ENROAD

Analysis of business models and governance and organizational issues (WP4)

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

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

WP 4: Objectives and tasks

The main objective is to develop a general customer-side renewable energy business model to be adjusted to specific business cases depending on selected variables: NRA interests, technologies and countries' regulatory, environmental, and economic circumstances.

The specific objectives are as follows:

- The design of the general business model is based on considering the associated variables of the different generation technologies.
- To promote the financial and environmental assessment of alternative business model scenarios, based on technical and economic parameters.
- To propose policies and/or recommendations for governments in the business model applications.

Task 4.1.- General description and proposal of the business models for market-price and electricity use analysis

Task 4.2.- General business model design

Task 4.3.- Application of the model

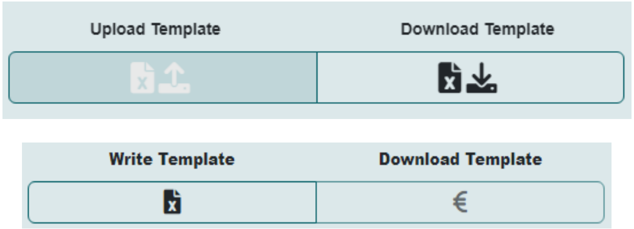
Task 4.4. Contrast study between business models and current regulatory framework barriers

Task 4.5. Proposal of policies and/or recommendations for governments in the business models applications

General description and BM proposal: provision of renewable electricity at a cost-competitive price to NRAs and its third parties:

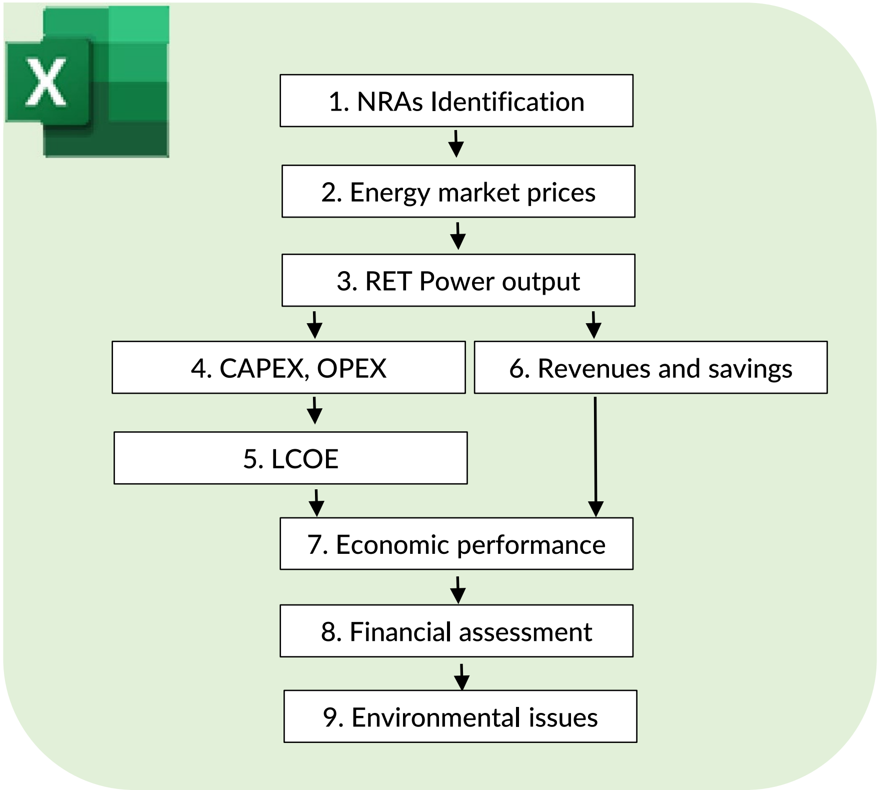
- Analysis of business models based on renewable energies.
- Business model based on the energy demand response.
- Software review of the market's principal renewable energy simulation tools (including economic and financial issues).
- General description of the proposal for the ENROAD's business model.

ENROAD GIS TOOL



The BM general design is linked to WP2 Analysis of renewable energy generation technologies for application in NRA's assets and topologies and WP3 Assessment of applicable legislative and regulatory frameworks, and its outcomes.

