

## DEVELOPMENT OF A WEBGIS FOR SOLAR PV RESOURCE AND INSTALLATION ASSESSMENT USING GEOSPATIAL TECHNOLOGIES

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### ABSTRACT:

The SINAG Web Portal, a web-based GIS platform that hosts spatial data and a forecasting model for solar PV installation assessment, serves as a repository for the products and outputs of the SolarPot and OutSolar components of a research project called Solar PV Resource and Installation Assessment Using Geospatial Technologies (SINAG). The website was developed with frontend and backend services which involved the use of a content management system, database systems, cloud virtual machines, Linux operating systems, programming languages, specifically Python and JavaScript, and a style scripting framework. All outputs generated by the two components of Project SINAG are stored on the dedicated cloud server of the website. It includes processed spatial data, a graphical summary of the created models, the ability to explore historical data, data requests and downloads, and the use of mapping tools. It is anticipated that the web portal will play a significant role in the assessment and decision-making process for selecting candidate sites for installing solar PV systems across the Philippine archipelago.

### 1. INTRODUCTION

The advent of digital era brought remarkable transformation on geographic data visualization and presentation. The development of Geographical Information Systems (GIS), which includes software applications and web services and the hosting of spatial data and features in the cloud, represents a significant advancement in the field of geospatial data analysis. The accessibility of these web-based systems from any location and on any device increases user engagement and broadens their audience.

Project SINAG (Solar PV Resource and Installation Assessment Using Geospatial Technologies) is a two-year research project funded by the Philippine Department of Science and Technology (DOST). The project consists of two research components namely, OutSolar and SolarPot for solar PV output forecasting and potential mapping, respectively. Through the user-friendly SINAG Web Portal, outputs from these components are made available online, enabling interested parties and stakeholders in solar PV systems to make use of digital maps and graphical user interfaces. The web portal has a robust backend system, efficient cloud storage, and a well-structured database schema. The outputs, which are kept on a separate cloud server, include spatial data that has been processed, model summaries in graphics, tools for exploring historical data, data request and download functionality, and mapping tools. The SINAG Web Portal is anticipated to play a significant role in the

evaluation and decision-making processes for choosing suitable sites for solar PV installation throughout the Philippine archipelago.

### 2. STUDY AREA

This paper discusses the development of a WebGIS platform for solar PV assessment, specifically within the context of Project SINAG implementation in the whole country of the Philippines. The Web Portal serves as a domain which holds the important outputs of the project SINAG from the OutSolar and SolarPot components.

The OutSolar component has been developing a locally adapted forecasting model that would accurately and realistically predict the output power of solar PV installations in the Philippines. Meanwhile, the SolarPot component had been focusing on the assessment of available solar PV resource potential in the Philippines. SolarPot has generated solar resource maps using high-temporal remotely sensed data and up-to-date processing techniques considering meteorological and geomorphological aspects of solar PV systems in the assessment. These outputs offer relevant stakeholders of solar energy access to digital maps, graphical interfaces, and forecasting capabilities.

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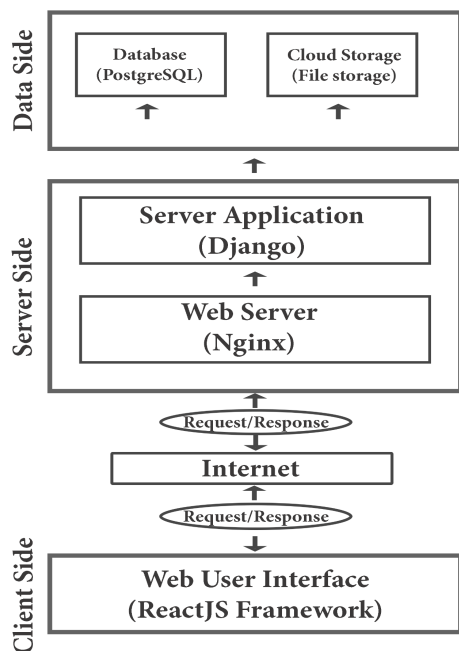
Overall, the Project SINAG webGIS portal showcases the available outputs and products of both SolarPot and OutSolar components as interactive layers where users can gather information related to solar energy resource assessment and forecasting in the Philippines.

