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

Deliverable 5.1 / Milestone 5.2

Principles and basic modules of the ENROAD GIS-based tool

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LIST OF ACRONYMS

AARR	Average Annual Rate of Return
CAPEX	Capital Expenditure
CSS	Cascading Style Sheets
GIS	Geographical Information System
GLP	General Public License
GNU	GNU's Not Unix
HTML	HyperText Markup Language
IRR	Internal Rate of Return
JS	JavaScript
LCOE	Levelized Cost of Energy
NPV	Net Present Value
NRA	National Road Administration
OPEX	Operational Expenditure
RET	Renewable Energy Technology
UX	User Experience
WMS	Web Mapping Service

1 INTRODUCTION

On the basis of the general aim of the ENROAD project "*To provide the NRAs with an accurate and easy to use tool that help the implementation of RE technologies along the road infrastructure with the highest possible benefit from the economic and environmental point of view*", this document presents the general characteristics and the methodologies followed for the development of the ENROAD tool, which is to be delivered as part of deliberable D5.2.

This report is divided in two main chapters. In chapter 1, the User Experience (UX) approach followed by the design team - formed by members of the University of Cantabria, Arup and SINTEF - for the definition of the general framework of the tool is presented. Following, chapter 2 is devoted to the definition of the main features of the tool: software and databases used, modes of operation, modules involved, etc.

It should be noted that the ENROAD tool is still under development, so although everything described in this report is intended to be implemented as it is explained, the current programming phase of the project may lead to delays in some parts of the tool or to slight deviations in its functionalities. Likewise, the final design of the tool in terms of its most aesthetic part (styles, colors, etc.) is not part of the current design process, so it is very likely that the final version of the tool will look like different from the initial (alpha or beta) version here introduced.

The models and methodologies integrated into the tool for the estimation of the energy generated by the RETs and the corresponding economic and financial assessment are explained in detail in the deliverables D2.2, D4.1 and D4.2. The information here displayed is of great interest as being the base for the outcomes provided by the ENROAD tool.

2 DESIGN CONCEPT AND UX APPROACH

User Experience is the perception or sensation we experience when we interact with a product or service to achieve an objective or solve a need. It has been proven that a good user experience results in a greater user satisfaction, better opinion of the brand, greater engagement, higher return, etc. UX Design covers everything from the definition of the application, the user journeys, to the prototype of all views for the final design of the user interfaces. So it is essential for the development of intuitive and effective apps that make it easier for the users to achieve their objectives. In the ENROAD project, the UX Design process was approached following the Design Council's double diamond framework, which is divided into the following four phases: Discover, Define, Develop, Deliver (Figure 1).

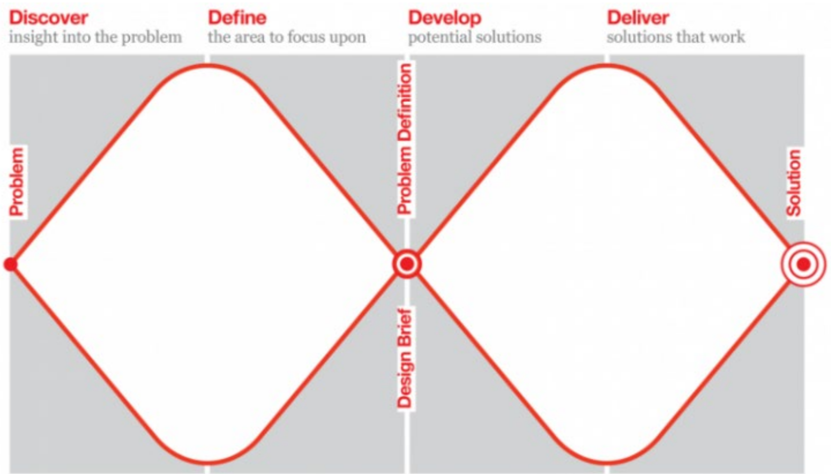


Figure 1: Design Council's double diamond framework.

In order to foster the participation and discussion of the partners involved in the UX design process, the visual collaborative whiteboard platform Miro was used (Figure 2).

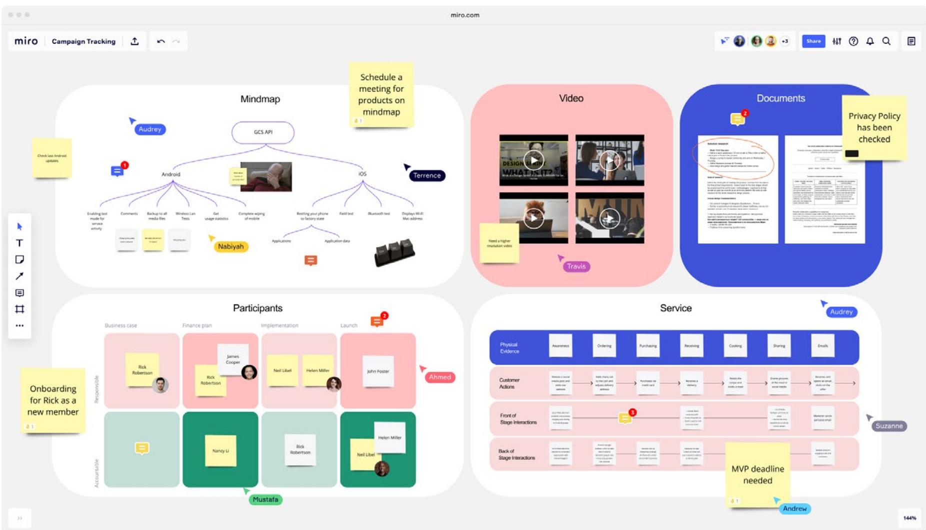


Figure 2: Example of a MIRO whiteboard.

This intuitive and flexible tool helps the participants to put different ideas, perspectives and contributions in common, something that is very important when the sometimes very different initial approaches of the academia (University of Cantabria) and the industry (Arup) are confronted. Also, it helps to better visualize and more easily discuss the different proposals, thus leading to more consistent and accurate results.

2.1 Discovery phase

In the Discovery Phase a workshop was organised with members of the University of Cantabria, and Arup's Sustainability and Digital Advisory teams. Coordinated by Arup, the aim of the workshop was to define the **challenges** and **aspirations of the project**, the main and secondary **goals** of the app, also to identify the **potential users** and they different **needs**, and to briefly analyse some similar existing apps (Figure 3).

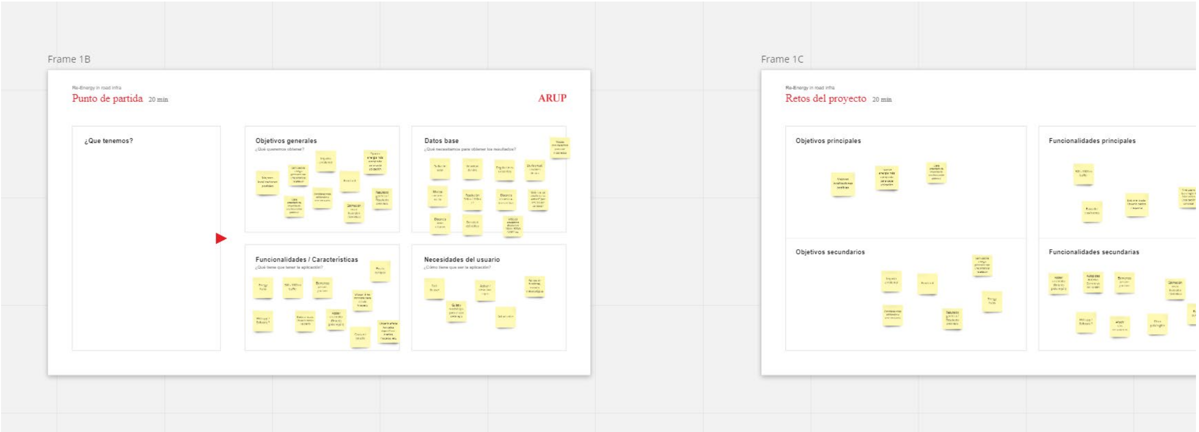


Figure 3: Screenshot of the Miro boards that were used to facilitate the discussion in the workshops.

2.2 Definition phase

The main outcomes of the first workshop were the following:

- **The challenge**: develop a digital tool that facilitates owners and managers of road infrastructure to identify and assess the best opportunities for renewable energy generation on their assets.
- **Main objectives of the app**:
  - Identify the best potential areas for renewable energy generation along roads.
  - Identify the most appropriate type of renewable energy for each possible location.
  - Obtain an estimate of the technical/financial feasibility for possible power plants.
- **Main users**:
  - Asset Manager (basic user): interested in an overview of opportunities.
  - Technical specialist (advanced user): interested in obtaining an accurate estimation of the renewable energy production, cost of implementation, return on investment, etc.

2.3 Design phase

The second workshop focused on the on the User Journeys, as well as the specific functionalities for each step of these journeys. Basically, the definition of the minimum essential steps for each user to achieve their objectives (Figure 4).

