# PLANNING AND ENGAGEMENT ARENAS FOR RENEWABLE ENERGY LANDSCAPES - PEARL*S*

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## Abstract

The present deliverable is compiled in the framework of WP4 of "Planning and Engagement Arenas for Renewable energy LandscapeS – PEARLS" project. The main objective of this report is to present and discuss the capabilities and the main functionalities, technological stacks and interdependencies (e.g., architecture, data types) of the Web-GIS Platform.

The PEARLS Web-GIS platform (https://pearls-webgis.geosystems-hellas.gr/) developed within WP4 corresponds to a novel state-of-the-art technological tool facilitating the assessment of the effects (e.g. landscape effects) of existing Renewable Energy (RE) projects, as well as the identification of potential sitting locations for new RE projects. The platform is applicable to different RE projects and relevant Renewable Energy Landscapes (REL), different spatial planning scales, different countries and for a variety of siting criteria. It has been developed using a bottom-up approach based on six (6) predefined Case Studies. For the implementation of the Web-GIS application only free and open-source libraries/tools have been utilized. PEARLS Web-GIS platform acts both as a dissemination platform for the PEARLS project results, but also as a public awareness tool upon the RE installation issues for all PEARLS Case Studies.

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## I. Introduction

The PEARLS Web-GIS platform developed within WP4 corresponds to a versatile online geographic information system aiming at: **(1)** assessing the effects (e.g. landscape effects) of ***existing*** Renewable Energy (RE) projects and **(2)** identifying potential sitting locations for ***new*** RE projects. For achieving objective **No. (1)**, the platform enables the inclusion of thematic maps representing landscape effects as well as data related to the perception and the views of the public on RE projects. On the other hand, for achieving objective **No. (2)**, the Web-GIS platform includes thematic maps of various siting criteria (representing technical, economic, legal, environmental, landscape-related and social factors) as well as thematic maps of areas identified suitable for RE projects' implementation. The latter maps have resulted from integrated site-selection processes and methodologies, developed within the project, where the opinion and the views of the public have been also taken into account in the relevant decision-making process. The platform is applicable to different RE projects and relevant Renewable Energy Landscapes (REL), different spatial planning scales, different countries and for a variety of siting criteria, while it has been developed using a bottom-up approach based on specific predefined Case Studies. The PEARLS Web-GIS platform can be currently accessed directly at the link https://pearls-webgis.geosystems-hellas.gr/. Access via the main website of the project under the banner Web-GIS will be provided by the end of the project.

In the following sections, the main functionalities, technological stacks and interdependencies (e.g., architecture, data types) of the Web-GIS Platform are described, while, furthermore, general information about the WP4 Case Studies used as a basis for developing the platform are cited.

## II. Web-GIS Platform Architecture and Features

This section includes the implementation steps and technological stacks used for the development of the PEARS Web-GIS tool. For the implementation of the Web-GIS application only free and open-source libraries/tools have been utilized. The following paragraphs narrate which tools are selected, the reasons that led to choose them and they briefly discuss their functionality.

For encompassing and deploying the interoperability framework a Docker environment is established as a state-of-the-art platform solution for building, running, and shipping applications, making development efficient and predictable by providing necessary and useful tools for the developing application solution lifecycle.

To efficiently establish a reliable connectivity between the different components of the developed interoperability framework, two individual containers have been created; the NGINX and the Geoserver container. Leveraging the enhanced capabilities of the former, the Flask application was developed and run within it, representing one of the two pillars of the overall sophisticated framework solution. The Flask application initialises and enwraps both the back-end and client components following the concept of the Client-Server approach. This approach consists of two independent entities identified as the Client and Web Server respectively and it is defined as a system that continuously requests the activity of one or more other systems, called servers, to accomplish specific tasks and to evenly distribute the workload. The general architecture of the application is show in Figure 1.

