Application of ENROAD Tool for Pre-feasibility Evaluation of Renewable Energy Projects Within the Road Environment

Eugenio Sáinz-Ortiz[1](✉), Francisco M. Somohano-Rodríguez[2], Pablo Pascual-Muñoz[3], Alberto Arroyo[1], Rene Barrera-Cardenas[4], and Hrefna Run Vignisdottir[5]

[1] GTEA Research Group, University of Cantabria, Santander, Spain
ugenio.sainz@unican.es
[2] Cátedra PYME, University of Cantabria, Santander, Spain
[3] GITECO Research Group, University of Cantabria, Santander, Spain
pascualmp@unican.es
[4] SINTEF Energy Research, Trondheim, Norway
[5] SINTEF Community, Trondheim, Norway

Abstract. Roads are vital infrastructures for the mobility of people, transport of goods and, in general, for every country's economic development. On the other hand, roads have a significant impact on the environment throughout their life cycle. Thus, GHG emissions from the transport sector in the EU have substantially grown in the last few years, unlike other sectors like energy or manufacturing industries, which managed to greatly reduce their GHG emissions.

Several solutions are currently in place to minimize the environmental impact of roads, such as the use of more sustainable materials, the use of biofuels by vehicles, the promotion of cycling and public transport, or the electrification of roads. The use of renewable energies, such as solar and wind energy, should also be considered to power road infrastructures and services such as lighting, signaling or even electric vehicle charging stations.

A case study is presented here for application with ENROAD, a web-based, open source, road-focused tool for decision making at a very early stage of investments in renewable energy projects. The solution provided shows the potential use of a specific site to cover the energy needs of a road infrastructure, also allowing the comparison between different generation alternatives.

Keywords: Roads · Emissions · GIS · Renewable energy · Solar · Wind

1 Introduction

It is very well known that road infrastructures are crucial for the social and economic prosperity of countries and citizens. Road networks not only ensure access to key public services, such as education and health, thereby contributing to people's quality of life, but their expansion has the potential to increase countries' GDP and employment rates.

C. McNally et al. (Eds.): TRAconference 2024, LNMOB, pp. 680–686, 2025.
https://doi.org/10.1007/978-3-031-89444-2_98

Hence, there is a need to build roads to help connect people and goods. On the other hand, investment in transport infrastructure represents: a considerable share of countries' GDP, a larger share of public investment, and a significant environmental impact associated with its entire life cycle.

In the last three decades, GHG emissions from the transport sector in the EU have grown by more than 30%, in contrast to other sectors that managed to reduce them considerably [2, 3]. The European Climate Law sets the goal of a climate-neutral EU by 2050 and sets a net reduction of GHG emissions of at least 55% compared to 1990 by 2030 [4]. Likewise, the European Green Deal [5] claims that a 90% reduction in GHG emissions from transport is required by 2050 to achieve that climate neutrality.

Considering that in 2020 the share of energy from renewable sources in the EU transport was only 10.2%, mainly due to the increased use of biofuels in Europe over the last years [6], it seems that there is still a long way to go for renewables to make a significant contribution to mitigating the environmental impact of roads.

In the context of this situation, the ENROAD project, funded by different National Road Administrations in the framework of the CEDR (Conference of European Road Directors) Research Call 2019 [7], aims to provide a pre-feasibility evaluation tool for renewable energy projects within the road asset with a technical, financial and environmental approach.

2 The ENROAD GIS-Based Tool: Framework and Particularities

General outcomes of the ENROAD project have been: the assessment and modelling of renewable solutions for potential implementation alongside the road asset; practical explanation of legislative framework across the evaluated countries regarding the generation and distribution of RE; definition of effective business model and cases for economic and financial assessment based on the technology and facility individually considered; and finally, the development of an easy-to-use tool aimed at providing a preliminary assessment NRAs assets' potential for the renewable power generation.

To comply with this pre-feasibility evaluation, the GIS tool has been designed to provide: an estimation of power and potential energy generation in a specific site; a financial pre-feasibility study of the renewable energy installation; a preliminary environmental assessment mainly associated with the core technology. It should be noted that this tool is intended to help NRAs in their decision-making process, but in no case can it be taken as a design software nor can it be used as a substitute for the professional advice that is mandatory when dealing with this type of project investments.

The solutions provided by the ENROAD tool are all based on the potential location of the energy technology that is planned to be installed. For this reason, a GIS system is needed to run behind the tool that is able to deal with the information contained in the different geodatabases used, most importantly the energy databases. End users can upload their own geodatabases, such as parcels, grid connection points, etc., to add precision in finding the most suitable location.

