# ENROAD GIS-based TOOL

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

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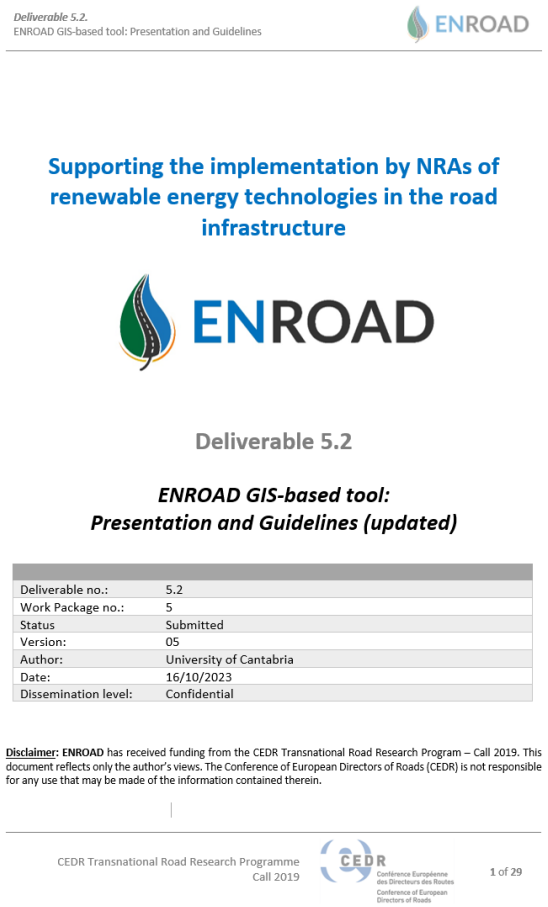

*Deliverable 5.2.*
ENROAD GIS-based tool: Presentation and Guidelines

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

Deliverable 5.2

***ENROAD GIS-based tool: Presentation and Guidelines (updated)***

| | |
|---|---|
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CEDR Transnational Road Research Programme
Call 2019

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* Also Deliverable 6.2

## AIM & CONTEXT

- The ENROAD tool is aimed at providing the NRAs with an easy to use tool for the pre-feasibility evaluation of renewable energy projects within the road infrastructure. Therefore, it has been carefully designed in order to become a user friendly tool and at the same time provide:
  - A preliminary estimation of power and potential energy generation in a specific location;
  - A financial pre-feasibility study of the renewable energy installation
  - A preliminary environmental impact assessment mainly associated with the core technology.
- The solution to an initially proposed study case shows the potential utilization of a specific location to fulfil the energy requirements of a road infrastructure, also allowing the comparison between different renewable generation alternatives.

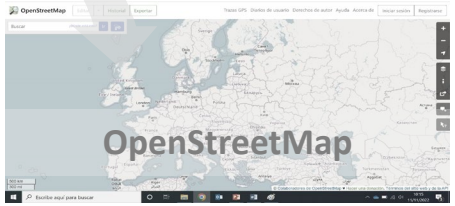
** Note: this tool is intended to help NRAs in their decision-making process, but in no case can it be taken as a design software nor can it be used as a substitute for the professional advice that is mandatory when dealing with this type of project investments.*

# ENROAD GIS-based TOOL

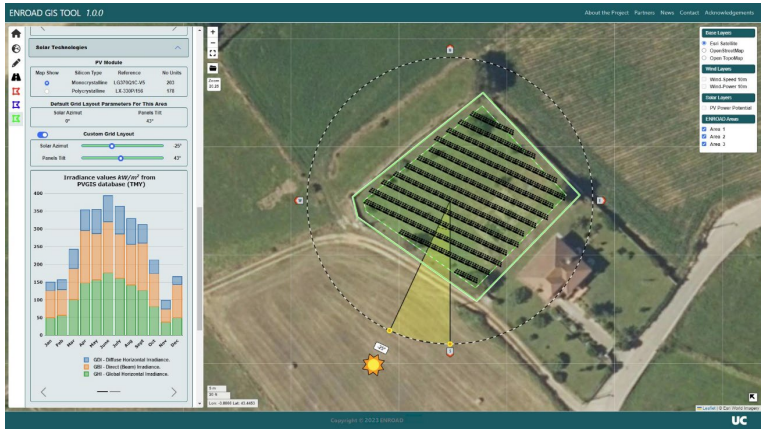
## AIM & CONTEXT

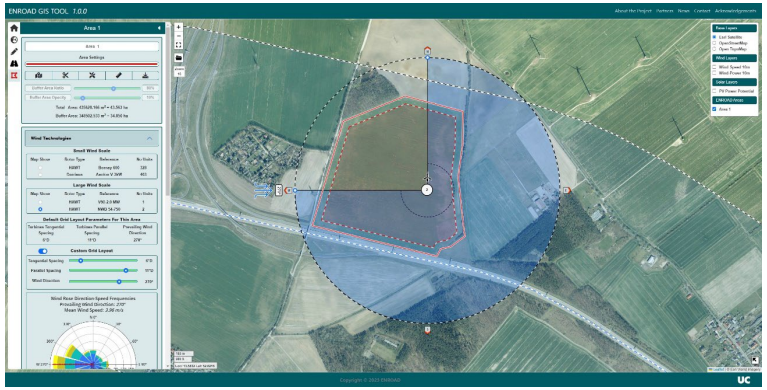
- Country
  - ✓Road
    - Area
      - No. Elements

