Wind and Solar resource mapping

Dugi Otok, Croatia

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CLEAN ENERGY FOR EU ISLANDS

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The Clean Energy for EU Islands Secretariat

Who we are

The launch of the Clean Energy for EU Islands Initiative in May 2017 underlines the European Union's intent to accelerate the clean energy transition on Europe's more than 1,400 inhabited islands. The initiative aims to reduce the dependency of European islands on energy imports by making better use of their own renewable energy sources and embracing modern and innovative energy systems. As a support to the launch of the initiative, the Clean Energy for EU Islands Secretariat was set up to act as a platform of exchange for island stakeholders and to provide dedicated capacity building and technical advisory services.

The Clean Energy for EU Islands Secretariat supports islands in their clean energy transition in the following ways:

• It provides technical and methodological support to islands to develop clean energy strategies and individual clean energy projects.

• It co-organises workshops and webinars to build capacity in island communities on financing, renewable technologies, community engagement, etc. to empower them in their transition process.

• It creates a network at a European level in which islands can share their stories, learn from each other, and build a European island movement.

The Clean Energy for EU Islands Secretariat provides a link between the clean energy transition stories of EU islands and the wider European community, in particular the European Commission.

1. Site and project description

Island description

Dugi Otok is a Croatian island which counts 1,655 inhabitants (2011) [1][2]. It is located west of Zadar, and it is 44.3 km long with a largest width of 4.7 km.

The western coast is tall and rugged. The island has 11 villages. Four of those are located in the southern part and seven villages are clustered in the eastern part. The southern part of the island is a protected area of Telašćica Nature Park, adjacent to the Kornati islands National Park.

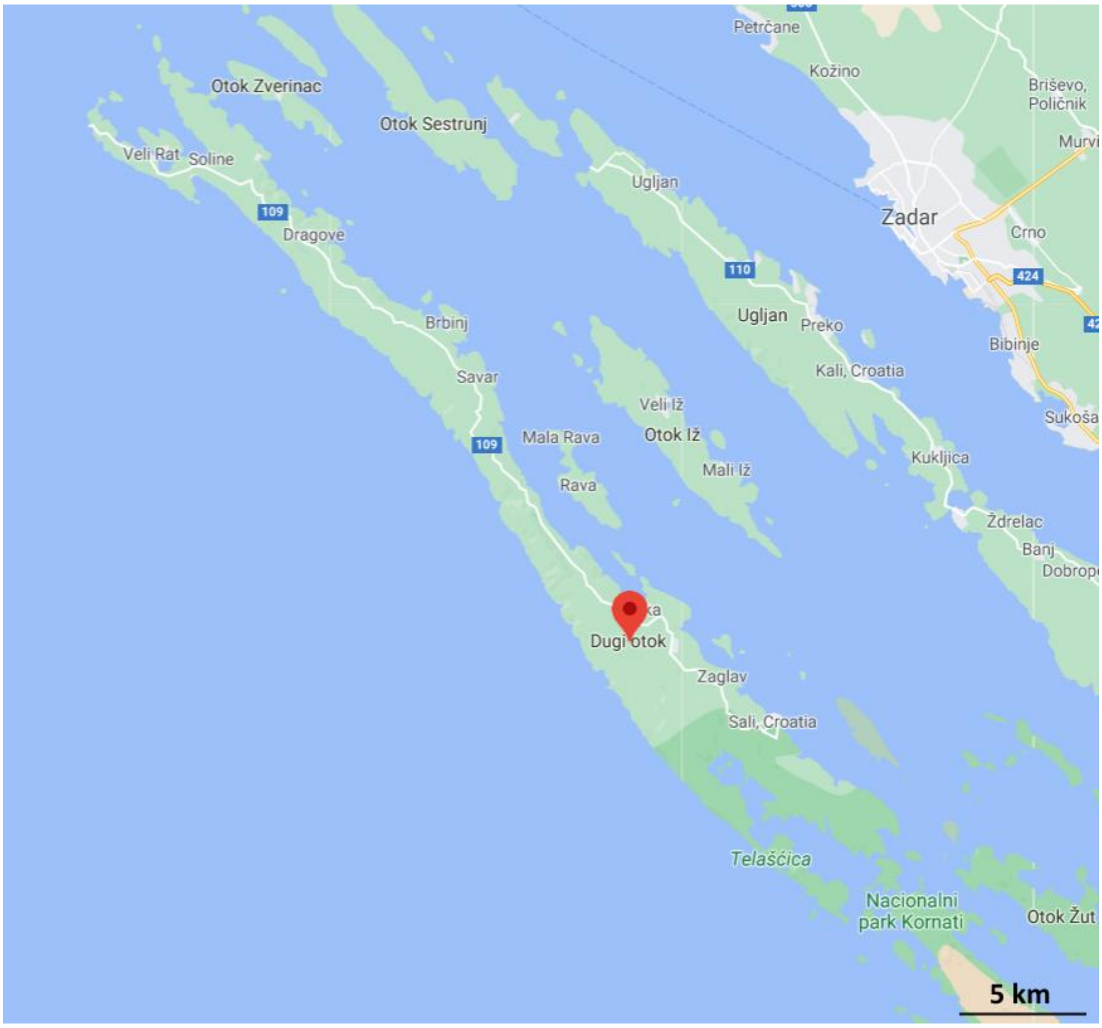

Figure 1: Location of Dugi Otok(source: Google maps)

Objective of the study

This study aims at analysing the wind and solar potential of Dugi Otok island. In the first instance, the best locations for renewable energy installations (solar and wind) are investigated considering both land restrictions and the available renewable energy resource potential. Secondly, based on the identified locations for potential wind power development, a first estimation of annual electricity production is given for two turbine types and two development scenarios.