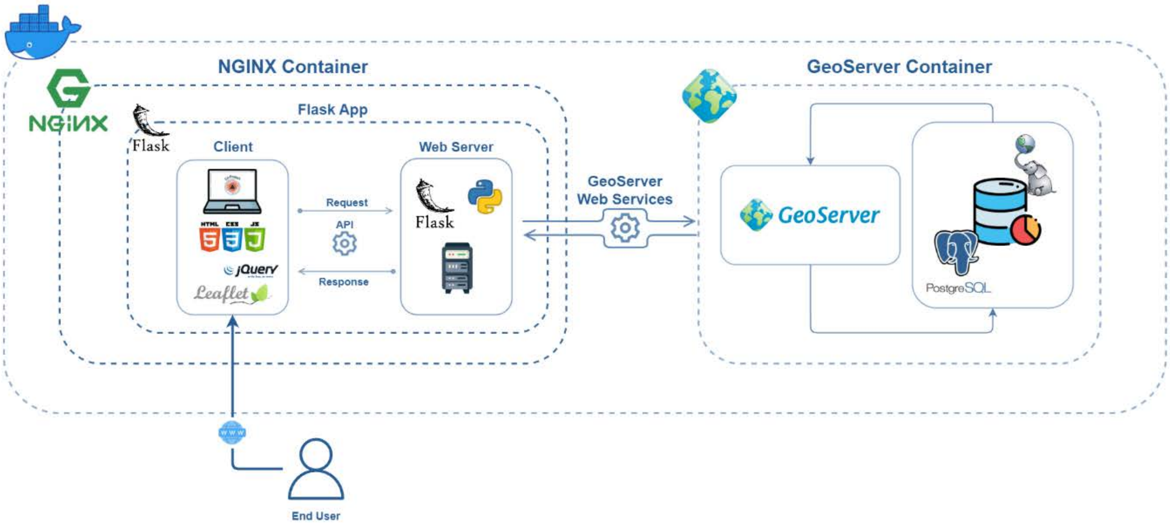


**Figure 1.** Schematic representation of the UML workflow depicting the architecture of the described geospatial data management solution.

## 1. Web Server Implementation

The client-side interacts with the Flask application, which runs within the NGINX container, by placing requests and receiving responses. These requests are processed by the Flask application, which provides the necessary replies ending up back to the client. The back-end of this set-up is written in the high-level general-purpose programming language Python3, in combination with the micro web framework Flask, which additionally provides a robust set of libraries dedicated to handling HTTP requests. The Flask application is mainly structured based on individual routes that handle the external HTTP request. The multiple data sources/providers approach requires a multiparametric back-end implementation, capable of handling and efficiently responding to variant requests. The spatial dimension of managing data, considering the great variety of different data formats (e.g., ESRI shapefile, geojson, GeoTIFF etc.), increases the need for a robust and well-structured application.

## 2. Web-GIS Database

The Web-GIS application incorporates the open-source RDBMS PostgreSQL[1] for storing and handling data. PostgreSQL (also known as 'Postgres') is a reliable database system with over 30 years of active development, released under the PostgreSQL License, a liberal Open Source license. For handling the geospatial data, the geospatial extension of PostgreSQL, PostGIS[2] is deployed. PostGIS is a spatial database extender that adds support for geographic objects allowing location queries and many other geographic functions to be run in SQL. PostGIS is released under the GNU Public License (GPLv2[3]).

PostgreSQL is a powerful open-source object-oriented data management system for storing and searching data through SQL queries. In order to insert geospatial information into the database, such as vector features, the PostGIS extension is required to extend its capabilities by adding support for storing, indexing and querying spatial data in specific geographic coordinate systems (EPSG) and performing specialized spatial searches.

[1] https://www.postgresql.org/

[2] https://postgis.net/

[3] https://opensource.org/licenses/gpl-2.0.php

## 3. The GeoServer Implementation

The scope and the methodological framework of PEARLS project stress the necessity of an integrated system to be produced, where the NGINX container through the Flask application interacts with the user, and at the same time, the GeoServer container organizes the storage, management, and distribution of the geospatial data. The implementation of a GeoServer v.2.23.1 is deployed within the GeoServer container and efficiently connected to a well-configured PostgreSQL 13 database.

The interconnection between the two individual containers is established by the web services that GeoServer natively offers. The web services that are used for data exchange and integration are based on unified standards, including Web Map Service (WMS) for serving collections of layers as map images and Web Feature Service (WFS) for serving data as vector features. To this end, the Web Server acts as a gateway server, when receiving client requests, for instance, a specific request to access geospatial data that are stored within the database, routing them to the GeoServer container. After this request is appropriately processed by the GeoServer the corresponding response is produced, and transmitted back to the Web Server, which redirects it to the client. The efficient link between the two containers establishes an effective performance of the integrated framework, allowing the simultaneous management of incoming client requests.

## 4. Data Uploading to GeoServer

Towards optimizing the dissemination and map creation for the data contained in PostgreSQL the Web-GIS tool utilizes GeoServer[4]. Geoserver is a Java-based server that allows users to view and edit geospatial data using open standards set forth by the Open Geospatial Consortium (OGC). The program is released as free software under GNU General Public License Version 2.0.