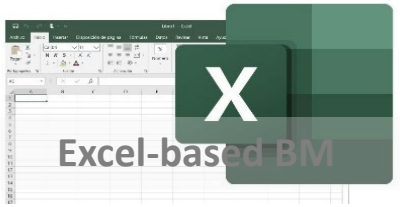
**INPUT DATA**

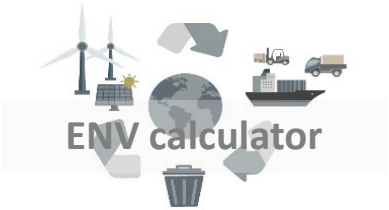








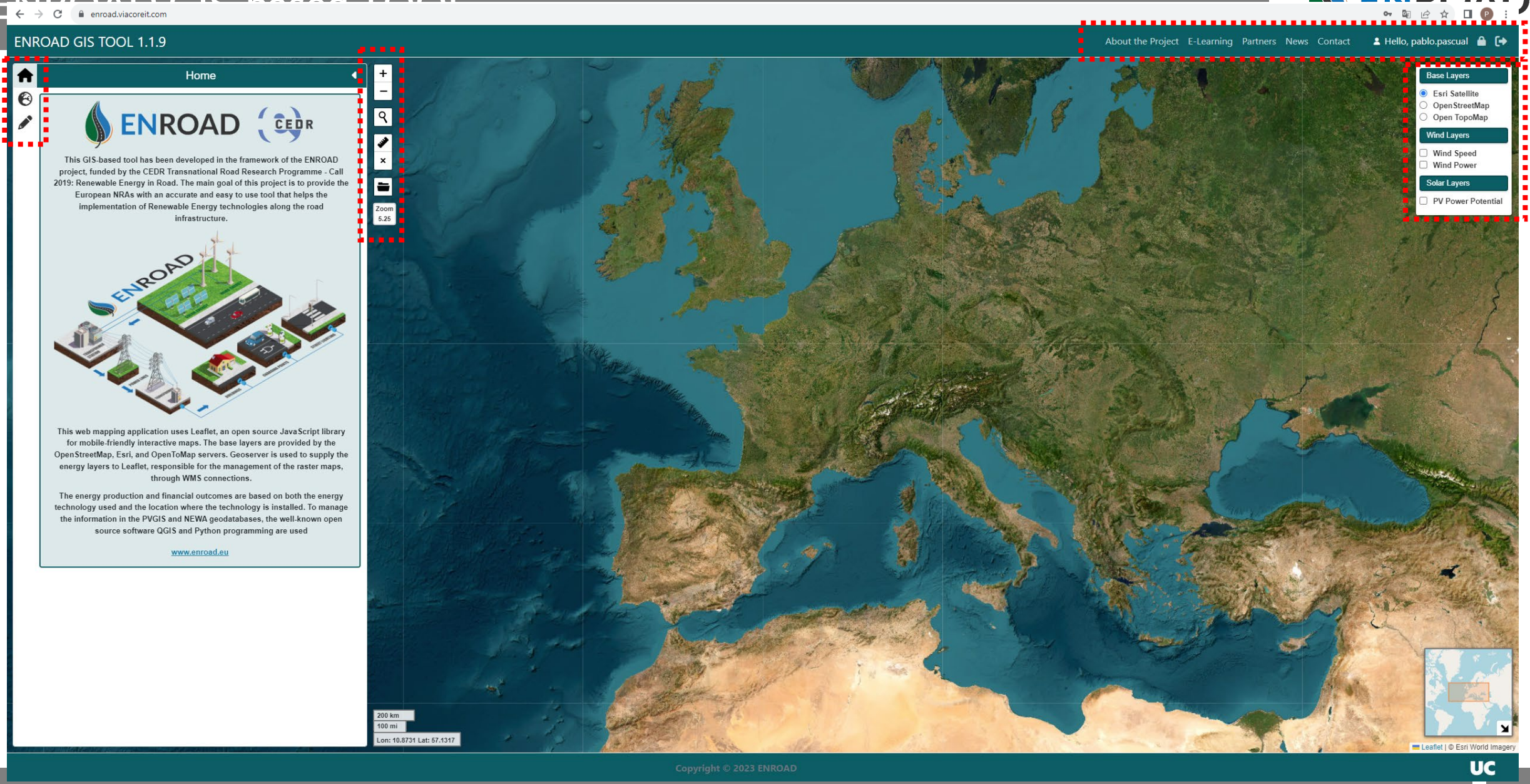

**OUTCOMES**

- Energy generated
- Financial assessment
- Environmental impact

## Main features of the ENROAD GIS-based tool

- GIS-based tool:
  - Solutions provided by the tool are based on the location of the renewable energy technology (RET).
  - Interaction with the different geodatabases, most importantly the energy databases.
  - End users are allowed to upload their own geodatabases for a more precise selection of the location.
- QGIS software: meets all required functionalities for ENROAD tool including good connection to Python.
- Web Map Service
  - WMS allow dynamic consultation of cartographic information generated from one or several sources.
  - Geoserver, an open source server for sharing geodata, is used to supply the energy layers to Leaflet, an open source library responsible for the management of the raster maps.
  - End user simply clicks on a link or enters a web site (no need of complex installations or configuration).