2. Analysis on restriction areas

The island presents restriction areas where neither wind power nor solar power can be legally installed. They are listed below and presented in Figure 2.

1. The southern part of the island, surrounding the Telašćica Nature park, is listed as a Natura 2000 zone (the largest coordinated network of protected areas in the world). In Croatian Nature Parks, economic activities are allowed as long as they do not threaten the natural environment;
2. The north-west of the island is also protected due to 'Significant landscape' – Znacajni krajobraz;
3. The region around Sali so called *Saljsko Polje* (Botanical olive garden) is also considered as a natural reserve.

Figure 2: Restriction areas on Dugi Otok (Source: Bioportal.hr)

3. Analysis on renewable energy potential

Wind potential

Within the studied area, a wind atlas has been created using the software WindPro[1]. The Wind Climate from the Global Wind Atlas [3] has been used to calculate a wind resource map of the island.

The wind speed is maximum where the mountain ranges stand, along the main road crossing the island from north-west to south-east. This is mainly due to the combination of low roughness and high altitudes. The maximum calculated wind speed is about 7.35m/s at 100m. The wind predominantly blows from the sectors east-north-east and east-south-east and most of the energy is available from the sector east-north east as shown in Figure 3.

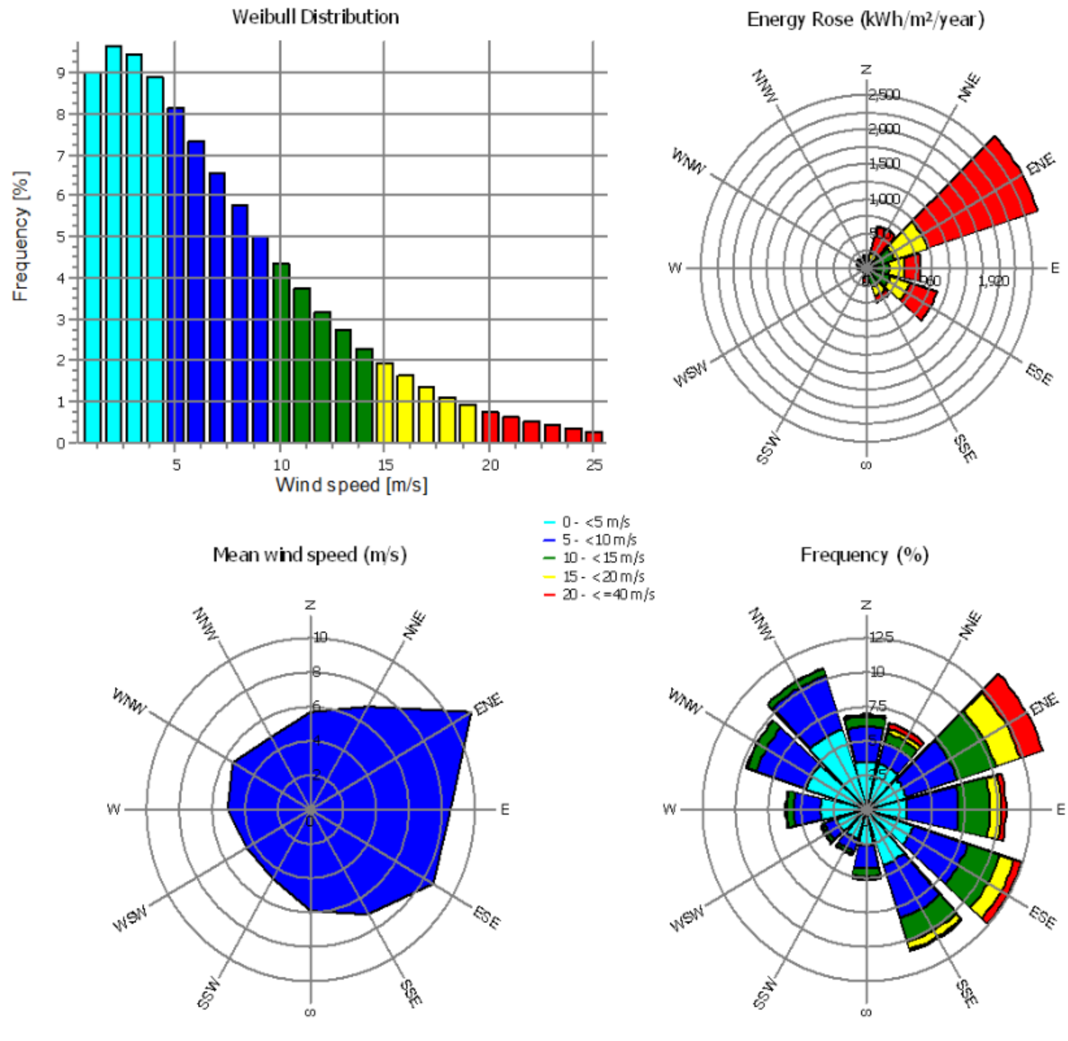

Figure 3: Wind regime in Savar region

Wind resource maps have been generated at two different heights above ground level, 98m and 60m corresponding to two pote