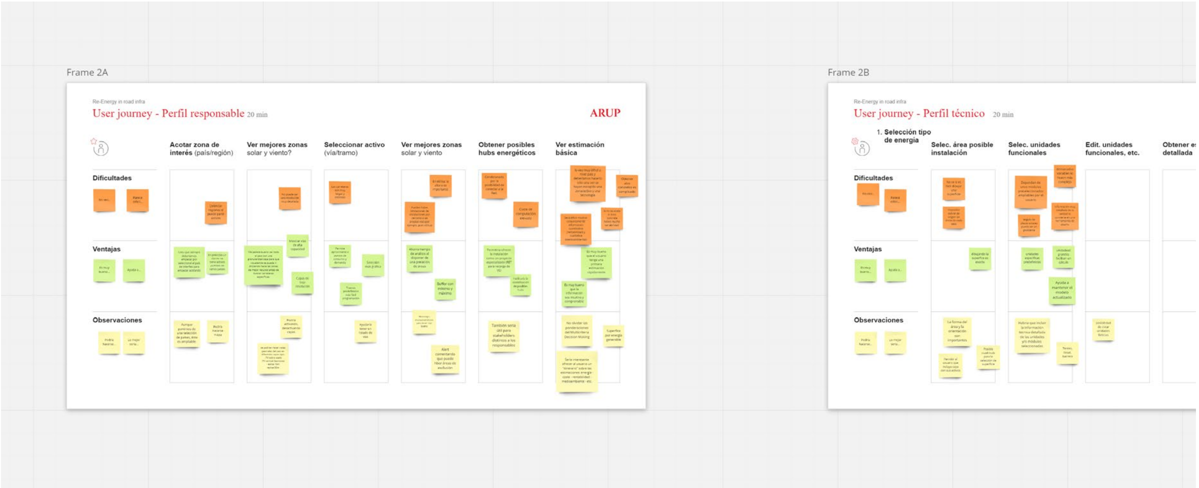
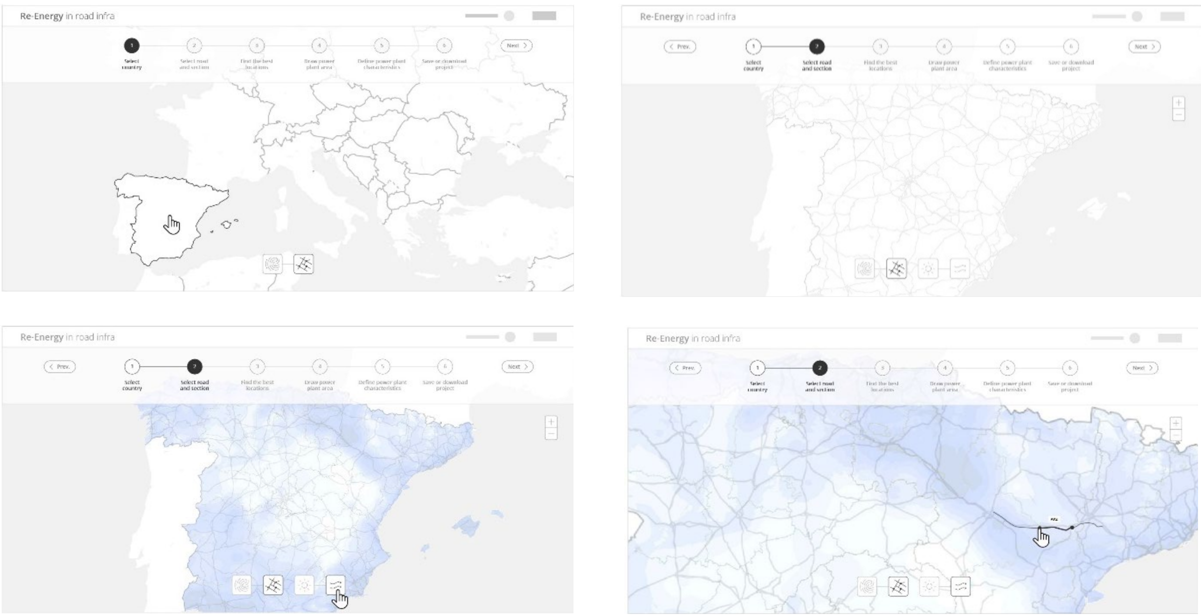


Figure 4: Screenshot of the Miro boards used to identify the strengths and weaknesses of the user journeys.

2.4 Delivery phase

The last phase of User Experience Design is the prototyping. The wireframes for all views were designed, approved and delivered to the design and development team of the University of Cantabria. It should be noted that the final design of the ENROAD tool will surely be inspired by these wireframes but it will not have to be an exact copy or even very similar to them (Figure 5).



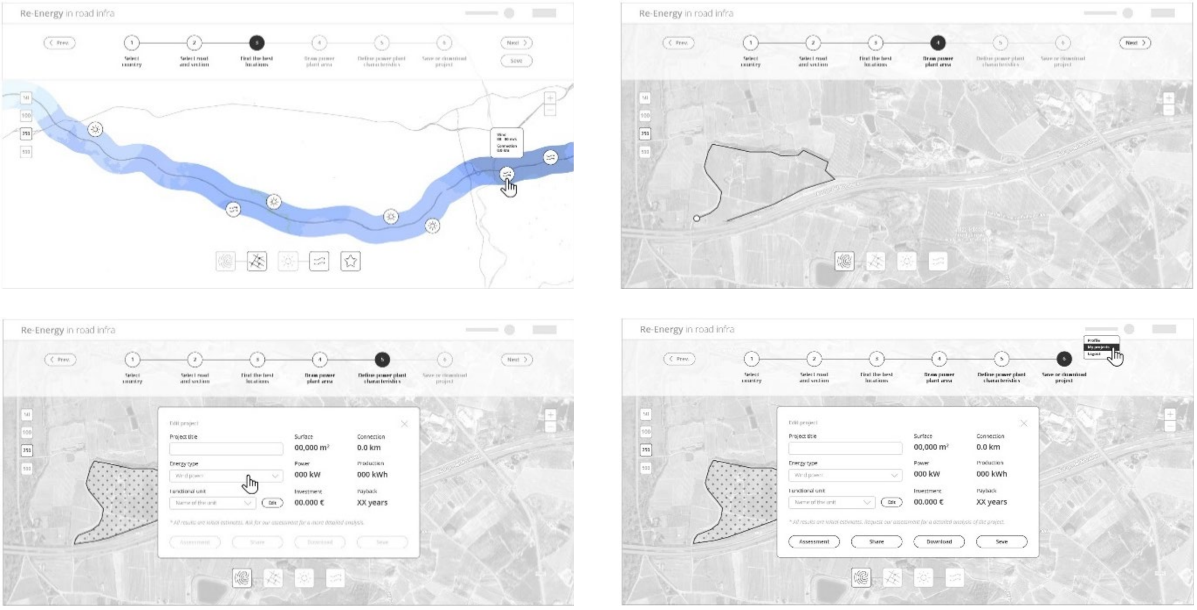


Figure 5: Wireframes of the different views of the app, following a user journey.

The complete proposal as submitted by Arup's Digital Advisory team after completion of the workshops is shown in Annex 1 (in Spanish though, as all the participants happened to be Spanish speakers).

3 PROGRAMMING AND MODULES

3.1 General information, principles and particularities

As stated in the proposal sent by the University of Cantabria (Coordinador) to the topic Renewable Energy in Road Infrastructure of the CEDR Research Call 2019, the ENROAD tool is aimed at *providing the National Roads Administrations (NRAs) with an accurate and* ***easy to use tool*** *that helps the implementation of RE technologies along the road infrastructure.* Therefore, the GIS-based app is being carefully designed as a user friendly tool that at the same time is able to provide: 1) an accurate estimation of the energy that a specific RET located along the road asset is able to deliver; 2) a comprehensive economic and financial feasibility study of the renewable energy installation according to the options selected in previous stages of the tool; and 3) an introductory environmental impact analysis of the renewable energy generation associated with its core technology. To date, the extent of this module of the ENROAD app is still under consideration, and it will depend mainly on the time needed for its further development. Likewise, the incorporation of other potential modules and/or functionalities to the tool would highly depend on the time available until the end of the project.

It should be clarified that this tool is intended to help technicians and managers of 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 projects and investments.

Regarding the general methodology for the development of the ENROAD tool, it has slightly changed as the project has evolved. Thus, although not the initial objectives nor the expected impact or results have changed, the methodology was decided to move from a more empirical approach that involved a more basic tool built on the basis of the outcomes from a static MCDM analysis, to a more interactive, scientific-oriented and accurate perspective. More specifically, instead of relying on the results of a conventional multi-criteria decision making analysis, with a pre-defined and restricted (i.e. difficult to expand) list of RET alternatives, and a set of criteria (potential energy generation, installation costs, maintenance costs, environmental impact, etc.) that are rigidly linked with the alternatives by the scores given to the decision matrix, the new tool is more adaptable and offers a more straightforward answer to the end user. Besides, some of those scores filling the decision matrix are difficult to determine, and worse, to update, and in some cases they come from scarce or not entirely reliable sources, thus giving the results of the analysis a certain level of undesirable uncertainty.

In summary, main advantages of the new methodology proposed are: 1) the UX approach provides a much more fluent interaction of the user with the app; 2) the app provides a more straightforward response to the user aspiration; 3) the results generated are more accurate; 4) more flexible and adaptable by the end-user (i.e. new models of turbines and panels can be added, and the default calculation parameters with a higher level of assumption can be adjusted by local end-users). On the other hand, the following drawbacks are behind the use of this new methodology for the development of the ENROAD tool: 1) less criteria are eventually used for the selection of the most appropriate RE technology; 2) the computational cost is much higher as well as the amount of information stored, so different solutions had to be provided not to compromise the smooth operation of the tool; 3) depending on the information requested by the final users, they might need moderately higher computer skills (the tool is still very user friendly, though).

ROAD-FOCUSED & RETs

Unlike other existing software for the assessment of the renewable energy resources and the evaluation of renewable energy technologies and projects (see in deliverable D4.1 a review of those focused on cost analysis and financial reporting), the ENROAD tool is focused on the use of RETs along the road asset. This means that, although the energy geodatabases used by the tool to make the calculations cover the entire European territory, a database with the main roads in Europe has been incorporated so that the user is assisted by the tool - throughout the process of inputs definition - in the selection of the road stretch and the area aside (or within) the road where the RET is planned to be installed (Figure 1).

The decision on the technologies for the renewable energy generation that can be selected in the ENROAD tool has been made based on the study carried out by the University of Cantabria and SINTEF Energi during the first part of the ENROAD project (see deliverables D2.1 y D2.2). In addition to technical criteria such as the technology readiness level (TRL) - maturity of technology -, performance, ease of integration in this type of tool, availability of the information required for the development of the models, etc., the results of the survery conducted at the beginning of the project were considered very relevant (in fact, out of the 28 European NRAs surveyed, at least one representative from 16 countries has sent a full answer to the survey to date) and therefore, were taken into account. Figure 2 shows the results to the question *Which of the following RETs would you consider for implementation? Check all that apply*. Answers are clearly in line with the implementation of small scale RETs, more specifically small PV systems. Small turbines and large PV also seem to be within the preferences of NRAs.