Within the Web-GIS platform, GeoServer is utilized as a middleware application by connecting the Web-GIS back and front end with the geospatial DataBase (DB). Geoserver creates OGC services namely WFS, WMS and WMTS for displaying data coming from the PostGIS DB. The advantages of using GeoServer over connecting directly the backend with the DBMS are many, including: use of OGC services, CRS handling, tile caching, security features and of course ease of use. GeoServer offers, among others, a GUI for the handling, the storage and the configuration of geospatial datasets (see below in Figure 2). Lastly, GeoServer functions as an OGC service creator for viewing and analyzing the data on external GIS tools. Formats supported from GeoServer are:

- WMS: AtomPub, GIF, GeoRSS, GeotTiff, GeoTiff 8-bits, JPEG, JPEG-PNG, JPEG-PNG8, KML (compressed), KML (network link), KML (plain), OpenLayers, OpenLayers 2, OpenLayers 3, PDF, PNG, PNG 8bit, SVG, Tiff, Tiff 8-bits, UTFGrid.
- WFS: CSV, GML2, GML3.1, GML 3.2, GeoJSON, KML, Shapefile, text/csv.

For uploading the individual layers in the GeoServer an automated process was developed leveraging the benefits and functions of the open-source Python library “geoserver-rest”, which establishes the connection link between the data storage, wherein the data are hosted, and the GeoServer. Additionally, widely used Python libraries (e.g., geopandas, sqlalchemy etc.) are used for the development of the whole data-uploading workflow. GeoServer was successfully organized following a data organization structure that is dependent on the different case study areas.

[4] http://geoserver.org/

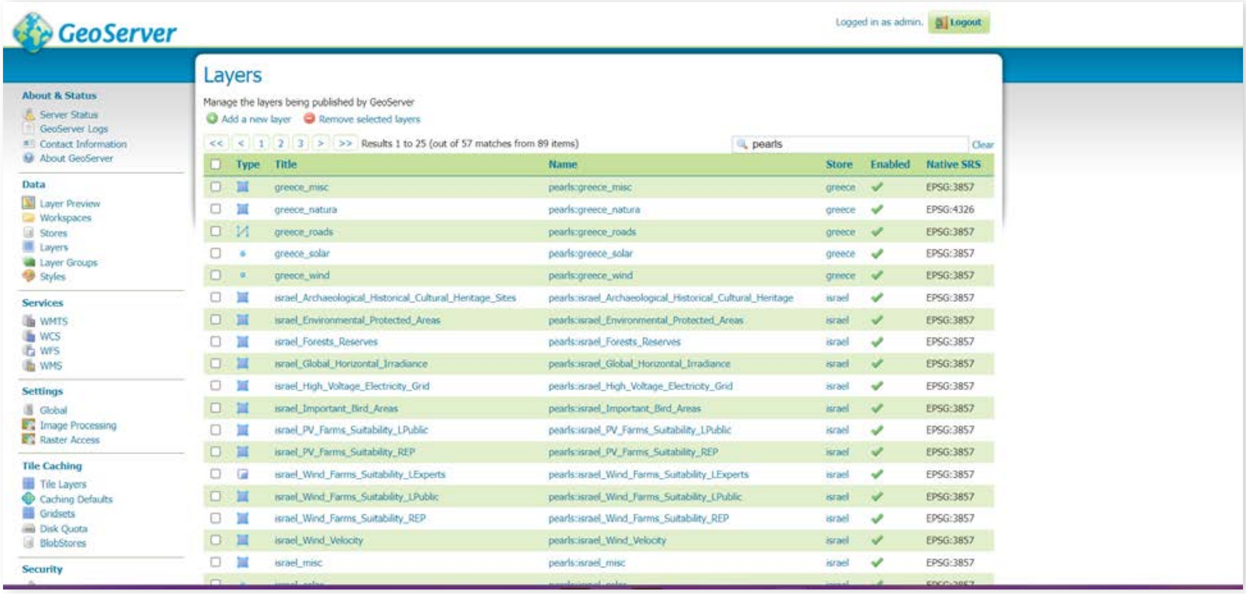


**Figure 2.** Geoserver interface and layer handling.

## 5. Web App Stack

### *5.1. Back-end*

For the operation of the back-end of the application, we made use of the programming language Python v. 3.10. This language is an open and widespread programming language and, in combination with the Flask library, enables the operation of a web-app server as well as an advanced capability of interacting with a database, editing data entry forms and building information interfaces (APIs) that meet all the requirements for the needs of PEARLS. The back-end of the application also manages the download of geospatial vector data via WFS as well as raster data via WMS from the GeoServer, which are then made available for use by the front-end environment.