[1] WindPRO is a software package for designing and planning wind farm projects. It uses WAsP to simulate wind flows. It is developed and distributed by the Danish energy consultant EMD International A/S. It is trusted by many investment banks to create wind energy assessments used to determine financing for proposed wind farms.

ntial hub heights for different turbine types. They are presented in the figures below.

The results show that the annual yield with a 2.3MW and 98m hub height wind turbine (i.e. Enercon E70 2.3MW @98m) ranges between 2,600 MWh/y in valleys and 5,800 MWh/y in the highest altitudes locations on the island. And, they show an annual yield between 1,500 MWh/y and 5,600 MWh/y with a 800kW and 60m hub height wind turbine (for example Enercon E48 0.8MW @60m). The best locations to develop a wind project would be along the main road crossing the island from north-west to south-east on the highest altitude points mostly between Bozava and Dragove and between Savar and Luka.

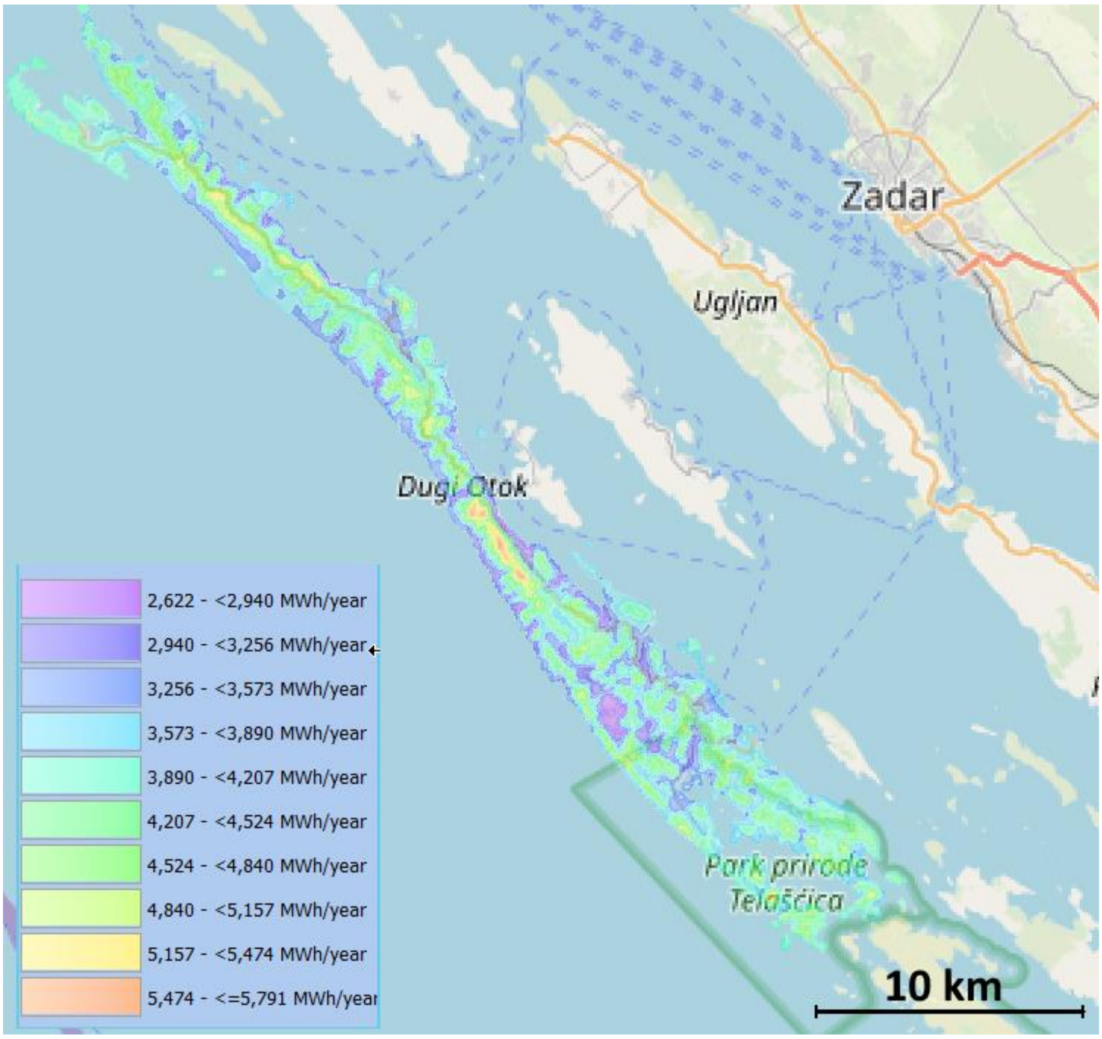

Figure 4: Annual wind production with Enercon E70 @98m above ground level [MWh/y]