- BM is supported by a Microsoft Excel template (file) configured with NRAs identification, and economic and financial parameters (e.g. country interest rate) and uploaded in GIS.
- GIS writes location primary energy data and facility optimization parameters in Excel. This file does calculations as it is opened automatically and generates the outcomes of economic, financial, and environmental assessments.
- The GIS generates one BM's easy-to-use Excel file for each location. Afterward, this file offers multiple simulations and analysis possibilities for RET's advanced users.



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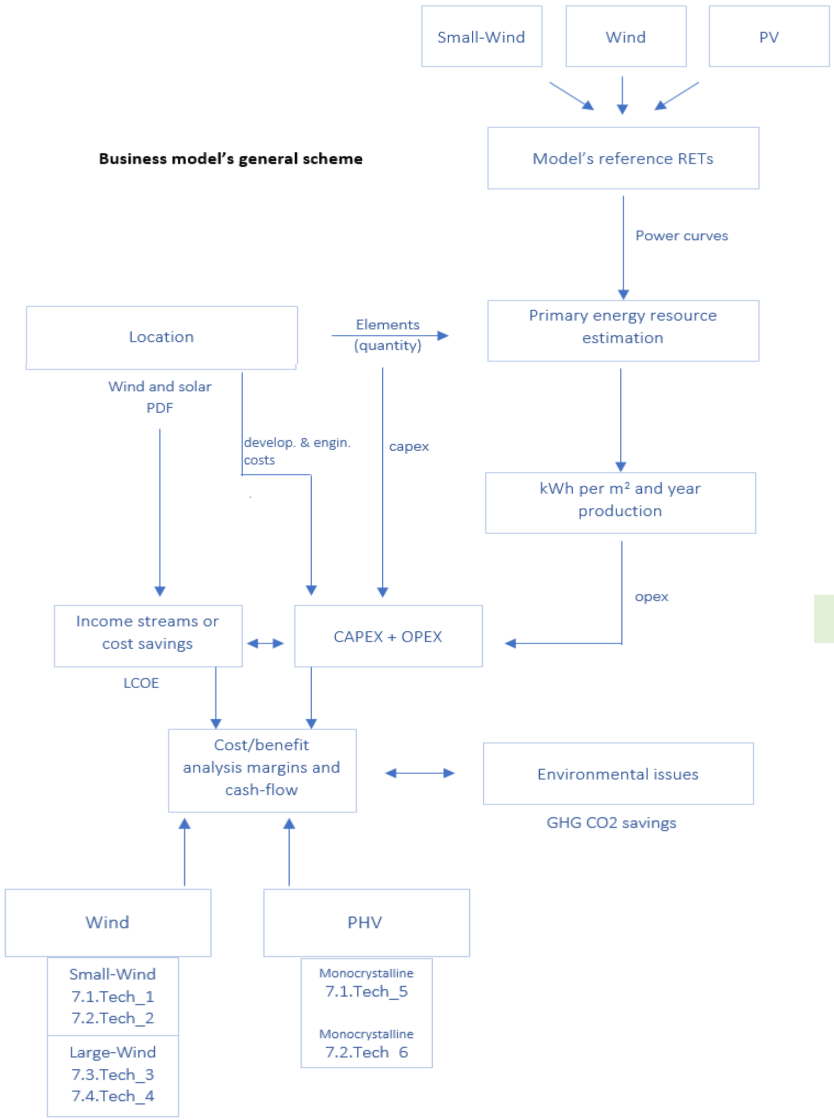

BM double approach:

- Supply model: production and sale of energy to an electric operator.
- Demand model: the needs of energy of the NRA are gathered and the percentage of coverage is estimated (Energy Storage Systems are included).

BM Excel Sheet Codes (Template)

ENROAD TOOL - Developed by the University of Cantabria within the context of the project "Supporting the implementation by NRAs of

Disclaimer: Project Aim and Disclaimer
Summary: Summary of main energy, financial and environmental outcomes
1.1 Config TC: Characteristics of RETs and Wind Power Curves
1.2 Config WNP: Wind Nominal Curves
1.4 Config Prices IR: Forward prices and Interest Rates
1.5 Config ESS: Energy Storage System
2.1 Input Loc: Location as coming from GIS
2.2 Input PRO: Project data required for financial outcomes
3.1 Out Prod&Costs: Main results of energy production and costs
3.2 Out CapEx OpEx: Capital expenditures, operational expenditures and Development & Engineering Costs (DEC)
3.3 Out Margins: Profit, looses and margins
3.4 Out Env: Introductory environmental impact
4.1 Tech 1: Specific data for RET1
4.2 Tech 2: Specific data for RET2
4.3 Tech 3: Specific data for RET3
4.4 Tech 4: Specific data for RET4
4.5 Tech 5: Specific data for RET5
4.6 Tech 6: Specific data for RET6

Deliverable 4.1 Overview of business model

BM design: investment performance (financial/environmental) with revenue streams (cost savings), CAPEX & OPEX, CO_2 savings, etc.

