Business Model for Wind Energy Production (WP4)

CEDR 2019 Renewable Energy in Road Infrastructure
FINAL CONFERENCE – 24 October 2023

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

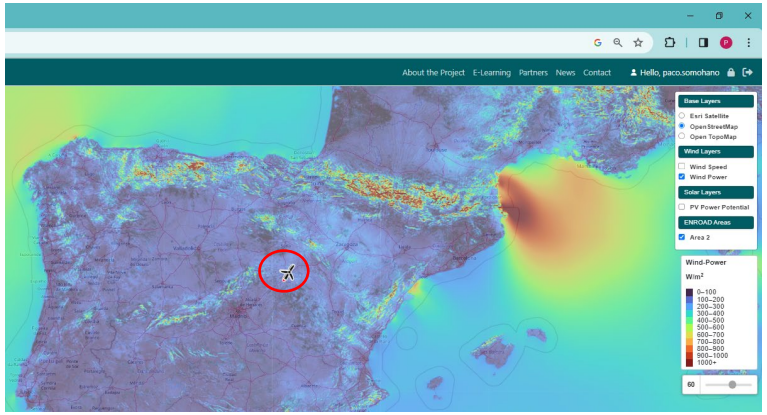
El Chaparro facility near Northwest A2 Highway

This is an example of GIS-based BM.

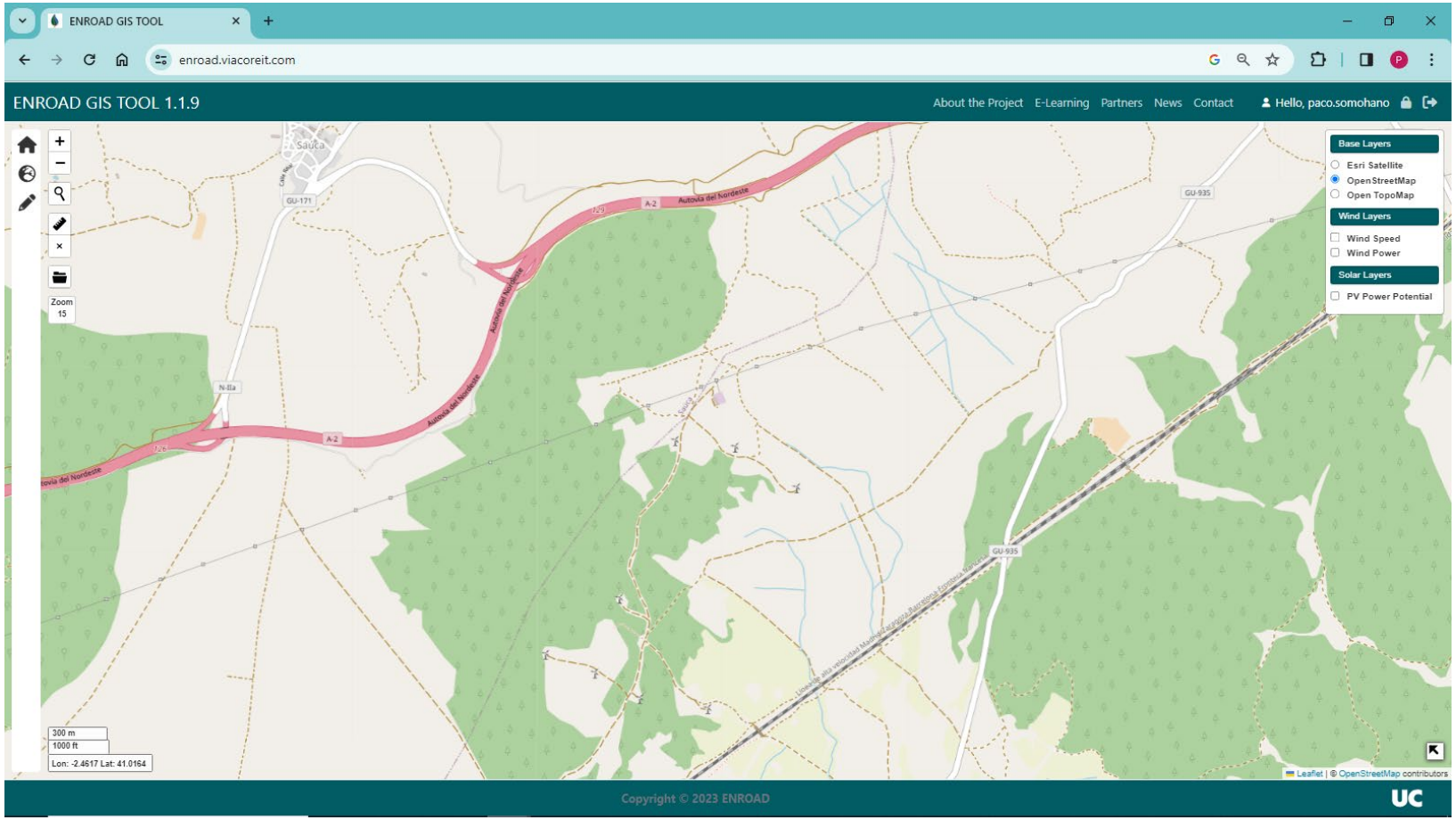
The existing RET facility in this location is used for BM validation.