The ENROAD tool is built up of two elements: (1) the GIS-based tool itself, a web service that makes use of certain input data and allows the user to select site and area for different energy technologies, and estimates the total capacity (number of units, MW) of the new renewable energy installation; (2) a Microsoft Excel template that has to be uploaded into the tool, where inputs and outcomes such as the annual energy generation (kWh) or the whole package of financial and environmental indicators, are displayed in the form of a complete study case for the area selected. The user decides the amount and complexity of input data that is introduced: from basic location, area, available financing or starting year of investment to the more specific energy demand for storage, inflation rate or OPEX standards.

In order to facilitate upgrading and maintenance to a certain extent, users with certain knowledge and access to technical data can modify the parameters of each of the 6 technologies initially incorporated into the tool (two small wind turbines, two large wind turbines and two types of PV panel), and even replace each of the technologies.

3 Application of the ENROAD Tool to a Case Study

As part of the ENROAD project, three study -business- cases were carried out using the ENROAD GIS-based tool, one of which was a charging station for EVs (customer-side or demand model) in Germany. The roll-out strategy was to offer a series of charging stations with specific agreements for parcel and logistics companies. In other words, the NRA (or a company on its behalf) builds a charging station in plots located next to the highway network, close to companies that can make use of those charging points at night schedule, with the installation including batteries for such schedule.

For the selection of the site, three requirements had to be met: (1) a good productivity in terms of primary energy; (2) an adequate level of traffic to help maintain a good level of use of the facilities to achieve the level of profitability; and, (3) the plot, which was assumed to be owned by the NRA, would increase in value with the new use. In this context, the ENROAD tool was used to find the area to place the renewable energy facility for energy generation, define the number of panels and turbines that can be displayed in that area, calculate the energy generated and provide a preliminary financial end environmental assessment.

For the simulation, users are encouraged to enter updated values of financial inputs such as the forward prices or the annual interest rates in the template. With regards to the charging prices at stations in Germany, 490.00 €/MWh seemed a feasible price on the basis of own market tracking, while the market price of the electricity considered was 122.71 €/MWh[1].

With both wind and solar PV primary energy in mind (the ENROAD tool provides the user the site's wind and PV power potential), and with the information gathered in the BAST website [8], the connection between the A6 Ludwigshafen-Nord 23 and the B9 highway (Mannheim, Frankfurt) was selected as a good site to install solar PV panels, due to the impracticability of using large wind on this spot (small wind was previously discarded). Three available parcels were therefore selected and their areas were entered

[1] Energy spot price in Germany in october 11th 2023.

into the ENROAD tool. Figure 2 shows site, number and arrangement of one of the types of Monocrystalline PV panels, as calculated by the ENROAD tool for those areas (Fig. 1).

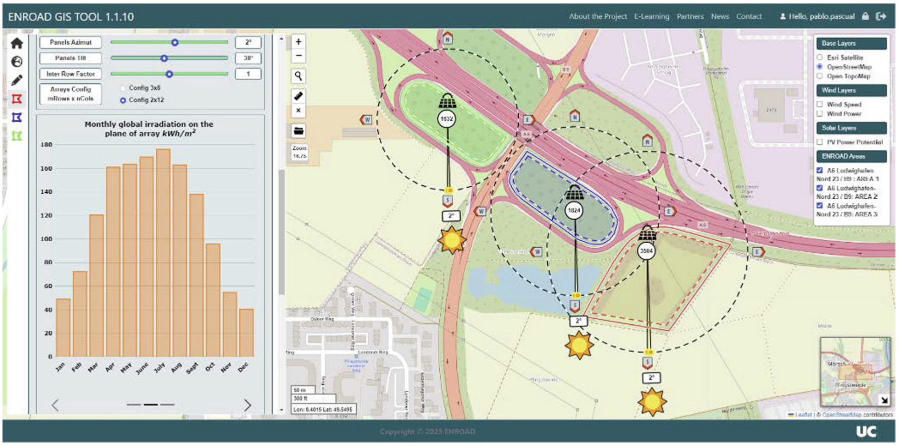

Fig. 1. Arrangement of solar PV panels in the parcels selected (ENROAD). Source: Authors

Table 1 shows the number of elements calculated by ENROAD for each previously defined parcel and the six eligible renewable energy technologies. The surface areas (m2) of these plots are 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	3,504	2,208
2	15,816	29	56	1	1	1,824	1,320
3	13,631	24	49	1	1	1,632	1,080
All	58,024	103	207	3	3	6,960	4,608

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

Having decided on PV as the most suitable energy source, the charging station was designed to have an initial charging capacity given by 8 charging points connected to 6,960 modules with 330 W maximum power or 4,608 modules with 530 W maximum power. On the other hand, if electric charging of high-end vehicles is considered, each of those charging points should be able to supply 250 kWp. In that case, the total peak power required for the two potential arrangements (2,000 kWp) would be lower than the 2,296 kWp and 2,442 kWp available.