- NRAs model configuration (uses, necessities, and opportunities) in location.
- Acquisition of electricity output from GIS.
- Country market prices (PPA when available).
- Facility investment configuration (including batteries) and cost estimation (CAPEX).
- Facility functioning and cost estimation (OPEX).
- Revenues estimation and cost savings from facility long-term energy production.
- Economic performance: cost/benefit analysis, Levelized Cost of Electricity (LCOE), and an Analytical Profit and Loss statement for each RET are offered.
- Financial assessment: Payback period, Accounting Rate of Return (instead of ROA), Net Present Value (NPV), and Internal Rate of Return (IRR) for each RET are offered.
- Flexibility: a copy of GIS's downloaded MS Excel file can be modified to go forward with analysis and simulations (e.g. ROE, spin-offs, etc.) (be careful not to upload to GIS after that).

Deliverable 4.1 Overview of business model

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Overview of business model: general proposal and description A report containing the model elements and its relations, the revenues and cost list (Tasks 4.1 & 4.2) (UC) (February 8th, 2022)

Deliverable 4.1.
Overview of business model: general proposal and description

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Deliverable 4.1

Overview of business model: general proposal and description

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Deliverable 4.1.
Overview of business model: general proposal and description

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The operation of the BM in the GIS is a multi-stage process based on alternative scenarios that starts with the NRA identification and energy necessities and uses, followed by the collection of energy market prices; the selection of feasible locations in terms of electricity production by technology; the CAPEX and OPEX estimation; the revenues and saving estimation; and the economic performance and financial assessment.

Deliverable 4.1 presents a design of the BM that shows a balance between the accuracy of the results and its ease of use within the GIS based on the Microsoft Excel platform.

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In the last version to date (V26), the GIS/BM use 6 RETs and 4 ESS.

1.1.- Technology Characteristics

TECHNOLOGY		CHARACTERISTICS		SMALL WIND		LARGE WIND		SOLAR ENERGY	
Group	ID	Item	Unit	Small Wind HAWT Bornay 6000	Small Wind Darrieus Aeolos-V 3kW	Large Wind HWAT V90-2.0 MW	Large Wind HWAT V112-3.3 MW	PV Monocrystalline A-330M GS PERC	PV Monocrystalline JAM72S30-530/MR
				HWAT	DARRIEUS	HWAT	HWAT	Monocrystalline	Monocrystalline
				Bornay 6000	Aeolos-V 3kW	V90-2.0 MW	V112-3.3 MW	A-330M GS PERC	JAM72S30-530
				BORNAY	Lotus Energy Tech	VESTAS	VESTAS	ATERSA	JA SOLAR
WIND TURBINE	GENERAL	Nominal Power	kW	6,0	3,0	2000	3300	-	-
		Peak Power	kW	6,2	3,8	2000	3300	-	-
		Rotor Diameter	m	4,0	2,8	90	112	-	-
		Rotor Height	m	-	3,6	-	-	-	-
		Nominal Wind Speed	m/s	12,0	11,0	11,5	14,0	-	-
		Cut-in Wind speed	m/s	3,5	2,5	4,0	2,5	-	-
		Cut-out Wind speed	m/s	20,0	20,0	25,0	25,0	-	-
		Survival wind speed	m/s	60,0	52,5	-	-	-	-
		Weight (excl. Tower)	kg	107	106	104000	138000	-	-
		Expected lifetime	years	20	20	30	30	30	30
PV MODULE	GENERAL	Number of cells	no.	-	-	-	-	60	144
		Module Length	mm	-	-	-	-	1640	2278
		Module Width	mm	-	-	-	-	992	1134
		Module Thickness	mm	-	-	-	-	35	30
		Module Weight	kg	-	-	-	-	17,5	27,8
		Maximum Power (at STC)	W	-	-	-	-	330	530
		Module Efficiency	%	-	-	-	-	19,78	20,50
		Maximum Power (at NOCT)	W	-	-	-	-	279	401

