARY EXPECTED ENERGY YIELD ASSESSMENT

The expected energy production of the Montemilone wind farm has been estimated with the wind turbine configurations requested, using the long-term frequency distribution at the hub height and adopting the WAsP 12 model propagation as embedded in WindPRO 4.0. 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. To be noted that for the energy assessment only the operational wind turbines have been included in the wake modelling.

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

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

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]		Wake Loss [%]	Net Hours [h]
						Gross of wakes	Net of wakes		
WTG01	575967	4542517	336	115.0	6.14	17.58	17.26	1.83	2465
WTG02	576643	4542735	335	115.0	6.10	17.36	16.01	7.76	2288
WTG03	578021	4541810	340	115.0	6.09	17.32	17.14	1.05	2448
WTG04	579127	4542620	330	115.0	6.13	17.49	16.01	8.45	2287
WTG05	579787	4542420	340	115.0	6.18	17.81	16.66	6.46	2380
WTG06	579353	4543851	320	115.0	6.12	17.41	16.80	3.50	2400
WTG07	579812	4544422	320	115.0	6.17	17.71	16.57	6.45	2366
WTG08	580930	4544363	320	115.0	6.13	17.47	15.70	10.17	2242
WTG09	580936	4545233	310	115.0	6.21	17.97	17.09	4.92	2441
WTG10	581930	4544146	330	115.0	6.35	18.69	17.57	5.99	2510
WTG11	582675	4546363	280	115.0	6.23	18.10	17.41	3.80	2487
WTG12	582093	4546942	290	115.0	6.45	19.34	18.65	3.57	2665
WTG13	582727	4547276	270	115.0	6.33	18.63	17.14	8.02	2448
				Average	**6.20**	**17.91**	**16.92**	**5.54**	**2417**
					Total	**232.87**	**219.98**		

Tab. 5 – Montemilone energy production

It should be noted that the energy production presented above accounts only for the losses due to air density and wake effects and no other losses are included. Overall, the wake losses are reasonable with a maximum loss of 10.2% on turbine WTG08.

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 **9/10%** 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.
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]
13xSG 70-170	91.0	219.98	2417	199.09	2188

Tab. 6 – 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.

5. CONCLUSIONS

The activity of the current assessment consisted in the preliminary estimation of the expected annual energy production of the Montemilone wind farm. The study was based on the analysis of the long-term wind regime representative of the area at the desired hub heights, 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.

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. Therefore, the results shall be intended as a **preliminary estimation only**.

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.

The analysis accounts for wake losses induced by n. 1 operational wind farm located nearby the Project. It is noted that several wind farms are under development in the area but have not been included in the assessment since not yet authorized. In case new information is available on the wind farms under development, it is recommended to update the study accordingly.

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 **9/10%** 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.

In addition, it is recommended to verify that the desired wind turbine model will be appropriate for the site according to IEC 61400-1 Standard Ed.3 by defining the site class in terms of the extreme wind speed at hub height with a recurrence period of 50 years averaged over a period of 10 minutes and the representative turbulence levels.

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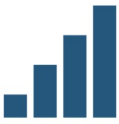

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