El Chaparro, near SAUCA (Guadalajara, Spain), to Spanish Northwest A2 Highway (Lat. 41.0200, Lon. -2.5050), and track of Madrid-Zaragoza high-speed train:

- Start year: 2011
- 8 wind turbines: Gamesa G90/2000 (power 2000 kW, diameter 90 m)
- Total rated power: 16 000 kW
- Developer and operator: Acciona Energia



Open StreetMap



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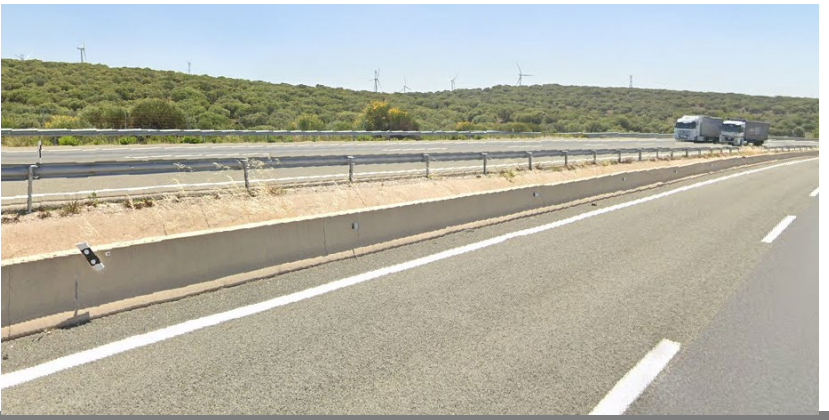
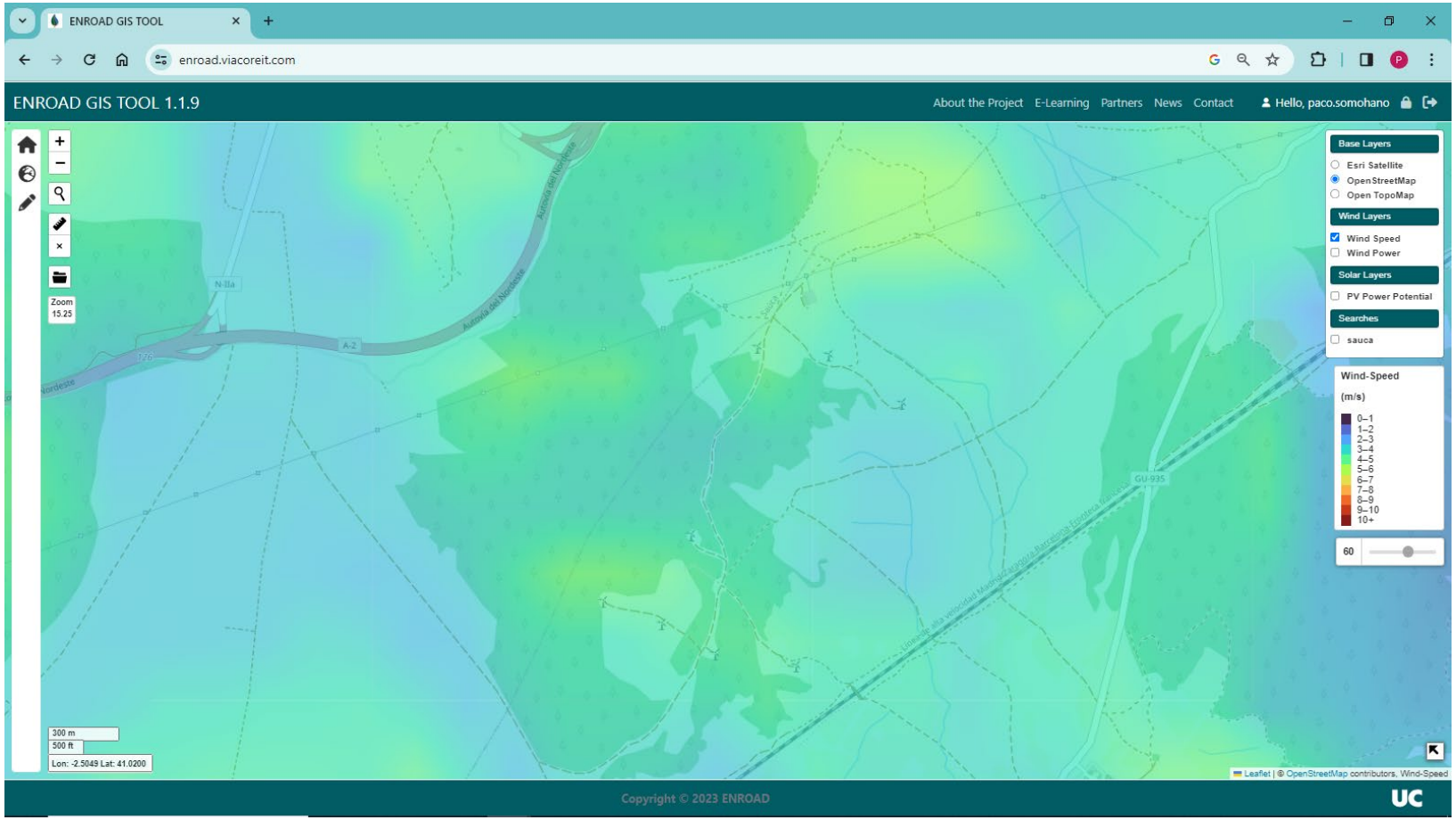