1.5.- Energy Storage System (ESS)

ESS CONFIGURATION PARAMETERS

Up to 800 kWh

BATTERY TECHNOLOGIES		(2 modules pack) BYD LVL 15.4	(1 module pack) HUAWEI LUNA2000-200	(1 module pack) CEGASA EBICK 280 pro	(2 modules pack) BYD LVL 15.4	(1 module pack) 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

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3.2.- CAPEX, OPEX & DEC

CAPital Expenditures - Investments

Facility Investments		Small Wind HAWT Bornay 6000	Small Wind Darrieus Aeolos-V 3kW	Large Wind HWAT V90-2.0 MW	Large Wind HWAT V112-3.3 MW	PV Monocrystalline A-330M GS PERC	PV Monocrystalline JAM72S30-530/MR
Power sources	EUR	7.320.000,00	7.565.000,00	6.400.000,00	4.200.000,00	25.522.667,87	21.460.946,07
Structures	EUR	1.830.000,00	3.631.200,00	824.000,00	540.000,00	0,00	0,00
Inverters/Converters	EUR	1.390.800,00	1.815.600,00	1.080.000,00	750.000,00	0,00	0,00
Transformers	EUR	2.108.160,00	2.602.360,00	1.660.800,00	1.098.000,00	5.104.533,57	4.292.189,21
Land & building constructions	EUR	2.579,87	2.393,69	1.840.720,00	1.598.520,00	263.611,93	266.773,89
Grid connection	EUR	10.666,16	10.030,85	44.265,61	38.912,89	202.618,13	204.962,41
Batteries	EUR	488.900,00	488.900,00	488.900,00	488.900,00	488.900,00	488.900,00
Government subsidies	EUR	-500.000,00	-500.000,00	-500.000,00	-500.000,00	-500.000,00	-500.000,00
Total CAPEX	EUR	12.651.106,03	15.615.484,54	11.838.685,61	8.214.332,89	31.082.331,51	26.213.771,59
Years	Years	20	20	30	30	30	30
Annualized CAPEX (Facility depreciation)	EUR	633.110,30	781.329,23	394.992,85	274.181,10	1.036.447,72	874.162,39
End-of-cycle depreciation and dismantling	EUR	328.777,65	402.887,11	308.467,14	217.858,32	63.164,66	53.427,54
Annualized EoC (Dismantling depreciation)	EUR	16.438,88	20.144,36	10.282,24	7.261,94	2.105,49	1.780,92

OPerational Expenditures

Annual Costs		HAWT Bornay 6000	Darrieus Aeolos-V 3kW	HWAT V90-2.0 MW	HWAT V112-3.3 MW	Monocrystalline A-330M GS PERC	Monocrystalline JAM72S30-530/MR
Manpower	EUR	48.440,00	48.440,00	0,00	0,00	83.000,00	82.500,07
Land lease	EUR	0,00	0,00	0,00	0,00	0,00	0,00
Maintenance	EUR	3.611,82	3.351,17	73.628,80	63.940,80	279.466,41	284.314,03
Insurances	EUR	91.500,00	111.962,00	223.516,00	194.106,00	131.805,97	133.386,94
Communications	EUR	2.000,00	2.000,00	31.555,20	27.403,20	31.633,43	32.012,87
Security	EUR	3.000,00	3.000,00	42.073,60	36.537,60	42.177,91	42.683,82
Monitoring	EUR	5.000,00	5.000,00	10.518,40	9.134,40	10.544,48	10.670,96
Energy purchased	EUR						
Other general and administrative costs	EUR	2.000,00	2.000,00	21.036,80	18.268,80	21.088,95	21.341,91
Interest	EUR	349.803,68	441.728,74	334.225,36	220.701,37	933.014,18	783.308,16
Total OPEX	EUR	505.355,50	617.481,91	736.554,16	570.092,17	1.532.731,32	1.390.218,76

CAPEX and OPEX estimation: initial investment and investment scaling (modules, structures, connections, transformers, inverters, BOS, batteries, and financing) and annual operation costs (manpower, maintenance, insurance, communications, security, monitoring, etc.).