### *5.2. Front-end*

The front-end constitutes the graphical interface between the end-user and the geospatial provided by the PEARLS project. Aiming to provide a modern, dynamic and user-friendly tool for geospatial data handling and visualization, where high-level programming languages (i.e., JavaScript ES6, HTML5, and CSS3) are used and a plethora of web-based advanced spatial and non-spatial libraries and technologies are combined, enhancing end-users experience. An effective combination of reliable and stable technologies is required to achieve an optimal result. “Leaflet.js” is an open-source library mainly written in JavaScript, offering a variety of functionalities related to web map visualisation and geospatial data, used to incorporate the map with interactive spatial features. In addition, Leaflet JS provides useful functions for spatial data handling and visualization dedicated to OGC data services (i.e., WFS and WMS). This library is the most widespread in the construction of Web-GIS applications due to the wide variety of plugins and open-source related tools that provides.

For enriching the functionality of the front-end component, the open-source JavaScript library “jQuery” is used, providing useful functionalities to simplify HTML DOM tree traversal and manipulation, as well as event handling and animation. By leveraging the tools that jQuery provides, the user interface is designed as a one-page web graphical interface with dynamic content and advanced user interactivity. In Figure 3, part of the base code developed for the back-end and front-end is shown.

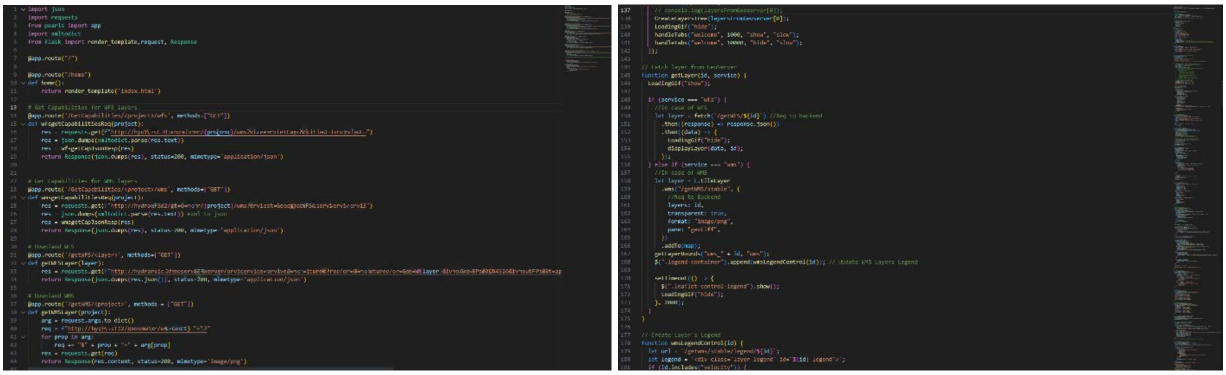

**Figure 3.** Base code for the back-end (left) and front-end (right) components of the PEARLS Web-GIS.

## 6. Features and Interfaces

The interface was developed in such a way that the user interaction is quick and efficient in attaining user goals. The basic layer map and all the supplementary aspects that collectively make up the User Interface (UI), were created using the PEARLS theme colours in line with the project's website and are displayed in Figure 4. On the left section of the geo-visualisation platform, the Layer Control Panel is displayed, allowing the user to interchange between the different spatial layers, structured by sectors, being able to choose among the Case Studies area of the project (Figures 5~6). Based on the user's interest, the different layers incorporated within the platform can be activated, or deactivated, offering the user valuable information for the selected area of interest (Figure 7). Concerning the top part of the main map frame, some additional map navigation tools were built (i.e., zoom in, zoom out, base maps control panel) to facilitate users' map interaction and capabilities, as well as the selection among the offered functionalities. Last but not least, in the bottom left part of the frame three additional buttons are displayed, offering the ability to minimize the layer control panel, extend in a full-screen mode, and print the visualized information in a PDF format, from the upper part to the lower part, respectively.