# ENROAD GIS based TOOL



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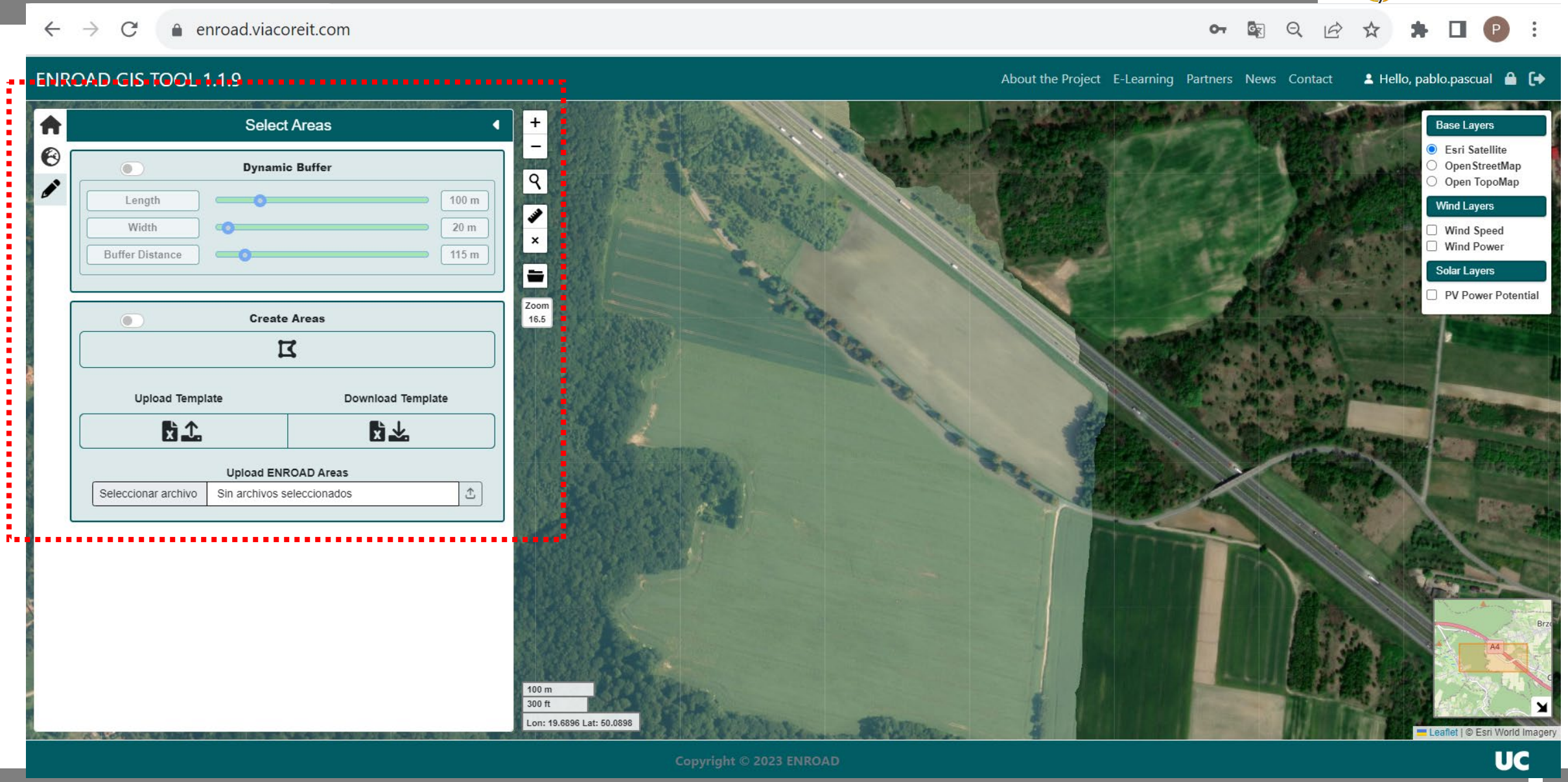

## Main features of the ENROAD GIS-based tool

- Oriented to road-related users:
  - Aimed at fostering the use of RETs along the road network and the NRAs lands.
  - User friendly.
  - Different free open-source databases incorporated to the tool to help the user with the location.
  - Tools included that help the user to find a place (city), measure distances or set buffer distances.

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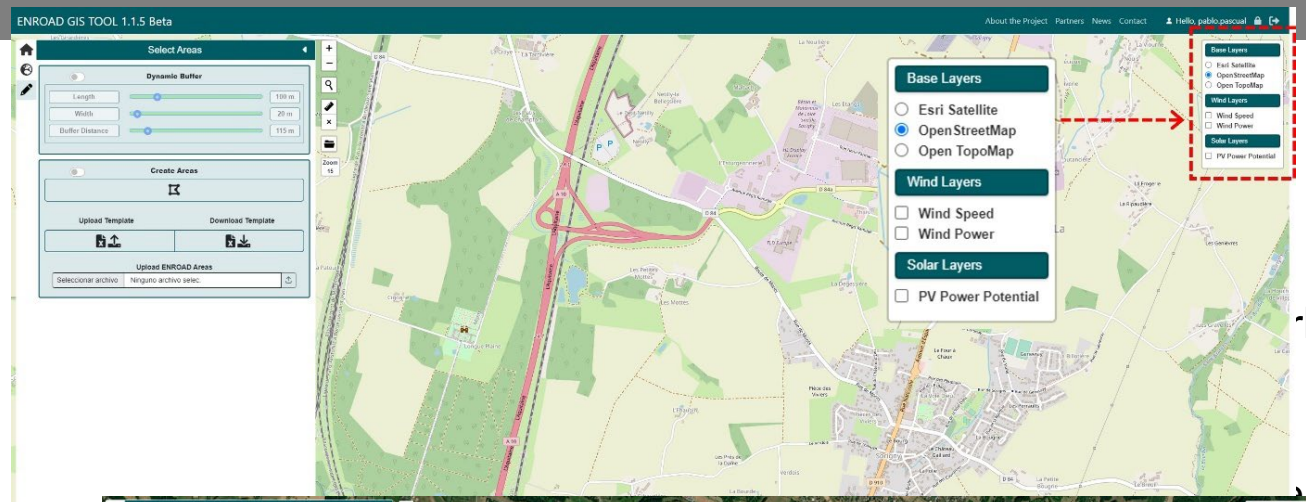
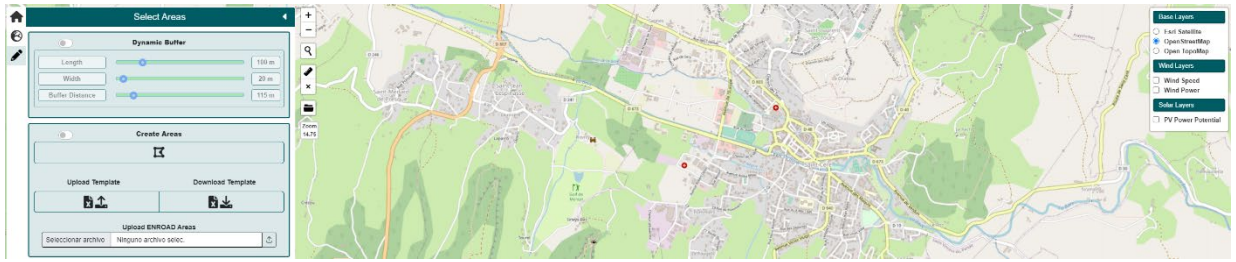
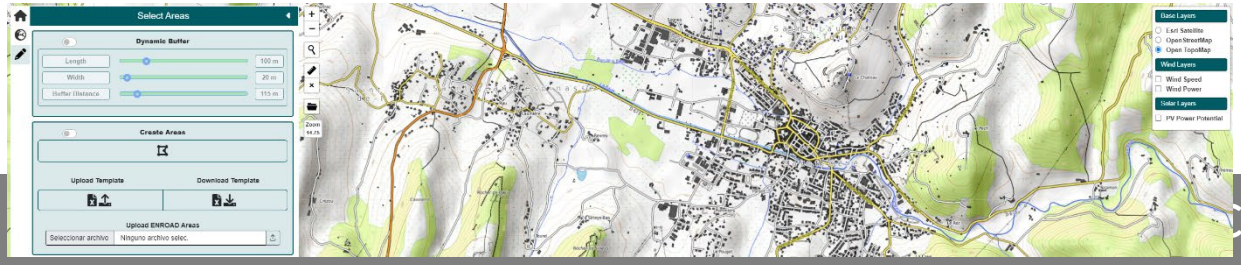
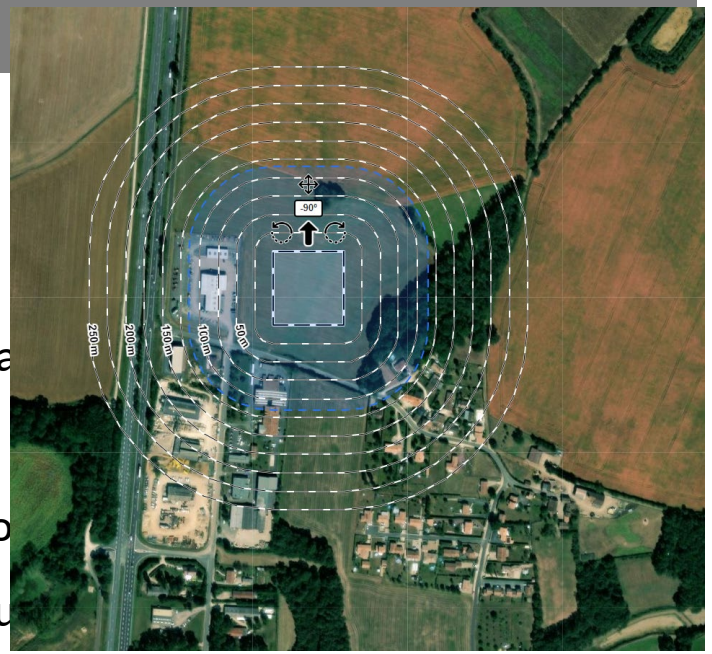
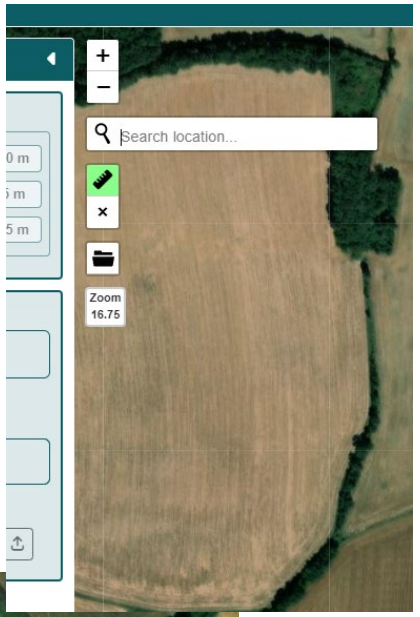