Open StreetMap & Wind Speed



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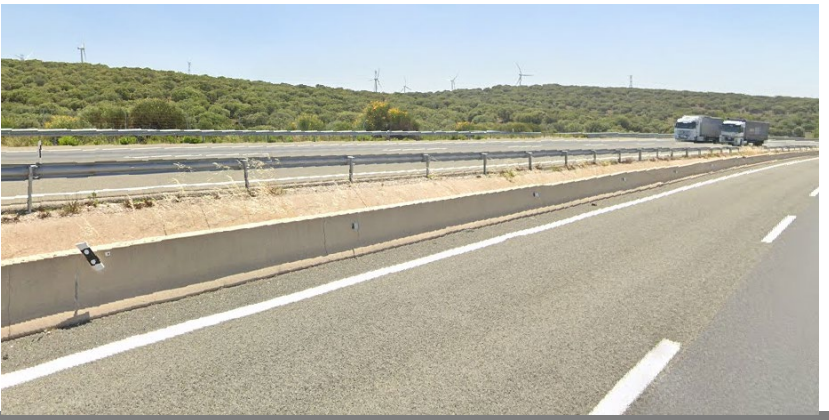
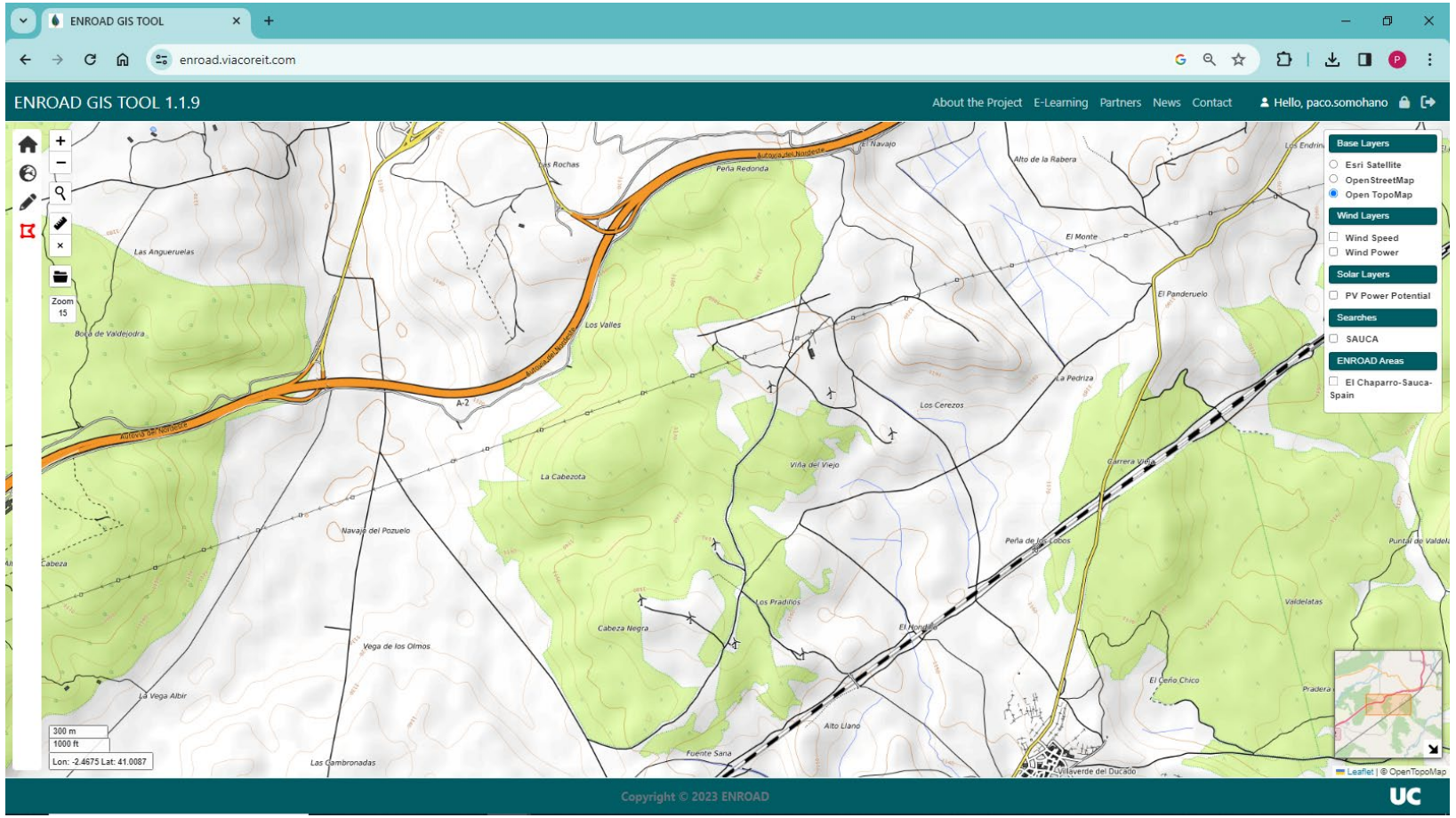