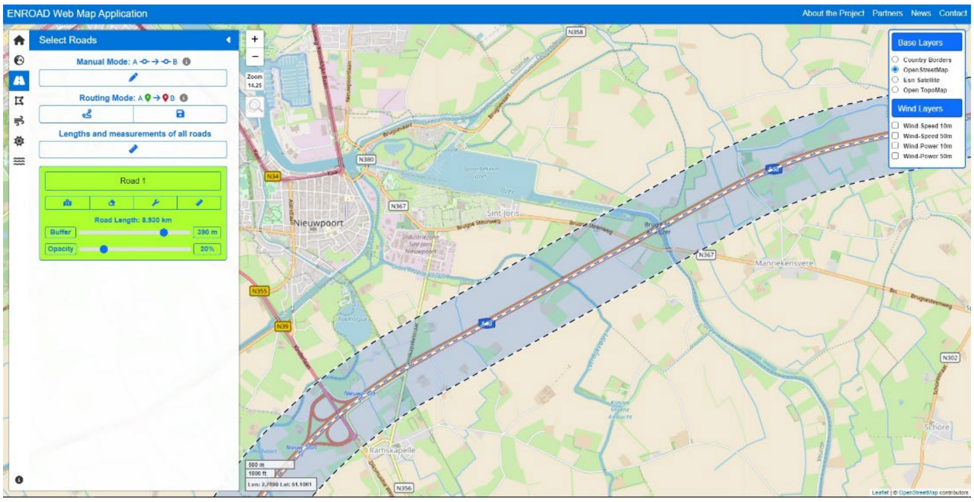


Figure 6: Selection of the road stretch in ENROAD tool

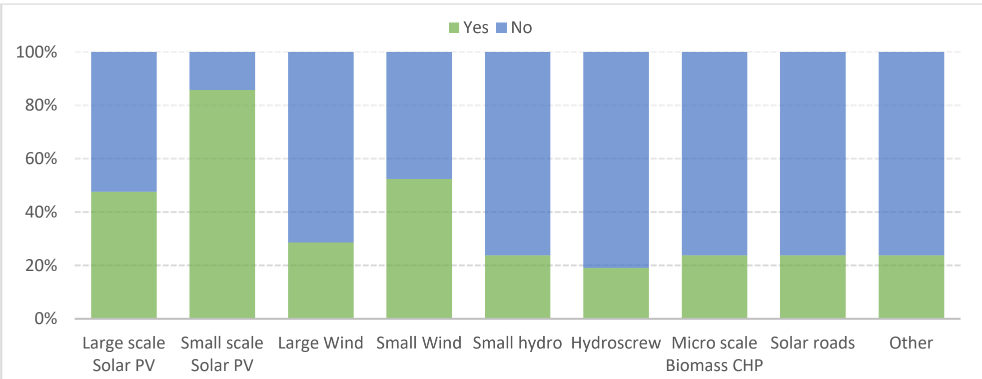


Figure 7: Results of survey on the RETs considered for implementation

Therefore, the following RETs can be selected in the ENROAD tool:

- Small Wind (up to 50 kW): HAWTs and VAWTs such as Savonious or Darreus.
- Large Wind (1-15 MW): HWATs
- Small & Large PV: Ground-mounted and PVNBs with Crystalline Silicon technologies.

Other photovoltaic technologies, such as thin film, have not been integrated into the first version of the application due to time constraints, but it could be done before the end of the project if time permits. On the other hand, the so-called solar roads (PV) were initially discarded due to the low peformance offered by these systems so far. In addition, the information about these systems that is required for the proper economic and financial assessment is very scarce and unreliable. The integration of small hydro able to harness energy from rivers and dams in areas close to the road asset has not been discarded yet but given that these systems are highly case dependent, need from geodatabases difficult to find and very difficult to update, and are more difficult to parameterize for integration into the tool, decision was made to leave this technology for the moment. Also, the energy production expected with this type of micro- and pico-hydro systems is much lower than with PV and Wind.

GIS-BASED TOOL & WEB MAP SERVICE (WMS)

The solutions provided by the ENROAD tool are all based on the location of the RET that is planned to be installed. For this reason, a Geographical Information System (GIS) is needed to run behind the tool that is able to deal with the information contained in the different geodatabases that have been used. In order to finally select the **QGIS software** for the management of the geo-referenced data instead of the more commercial ArcGIS, several aspects were taken into account such as the required functionality as well as the compatibility and handling capacity. ArcGIS, developed and commercialized by ESRI, a big company with multitude of resources and highly qualified personnel, is composed of several tools: ArcReader, ArcMap, ArcCatalog, ArcToolbox, ArcScene or ArcGlobe, among others, which can be used depending on the license level acquired. Based on the experience, the ArcGis Model builder is more stable and its export to a Phyton script is easier as only the Arcpy module is necessary.

On the other hand, QGIS is an open source software, operating under GNU and GLP licenses, that can be modified, being the users the main tools and functionalities developers. It allows to manage georrefenced data through GDAL library. The fact that the software is progressively developed by end users can make things challenging sometimes, especially when looking for a specific tool or characteristic, but it is also true that: a) all the required functionalities for the ENROAD tool can be found in QGIS, including a proper connection to Python; and 2) the fact that QGIS is non-profit makes it potentially recheable to any person with the required skills. Finally, one of the main differences between these two packages is that QGIS is an open source software whereas ArcGIS is a payment software (≈ 6000 € per single license). Based on all the aforementioned, it was concluded that QGIS was the software that best adapted to the casuistry of this project by obtaining the best compromise between power, flexibility accessibility and cost.

The geodatabases used for the development of the tool are all free and open source can be divided in two main different groups:

- General purpose layers:
    - Borders, toponymy and roads: OpenStreetMap
    - Satellite: EsriSatelite
    - Topography: OpenTopoMap

- Energy layers:
    - Wind: Global Wind Atlas
    - PV: Global Solar Atlas

The resolution for both the wind and solar resource is of 250 m, very suitable for the purpose of the tool under development (Figure 8). On the other hand, this high resolution makes the maps extremely heavier, which results in a slower and more difficult management of the geo-referenced data and hence, in a worse user experience. In order to solve this issue, the energy layers were decided not to be stored in local, but in a more powerful external server. This web map server would be responsible for supplying the different energy layers to Leaflet (JavaScript open source library) through WMS connections.

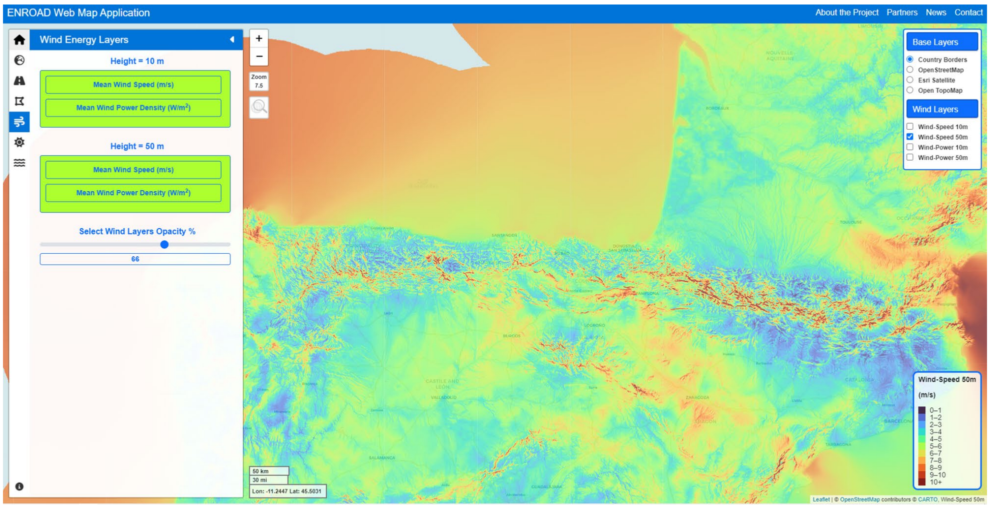


Figure 8: Screenshot of the wind energy layers in the ENROAD tool

In short, Web Map Services (WMS) allow the dynamic consultation of cartographic information generated from one or several sources and loaded from one or several servers (Figure 9). For the purpose of this project, raster maps (TIF) with the information from the solar and wind resource are stored in the external server not to have them locally consuming resources and making the processes slower, and **Geoserver**, an open source server for sharing geodata that is installed in the exernal server with the maps, is used to supply the energy layers to **Leaflet**, an open source library, through WMS connections. Thus, after some necessary adjustments for the maps to be ready for their implementation, leaflet is used for connecting to the layers by pointing to the IP address of the server where the required map is stored. Geoserver and Leaflet are therefore responsible for the management of the maps' raster tiles, which would depend on the specific location and the zoom level selected by the end user from the browser.

Finally and very importantly, the refinement of the energy databases (necessary for a correct visualization) is also performed from Geoserver by cubically interpolating the raster maps - both in colour gradient and numerical pixel value - when zooming in and zooming out them.

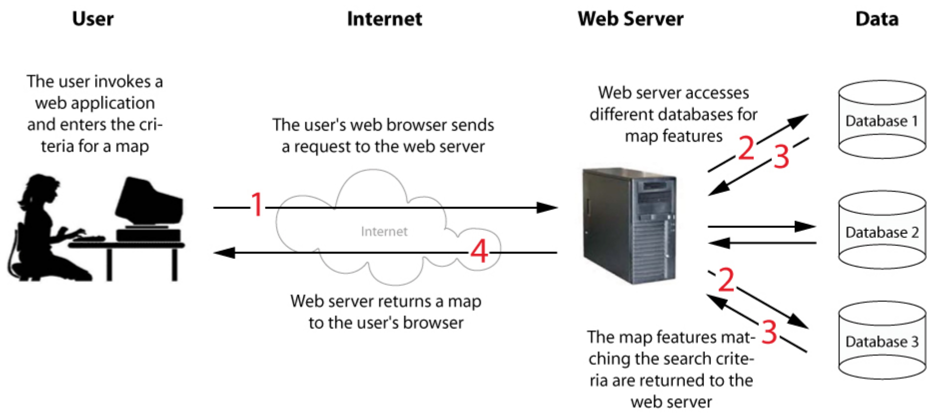


Figure 9: Basic scheme of how a WMS works

General advantages from using an external server instead of a local host/cloud are:

- *Maintenance*: taking care of operating system security or keeping libraries and software updated are very time-consuming activities, and require from a certain level of knowledge.
- *Risk of downtime*: if installed in a local cloud, any failure of software or hardware might leave the users of that cloud without service for a long time.
- *Connectivity*: the quality and speed of access to the information are expected be much better and higher, respectively.
- *Security*: the proper protection against hackers incursions and data theft is (somehow) ensured.

There are of course some advantages from using an external server (e.g., *loss of privacy* and *scalability*) but their impact is very limited in this case.

OPEN SOURCE TOOLS

Other different open source tools have been necessary for the programming of the ENROAD tool. **HTML and CSS** have been the programming languages used for the FrontEnd web development, i.e. they provide the web page with the actual structure and style.

JavaScript (JS) is an interpreted programming language. It is object-oriented, prototype-based, weakly typed, imperative and dynamic. For the purpose of this project, it has been used in three different ways:

- In its native form (without using libraries such as React or Angular) it has been used for FrontEnd development, aimed at making the application a dynamic and interactive environment: buttons, sliders, animations, menu management, forms, change of styles and content, etc.
- Using **Leaflet**. Leaflet is an open source JS library used to build and edit web mapping applications (FrontEnd). It is a highly optimised library with the support of a large community of developers in charge of complementing it by creating new plugins. As said before, Leaflet is used in this project for the connection with geoserver and the management of the energy layers in the map server.

- Using **Node.js / Express.** Node is an open-source, cross-platform runtime environment that allows developers to create server-side tools and applications. Express is a flexible Node web application framework that provides broad a robust set of features for building web and mobile applications. In this project, Express have been used for BackEnd development, more specifically HTTP requests (to access resources on the server) and access to the File System. The main benefit of Node.js is that it allows the programming language in FrontEnd and BackEnd to be the same.