### 3. WEB GIS DEVELOPMENT

The WebGIS development involved dividing the system into two parts: the frontend, which is the client side; and the backend, which is the server side. These two components of the WebGIS are shown in Fig. 1. The frontend refers to the part of the system that runs on the user's device, such as a computer or smartphone. It is responsible for displaying the interface and allowing users to interact with WebGIS. On the other hand, the backend handles the behind-the-scenes operations. It includes the database, cloud storage, APIs, and other sophisticated web services that are the backbone of all endpoint requests and responses (Fig. 2).



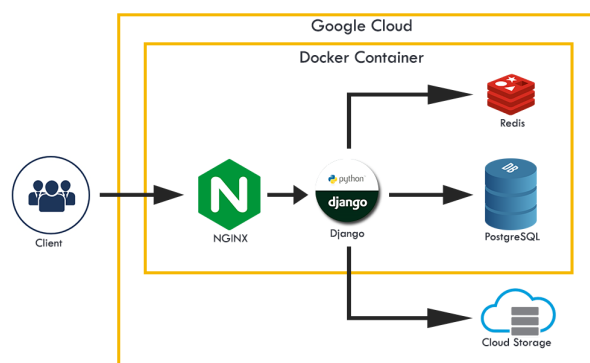
**Figure 1.** The server-side and the client-side of the WebGIS platform.



**Figure 2.** The full schematic of SINAG WebGIS architecture.

### 3.1 Architecture of the Backend Application

The backend architecture of the web application, hosted in the Google cloud platform, comprised several components working together to provide a seamless user experience. It has a nginx server, which acts as an intermediary between the client and the application. The application itself was built using Django (*Django*, 2012/2023), a widely used web framework written in Python that utilized Object-Relational Mapping (ORM) to interact with the PostgreSQL database (*PostgreSQL 16*, 2023), where user data and project information were stored. Additionally, a cloud storage database was employed to store media files such as GeoTIFF images and CSV sheets, which were referenced in PostgreSQL. All of these microservices were containerized using Docker (*Docker*, 2023).

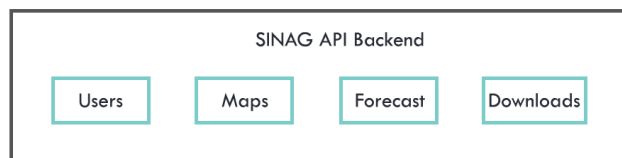


**Figure 3.** The backend architecture of the SINAG WebGIS.

### 3.2 Sub-applications of Backend

The WebGIS backend project comprised four sub-applications: users, maps, forecasts, and downloads, as shown in Fig. 4. Each of these applications plays a crucial role in the overall functionality of the system.

The user's app is responsible for handling the creation and management of user accounts, user subscriptions, and payments. The Maps app manages the storage of the Solar PV potential layers and their associated data. The forecast app manages data related to different forecast files. Finally, the downloads app handles the delivery of forecast requests and templates.



**Figure 4.** The backend application of the WebGIS

### 3.2.1 Users

The relationship of data between the user's information and the payment subscription system is shown in Fig. 5.

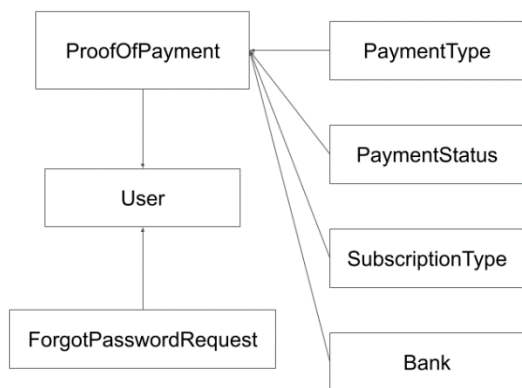
The *User* model plays a crucial role in the authentication and authorization processes of the system. It stores the user's email and password, essential for logging in. Additionally, it stores the user's information, such as name and contact details.