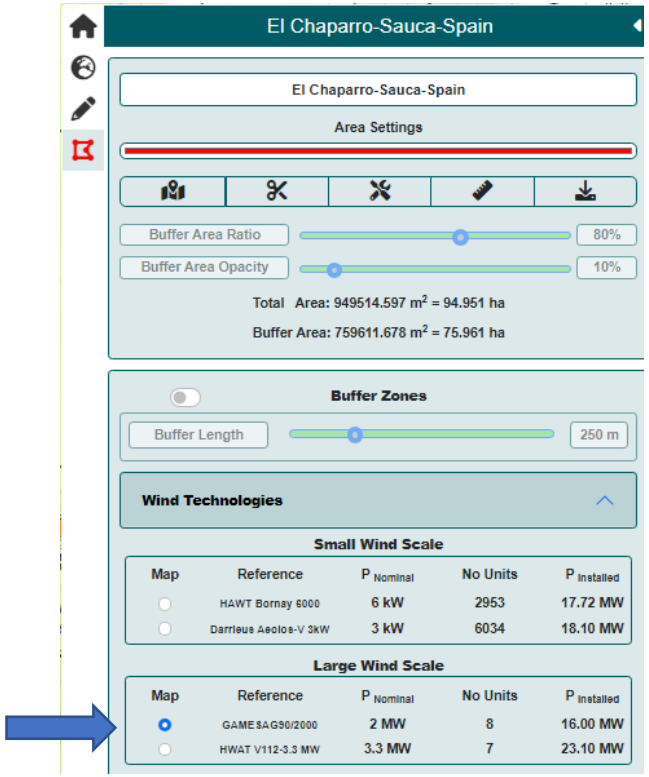
Open TopoMap



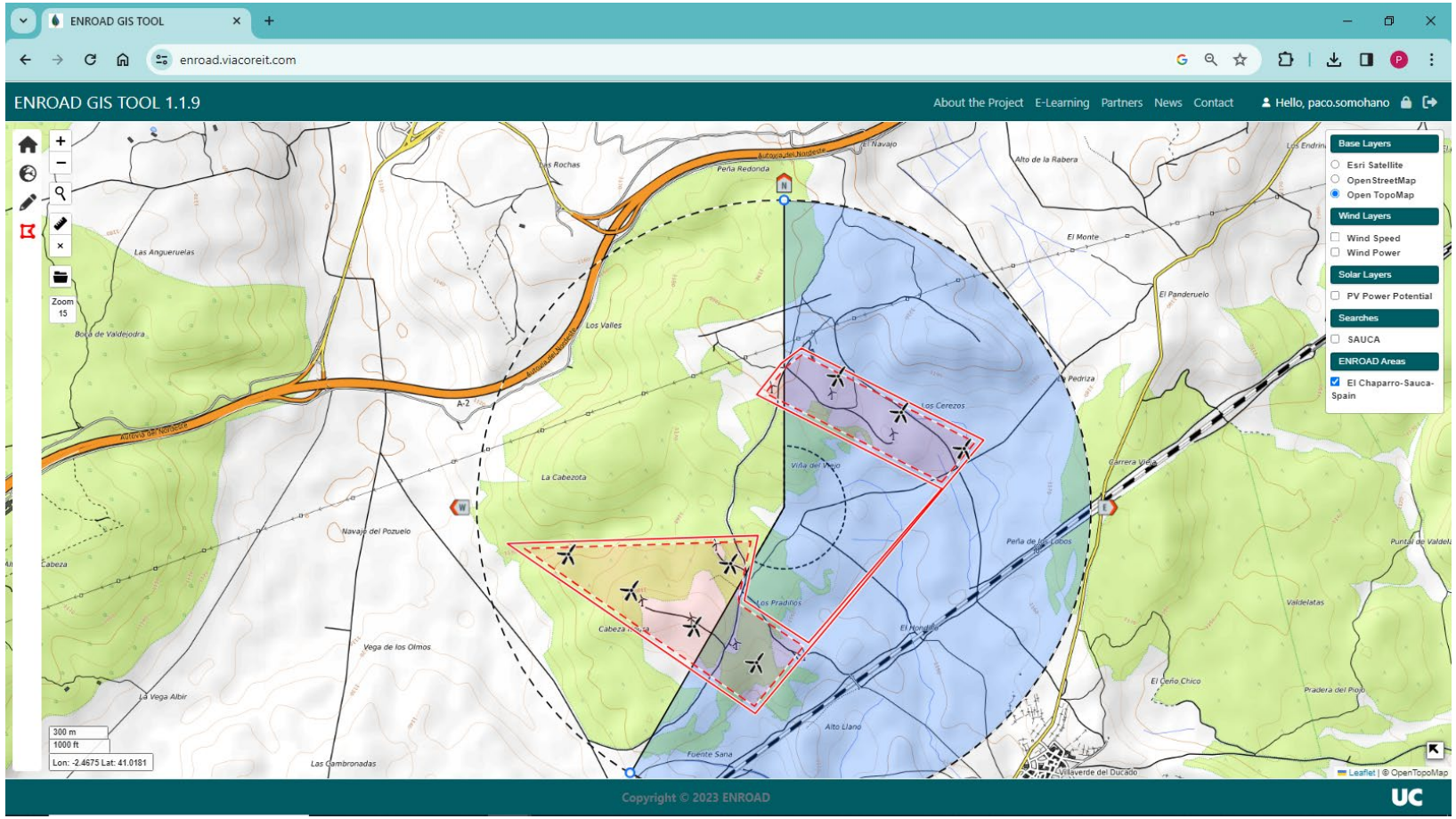
ENROAD GIS area selection

ENROAD GIS optimizes the location of wind turbines based on the prevailing wind direction.

The area is selected in such a way that ENROAD wind turbines icons are located near the real ones to download NEWA database parameters.



Open TopoMap



The Excel template's machine parameters (Sheet 1.1 Config TC) were updated with GAMESA G90/2000 data and uploaded.