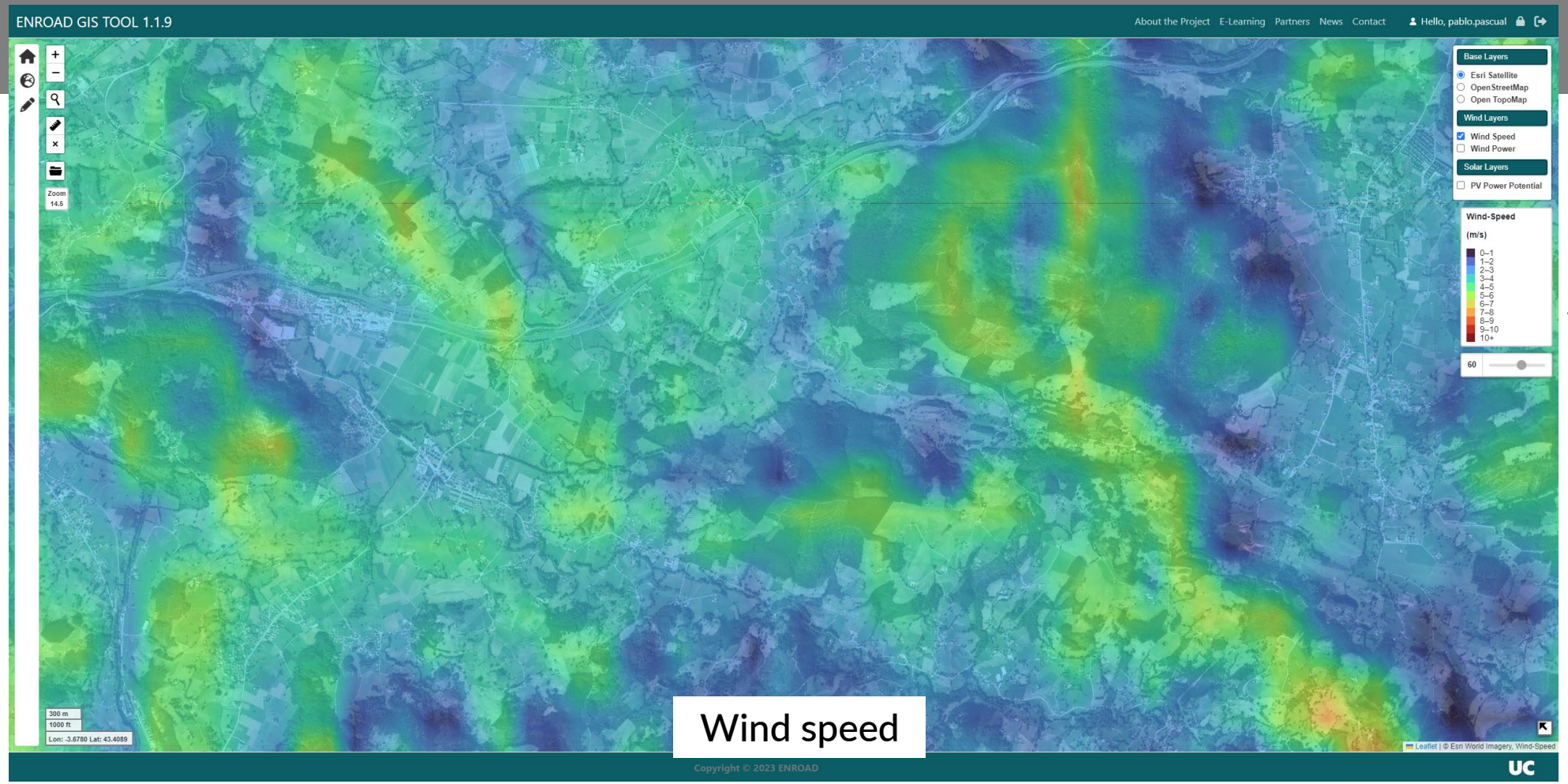




## Main features of the ENROAD GIS-based tool

- Oriented to road-related users:
  - Aimed at fostering the use of RETs along the road network and the NRAs lands.
  - User friendly.
  - Different geodatabases incorporated to the tool to help the user with the location of the site.
  - Tools included that help the user to find a place (city), measure distances or set buffer distances.
- Languages and open source tools:
  - Different programming languages, libraries and free open-source databases used.
  - HTML, CSS and JavaScript used for the FrontEnd web development, while Java and Node.js used for the BackEnd.