The total sum of both expenditures per MWh levelized per year (LCOE) and the total cost of the first year per MWh (FYTC) will be considered as the reference for each technology configuration and technical life-cycle of the facility.

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RESULTS FOR THE DIFFERENT 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	
Number of turbines/modules	No.	754	1.517	4	2	115.440	72.744	
Total Annual Energy Production	MWh year	1.051,0	369,2	15.589,6	16.149,9	76.959,7	59.184,1	
Energy Production per m2	kWh/m2 year	2,10	0,74	31,17	32,29	153,88	118,34	
Covered demand for energy	%	32%	11%	475%	492%	2343%	1802%	
Total installed peak capacity	MWp	1,5	1,4	7,6	6,6	38,1	38,6	
Yearly efficiency looses	%	0,00%	0,00%	0,00%	0,00%	0,30%	0,30%	
First Year Total Cost (FYTC)	EUR/MWh	1.098,81	3.842,95	73,58	53,05	33,44	38,33	856,69
LCOE	EUR/MWh	1.238,90	4.310,50	91,99	67,75	41,75	48,42	966,55
LCOE's best technology (LCOE)	EUR/MWh					41,75		
Starting total Investment	EUR	12.651.106	15.615.485	11.838.686	8.214.333	31.082.332	26.213.772	17.602.619
Total Energy Revenues	EUR	1.456.386	511.633	30.751.567	31.856.893	145.624.490	111.989.163	53.698.355
Project Duration (and loan repayment)	Years	20	20	30	30	30	30	
Debt (bank loan) over Investment	EUR	12.492.988,63	15.776.026,48	11.936.619,93	7.882.191,71	33.321.934,88	27.975.291,56	18.230.842,20
Payback period	Years	34	34	34	34	10	14	
NPV	EUR	-26.759.146	-34.011.113	-15.171.102	-5.203.302	15.565.132	3.013.916	
IRR	%	negative	negative	negative	negative	7,60%	4,37%	
AARR	%	-7,46%	-7,75%	-1,74%	1,15%	7,53%	5,55%	
Sales for Break-even Point Based on First Year Production	EUR YR	1.154.904,68	1.418.955,50	1.147.019,25	856.725,21	2.573.591,20	2.268.468,73	
CO2 Emissions Savings	Tonne CO2/kWh year	-	-	7.090	7.363	32.924	24.624	

For a potential location and load demand, based on a cost and benefit analysis, the business model analytical application will determine different financial and environmental scores, so scenery assessment and technology proposal should be indexed and reported.

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).

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Methodology for the economic and financial assessment. A spreadsheet-based model and several applications. (Task 4.3) (UC) (October 27th, 2022)

Deliverable 4.2.
Methodology for the economic and financial assessment

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Supporting the implementation by NRAs of renewable energy technologies in the road infrastructure

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Deliverable 4.2

Methodology for the economic and financial assessment

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Deliverable 4.2.
Methodology for the economic and financial assessment

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A financial dashboard is provided with these four Key Performance Indicators (KPIs)

Energy average price 2024-2044	Recommended RET
70,98	**Monocrystalline A-330M GS PERC**
EUR/MWh	-
First Year Total Cost (FYTC)	COST GAP (LCOE - FYTC)
33,44	**8,31**
EUR/MWh	EUR/MWh
LCOE for selected RET (LCOE)	COST GAP (LCOE - FYTC)/ FYTC
41,75	**25%**
EUR/MWh	-

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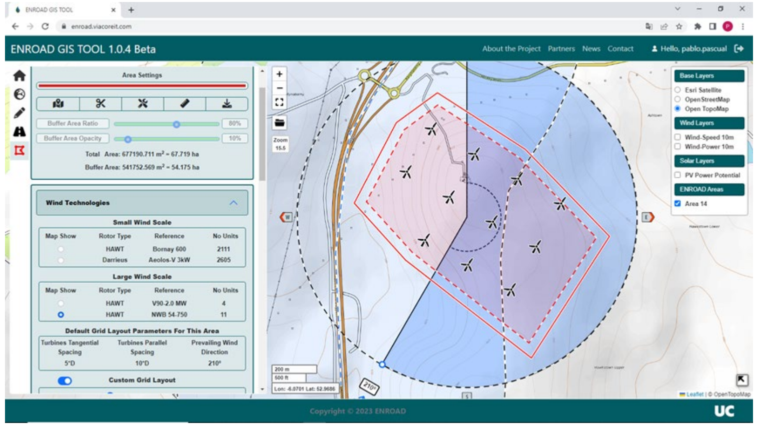
Model validation: BM application for a potential location (load demand), technologies, and social and environmental issues. Selection of representative cases (BMs) for typical locations and techs.