Prevailing wind direction and layout

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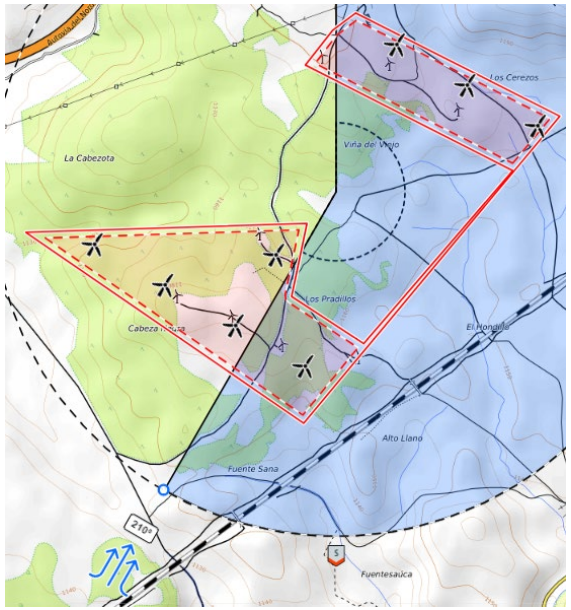
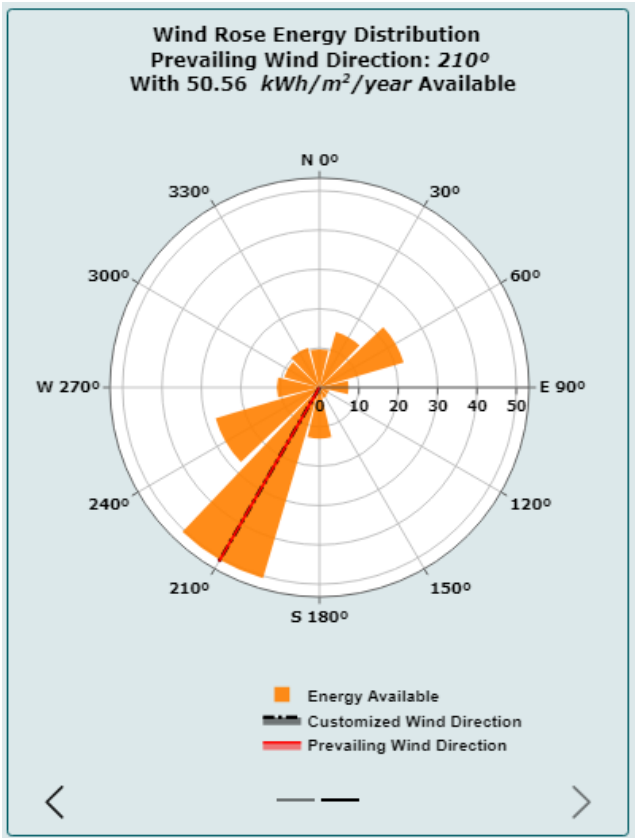
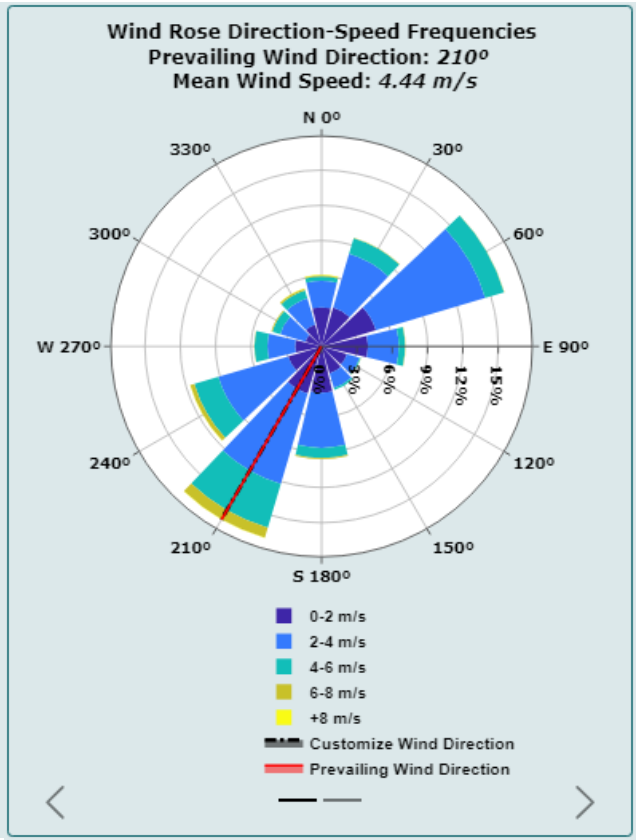
The area is selected in such a way that ENROAD wind turbines icons are located near the real ones to download NEWA database parameters.

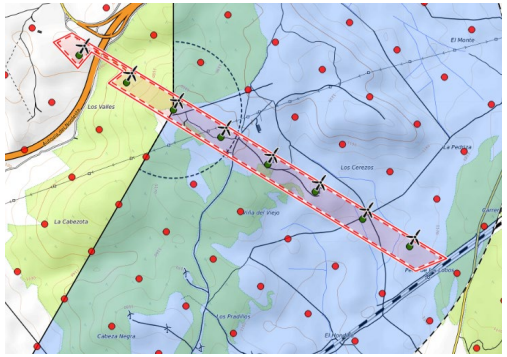


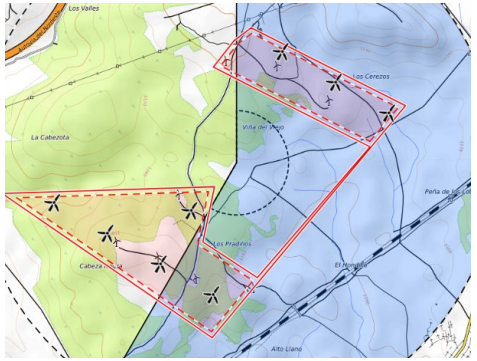




Outcome BM file

The ENROAD GIS estimates the effect of turbulences that reduces the efficiency of wind turbines rows downstream.





RESULTS FOR THE DIFFERENT TECHNOLOGIES		*Tech_3* GAMESA G90/2000	*Tech_4* HWAT V112-3.3 MW	*Tech_5* Monocrystalline A-330M GS PERC	*Tech_6* Monocrystalline JAM72S30-530/MR
		Large Wind	Large Wind	PV	PV
Number of turbines/modules	No.	8	7	167.664	105.600
Total Annual Energy Production	MWh year	65.486,0	109.134,7	97.219,0	74.973,2
Energy Production per m2	kWh/m2 year	347,46	579,05	515,83	397,80
First Year Total Cost (FYTC)	EUR/MWh	29,78	22,40	31,90	34,05
LCOE	EUR/MWh	41,28	31,67	44,79	47,96
NPV	EUR	-11.963.730	5.239.704	-22.170.623	-21.152.950
IRR	%	negative	negative	negative	negative
AARR	%	0,24%	2,20%	-0,87%	-1,64%

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		Large Wind	Large Wind	PV	PV
Number of turbines/modules	No.	10	8	165.312	104.016
Total Annual Energy Production	MWh year	50.150,2	88.301,9	95.765,5	73.768,2
Energy Production per m2	kWh/m2 year	266,09	468,52	508,12	391,40
First Year Total Cost (FYTC)	EUR/MWh	37,22	26,18	31,93	34,09
LCOE	EUR/MWh	45,04	32,63	44,84	48,01
NPV	EUR	-15.824.244	2.194.131	-21.922.786	-20.891.474
IRR	%	negative	negative	negative	negative
AARR	%	-0,23%	2,10%	-0,88%	-1,65%