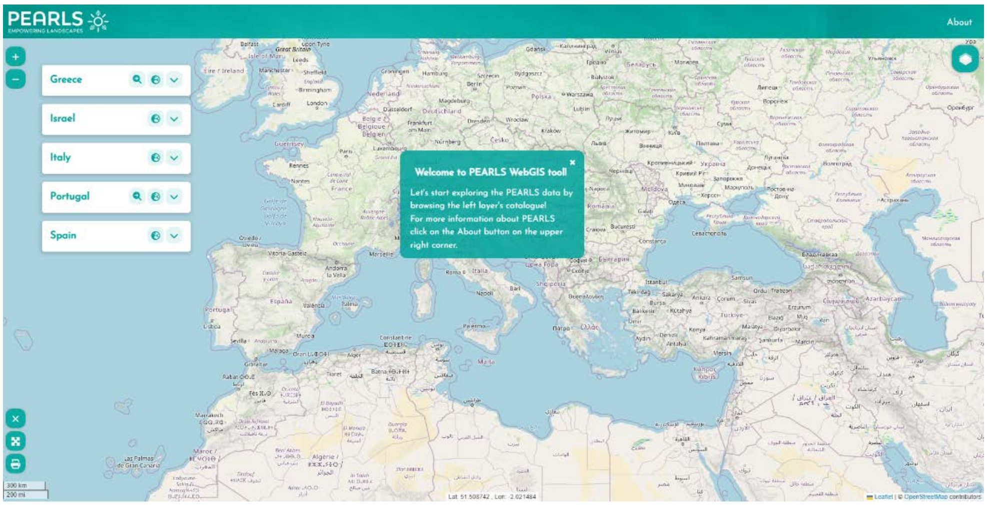


**Figure 4**. PEARLS Web-GIS landing page and main interface.

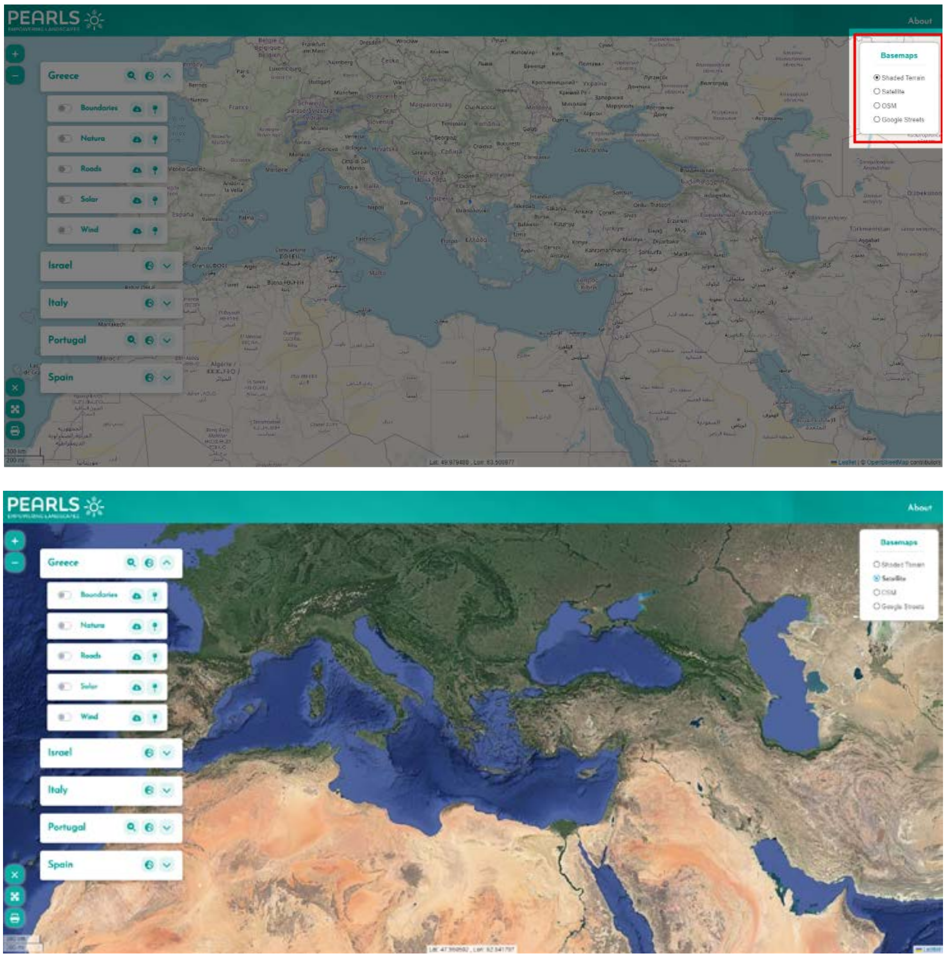


**Figure 5**. PEARLS Web-GIS basemaps selection.

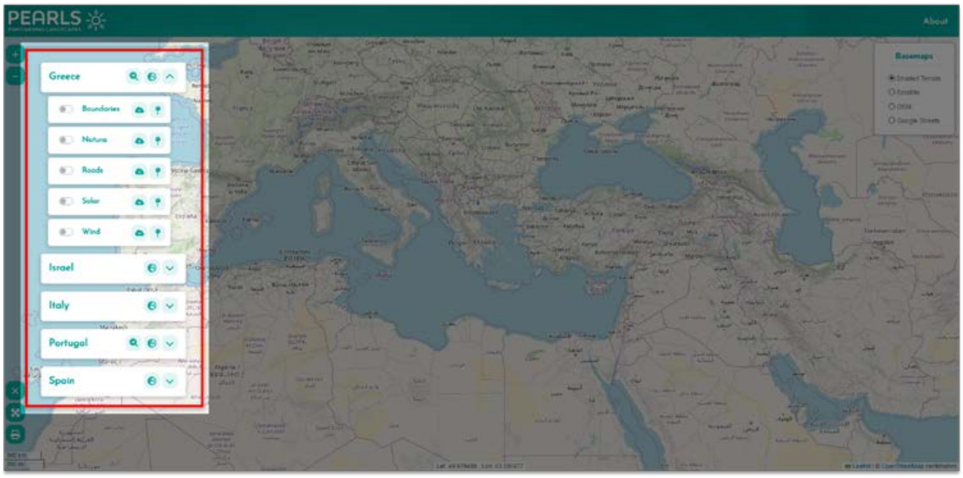


**Figure 6.** PEARLS Web-GIS general layer selection at country level.

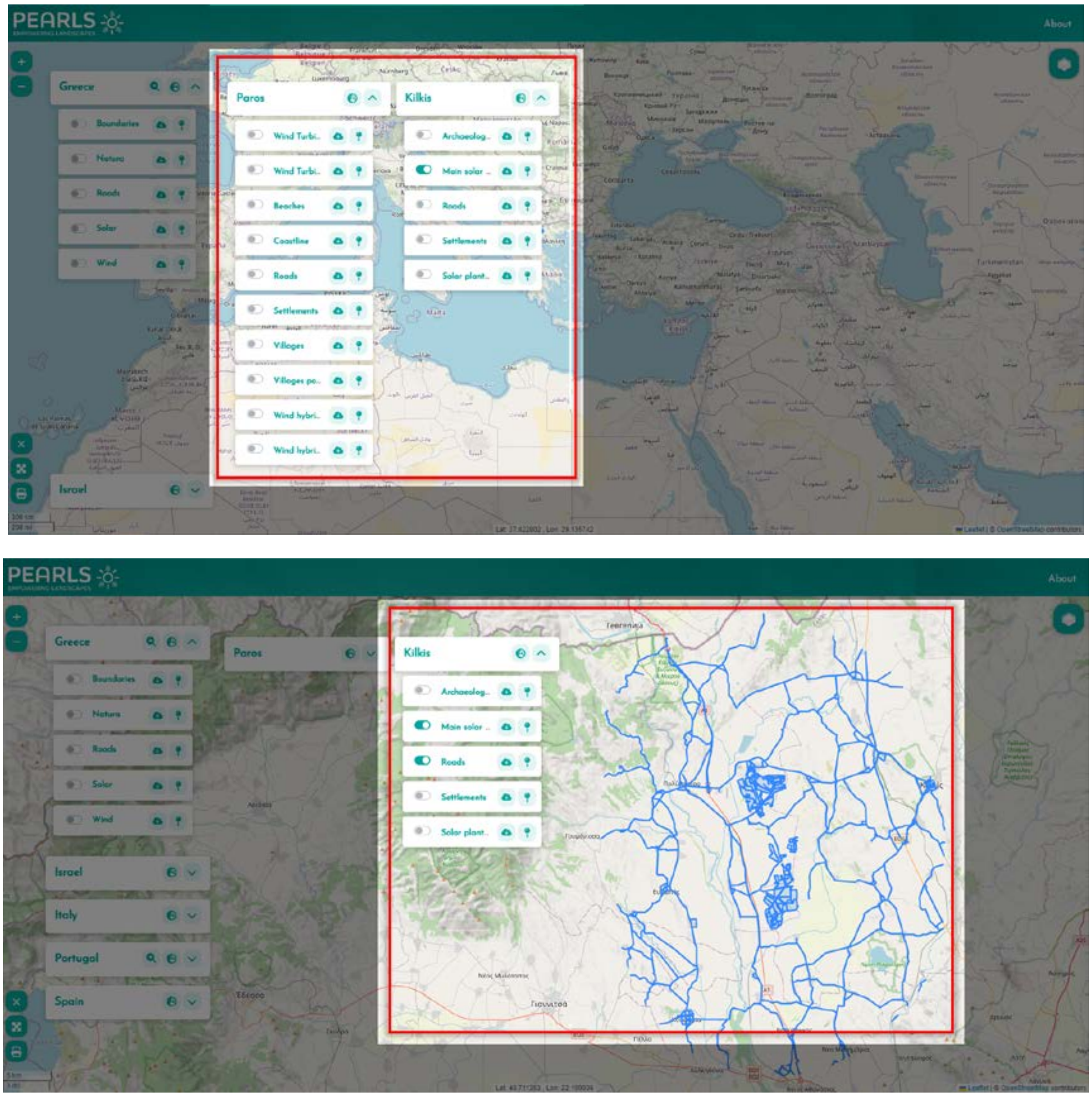


**Figure 7.** PEARLS Web-GIS layer selection for the case studies of each country.

## 7. Data Requests and Handling

The front-end geo-visualization platform is strictly interconnected and strongly dependent on the back-end implemented component. Simultaneously with the rendering of the platform, an initial request is forwarded to the back-end to retrieve the “GetCpabilities” from the GeoServer, which offers an in-detail description of each integrated spatial dataset that is provided for visualization. Following the hierarchical structure of the “GetCpabilities” response, the Layer Control Panel is structured automatically, listing all the offered datasets. In the case where the user activates a layer, a new dedicated request is structured, including the needed layer information, which is then forwarded to the back-end where the corresponding functions are triggered to retrieve the selected layer’s dataset