In terms of the energy production in the area selected, the ENROAD tool estimates yearly values of 2,418,727 kWh and 2,570,891 kWh for the two technologies. Based on the standard of one hour of recharge point occupancy per vehicle, a total of 9,675 and 10,283 operations per year would be possible, i.e. 26 and 28 operations per day, and annual energy demands of 2,372,500 kWh and 2,555,000 kWh would be required. With an energy price of 0.490 €/kWh, revenues would amount to 1,185,176 € and 1,259,736 €, respectively.

As a first and fast approach to the capacity and performance of the PV system, the ENROAD tool generates a financial dashboard with four key performance indicators (KPIs) for the recommended renewable energy technology (Fig. 2), which in this case turned out to be Monocrystalline JA Solar 330W (the use of wind turbines was technically discarded for their proximity to the highway). This dashboard explains the effect of the RET's yearly efficiency losses; the inflation rate (Harmonized Index of Consumer Prices); the debt interests; and the financial market interest rate for financial discounts, over the installation operative life, comparing the cost of the starting year with the Levelized Cost of the Energy (LCOE) effectively produced.

Energy average price 2024-2044	Recommended RET
490.00	**Monocrystalline JAM60S10-330/PR**
EUR/MWh	-
First Year Total Cost (FYTC)	COST GAP (LCOE - FYTC)
41.14	**56.88**
EUR/MWh	EUR/MWh
LCOE for selected RET (LCOE)	COST GAP (LCOE - FYTC)/ FYTC
98.02	**138%**
EUR/MWh	-

Fig. 2. LCOE Dashboard generated by the ENROAD tool. Source: Authors

In addition to the dashboard, a selection of financial indicators for the 6 technologies in the ENROAD tool are presented in the Summary sheet of the template that includes starting total investment, Net Present Value, Internal Return Rate, Accrual Accounting Return Rate, sales for break-even point and CO2 emissions savings. In Fig. 3, the values of these indicators only for the PV technologies are shown. The solar PV systems seems to generate good financial returns as a starting point for the elaboration of a business plan with own CAPEX and OPEX for the EV charging station.

If instead of a price of 490.00 €/MWh, a reference market price of 122.71 €/MWh is adopted to simulate the sale of energy to the grid (supply-side model), more moderate results would be obtained, but still adequate for the financial investment (Fig. 4).

RESULTS FOR THE DIFFERENT TECHNOLOGIES		Tech_5 Monocrystalline JAM60S10-330/PR	Tech_6 Monocrystalline JAM72S30-530/MR
Payback period	Years	3	3
NPV	EUR	16,772,212	18,830,669
IRR	%	35.76%	44.38%
AARR	%	112.06%	136.93%
Sales for Break-even Point Based on First Year Production	EUR YR	99,513.88	90,127.29
CO2 Emissions Savings	Tonne CO2/kWh year	952	1,012

Fig. 3. Some of the financial indicators delivered by the ENROAD tool. Source: Authors

RESULTS FOR THE DIFFERENT TECHNOLOGIES		Tech_5 Monocrystalline JAM60S10-330/PR	Tech_6 Monocrystalline JAM72S30-530/MR
NPV	EUR	96,716	1,106,103
IRR	%	3.34%	6.34%
AARR	%	20.96%	26.84%

Fig. 4. Financial indicators delivered by ENROAD for a supply-side model. Source: Authors

4 Conclusions

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.

Acknowledgements. The work carried out has received funding from the CEDR Transnational Road Research Programme - Call 2019: Renewable Energy in Road, "Supporting the implementation by NRAs of renewable energy technologies in the road infrastructure".

References

1. Adler, M., et al.: Roads, market access and regional economic development. OECD Regional Development Papers, No. 06, OECD Publishing, Paris (2020). https://doi.org/10.1787/8b9eca17-en. ISSN: 27094065
2. Masterson, V.: The EU has cut greenhouse gas emissions in every sector - except this one. The World Economic Forum (2022). https://www.weforum.org/agenda/2022/09/eu-greenhouse-gas-emissions-transport/
3. Eurostat: Greenhouse gas emissions falling in most source sectors. Eurostat News articles (2022). https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/ddn-20220823-1
4. EU: European climate law (2021). http://data.europa.eu/eli/reg/2021/1119/oj
5. EU: The transport and mobility sector (2020). https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/transport-and-green-deal_en

6. EEA: Decarbonising road transport — the role of vehicles, fuels and transport demand. Transport and environment report 2021. European Environmental Agency (2022). https://www.eea.europa.eu/publications/transport-and-environment-report-2021/download
7. CEDR: Call 2019 Renewable Energy in Road Infrastructure. https://cedr.eu/peb-call-2019-renewabl-energy
8. BASt: Forschungseinrichtung im Ressort des Bundesverkehrsministeriums (2022). https://www.bast.de/DE/Verkehrstechnik/Fachthemen/v2-verkehrszaehlung/zaehl_node.html