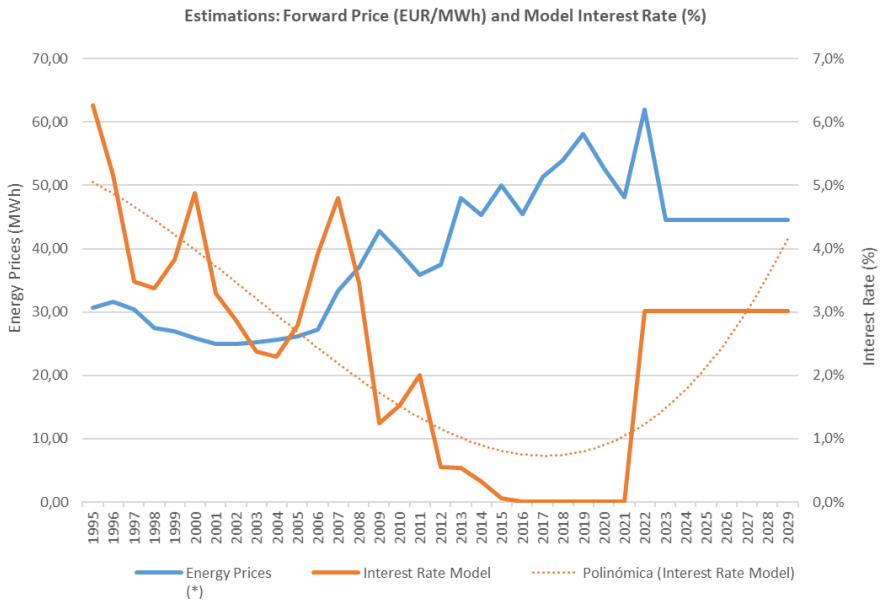
ENROAD BM is set up to correct the performance diminishing in multiple rows arrengement.

Accrual Accounting Return Rate only considers the facility investment while the Return on Assets considers all the assets of a company

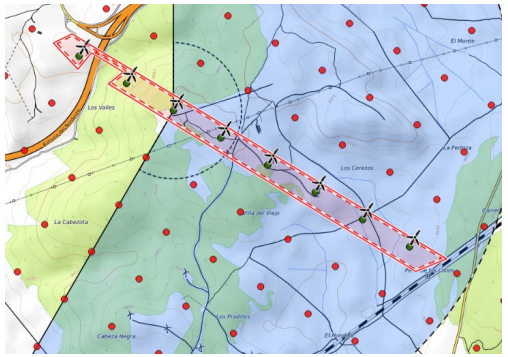
Energy prices and Interest Rate

We have estimated the El Chaparro sale energy prices. The average price for the exploitation period 2011-2021 is 47,83 EUR/MWh.

The interest rates data source is the Bank of Spain for 1995-2023.



Energy average price 2011-2021	Recommended RET
47,83	GAMESA G90/2000
EUR/MWh	-
First Year Total Cost (FYTC)	**COST GAP (LCOE - FYTC)**
29,78	11,51
EUR/MWh	EUR/MWh
LCOE for selected RET (LCOE)	**COST GAP (LCOE - FYTC)/ FYTC**
41,28	39%
EUR/MWh	-



Profit and loss statement

ENROAD BM estimates the first year's Profit and Loss Statement (2011) and the annual net margins.

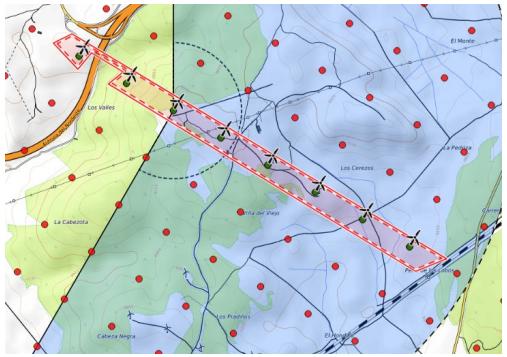
3.3.- PROFIT & LOSS, MARGINS

Facility Investments	Unit	Date	Large Wind GAMESA G90/2000	Large Wind HWAT V112-3.3 MW
Electricity production	MWh year	-	**65.486,02**	**109.134,74**
Unit Price	EUR/MWh	2011	**35,87**	**35,87**
ENERGY REVENUE OR SAVINGS	**EUR**		**2.349.123,02**	**3.914.895,34**
EXPENDITURES:	**EUR**		**-921.670,17**	**-1.357.446,92**
Manpower	EUR		0,00	0,00
Land lease	EUR		0,00	0,00
Maintenance	EUR		-85.680,00	-129.360,00
Insurances	EUR		-115.200,00	-392.700,00
Communications	EUR		-34.560,00	-55.440,00
Security	EUR		-46.080,00	-73.920,00
Monitoring	EUR		-11.520,00	-18.480,00
Energy	EUR		0,00	0,00
Other general and administrative costs	EUR		-23.040,00	-36.960,00
Interest	EUR		-605.590,17	-650.586,92
ANNUAL NET MARGIN BEFORE DEPRECIATIONS	EUR		1.427.452,85	2.557.448,42
Facility depreciation	EUR		-999.697,62	-1.056.695,65
End-of-cycle depreciation and dismantling	EUR		-24.992,44	-26.417,39
ANNUAL NET MARGIN BEFORE DEC	EUR		402.762,79	1.474.335,38
DCE depreciation	EUR		-3.600,00	-3.600,00
ANNUAL NET MARGIN AFTER DEC	EUR		399.162,79	1.470.735,38
ANNUAL NET MARGIN AFTER DEC PER KILOWATT HOUR	**EUR/kWh**		**0,00610**	**0,01348**
FIRST YEAR TOTAL COSTS	EUR		-1.949.960,23	-2.444.159,96
FIRST YEAR TOTAL COST PER KWH	EUR/kWh		0,029777	0,022396
FIRST YEAR CAPITAL COST	EUR		-1.024.690,06	-1.083.113,04
FIRST YEAR CAPITAL COST PER KWH	EUR/kWh		0,016	0,010