from the GeoServer. On the front-end side, when the response arrives the data is handled and processed accordingly, based on the format (geojson or png “map tiles”) and displayed on the map with the use of dedicated Leafle.js tools.

In Table 1 below, all PEARLS collected and harmonised datasets that can be retrieved for visualization through the PEARLS Web-GIS platform are presented, categorised per country and relevant case study.

**Table 1.** Summary of harmonized data for publishing through PEARLS Web-GIS.

<table>
<tr><th>Country</th><th>Case Study</th><th>Layers</th></tr>
<tr><td rowspan="1">Israel</td><td>CS1 (country level)</td><td>Archaeological Historical Cultural Heritage Sites<br>Environmental Protected Areas<br>Forests Reserves<br>Global Horizontal Irradiance<br>High Voltage Electricity Grid<br>Important Bird Areas<br>Wind Velocity<br>Site Suitability Analysis results:<br>- PV Farms Suitability LExperts<br>- PV Farms Suitability LPublic<br>- PV Farms Suitability REP<br>- Wind Farms Suitability LExperts<br>- Wind Farms Suitability LPublic<br>- Wind Farms Suitability REP</td></tr>
<tr><td rowspan="2">Spain</td><td>C2a (Arcos de la Frontera)</td><td>Visibility from public spaces (500 m)<br>Visibility from public spaces (1200 m)<br>Visibility from public spaces (2500 m)</td></tr>