The *ProofOfPayment* model stores the information every time a user submits a receipt of their payment. It contains the payment details, including the payment type, payment status, subscription type, and bank information. These details help verify the payment and ensure the user's subscription remains active.

The *PaymentType* model stores the different types of payment methods available for the user to choose from, such as credit card or bank transfer. The *PaymentStatus* model tracks the payment status, whether it is pending, completed, or canceled. The *SubscriptionType* model defines the different subscription plans available to users.

The *Bank* model stores the details of the bank where the payment was made, such as the bank name and account number. This information is important in verifying the payment and ensuring the transaction was made to the correct account.

Finally, the *ForgotPasswordRequest* model stores the information when a user requests a password reset. This includes details such as the user's email address and the time the request was made.



**Figure 5.** The relationship of the User table and the other table of the database

### 3.2.2 Maps

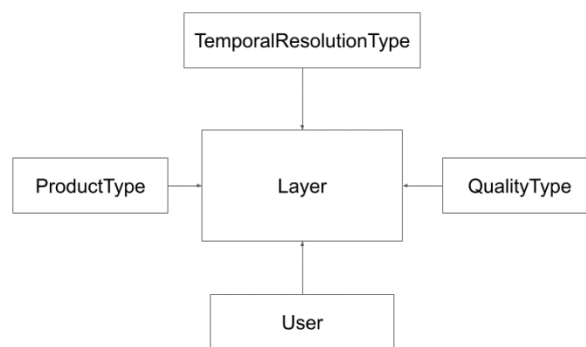
The Maps app is responsible for managing the solar PV potential layer data. The Layer model is a crucial app component as it stores information about the raster files associated with solar PV potential assessment. The *Layer model* contains various attributes that provide additional information about the layer data.

The *TemporalResolutionType* model holds different classifications of temporal resolutions associated with the layer data.

The *QualityType* model stores the two types of quality associated with the layer data: high and low. Subscribed users can access high-quality data, while unsubscribed users can only access low-quality data. This feature encourages users to subscribe and provides an incentive to maintain an active subscription.

The *ProductType* model handles the products associated with the solar PV potential layer data. This model allows users to identify and filter data based on the specific product they are interested in.

Finally, the *Layer* model stores which user uploaded the file. This information is important for managing the data and ensuring it is accurate and up-to-date.



**Figure 6.** Map details are stored in the Layer table, including its relationship with the other table of the database.

### 3.2.3 Forecasting

The *Forecast* model stores the information on sheets containing forecasts of Solar PV in different locations using different forecast models.

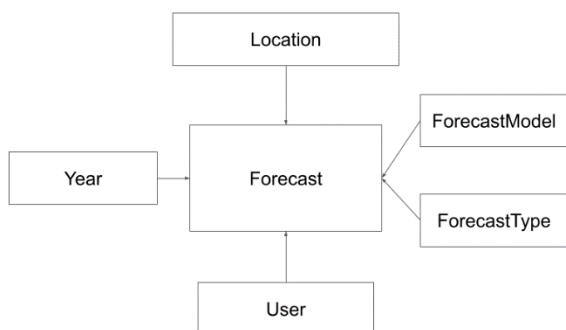
The *Year* attribute specifies the year that the forecast was made. This information can be useful for tracking trends and changes in the forecast data over time.

The *Location* attribute indicates the location for which the forecast was made. This attribute can be used to filter data based on specific geographic regions.

The *ForecastModel* attribute stores information about the model used to generate the forecast. This information can be used to assess the accuracy and reliability of the forecast data.

The *ForecastType* attribute indicates the type of forecast made, such as short-term or long-term. This attribute can be used to filter data based on specific forecast types.

Finally, the Forecast model stores information on which user has uploaded the file.