- General case configuration: canvas and description; technical parameters and country's energy forward prices; road selection; area selection and configuration; economic and financial assessment; preliminary environmental assessment; summary analysis; and, conclusions.
- Case 1. Wind energy production and sale in Ireland.
- Case 2. Highway tunnel services with PV in Belgium.
- Case 3. PV Electric car charging station in Germany.

Deliverable 4.4 Model application and general conclusions

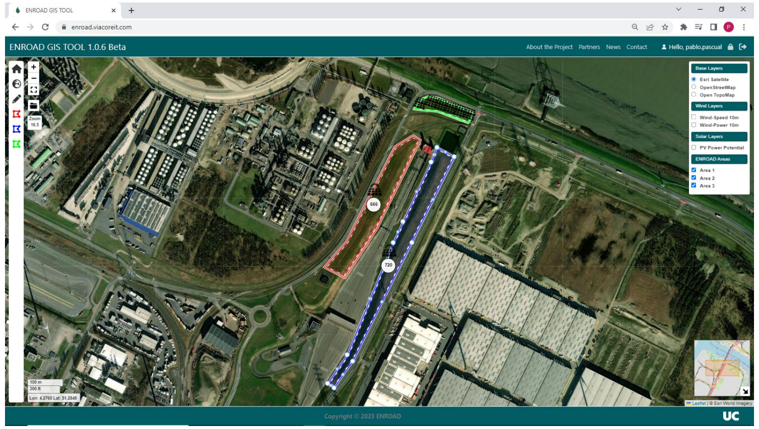
For a potential location and load demand, based on a cost and benefit analysis, the business model analytical application will determine different financial and environmental scores, so scenery assessment and technology proposal should be indexed and reported.

Case 1: Energy production and sale in Ireland



Energy average price 2023-2057	Selected RET
50,72	Polycrystalline LX-330P/156-72+
EUR/MWh	-
First Year Total Cost (FYTC)	COST GAP (LCOE - FYTC)
36,64	21,08
EUR/MWh	EUR/MWh
LCOE for selected RET (LCOE)	COST GAP (LCOE - FYTC)/ FYTC
57,72	58%
EUR/MWh	

Case 2: Tunnel services in Belgium



Energy average price 2023-2057	Selected RET
103,48	Polycrystalline LX-330P/156-72+
EUR/MWh	-
First Year Total Cost (FYTC)	COST GAP (LCOE - FYTC)
130,07	51,89
EUR/MWh	EUR/MWh
LCOE for selected RET (LCOE)	COST GAP (LCOE - FYTC)/ FYTC
181,96	40%
EUR/MWh	

Case 3: Electric car charging station in Germany

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	-

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Model application and general conclusions. A report with the general conclusions based on a if-then analysis. (task 4.5) (UC) (May 17th, 2023)

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Deliverable 4.4

Model application and general conclusions

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All the cases are based on the same model structure which had been adapted in economic terms by taking into consideration the EU countries' labour cost levels (compensation of employees plus taxes minus subsidies) in industry, construction, and services (except public administration, defense, and compulsory social security). We made each case with reference to the Spanish costs investments and costs and for the selected countries weighted them with the EUROSTAT's labour cost index (LCI) in 2021. Table 1 offers the weight values for ENROADs countries.

	2021		WEIGHT
Belgium	41,6		1,82
Denmark	46,9		2,05
Germany	37,2		1,62
Ireland	33,5		1,46
Spain	22,9		1,00
Netherlands	38,3		1,67
Austria	37,5	p	1,64
Sweden	39,7		1,73
Norway	51,1		2,23
United Kingdom	29,80	Est	1,3

Table 1. LCI based cost weights for ENROAD countries (Spain based).

Proposals of policies and/or recommendations:

- Case analysis offers insight into economic, financial, and environmental issues depending on geographical locations and RETs.
- Recommendations include surplus energy sales, battery configuration for storage, and their economic effects.
- ENROAD's flexibility, based on an Excel file, offers multiple options for configuring solutions and scenarios of decisions.

ENROAD

THANK YOU!

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