<tr><td>C2b (La Palma del Condado)</td><td>Boundaries<br>Optimum PV parcels (for Max Dist from Grid = 7 km & Total PVs Area = 2 km$^2$)<br>SDIS map</td></tr>
<tr><td rowspan="2">Greece</td><td>CS3a (Paros island)</td><td>Beaches<br>Coastline<br>Roads<br>Settlements<br>Villages<br>Villages points<br>Wind Turbines Visibility (Operational)<br>Wind Turbines Visibility (Production licence)</td></tr>
<tr><td>CS3b (Kilkis regional unit)</td><td>Archaeological sites<br>Main solar plants<br>Roads<br>Settlements<br>Solar plants with Operational License (30km around main plants)</td></tr>
<tr><td rowspan="2">Portugal</td><td>CS4 (Municipality of Mértola)</td><td>Suitability Index PV Sites (AHP & TOPSIS)<br>Suitability Index PV Sites (ENTROPY & TOPSIS)<br>Suitability Index PV Sites (EW & TOPSIS)</td></tr>
<tr><td>CS4 (Country level)</td><td>Archaeological, Historical and Cultural Heritage Sites<br>Global Horizontal Irradiance<br>Important Bird Areas<br>Practical PV Energy Output<br>Prioritization Results for PV deployment in municipalities</td></tr>
<tr><td>Italy</td><td>CS5</td><td>Under development</td></tr>
<tr><td colspan="2">Common layers for all countries</td><td>Boundaries<br>NATURA areas<br>Solar farms<br>Wind farms</td></tr>
</table>