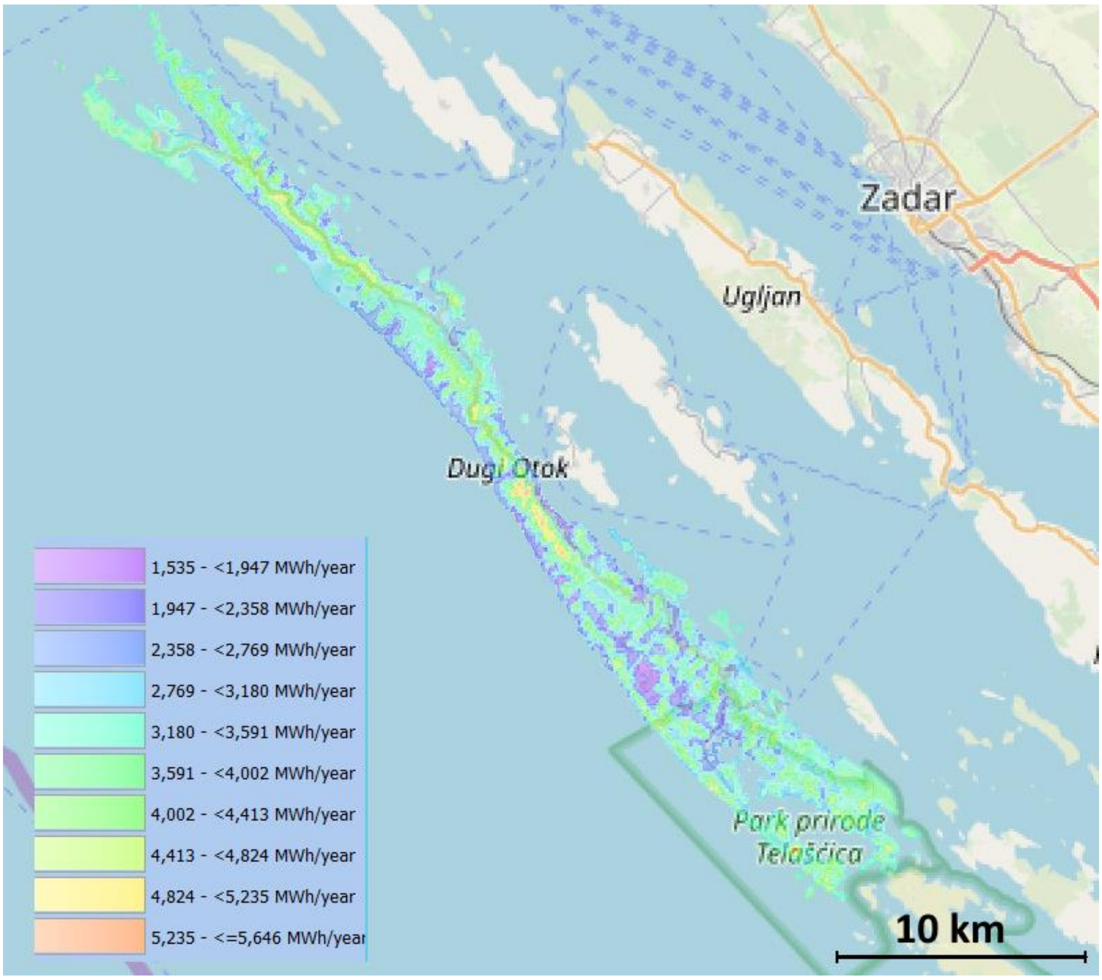

Figure 5: Annual wind production with Enercon E48 @60m above ground level [MWh/y]

Solar potential

The potential solar power production of an area depends on the solar irradiation incident in that specific location. Solar irradiation is the incident energy per unit area over a given period of time. The study uses the global horizontal irradiation, which is the total amount of direct and diffuse solar radiation incident falling on a horizontal surface, as a measure for solar potential. It is expressed in kWh/m^2. The assessment is made using satellite data from 3E's data services[2]. The results are organized in a map showing the repartition of the horizontal solar irradiation over the island.

Figure 6 indicates that the average solar potential on the island is about 1,480 kWh/m^2 and that there is only little variation (±2%) between the island's north and south. The resource is higher in the south of the island where the Natura 2000 restriction area is. In general, the west coast of the island shows the most solar potential and solar power development is also possible in the island's centre.

Reference values for the annual power output for two types of solar power development are shown in Table 1. These results are simulated using satellite data considering a location in the centre of the island (shown by the red arrow in Figure 6). Small-scale rooftop solar installations,

[2] https://solardata.3e.eu/

such as those installed by island residents on their homes, are expected to produce around 1400 kWh per year per kWp of installed capacity. Ground mounted solar installations are expected to have a slightly higher annual yield at an annual 1450 kWh/kWp.