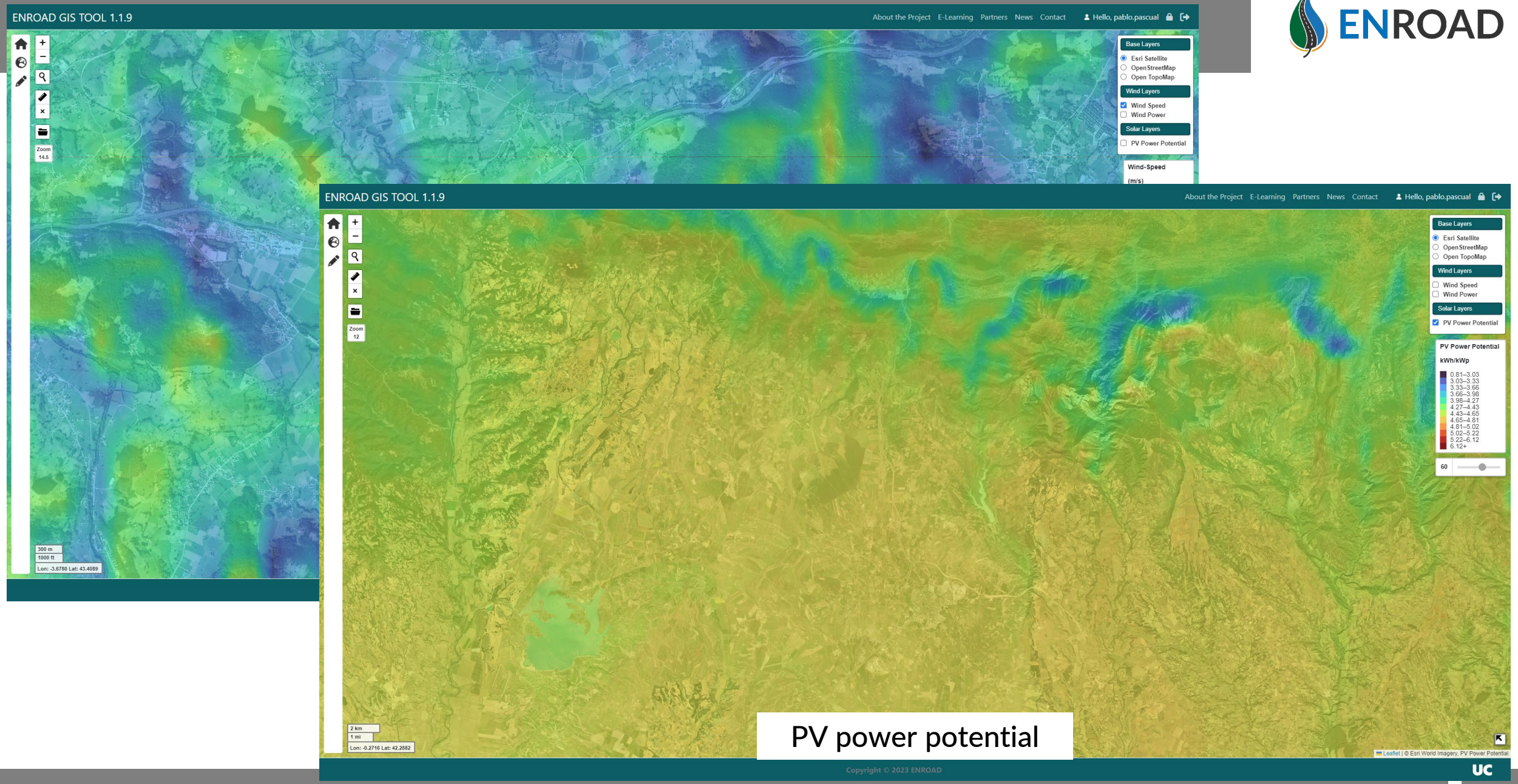
## Main features of the ENROAD GIS-based tool

- Renewable Energy Sources (energy databases):
  - Resolution for both the wind and solar resource is of 50m-250m, very suitable for the purpose of the tool.
  - Heavy energy layers, not to be stored in local, but in a more powerful external server.
  - Energy databases used:
    - PVGIS, https://re.jrc.ec.europa.eu/pvg_tools/es
    - NEWA, https://map.neweuropeanwindatlas.eu
    - Updated over time (instead of average of recent –or not– time series).




Wind speed

the tool.




PV power potential

## Elements, modules and operation

- 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 to:
    - Allow the user to select site and area for the different energy technologies.
    - Estimate the total capacity (number of units and MW) of the new renewable energy installation.