## III. WP4 Case Studies General Characteristics

As already mentioned above, the PEARLS Web-GIS platform has been developed using a bottom-up approach based on specific predefined Case Studies. Up to now, six (6) Case Studies (1 for Israel, 2 for Spain, 2 for Greece, 1 for Portugal) have been developed and deployed in the Web-GIS. Three (3) Case Studies have been developed explicitly at local/municipality scale, one (1) at regional scale, one (1) at national scale, and one (1) at both national and local/municipality scale. Among those Case Studies, two (2) focus on onshore wind projects and four (4) on PVs projects. Furthermore, five (5) Case Studies deal with new RE projects and one (1) with existing projects. The main characteristics of the Case Studies are cited in Table 2 of the present document. It is emphasized that one more Case Study (Italy) is currently under development. The corresponding data will be incorporated in the PEARLS Web-GIS platform before the completion of the project.

**Table 2.** Main characteristic of WP4 Case Studies.

| ***Case Study ID*** | ***Country*** | ***Planning Scale*** | ***Renewable Energy Source Type*** | ***Secondments*** |
|---|---|---|---|---|
| **CS1** | **Israel** | **National** | **Onshore wind** & **Solar** (**new** RE projects) | AUTh to SP Interface |
| **CS2a** | **Spain** | **Local/Municipality** (Arcos de la Frontera) | **Solar** (**new** RE projects) | UNITN to Territoria |
| | | **Local/Municipality** (La Palma Del Condado) | **Solar** (**new** RE projects) | AUTh to Territoria |
| | | | **Solar** (**social perception** on **existing & new** RE projects) | UNITN to Territoria |
| **CS3a** | **Greece** | **Local/Municipality** (Paros island) | **Onshore wind** (**existing** RE projects) | UHU to GSH |
| | | | **Onshore wind** (**existing & new** RE projects – **social perception**) | UNITN to GSH |
| **CS3b** | | **Regional** (Kilkis regional unit) | **Solar** (**new (licensed)** RE projects) | CONSORTIS Geo to UNITN |
| | | | **Solar** (**new (licensed)** RE projects) – **visual impact analysis**) | UHU to CONSORTIS Geo |
| | | | **Solar** (**new (licensed)** RE projects) – **social perception**) | UNITN to CONSORTIS Geo |
| **CS4** | **Portugal** | **National** & **local/municipality** | **Solar** (**new** RE projects) | AUTh to ENERCOUTIM |

Regarding the objectives of the WP4 Case Studies, CS1 aimed at developing a Sustainable Spatial Energy Plan (SSEP) for Israel at national spatial planning scale, related to the installation of new RE projects (onshore wind and solar technologies). Details about the whole relevant methodology can be found at Spyridonidou et al. (2021). CS2a focused on the development of a Sustainable Energy Plan for the

Municipality of Arcos de la Frontera in Spain including public perception and landscape considerations for new PV installations. As for CS2b, this Case Study had a twofold objective. The first objective was to determine optimum areas for new PV plants at the La Palma Del Condado municipality in terms of minimizing visual disturbance, while satisfying spatial constraints (land use, environmental & techno-economic siting factors). Details about the relevant methodology can be found at Nagkoulis et al. (2022). The second objective was to investigate the social perception for existing and new PV projects in the examined area. Moving on to CS3a, this Case Study aimed at assessing landscape effects of existing onshore wind farms located at Paros island (Kontopoulos et al., 2020). Furthermore, in this Case Study the social perception on existing & new wind farm projects in the island was investigated. CS3b had also a twofold objective corresponding to: (1) the visual impact assessment of new (licensed) PV plants at the Kilkis regional unit and (2) investigation of the social perception on new (licensed) PV plants in the area (Codemo et al., 2023). Finally, the last Case Study (CS4) aimed at the development of a decision-support framework to identify most and least suitable sites for new installations in Portugal both in national and municipality spatial palling scale (Spyridonidou et al., 2022).

## IV. Conclusions

The present deliverable contains an overview of the capabilities and the main functionalities, technological stacks and interdependencies of the PEARLS Web-GIS Platform. The platform corresponds to a novel state-of-the-art technological tool acting both as a dissemination platform for the PEARLS project results, but also as a public awareness tool upon the RE installation issues for all PEARLS Case Studies.

The use of the Web-GIS solution can provide a wealth of benefits, by visualizing and analyzing spatial data related to RE installations and REL sustainable management. Accordingly, it produces added value information, such as promoting policies, prioritizing energy-related measures and relevant funding and raising public awareness.

Finally, the implementation steps of the Web-GIS platform result to a fully operational tool, developed with minimum open-source technologies and libraries, ensuring its reproducibility and easy migration to several other relevant case studies across all EU member states.

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