The energy average price is higher for the period

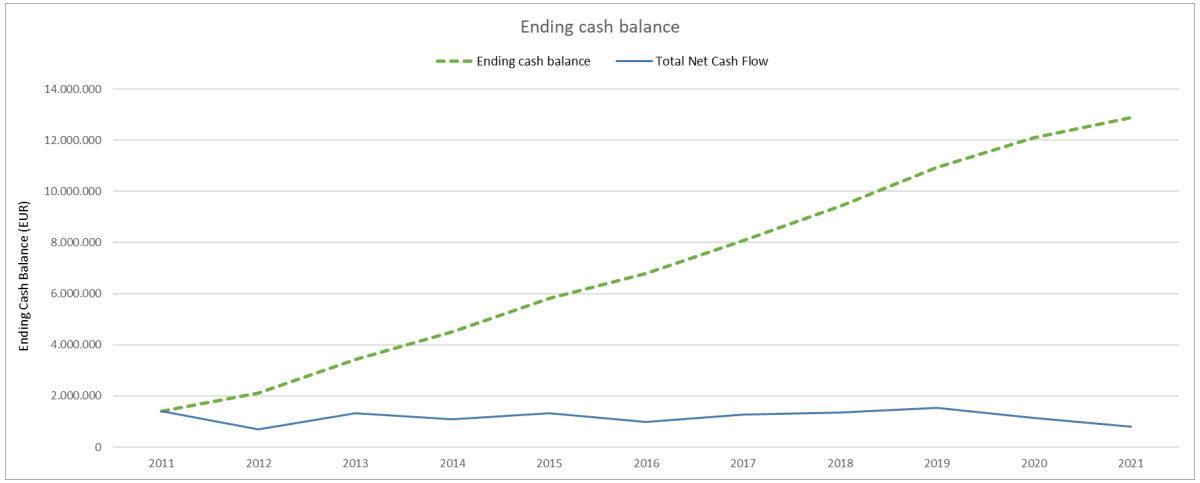
The FYTC is calculated with the expenditures of 2011 and the electricity production

Energy average price 2011-2021	Recommended RET
47,83	**GAMESA G90/2000**
EUR/MWh	-
First Year Total Cost (FYTC)	**COST GAP (LCOE - FYTC)**
29,78	**11,51**
EUR/MWh	**EUR/MWh**
LCOE for selected RET (LCOE)	**COST GAP (LCOE - FYTC)/ FYTC**
41,28	**39%**
EUR/MWh	-



Financial Assessment

ENROAD BM estimates the cash inflows and outflows for the life cycle of the facility. Since the bank debt is 27.5 MM EUR, the accumulated ending cash flow in 2021 should be 12.89 MM EUR while the debt ending balance that year should be 17,22 MM EUR, so there is a negative balance.



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47,83	GAMESA G90/2000
EUR/MWh	-
First Year Total Cost (FYTC)	COST GAP (LCOE - FYTC)
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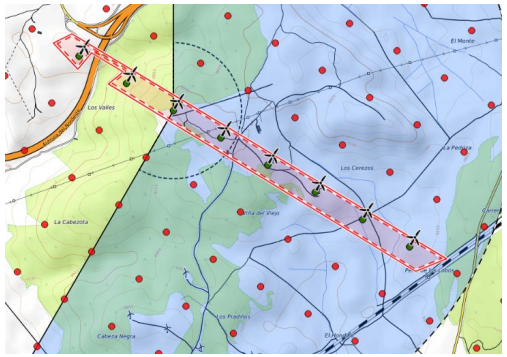
EUR/MWh	-



ENROAD is different from other tools because of the analysis of the long-term effects in the financial result, individually or as a whole, of the loss of RET technical efficiency, as well as of the macroeconomic variables (EU country's reference interest rates and inflation). These together with the RNA's loan interest (if it exists) explain the difference in values between LCOE and FYTC (Cost GAP).

The LCOE is estimated with the annual margin before the development and engineering cost depreciation (DEC depreciation). Modern windmills are considered not to lose efficiency because of optimal maintenance works.

The cost gap is the difference between FYTC and LCOE.

Energy Storage System

ENROAD BM incorporates the Energy Storage System configuration (technology and cost). It is activated with the 2.2 Input PRO sheet configuration.

1.5.- Energy Storage System (ESS)

ESS CONFIGURATION PARAMETERS

			* Up to 800 kWh			
		(2 modules pack)	(1 module pack)	(1 module pack)	(2 modules pack)	(1 module pack)
BATTERY TECHNOLOGIES		**BYD LVL 15.4**	**HUAWEI LUNA2000-200**	**CEGASA EBICK 280 pro**	**BYD LVL 15.4**	**HUAWEI LUNA2000-2M**
Cell Material	-	**LFP**	**LFP**	**LFP**	**LFP**	**LFP**
Module(s) nominal capacity	kWh	15,36	16,13	13,44	15,36	16,38
Nominal rated voltage	V	51,20	57,60	48,00	51,20	51,20
Maximum rated current	A	250,00	200,00	175,00	250,00	200,00
Maximum capacity ESS	kWh	983,00	193,50	2000,00	983,00	2064,00
Maximum no. modules	no.	64	12	149	64	126
INVERTER SYSTEM TECHNOLOGIES		**SMA STS 110-60**	**SUN2000 100KTL-M1**	**FRONIUS Tauro D ECO**	**SUN2000 330KTL-H1**	**SMA SCS 3450 UP**
Rated power	kW	110,00	100,00	100,00	300,00	3450,00
Maximum rated current	A	160,00	260,00	175,00	390,00	4750,00
Operating voltage range	V	500-800	200-1000	580-1000	500-1500	880-1500
COST OF TECHNOLOGIES						
Module cost	EUR	8.500,00	9.500,00	8.500,00	8.500,00	9.500,00
Inverter cost	EUR	7.500,00	6.500,00	11.500,00	11.800,00	100.000,00
ESS unit cost	EUR	3.000,00	3.000,00	3.000,00	3.000,00	3.000,00
ESS DEMAND						
NRAs Renewable energy demand for storage			kWh/day	0,00		
NRAs Renewable peak power demand for using energy stored			kW	0,00	Ok	

2.2.- PROJECT DATA BY NRAs

Item	Unit	
Only connected to the grid? *	-	Yes
NRAs general renewable energy demand	kWh/day	8.000
NRAs renewable energy demand for storage	kWh/day	2.500
NRAs renewable peak power demand for using the energy stored	kW	2250
Financing (NRAs equity)	EUR	€ 392.000,00
Government subsidy	EUR	€ 0,00
Period Average HICP	%	4,50%
Debt Interest Rate (fixed)	%	2,20%
Price per square meter	€/m2	0
Project starting year	Year	2011

** 'No' means that energy is sold and partially self-consumed with an ESS based system.*

When the selected option is 'Yes' for "Only connected to the grid?' it means that electricity is sold to the network. So, ESS is not considered.