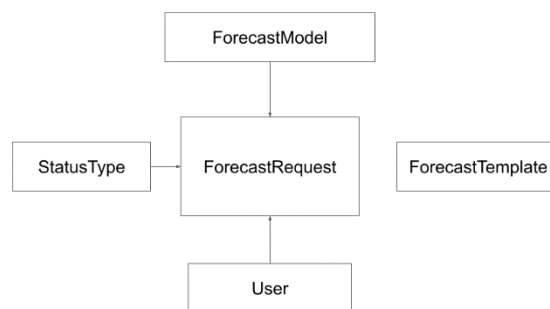
**Figure 7.** Forecasting details are stored in the Forecast table, including its relationship with the other table in the database.

### 3.2.4 Downloads

The Downloads app manages the forecast request and template. It contains two essential models: the ForecastRequest and the ForecastTemplate.

The *ForecastRequest* model stores information about the user's requests for forecasts on specific locations. This model contains information about the user's dataset and the forecast results.

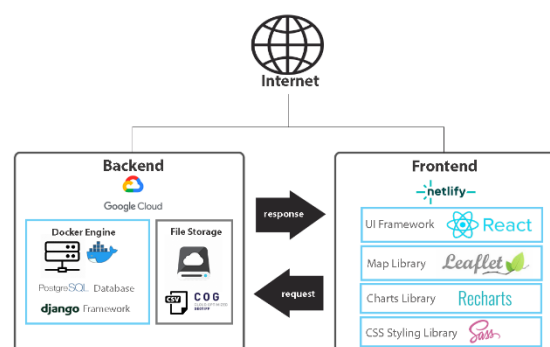
The *ForecastTemplate* model handles the latest template that a user can use to request a forecast. This model contains the data format required for requesting a forecast and ensures that users can easily request forecasts without worrying about data formatting.



**Figure 8.** Data request for forecasting are stored in the ForecastRequest table. The ForecastTemplate has no relationship with any of the table in the database.

### 3.3 Framework and Libraries of Frontend Application

The SINAG WebGIS's frontend is developed using the React and Node.js (Node.Js, 2014/2023) environments, and it is hosted on Netlify (Netlify, 2023), a cloud-based platform that streamlines web development processes. To improve its functions and user experience, it uses a variety of technologies. React (ReactJS, 2023) is the Javascript framework used. Recharts is integrated for data visualization, while React Leaflet (React Leaflet, 2023) is the map package of choice for mapping features. Because the full source code is hosted and deployed on Netlify (Netlify, 2023), updates and accessibility are guaranteed. A responsive and interactive user interface is made possible by the harmonious interaction of these technologies with the hosting platform.



**Figure 9.** The cloud infrastructure of the WebGIS with different frameworks and libraries used during the development.

## 4. PRODUCTS AND OUTPUTS

The Maps application is responsible for exploring or viewing the SINAG layer data. The Layer page is a crucial component of web GIS, as it stores information on the different products in raster files

associated with solar PV potential assessment. The model contains various attributes that provide information about the layer data.

Each raster file holds different classifications of temporal resolutions associated with the layer data. It also has two types of quality associated with the spatial resolution of the layer data - high and low. Subscribed users can access high-quality data, while unsubscribed users can only access the low-quality data. This feature encourages users to avail premium subscription and provides an incentive to maintain an active subscription.

A sample map as shown in Fig. 10 can be displayed in the Layers page which can be used to study or visualize any SINAG layer data more efficiently. It includes information on numerous raster products associated with solar PV potential assessment, which is a crucial component of the webGIS. In addition, all forecasts are displayed on the Forecasts page as shown in Fig. 11. The model includes forecast data for solar PV systems for different locations, generated using multiple options for forecasting models. The Forecasts page has properties including year, location, type of forecasting model, type of solar irradiance data, and date range.