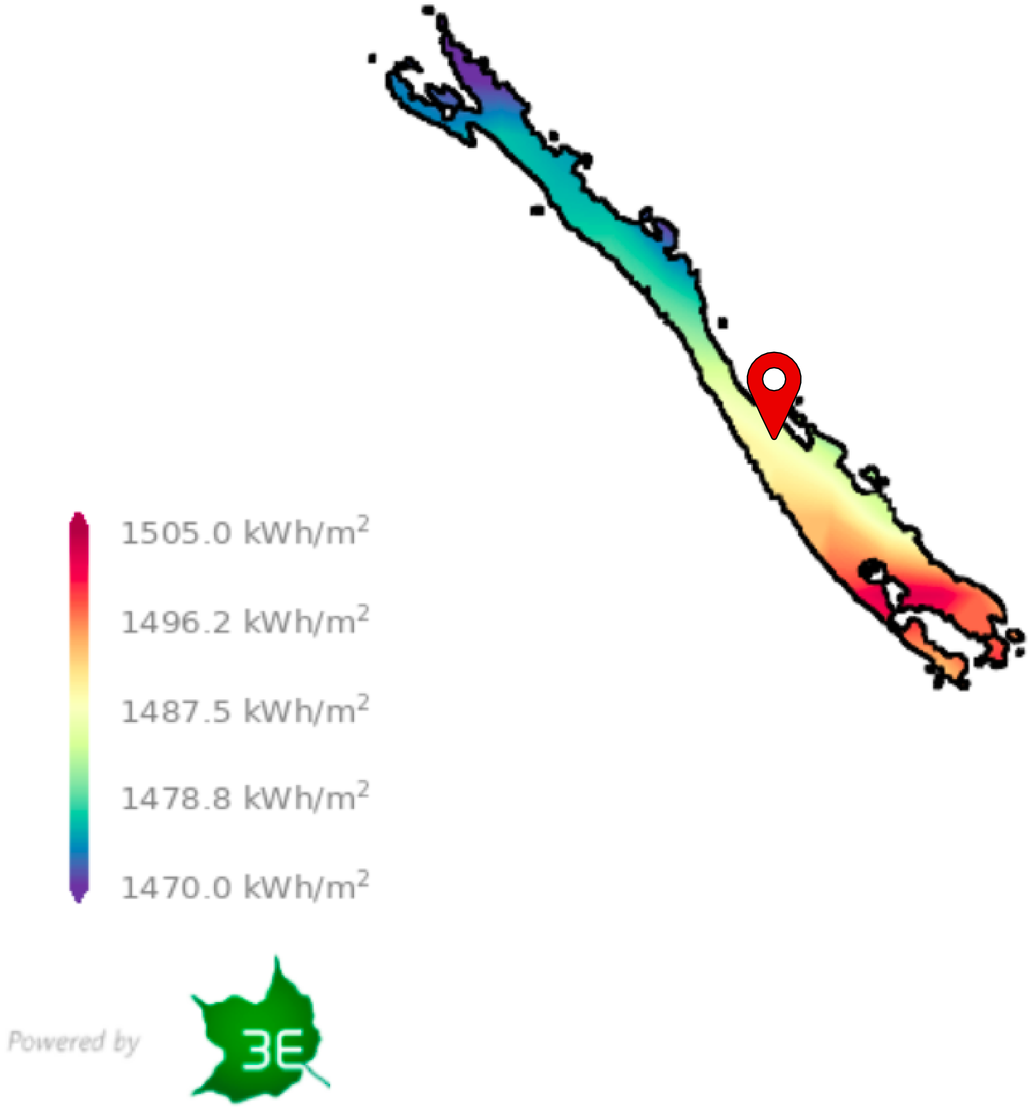

Figure 6 Distribution of horizontal solar irradiation on Dugi Otok.

Table 1 Solar power production for a site in the centre of the island[3].

PV system	Small residential (rooftop)	Ground-mounted large scale
Location	43°58'14", 15°04'58"	43°58'14", 15°04'58"
Azimuth of PV panels	180°	180°
Tilt of PV panels	34° (optimal)	34° (optimal)
Air temperature	15.7°C	15.7°C
Installed capacity	1 kWp	1 kWp
Net Energy production	1.398 MWh/year	1.454 MWh/year

[3] Data obtained from the "Global Solar Atlas 2.0, a free, web-based application is developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info

4. Power production

Wind

Production from wind turbines is highly dependent on the wind conditions on a specific site. Unlike with solar power, it is difficult to provide a generic reference value for the wind potential that is valid for the entire island. The potential of wind power production on Dugi Otok is therefore investigated by means of a scenario analysis, in which the annual power production of different combinations of turbine location and turbine technology are calculated. These scenarios give a first insight of the potential power production from wind power on the island.

The following turbine types are used in the analysis. They are representative of turbine technologies currently employed in wind projects in similar contexts.

- Enercon E48 with 48m rotor diameter and 60m hub height and a rated power of 0.8MW
- Enercon E70 with 70m rotor diameter and 98m hub height and a rated power of 2.3MW.

Two potential layouts have been studied.