Finally, **Docker** is an open source project that automates the deployment of applications inside software containers, providing an additional layer of abstraction and automation of application virtualisation across multiple operating systems. This is a very important feature due to the nature of the ENROAD tool. Thus, one of the first steps when running the tool is selecting the road along/within which the RE technology is planned to be located. For this, the user will be able to choose between two options:

- Manual mode: once situated in a specific country, the user manually look for the target road.
- Routing mode: the tool will assist the user in the search of the target road.

Docker is part of the BackEnd and makes it possible the calculation of routes - from point A to point B - that in the FrontEnd are actually represented as roads. In other words, Docker is a container used for the creation of the OSRM (Open Source Routing Machine) routing engine in the application's BackEnd. This OSRM engine supports the Leaflet routing machine plugin which, combined with OpenStreetMap maps, allows the end user to select the target road from given start and end points.

Table 1 shows the open-source licenses of the different software, libraries and geodatabases used so far (design and programming tasks are still ongoing) in the development of the ENROAD tool.

Table 1: Open-source licences used for the ENROAD tool.

Software / Library / Database	Open-Source License
Leaflet	BSD 2-Clause
Leaflet-Plugin-Geoman	MIT
Leaflet-Plugin-Routing	ISC
Node.js	MIT
Geoserver	GPL
QGIS	GPL
Docker-OSRM	MIT
OpenStreetMap	ODbL
OpenTopoMap	CC-BY-SA
Global Wind Atlas	CC BY 4.0
Solar Global Atlas	CC BY 4.0

3.2 Operation and Modules involved

As stated in chapter 2, one of the conclusions drawn from the workshops with Arup's UX specialist team was that it would be interesting if the ENROAD tool could be used by **two types of end users** with different knowledge or feedback, profiles and needs:

- **Basic user**: with a more executive and transverse profile, whose objective was to obtain an overall view of the opportunities for renewable energy generation in the road asset.
- **Advanced user**: with more of a specialist or technical profile, whose objective was to gain a more detailed knowledge of the possible solutions for renewable energy generation.

Even though to date it has not yet been decided how to translate this into the tool under development, it does seem clear that the form of access to the results of the more advanced user would be slightly more complex, being necessary the introduction of a few more inputs. Anyway, this is expected to be solved by the presentation of the alpha (or beta) version of the software.

MODES OF OPERATION

As in the previous case for the type of user accesing the app, the modes of operation established for the ENROAD tool are intended to improve the end-user experience. More specifically, the following 2 modes of operation are planned to be implemented:

1. **Supply model**: in this model the location of the RET is first selected and the result obtained is the energy generated that can be offered to the marketer (or third party) at a given price, with the consequent profitability.
2. **Demand model**: in this model the amount of energy that needs to be produced (i.e. demanded by the NRA) to supply lighting, signals, etc., is entered and then the location of the RET is selected, the results being the percentage of energy covered and the cost savings obtained according to the available price.

MODULES & GENERAL SCHEME OF INPUTS AND OUTCOMES

In terms of the **outcomes** provided, the ENROAD tool is mainly composed of 3 modules, each one offering the end user a series of results depending on the renewable energy technology selected: 1) the renewable annual energy production; 2) an economic and financial assessment; and 3) a preliminary estimation of the environmental impact associated to that technology (Figure 10). The methodologies and calculations that are the basis for the operation of the first two modules are presented in detail in deliverables D2.2, D4.1 and D4.2. In particular, deliverable D4.2 is formed by an Excel template with a macro that allows to perform all those calculations, and whose structure will be the one that will be integrated in the ENROAD tool. Several study cases are also included. As for the environmental module, this is still in progress. A first version of the model with the necessary calculations has been already generated – a paper was submitted to the TRA 2022 Conference that has been accepted for poster/oral presentation – but it must be adjusted to fit the methodology of the last version of the ENROAD tool.

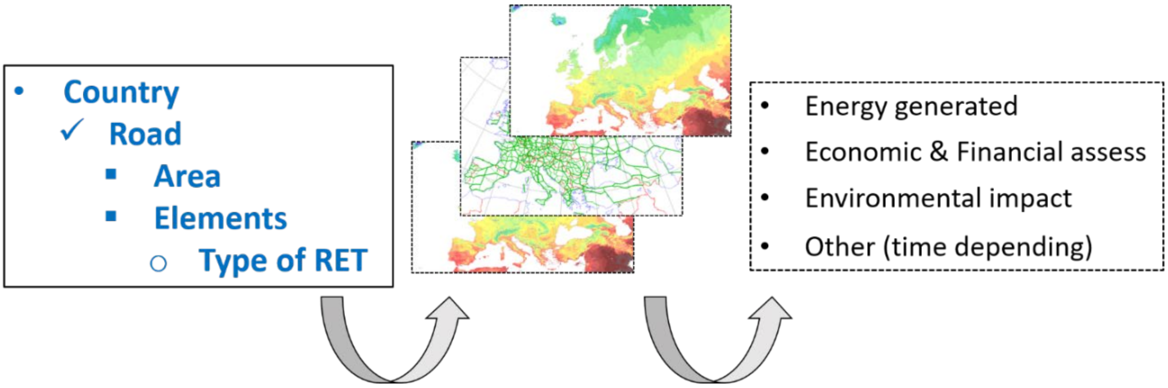


Figure 10: Basic scheme of inputs and outputs of the ENROAD tool

To obtain those results, and depending on the type of user (basic or advanced) and the mode of operation (supply or demand) selected, a series of **inputs** will have to be introduced by the end user. Main inputs of the ENROAD tool are:

COUNTRY	The country where the NRA user operates. In order to facilitate this process, the tool will assist the user in the selection.
ROAD	The road stretch. For a quicker selection, the tool can assist the user with the search of the road in the map offered by OpenStreetMap and then the specific section where the RET is going to be installed, although the user can opt for a manual selection.
AREA	The area aside/within the road where the number of elements of the RET is installed. The tool will provide the user a straightforward way of defining this area.
RET	The RET that is to be installed (Wind or PV, small or large). Depending on the selection made, the corresponding **ENERGY LAYER** (Figure 11) would become activated.
ELEMENTS	The number of elements of the selected RET. Once again, the tool would help the end user to introduce a specific number of elements (e.g. PV panels) or to automatically optimize it.
Other	Other specific inputs of economic and financial nature depending on the type of user and the mode of operation.

With all these inputs, the ENROAD tool will be able to provide the required results in screen. In addition, the tool will allow the printing of reports with those results.

ENERGY GENERATION

The model developed for the estimation of the energy production of the RETs (Wind and PV) is based on the theoretical development in deliverable D2.2, and is conveniently described in D4.1 and developed in D4.2. More specifically, the version deployed in the Excel spreadsheet of D4.2 is the one corresponding to a supply model for a grid-connected installation. The versions corresponding to the demand model and battery storage are in progress, almost finished for integration into the tool.

Quickly described, the process begins with the selection by the user of the location (country-road-area) for the RET, the preferred RET and the number of units that can be installed in the selected area according to the potential technical constraints. Then, the annual energy production is estimated taking into account the efficiency losses.

Figure 11: Activation of energy layer after the selection of the road and the definition of area

In the case of wind energy, the final **number of turbines** is multiplied by the production in kWh obtained from the Weibull distribution function for the specific selected location (see D4.2 for a detailed review of the parameters used for the calculation). As for the PV systems, the **number of panels** is multiplied by the production (kWh) per panel estimated on the basis of the annual hourly radiation, eventually provided by the corresponding energy geodatabase (see D4.2 for a detailed review of the long list of parameters used for the calculation, and note the for the excel version another source has been used for the annual hourly radiation instead of the geo-referenced databases).

ECONOMIC AND FINANCIAL ASSESSMENT

The purpose of the model is to provide the NRAs with an estimation of the energy generated by the RET selected, as well as the corresponding estimated cost of investment (CAPEX, OPEX and Development and Engineering costs). For this, the model has been designed with a bottom-up approach, i.e. the calculations are elaborated considering the disaggregated data from the manufacturers of the RETs, the locations and the energy resources (wind speed and solar radiation). This way, the tool not only provides the user with an accurate estimation of the energy production, but also with an effective analysis of the cost structure and the economic, financial and environmental outcomes associated to the solution proposed, all of which offered in an intuitive and understandable way.

Those economic and financial outcomes are offered by the ENROAD tool in two different ways depending on the type of end user (basic or advanced) accesing the tool.

Thus, a **basic user** (a user looking for a more global approach) running a **supply model**…:

- … would enter or modify the default values of:
    - Country and location (road-area)
    - Starting year of the investment
    - Interest rate percentage
    - Available financing
- … and would obtain the following outcomes for each RET included in the model:
    - Total Annual energy production
    - Total installed peak capacity
    - Levelized Cost of Energy (LCOE)
    - Best technology's LCOE
    - Starting total Investment
    - Total energy revenues or savings
    - Project Duration (and loan repayment)
    - Debt (bank loan) over Investment
    - Payback period
    - Net Present Value (NPV)
    - Internal Rate of Return (IRR)
    - Average Accounting Rate of Return (AARR)
    - CO2 savings

On the other hand, an **advanced user** (looking for a more detailed knowledge) running a **supply model**…:

- … would enter or modify the default values of:
    - Country and location (road-area)
    - RETs and configuration
    - Starting year of the investment
    - Interest rate percentage of the loans
    - Inflation rate
    - Available financing
    - CAPEX, OPEX and Development & Engineering Costs of the RET
- … and would obtain the following outcomes for each RET included or selected:
    - Total annual energy production
    - Total installed peak capacity
    - Annual net margin before Development & Engineering Costs, per kWh

- Annual net margin after Development & Engineering Costs, per kWh
- Levelized Cost of Energy (LCOE)
- Best technology's LCOE
- Starting total Investment
- Total energy revenues or savings
- Project Duration (and loan repayment)
- Debt (bank loan) over Investment
- Annual Cash budget and Cash-flow
- Payback period
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Average Accounting Rate of Return (AARR)
- CO2 savings

ENVIRONMENTAL IMPACT

The sustainability of large-scale solar power plants has been questioned in the literature as potentially resulting in problem shifting between the different sustainable development goals, e.g. due to the toxicity in production and waste handling. However, solar PV plants do not produce noise unlike the wind farms, nor bad smell unlike biowaste plants. Besides, visual impact does not seem to affect nearby residents.

As said before, a very first version of the model for the estimation of the environmental impact associated to the installation of RETs along/within the road asset has been produced. However, this model needs to be substantially updated before its integration into the ENROAD tool in order to fit the current operating procedure. In this first version, the results are presented as a range of values for each region and is to give an early indication of the magnitude of the environmental impact, and should only be used for comparison purposes. This is due to the high uncertainty in the input data, e.g. material suppliers, transport distances, construction work needed for installation, maintenance and removal, as well as extraction and processing of materials. It is thought (time permitting) that the end user can add some of these data, but the level of uncertainty is expected to remain medium-high as finding this kind of information from reliable sources is not easy for most of the users.