#### 4.1 SINAG Layers

Table 1 shows the processed data for a specific year as the output of the project SINAG. It includes six different product layers of raster files in \*.tiff format. Shortwave radiation ( $R_{SWR}$ ) was extracted from Advanced Himawari Imager-8/9 (AHI-8/9) Level 2 Photosynthetically Available Radiation (PAR) product Adjusted Shortwave Radiation ( $R'_{SWR}$ ) product of Project SINAG is the shortwave radiation adjusted using cloud optical thickness product from AHI-8/9 to compute the maximum potential solar PV radiation received by a unit area (EORC & JAXA, 2022; Sotto et al., 2023). Cell temperature, used to compute the loss in efficiency due to temperature effects, is defined as the solar PV panel temperature computed from remotely sensed shortwave radiation, ambient temperature, and wind speed data (Principe et al., 2023; Principe & Takeuchi, 2019). The combined effects of dust and precipitation were calculated using the AirRGB decomposition method, which requires values of Aerosol Optical Depth (AOD) and Angstrom Exponent (AE). In the Philippines, primarily, the R component of AirRGB is associated with high AE and high AOD (Bauzon et al., 2022). The final product used in the WebGIS Layers is the Solar PV Power Resource Potential (PPV). PPV uses the adjusted shortwave radiation as the input product and accounts for the effects of meteorological and geomorphological factors defined by the project (Principe et al., 2023).

Layers	Spatial Resolution	Temporal Resolution	Year
Shortwave Radiation	5 km	Monthly	2020
Adjusted Shortwave Radiation	5 km	Monthly	2020
Cell Temperature	5 km	Monthly	2020
Dust Effects	5 km	Monthly	2020
Temperature Effects	5 km	Monthly	2020
Solar PV Power Resource Potential	30 m (Low) 1 m (High)	Monthly	2020

Table 1. Output Product of SolarPot Component.

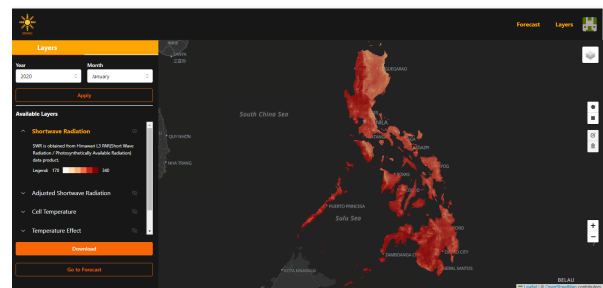


Figure 10. The Layers Page

#### 4.2 SINAG Forecasting

For the WebGIS application, all forecast models are displayed on the Forecasts page. The models include forecast data for solar PV installations in different areas, produced using multiple forecast models. It has properties including year (to observe trends over time), location (to filter data based on geographic locations), and forecasting model (to evaluate accuracy and dependability).

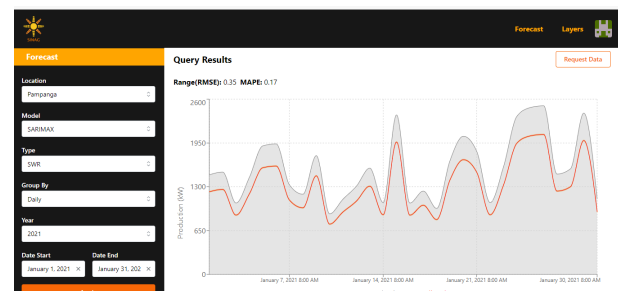


Figure 11. The Forecasting Page

Table 2 shows the list of models used for forecasting the PV output from a historical dataset with varying parameters and locations.

Product	Items/Models Available
Forecast Models	SARIMA
	SARIMAX
	XGBOOST
	LSTM
	HYBRID MODEL

Table 2. The list of models used by OutSolar Components.

## 5. CONCLUSIONS AND RECOMMENDATIONS

The SINAG WebGIS offers access to solar PV potential maps and forecasting data throughout the Philippines. It uses web GIS services for digital map display and download, graphical interfaces, and forecasting capabilities. For efficient data storage and processing, the backend design makes use of Django, PostgreSQL, and Docker. The React framework and Node.js environment, which are used for front-end development, ensure an engaging user experience.

Recommendations for further improving the webGIS include frequent updates and debugging of the source code through client feedback. The development of mobile applications is also highly recommended to widen the audience or prospective users of the SINAG web portal. To further enhance the functioning, accessibility, and usability of the portal, real-time data must be integrated for both map layers and forecasting outputs. Access to these data may enable several types of methods for bolstering informed decision-making and sustainable energy solutions with the participation of the public, private organizations, government, and other relevant stakeholders of solar PV systems.

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