- Scenario 1: development on plots owned by Sali municipality. The municipality of Sali owns large plots of land where projects can be developed. They are the cadastral plots 1139/1 in the Savar aera and 253/1 in the Brbinj area as shown Figure 7.

Figure 7: Cadastral plots owned by the Municipality suggested as developing areas

- Scenario 2: development in the optimal locations based on the wind resource map and access road.

For each scenario and per technology, a layout of the turbines is modelled, and the annual power production is simulated.

An estimated loss for availability, performance, electrical and environmental losses of 10% has been deducted from the gross production to illustrate a realistic net production of electricity from wind turbines at the sites. Those values should be reviewed in a further development stage of a wind farm.

The layout of the wind turbines has been determined based on best practices: the wind turbine spacing should be of at least five rotor diameters along the prevailing wind directions and three rotor diameters across. The coordinates of the turbine locations are available in Annex A.

Scenario 1

The island of Dugi Otok suggested two potential areas owned by the Municipality, where, at first sight, a renewable energy project development is feasible.

The cadastral plot numbered 235/1 (Brbinj area) presents a high slope towards the west coast. This is not recommended for wind turbine installation.

However, the cadastral plot numbered 1139/1 (Savar area) presents a rather high wind potential with good access from the road. This plot has been further selected to define an optimal wind turbine location given the topography of the plot, the access to the road.

The wind resource map is shown in Figure 8. The suggested layout for the 2.3MW and 0.8MW turbine are shown in Figure 9 and Figure 10 respectively. The calculated project parameters are summarized in Table 2. The configuration with one larger turbine leads to a net energy production of about 4 GWh annually. While 2 turbines are installed in the configuration with small turbines, the net energy production is about 3.2 GWh. Considering an annual electricity demand of 4.5 MWh per household, this wind development scenario could provide electricity for around 700 – 900 households. This can be slightly oversized for the consumption of the island. The local grid's ability to evacuate the wind power production, including the interconnection with the mainland, should therefore be explicitly considered in the design process of the wind project.

Table 2: Estimated production - Scenario 1

Configuration		Enercon E70 2.3MW @98m	Enercon E48 0.8MW @60m
Number of wind turbines		1	2
Installed capacity	[MW]	2.3	1.6
Gross Energy production	[MWh/year]	4,440	3,556
Wake losses	[%]	0	0.4
Estimated losses	[%]	10	10
Net Energy production	[MWh/year]	3,996	3,186
Number of equivalent hours	[h/year]	1,737	1,991

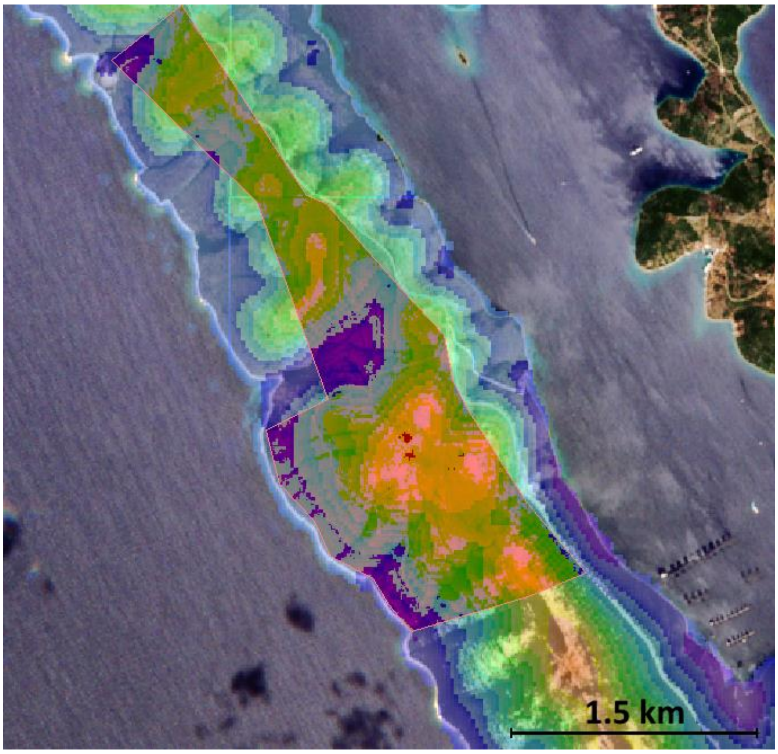

Figure 8: Wind resource map focused on the cadastral plot 1139/1(red slot) – warmer colour denotes higher wind speed