The life-cycle stages included are based on the European standard EN 15804 (European Committee for Standardization, 2013) and focus on A1-A5 (production and installation), and B1 (use, energy production) without excluding the possibility to also include maintenance (B2), End-of-life (C1-C4) and possible reuse (D) if/where the information is available.

For the estimation of the environmental impact of wind turbines, two sizes have been included from the Ecoinvent database so far that offer a good range, 2 MW and 750 kW onshore turbines. The dataset used has been adjusted mostly to represent the European situation instead of the global market. Regarding the estimation of the environmental impact of PV panels, a ground-mounted, polycrystalline silicon PV panels have been selected so far from the Ecoinvent database because of their slightly higher technological and market readiness level. Like with wind turbines, the dataset has been adjusted to represent the European situation rather than the global market.

Preliminary results obtained with the model for different simple study cases show that for the life-cycle analysis of wind power, the potential energy generation, the number of turbines and the wind conditions are crucial. Likewise, the location of the wind turbines is very relevant for the environmental assessment of the technology for important reasons such as the transportation distance or the construction work that is required for the installation of the infrastructure. As for the solar power plants, the energy harvested largely clearly depends on the existing solar radiation, which is highly affected by the location and angle, as well as by the efficiency of the solar PV panel. Therefore, their life-cycle impact per MWh varies highly between locations.

OTHER MODULES

Decision has not been made yet on other capacities or functionalities considered throughout the ENROAD project. This decision will be certainly based on the time required for its accurate implementation as well as on the access to the information that is required. But for now, the design of the ENROAD tool is focused on the development of the 3 modules previously described.

3.3 Validation and Guidelines

As stated in the proposal submitted to the CEDR Research Call 2019, the performance of the ENROAD tool is planned to be calibrated and validated via the conduction of 3-4 study cases corresponding to specific different locations in Europe. For each of these study cases, a complete technical analysis of the situation is planned to be made for the results to be compared to those provided by the ENROAD tool. Particularly, a first study would be made for the calibration of the tool that should result in the implementation of the necessary changes (if any) in the models and/or the programming. The remaining cases would be used for the validation of the changes made and the verification of the adequate performance of the tool.

After the validation process, paper-based and video-based guidelines are planned to be produced for the final users to get to know how to operate with the ENROAD tool and how to update elements and values with more accurate local data in order to make the tool their own.

LIST OF REFERENCES

Express. https://expressjs.com/

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Global Wind Atlas. https://globalwindatlas.info/

QGIS. https://www.qgis.org/en/site/

Leaflet. https://leafletjs.com/

Miro. https://miro.com/

Node js. https://nodejs.org/en/

OpenStreetMap. https://www.openstreetmap.org/#map=6/40.007/-2.488

OpenTopoMap. https://opentopomap.org/#map=5/49.023/10.020

UNE-EN 15804:2012+A2:2020. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

ANNEX 1: WORKSHOPS FOR UX APPROACH

ARUP

UX Design

Fase 1: Descubrir

10 Marzo 2022

UX Design

Workshop 1

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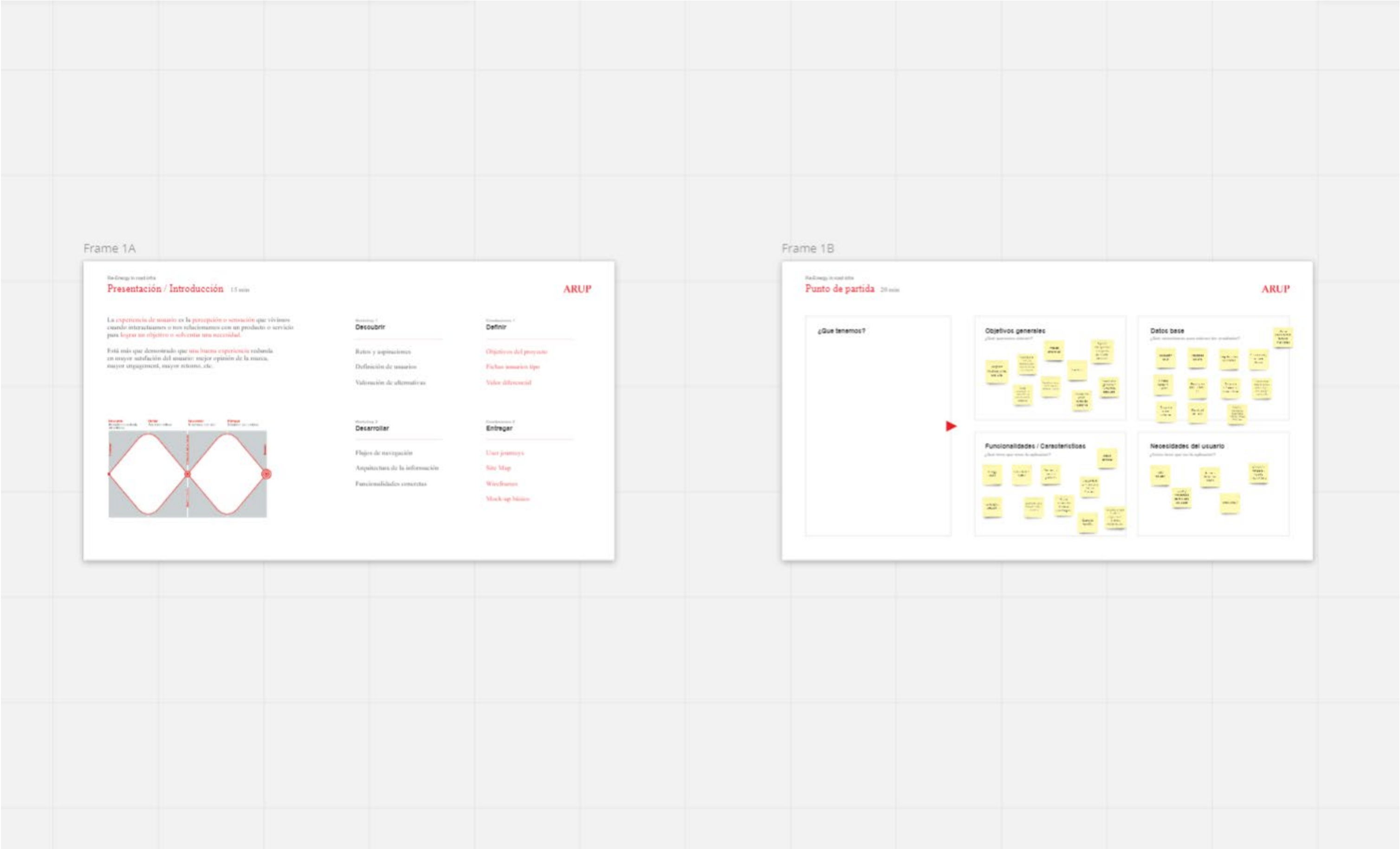
Contenido

- Retos y aspiraciones
- Objetivos (prioritarios y secundarios)
- Definición de usuarios
- Análisis de alternativas



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UX Design

Fase 2: Definir

10 Marzo 2022

Punto de partida

ARUP

Contexto

- Los propietarios y gestores de las infraestructuras viarias tienen interés en reducir el impacto ambiental de sus activos.
- La demanda de energía renovable seguirá en aumento.
- Las zonas buffer de las infraestructuras viarias pueden ser apropiadas para la generación de energía renovable.
- Los propietarios y gestores de estas infraestructuras no son expertos en el sector energético, no saben cuáles son las mejores localizaciones potenciales, cuál sería el coste de implementación, ni el beneficio a medio o largo plazo.

El reto

Crear de una aplicación que facilite a los propietarios y gestores de infraestructuras viarias identificar y valorar las mejores oportunidades para la generación de energía renovable en sus activos.

Objetivos de la aplicación

Principales

1. Identificar las mejores áreas potenciales para la generación de energía renovable alrededor de carreteras.

2. Identificar el tipo de energía renovable más apropiado para cada posible localización.

3. Obtener una estimación de la viabilidad técnico/financiera para posibles instalaciones concretas.

Secundarios

1. Obtener la localización de posibles hubs energéticos.

2. Obtener la estimación de energía producida por la potencial planta.

3. Mostrar unos resultados lo más exactos posibles.

Perfil de usuario (1/2)

Responsable

(económico, ambiental, del activo, etc.)

Metas:

- **Identificar los activos** con mayor potencial para la generación de energía renovable.
- Identificar las mejores localizaciones para posibles **hubs energéticos**.
- Obtener una **estimación** de la energía que se podría producir, de la viabilidad técnico/financiera, etc.
- Obtener una estimación del **impacto ambiental**.
- Poder tomar **decisiones estratégicas** en base a estos datos.

Frustraciones:

- Muchas responsabilidades, gestiona varios proyectos y equipos en paralelo.
- No tiene el tiempo ni la necesidad de entrar al detalle.
- No tiene un perfil técnico, no es especialista energético, ni tiene datos sobre precios, unidades funcionales, etc.

Necesidades:

- Facilidad de uso (pocos pasos y muy intuitivos).
- Resultados generales para la toma de primeras decisiones estratégicas.
- Datos entendibles (equivalencias didácticas).

Perfil de usuario (2/2)

Especialista técnico

(energético, económico, ambiental, etc.)

Metas:

- **Prediseñar** una potencial instalación en una localización concreta.
- Obtener **cálculo exacto** de la energía que produciría la instalación, coste de implementación, retorno de la inversión y beneficio a medio o largo plazo.

Frustraciones:

- Tiene que analizar muchas posibles instalaciones.
- Tiene que entregar informes lo más detallados posibles, no puede quedarse en los datos generales.
- Le piden comparativas de alternativas constantemente.

Necesidades:

- Dibujar de forma sencilla la superficie exacta de la potencial instalación.
- Seleccionar entre los diferentes módulos disponibles.
- Editar los precios, unidades funcionales, etc. por defecto, para un cálculo todavía más ajustado.

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Funcionalidades / Avance user journeys

Perfil responsable

- Acotar zona de interés (país/región).
- Ver zonas con mayor potencial para la generación de cada tipo de energía.
- Selector de activo (vía) y tramo.
- Obtener propuesta de posibles hubs energéticos.
- Obtener estimación de coste/beneficio, energía que podría generarse e impacto ambiental.

Perfil técnico

- Dibujar área concreta de posible instalación.
- Seleccionar entre los unidades funcionales disponibles.
- Posibilidad de añadir precios, añadir o editar unidades funcionales, etc.
- Obtener datos detallados y muy exactos de coste/beneficio, energía que podría generarse e impacto ambiental.