Environmental impact

ENROAD BM estimates the effect of the installation with the 2 MW turbine parameters, the GHG/MWh, and CO2 annual savings compared with the emissions of natural gas combined cycle (465 kg CO2/MWh).

Estimated environmental impact per 2 MW turbine

Impact category indicator	Unit	For one 2MW turbine	For the total No. of turbines
Global warming	kg CO2 eq	1194091,049	9552728
Ionizing radiation	kBq Co-60 eq	91160,258	729282
Ozone formation, Human health	kg NOx eq	3390,989	27128
Fine particulate matter formation	kg PM2.5 eq	2597,680	20781
Terrestrial ecotoxicity	kg 1,4-DCB	14041314,053	112330512
Freshwater ecotoxicity	kg 1,4-DCB	490923,500	3927388
Marine ecotoxicity	kg 1,4-DCB	614921,406	4919371
Human carcinogenic toxicity	kg 1,4-DCB	425363,527	3402908
Human non-carcinogenic toxicity	kg 1,4-DCB	4062453,311	32499626
Land use	m2a crop eq	90738,247	725906
Mineral resource scarcity	kg Cu eq	36731,168	293849
Fossil resource scarcity	kg oil eq	350707,273	2805658
Water consumption	m3	13283,865	106271

GHG Emissions

Lifespan (operation)	years	25
Number of turbines	-	8
Total Annual Energy Production	MWh/year	65.486,02
Total Energy Production	MWh	1637150,625
GHG / MWh	**kg CO2 eq/MWh**	**5,83**
CO2 Annual Savings *	**Tonne CO2/MWh**	**30068,89**

Case Study: charging station for Evs in Germany

A charging station for electric vehicles (customer-side or demand model) whose implementation strategy consists of offering a number of charging stations with specific agreements for parcel delivery and logistic companies based on vans next to a cafe bar to liven up the waiting times. NRA (or a company on its behalf) builds a charging station in plots located in the motorway network, close to companies that can make use of the charging points at night schedule, with an installation that adds batteries for such schedule. The energy is certified free from GHC.

Location: Connection between the A6 Ludwigshafen-Nord 23 and the B9 highway (Mannheim, Frankfurt)

Aerial view of the site for the energy installation (Source: google maps)

Arrangement of solar PV panels in the parcels selected (ENROAD)

Case Study: charging station for Evs in Germany

Table 1 shows the number of elements calculated by ENROAD for each previously defined parcel and the three eligible renewable energy technologies. The surface area (m2) of these plots is also shown.

Table 1. Units of RETs as calculated by ENROAD for the selected areas

Area	m^2	SW1	SW2	LW1	LW2	PV1	PV2
1	28,577	50	102	1	1	3,648	2,208
2	15,816	29	56	1	1	2,016	1,320
3	13,631	24	49	1	1	1,728	1,080
All	58,024	103	207	3	3	7,392	4,608

SW1: Bornay 6000 (6 kW); SW2: Aeolos-V (3 kW); LW1: Vestas V90 (2MW); LW2: Vestas V112 (3.3MW); PV1: Atersa 330 (330W, Mono); PV2: JA Solar (530W, Mono).

Selected RET: Monocrystalline PV panels (JAM72S30-530/MR)

Number of charging points: 8.

Connected to 7392 modules with 330W maximum power or 4608 modules with 530W maximum power.

Considering the charging of high-end vehicles it is necessary to supply 250 kWp at each of these points, the total peak power required for both potential arrangements would be lower than the 2439 kWp (2442 kWp available).

Starting with a standard of one hour of charging and 32 charging operations per day for this simulation, an energy demand of 8000 kWh per day results in an energy demand of 2920000 kWh per year, for which both technologies are technically adequate. Thus, the ENROAD tool estimates yearly productions of 2855231 kWh and 2233375 kWh, respectively, thereby enabling 11978 and 12233 operations per year, respectively. With an energy price of 0.12 €/kWh, revenues amount to 1,467,279 € and 1,498,538 €, respectively.

Case Study: charging station for Evs in Germany

The recommended renewable energy technology, which in this case turned out to be the Monocrystaline A-330M GS PERC.

The solution provided by the ENROAD tool to this case study confirms its validity to provide a very first approximation to the capacity of renewable energy technologies to generate energy in a selected area.

Financial dashboard

Energy average price 2024-2044	Selected RET
490,00	Monocrystalline A-330M GS PERC
EUR/MWh	-
First Year Total Cost (FYTC)	COST GAP (LCOE - FYTC)
34,37	19,82
EUR/MWh	EUR/MWh
LCOE for selected RET (LCOE)	COST GAP (LCOE - FYTC)/ FYTC
54,18	58%
EUR/MWh	-

Summary

TECHNOLOGIES		Tech_1 HAWT Bornay 6000	Tech_2 Darrieus Aeolos-V 3kW	Tech_3 HWAT V90-2.0 MW	Tech_4 HWAT V112-3.3 MW	Tech_5 Monocrystalline A-330M GS PERC	Tech_6 Monocrystalline JAM72S30-530/MR	Average
		Small Wind	Small Wind	Large Wind	Large Wind	PV	PV	
Payback period	Years	34	34	34	34	2	2	
NPV	EUR	-5.500.239	-3.012.248	-30.306.694	-27.216.636	30.601.465	30.433.323	
IRR	%	negative	negative	negative	negative	97,21%	89,46%	
AARR	%	-8,41%	-8,82%	-1,27%	1,14%	69,43%	63,79%	
Sales for Break-even Point Based on First Year Production	EUR YR	n.d.	142.879,20	1.985.621,72	2.753.532,30	102.910,99	118.290,40	
CO2 Emissions Savings	Ton CO2/KWh year	-	-	2.122	3.603	1.210	1.183	

THANK YOU!

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