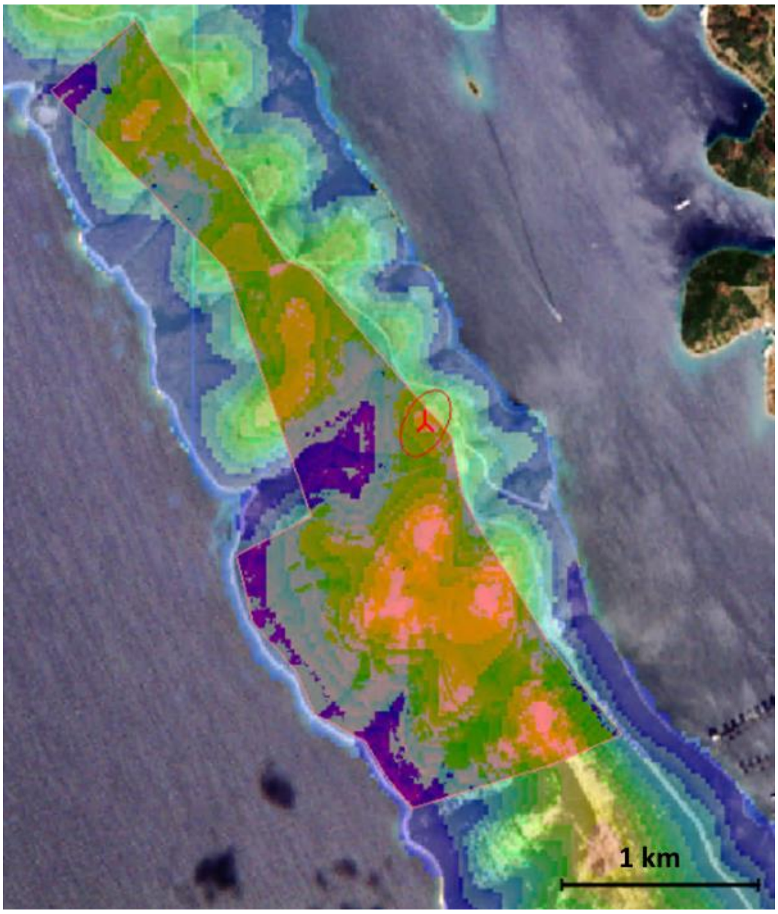

Figure 9: Suggested layout on cadastral plot 1139/1 for configuration E70 2.3MW @98m (1 WTG)

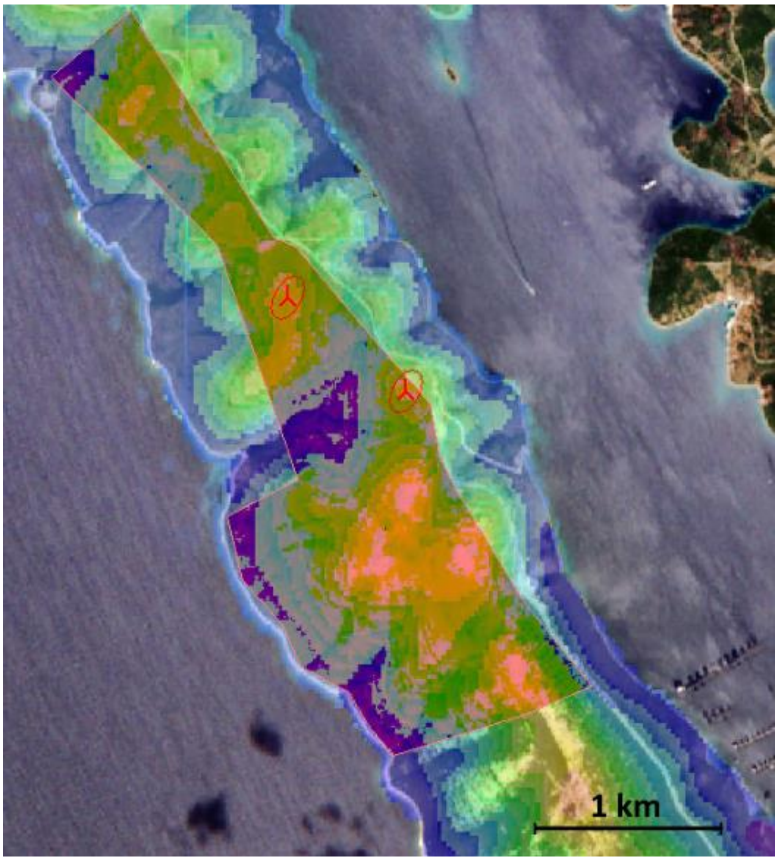

Figure 10: Suggested layout on cadastral plot 1139/1 for configuration E48 0.8MW @60m (2WTGs)

Scenario 2

Based on the wind resource map, a second potential area south of cadastral plot 1139/1 has been selected.

The suggested layout for the 2.3MW and 0.8MW turbine are shown in Figure 11 and Figure 12 respectively. The calculated project parameters are summarized in Table 3. The configuration with larger turbines leads to a net energy production of around 4.8 GWh annually. The net energy production for the smaller turbines is around 3.5 GWh. Considering an annual electricity demand of 4.5 MWh per household, this wind development scenario could provide electricity for around 780 - 1,000 households. This might be slightly higher than the island's population needs. This is an indication that the local grid's ability to evacuate the wind power production should be explicitly considered in the design process of the wind project.