Valor diferencial de la aplicación

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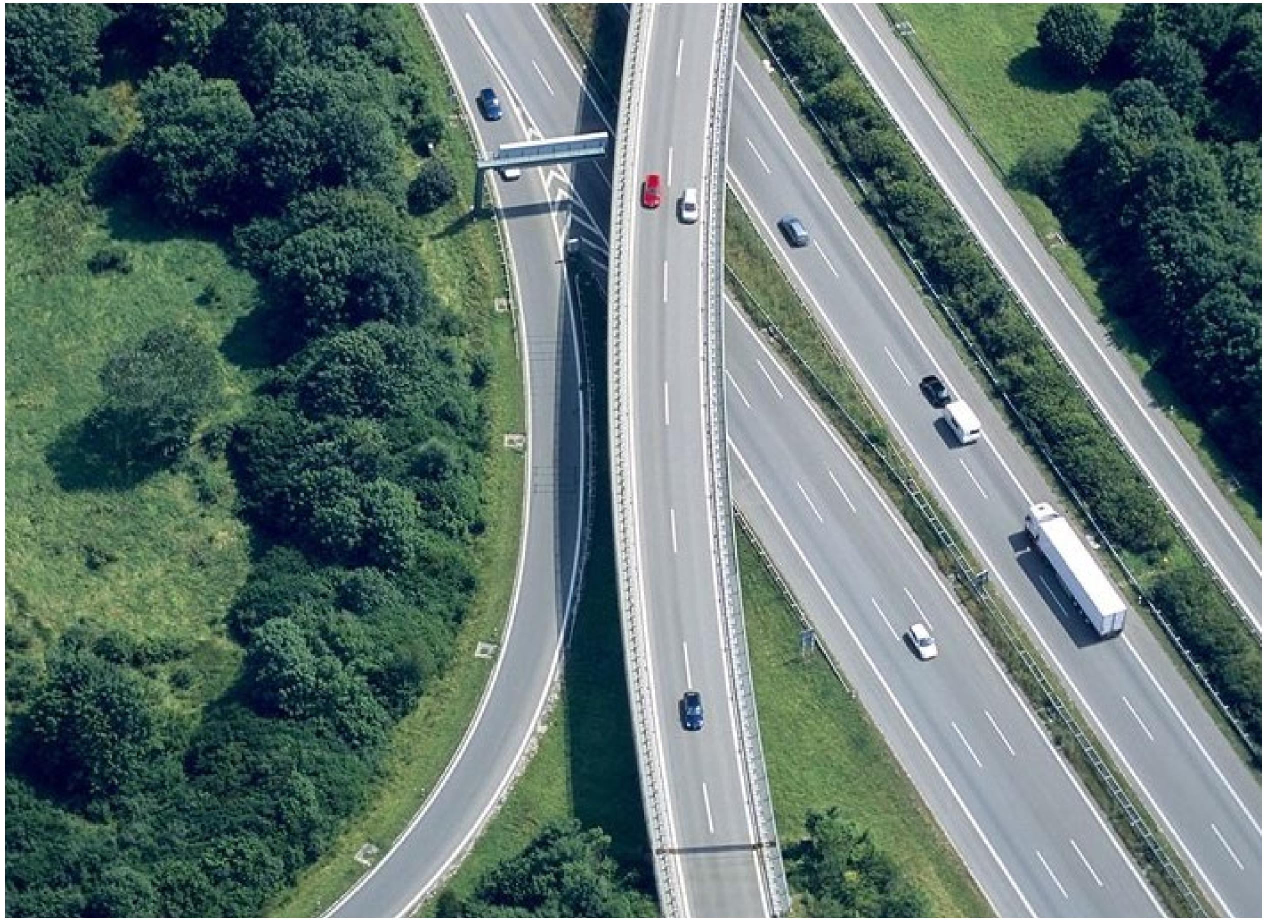
Público objetivo muy concreto:

- Aplicación específica para el sector de las infraestructuras viarias.

Doble nivel de profundidad:

- Nivel pasivo: Resultados generales para perfiles responsables.
- Nivel activo: Resultados muy detallados y posibilidad de editar datos base para perfiles técnicos.



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Fase 3: Desarrollar

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Workshop 2

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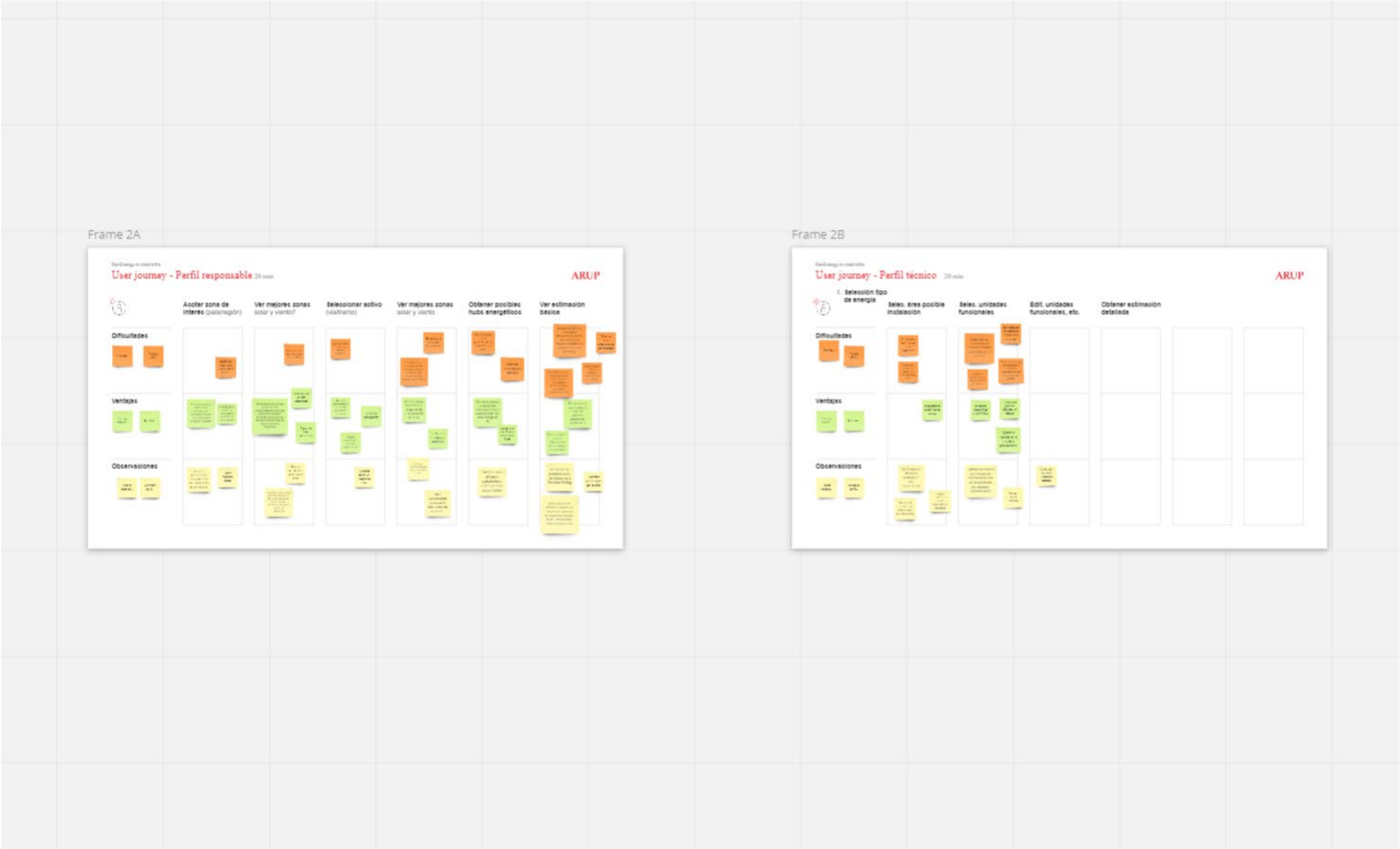
Contenido