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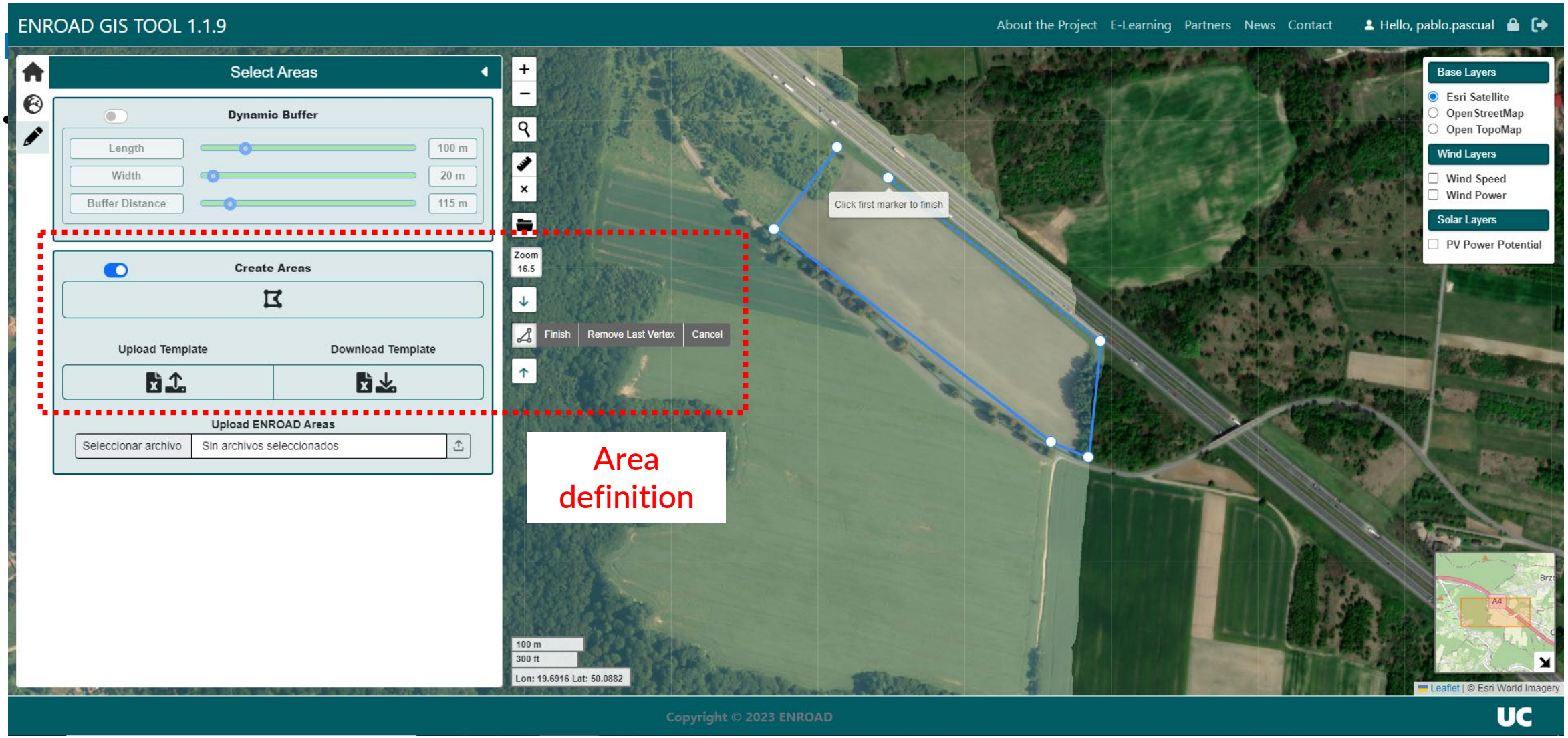


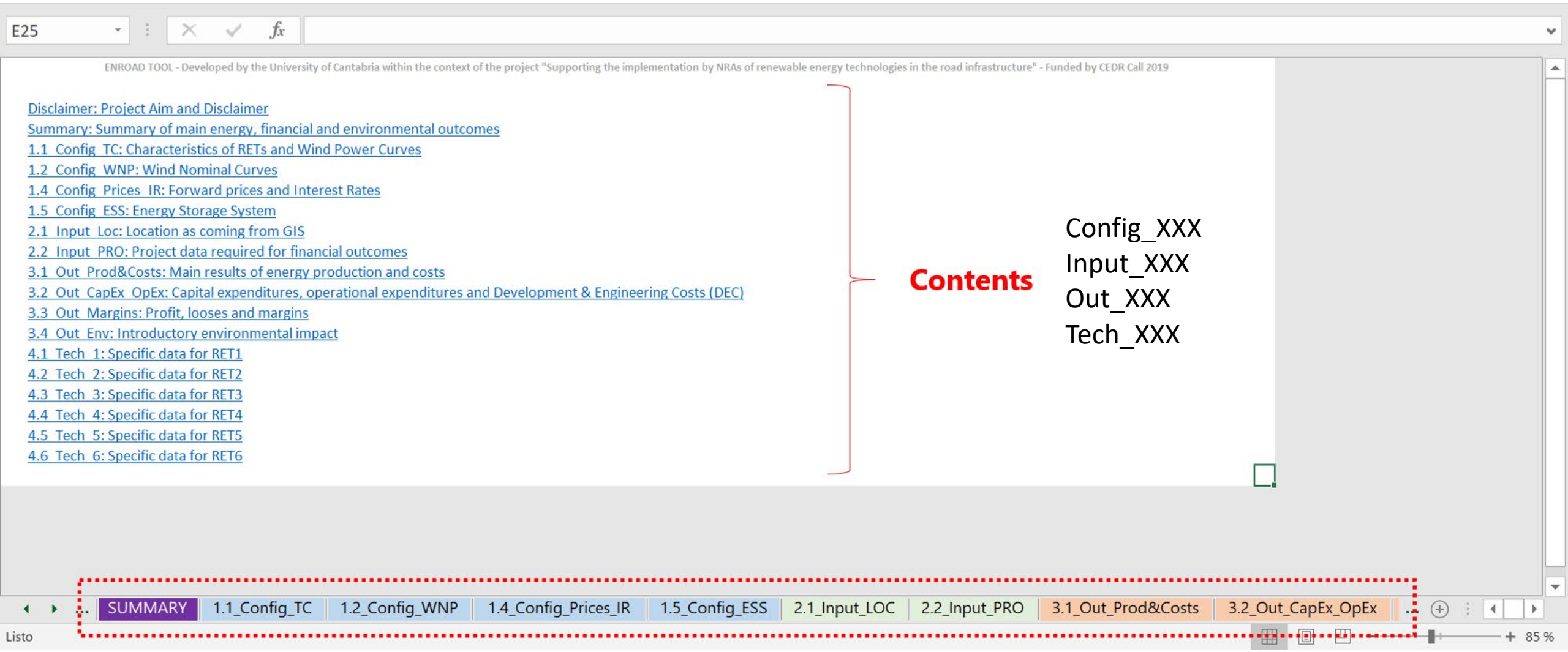
# ENROAD GIS-based TOOL

## Elements, modules and operation

- 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 to:
   - Allow the user to select site and area for the different energy technologies.
   - Estimate the total capacity (number of units and MW) of the new renewable energy installation.
2. A Microsoft Excel template that has to be uploaded into the tool, where inputs and outcomes are shown in the form of a complete study case for the area selected:
   - The annual energy generation (kWh) of the RETs in the area defined before.
   - The whole package of economic and financial indicators.
   - The indicators resulting from the preliminary environmental assessment.