Table 3: Estimated Production – Scenario 2

Configuration		Enercon E70 2.3MW @98m	Enercon E48 0.8MW @60m
Number of wind turbines		1	2
Installed capacity	[MW]	2.3	0.8
Gross Energy production	[MWh/year]	5,402	4,021
Wake losses	[%]	0	1.9
Estimated losses	[%]	10	10
Net Energy production	[MWh/year]	4,862	3,543
Number of equivalent hours	[h/year]	2,114	2,214

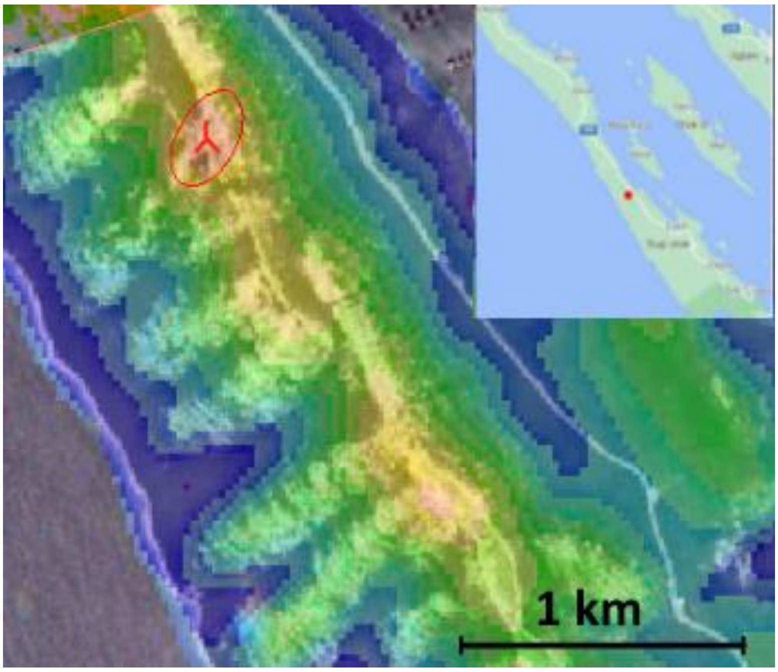

Figure 11: Suggested layout for configuration Enercon E70 2.3MW @98m

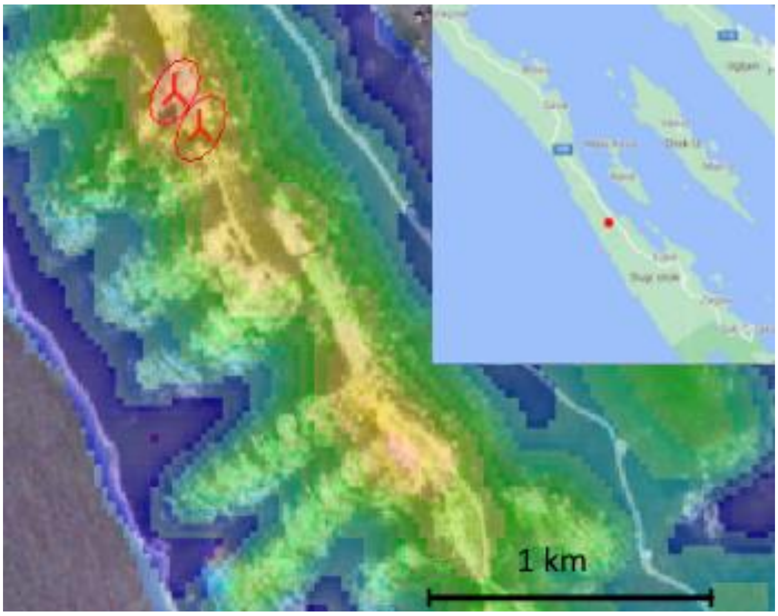

Figure 12: Suggested layout for configuration Enercon E48 0.8MW @60m (2 WTGS)

5. Conclusion

In this report, the potential for onshore wind turbines and solar installations on Dugi Otok has been investigated.

The results show that:

- Most of the wind is blowing from the sector north-east. The best locations to develop wind project would be along the main road crossing the island from north-west to south-east on the highest altitude points mostly between Bozava and Dragove and between Savar and Luka.
- The solar potential does not differ much across the island. Availability is highest in the south of the islands and generally along the west coast of the island. However, due to natural restrictions in the south of the island, solar development will need to be shifted to the west coast.

References

[1] Wikipedia. Consulted on 01/10/2020. https://en.wikipedia.org/wiki/Dugi_Otok#cite_note-dzs-1
[2] Information about Dugi Otok shared by Jona Petesic on 09/2020
[3] Global wind Atlas. Consulted on 01/10/2020, https://globalwindatlas.info/

Annex: Turbine Coordinates

Scenario 1

Table 4: Turbines coordinates Scenario 1 (on cadastral lot) - WGS84 (ddmmsss)

	E70 2.3MW @98m		E48 0.8MW @60m	
	X	Y	X	Y
1	15.037708° E	44.019793° N	15.029812° E	44.024113° N
2			15.037708° E	44.019793° N

Scenario 2

Table 5: Turbine coordinates: Scenario 2 - WGS84

	E70 2.3MW @98m		E48 0.8MW @60m	
	X	Y	X	Y
1	15.048951°E	44.001226°N	15.048951°E	44.001226°N
2			15.050050°E	44.00080°N

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