- User Journeys
- Funcionalidades específicas
- Tipo de aplicación



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UX Design

Fase 4: Propuesta

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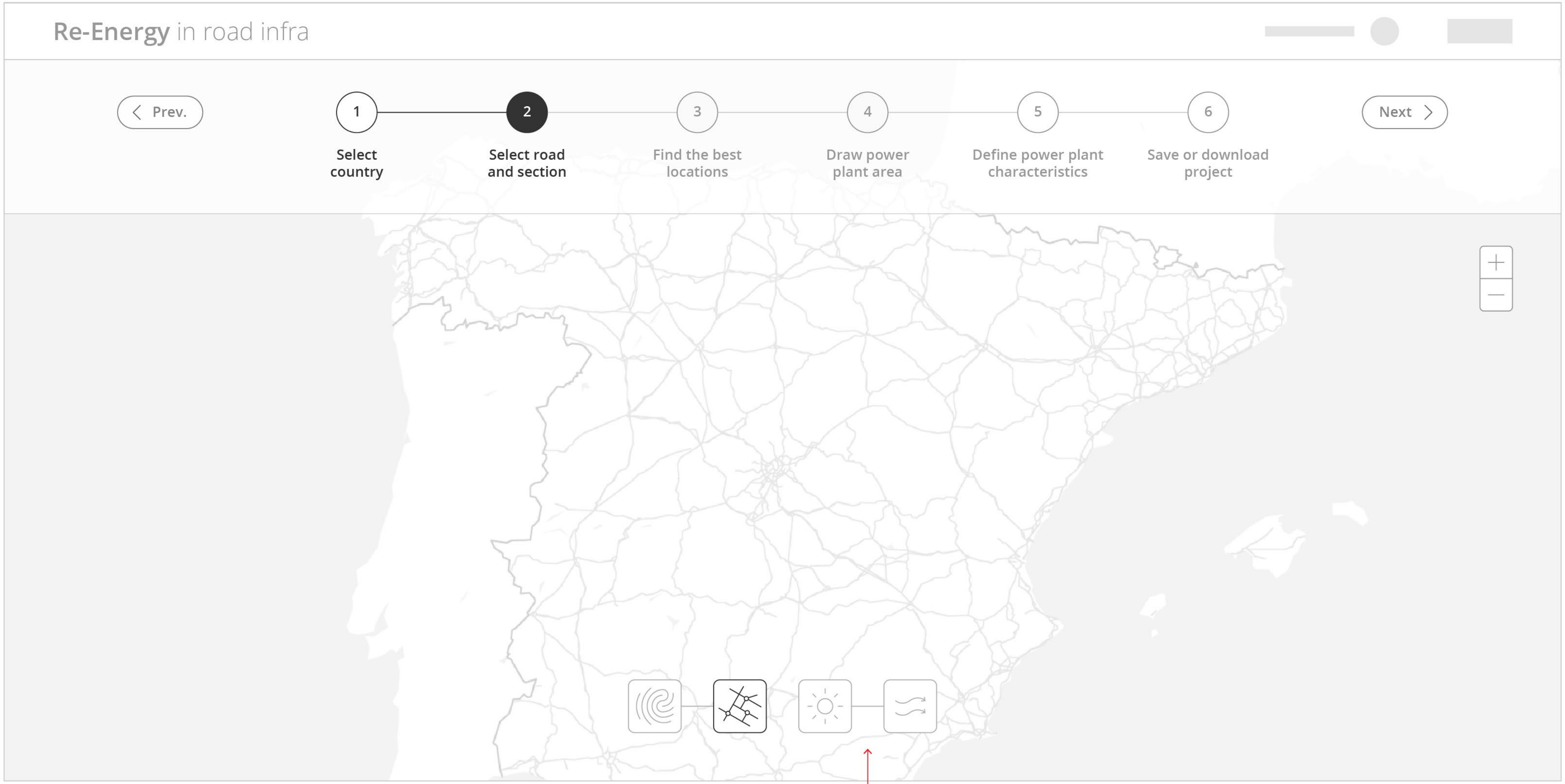
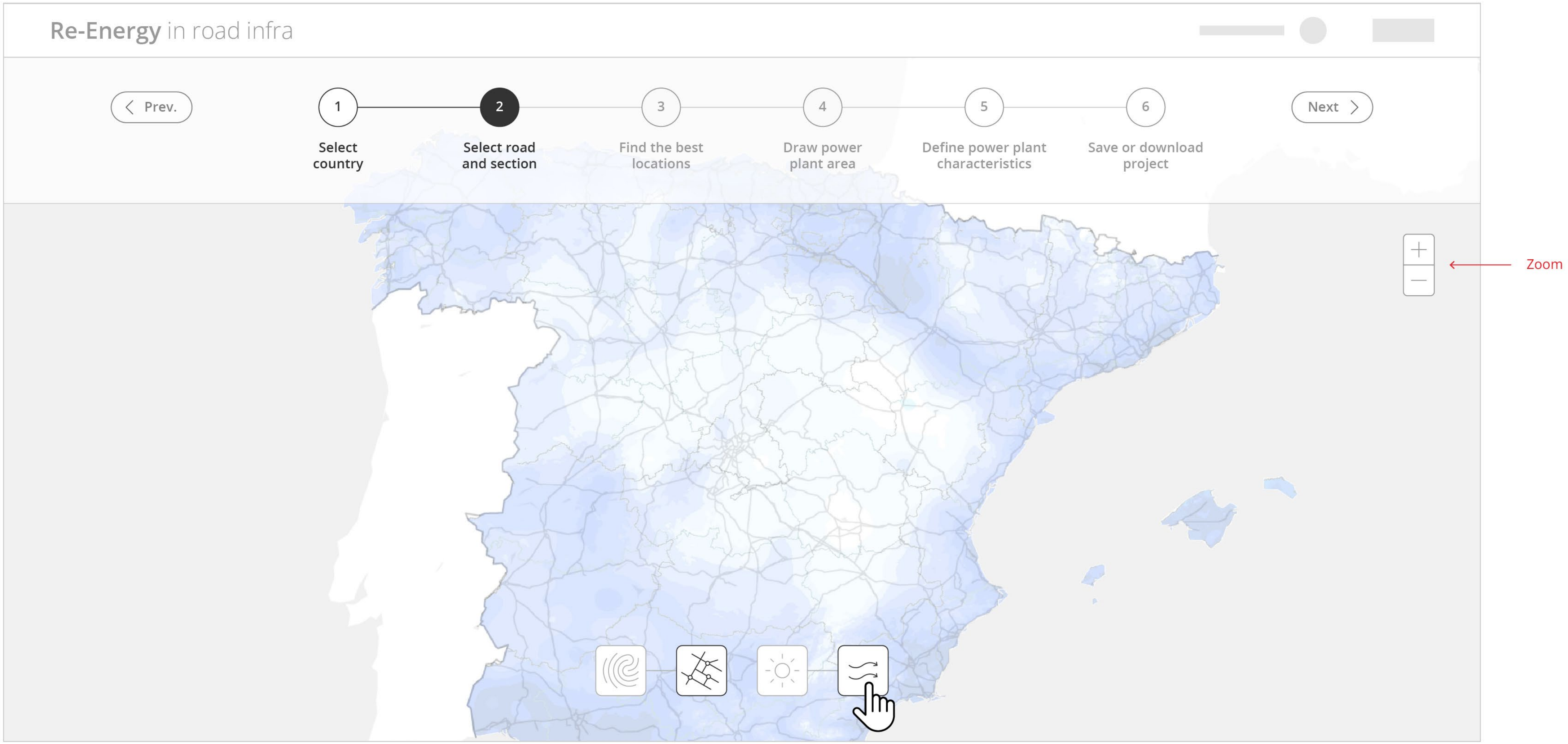
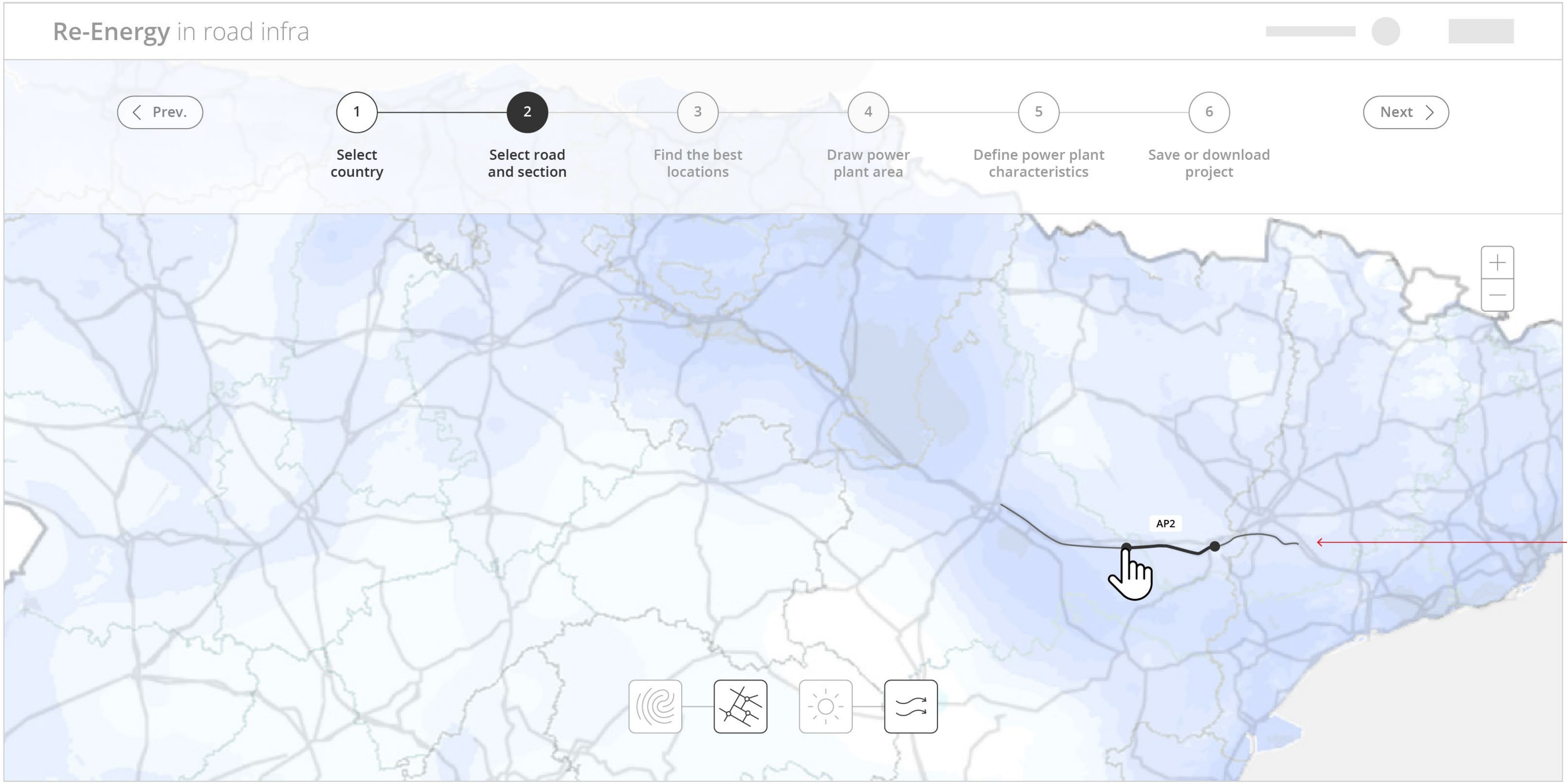
User path
visual guide