# ENROAD GIS-based TOOL



## Elements, modules and operation

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ENROAD TOOL - Developed by the University of Cantabria within the context of the project "Supporting the implementation by NRAs of renewable energy technologies in the road infrastructure" - Funded by CEDR Call 2019

| GENERAL PARAMETERS | | |
|---|---|---|
| Only connected to the grid? * | - | No |
| NRAs general renewable energy demand | kWh/day | 9000 |
| Financing (NRAs equity) | EUR | 1.600.000,00 € |
| Government subsidy | EUR | 500.000,00 € |
| Period Average HICP | % | 3,00% |
| Debt Interest Rate (fixed) | % | 2,80% |
| Mean wind at reference height | m/s | 2,55 |
| Starting year | - | 2024 |
| Date of analysis | - | 22/10/2023 |
| Energy average price 2024-2044 | EU/MWh | 70,98 |

| LOCATION | |
|---|---|
| LATITUDE | 37,35328422 |
| LONGITUDE | -5,797872222 |
| ALTITUDE | 99 |
| Available area (m2) | 500.120,8 |
| FILE NAME | template.xlsx |

| 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 | - |

are

- The whole package of economic and financial indicators.
- The indicators resulting from the preliminary environmental assessment.

# ENROAD GIS-based TOOL

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## Element

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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% | |
| es for Break-even Point Based on First Year Produc | 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 | |

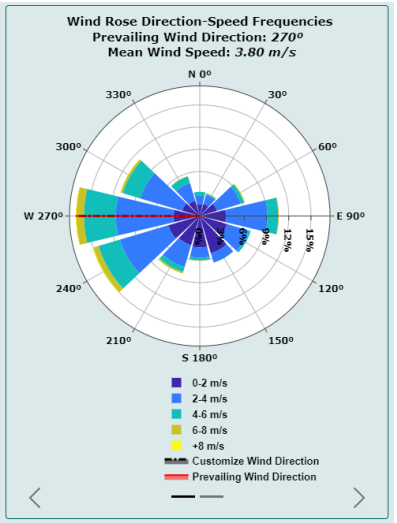
## Elements, modules and operation

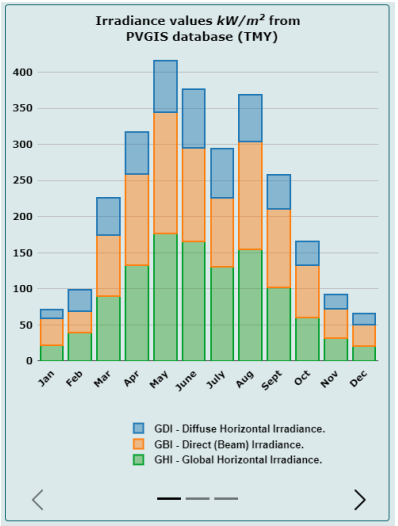
- Users approach: the user decides the amount and complexity of input data to be introduced
  - Basic user: location, area, available financing or starting year of investment.
  - Advanced user: energy demand for storage, inflation rate, OPEX standards, etc.
- Renewable Energy Technologies (RETs)

| RET type | Rotor Architecture - Reference | Manufacturer | Nominal Power | |
|---|---|---|---|---|
| Small Scale Wind Turbine | HAWT - Bornay 6000 | BORNAY | 6 kW | |
| | Darrieus - Aeolos-V 3kW | Lotus Energy Tech | 3 kW | |
| Large Scale Wind Turbine | HWAT - V90-2.0 MW | VESTAS | 2000 kW | |
| | HWAT - V112-3.4 MW | VESTAS | 3300 kW | * Updated |
| **RET type** | **Cell type - Reference** | **Manufacturer** | **Nominal Power** | |
| PV Module | Monocrystalline A-330M GS PERC | ATERSA | 330 kW | |
| | Monocrystalline JAM72S30-530 | JA SOLAR | 530 kW | * Updated |

## Calculation of energy generation and storage

- Annual Energy Production (MWh/Year) of the PV or Wind power plant depends on:
  - Wind and solar resource at the selected location: magnitude and orientation
  - Type and power of the module or turbine
  - Layout: spacing btw turbines (wake effect), distance btw panels (shading effect)
  - Optimal elevation and azimuth angles of the PV arrays
  - Number of modules or turbines arranged
- Initial approach to the need of storage as based on:
  - User renewable energy demand for storage (kWh/day)
  - User renewable peak power demand for using the energy stored (kW)



## Inputs and outcomes to the financial assessment

- **A basic user...**
  - **would enter or modify the default values of:**
    - Location
    - starting year of the investment
    - interest rate percentage
    - available financing
  - **would obtain these outcomes for each RET:**
    - Levelized Cost of Energy (LCOE)
    - starting total investment
    - total energy revenues or savings
    - debt over investment
    - payback period
    - Net Present Value (NPV)
    - Internal Rate of Return (IRR)
    - Average Accounting Rate of Return (AARR)
    - CO2 savings
- **A basic more advances user...**
  - **would enter or modify the same default values plus:**
    - RETs configuration
    - CAPEX, OPEX and DECs standard
  - **would obtain the same outcomes plus:**
    - annual net margin before DECs per kWh
    - annual net margin after DECs per kWh
    - annual cash budget and cash-flow

*By-default estimations are given at a European level, however, due to the changing nature of the figures here referred, the tool allows the user to change the different financial parameters in order to adjust that estimation to the particularities of each country.*

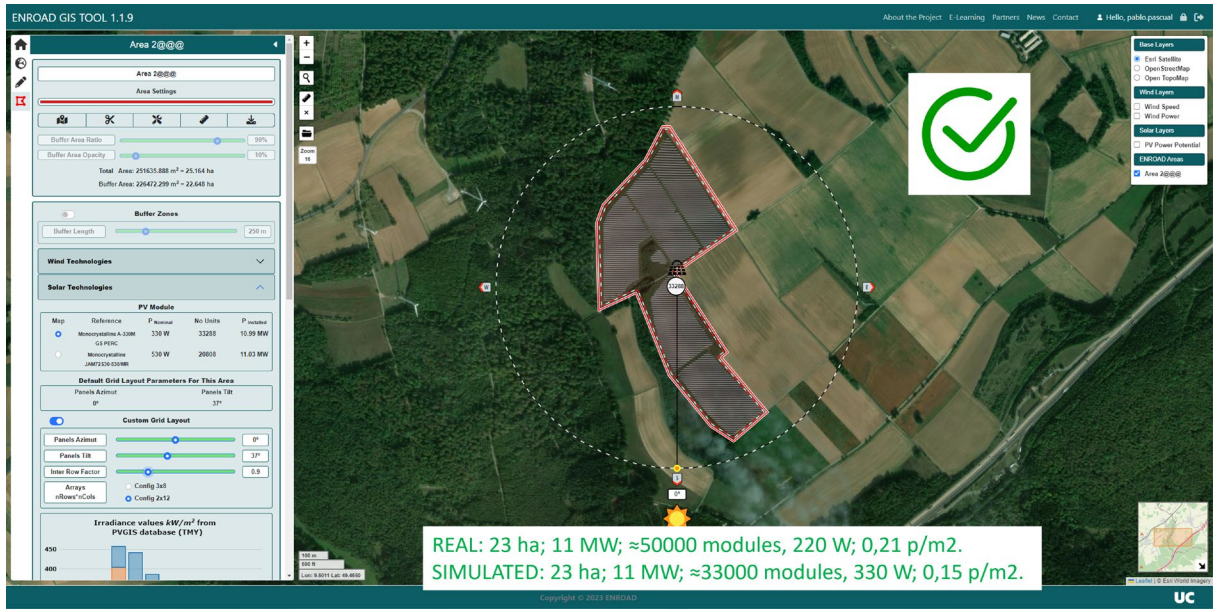
## Environmental impact indicators

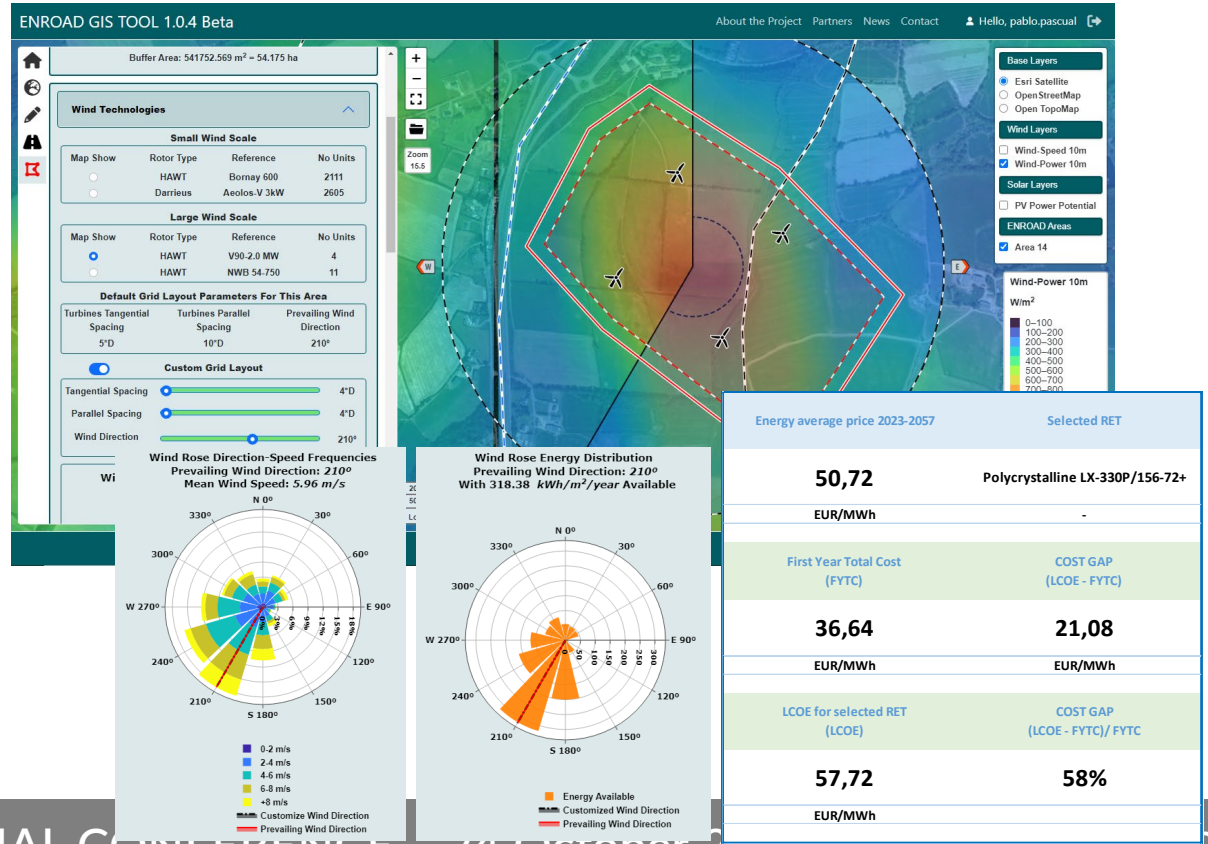
- Resulting from the LCA carried out by SINTEF AS.
- Craddle-to-gate approach involving *:
  - Extraction
  - Manufacturing
  - Construction
  - Connection to grid of RETs
- Transport is partially included (materiales to the manufacturing plant).
- Main outcome: Life Cycle Inventory for the four large scale RETs, including (among other impacts) GHG emissions (kg CO2 eq/MWh) and annual CO2 savings ** (Tonne CO2/MWh).

** Extraction, manufacturing and construction phases account for the vast majority (85-90%) of the energy consumption and emissions.*
*** Based on the values of GHG emissions by a combined cycle gas turbine (US DOE, 2022 and Hou et al., 2016).*

## Calibration and study cases

- Calibration actions and 3 complete case studies applying ENROAD tool.
- Consulted different experts on energy: different companies and departments.



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# THANK YOU!

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