Map / Satellite
backgrounds

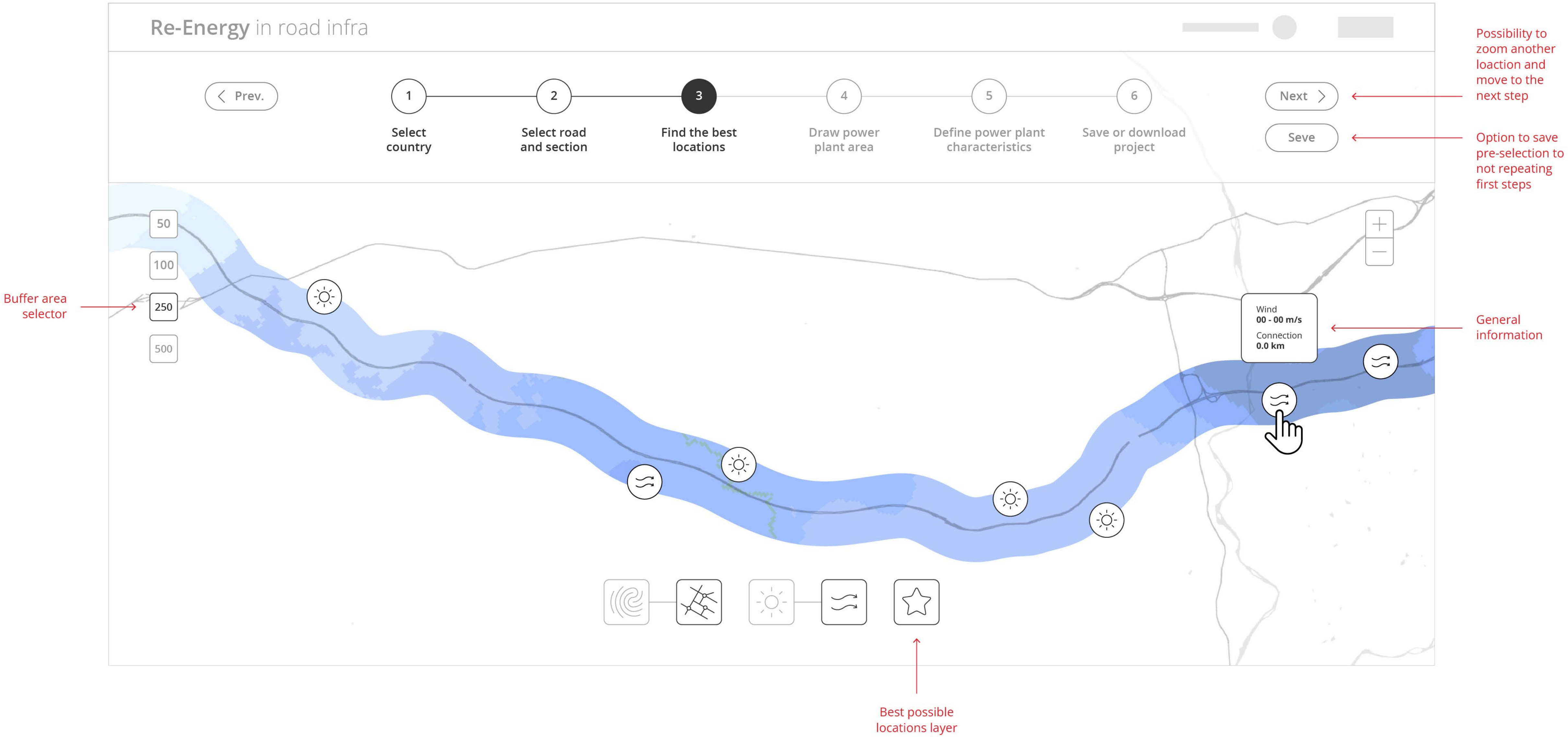


Sun / Wind layers


Re-Energy in road infra
Prev.
1
Select country
2
Select road and section
3
Find the best locations
4
Draw power plant area
5
Define power plant characteristics
6
Save or download project
Next
Zoom

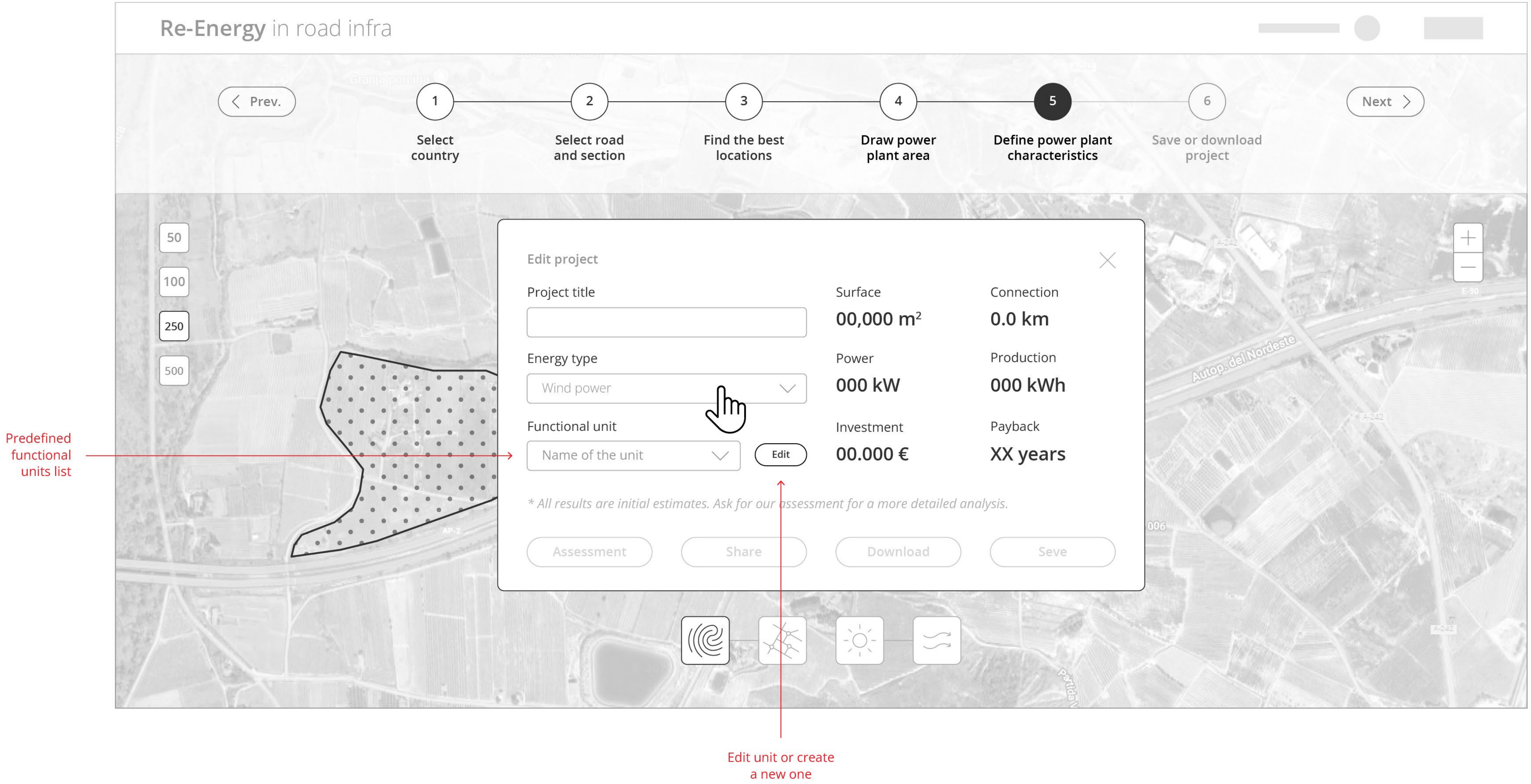


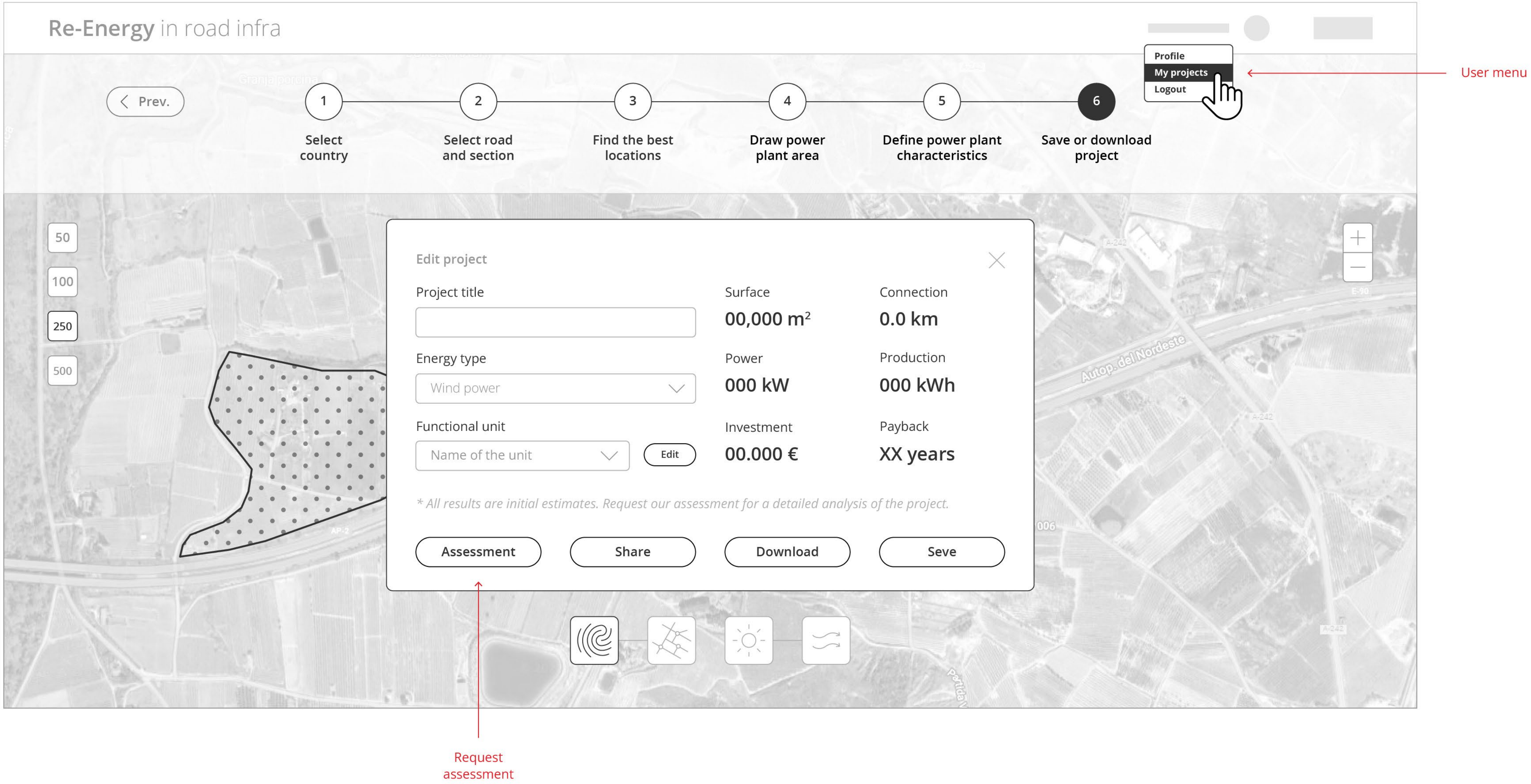
Visual selector



Re-Energy in road infra
Prev.
1
Select country
2
Select road and section
3
Find the best locations
4
Draw power plant area
5
Define power plant characteristics
6
Save or download project
Next
Seve
Possibility to zoom another loaction and move to the next step
Option to save pre-selection to not repeating first steps
50
100
250
500
Buffer area selector
Wind
00 - 00 m/s
Connection
0.0 km
General information
Best possible locations layer

Visual tool for drawing area


Re-Energy in road infra
Prev.
1 Select country
2 Select road and section
3 Find the best locations
4 Draw power plant area
5 Define power plant characteristics
6 Save or download project
Next
50
100
250
500
Edit project
Project title
Energy type
Wind power
Functional unit
Name of the unit
Edit
Surface
00,000 m²
Connection
0.0 km
Power
000 kW
Production
000 kWh
Investment
00.000 €
Payback
XX years
* All results are initial estimates. Ask for our assessment for a more detailed analysis.
Assessment
Share
Download
Seve
Predefined functional units list
Edit unit or create a new one


Re-Energy in road infra
Profile
My projects
Logout
User menu
Prev.
1
Select country
2
Select road and section
3
Find the best locations
4
Draw power plant area
5
Define power plant characteristics
6
Save or download project
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500
Edit project
Project title
Energy type
Wind power
Functional unit
Name of the unit
Edit
Surface
00,000 m²
Connection
0.0 km
Power
000 kW
Production
000 kWh
Investment
00.000 €
Payback
XX years
* All results are initial estimates. Request our assessment for a detailed analysis of the project.
Assessment
Share
Download
Seve
Request assessment