

AI-Assisted Solar Energy Generation Prediction System

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Abstract

The explosive growth of renewable energy has led to a higher need for tools that assist people in determining the viability and benefits of solar power installation. However, there are many potential users who do not have accessible platforms that integrate accurate solar generation prediction, financial analysis, and easy-to-use visualisation. This research introduces the AI-Assisted Solar Energy Generation Prediction System, a web-based application that approximates the solar energy generation based on the geographic location and the electricity consumption.

The system combines several external data sources and the latest web technologies to deliver precise and interactive solar potential analysis. Geographic coordinates of chosen city are used to retrieve solar production estimates from the NREL PVWatts API and real time weather information is retrieved using the OpenWeather API. The backend, which was created with Python and Flask, takes these inputs and calculates solar generation, energy offset, financial savings, system coverage and environmental benefits such as CO2 reduction. The frontend interface is used to visualise the results in the form of interactive charts and comparison tables, allowing the user to compare different solar system sizes.

In addition, the system includes an AI-based assistant, based on a large language model, to provide personalised insights and recommendations about solar installation. By integrating solar prediction algorithms, financial calculations and AI-generated analysis in one platform, the proposed system offers users an intuitive and informative decision support tool for solar energy adoption.

KEYWORDS: *Solar Energy Prediction, Renewable Energy Systems, PVWatts API, Artificial Intelligence, Energy Consumption Analysis, Solar Power Estimation.*

1. Introduction

The increasing energy demand and the environmental consequences of the increasing use of fossil fuels due to their increasing demand have also contributed to the faster shift towards renewable sources of energy. Solar energy has been one of the most promising and widely used renewable energy solutions because it is abundant, accessible and its cost of installation is declining as the adoption rate goes up. Solar Photovoltaic (PV) systems can allow households and businesses to produce electricity directly using sunlight, which does not need to be relying on traditional power systems thus also reduce greenhouse gas emissions.

Over the last couple of years, governments and other organisations all over the world have promoted the use of solar energy by offering incentives, subsidies, and creating awareness. In spite of these attempts, a good number of

people who are thinking of installing solar plants are not sure about the possible energy output and the economic rewards in their respective sites. The production of solar energy greatly depends on many factors including geographic location, solar radiation, weather conditions, system set up, etc. Consequently, estimation tools can be applied to assist users to make sound judgments prior to investing in solar technology.

Conventional solar evaluation techniques need technical skills or advice of solar installer experts. These methods may be time consuming and costly to most users. As the web technologies, data-driven applications, and artificial intelligence progress, one can develop intelligent systems that will give predictions of the location-specific solar energy with the help of simple user interfaces.

This study suggests AI-Assisted Solar Energy Generation Prediction System, a web-based application, which is aimed at calculating and estimating solar power generation and examining the possibility of solar installation in various areas. The system uses third-party APIs, e.g., NREL PVWatts API to estimate solar generation and Open Weather API to access real-time weather. The python and Flask are used to implement the backend processing and the front-end interface to display the results in interactive visualisations and comparison tools. One of the most outstanding characteristics of the suggested system is the incorporation of artificial intelligence that can offer personalised information and advice on the way to use solar energy. The AI component is able to create human-understandable explanations and guidance based on the analysis of forecasted generation data, and financial metrics. Such an integration of predictive modelling, financial analysis, and interpretation with the AI makes the system a decision-support tool of individuals interested in solar energy.

Our research aims to create and deploy an easy-to-use, data-driven solar forecasting platform that enables users to assess the potential of solar energy, compare various systems, and learn about the economic and environmental advantages of solar energy.

1.1. Motivation

The growing demand of energy all over the world coupled with the issue of climate change and environmental sustainability has brought forth the need to move towards renewable sources of energy. Solar energy is among them and has been one of the most appealing solutions because of its availability, scalability, and non-sensitivity to the environment. Solar power in countries such as India, which have a high level of solar irradiance throughout the year, can greatly limit reliance on fossil fuels and traditional grid electricity.

Although there is an increasing interest in solar energy, most people are reluctant to invest in solar installations due to lack of clear information regarding the possible energy production and the financial gains of the particular place. The solar system performance is based on several factors that include geographic location, availability of sunlight, weather conditions, panel orientation and energy consumption patterns. Devoid of precise forecasting and clear cut analysis, prospective users might struggle to decide on the size of the system to instal or assess the cost-effectiveness of installing solar.

The available solar assessment tools are usually complicated, technical, or they offer little information to the final user. Most portals are interested in the estimates of energy generation only without regarding other significant aspects like electricity use, monetary savings, or even environmental effects. Moreover, the vast majority of users are fond of digital tools that are not complex and can deliver understandable insights in a short period of time, as opposed to technical reports.

This inspired the creation of the AI-Assisted Solar Energy Generation Prediction System that would streamline the assessing of solar potential. The system integrates solar generation forecasting, financial savings analysis, and environmental impact analysis into a coherent interactive platform. The application can also offer personalised explanations and recommendations by incorporating artificial intelligence to assist users to understand solar energy systems better and make informed decisions regarding the installation process.

The main reason of doing this is to establish an easy to use system that will close the gap between the difficult solar analysis systems and common people who want to know more about the renewable energy solutions to their homes or businesses.

2. Literature Review

The rising use of solar photovoltaic (PV) systems has stimulated the widespread research in the spheres of solar radiation forecasting, photovoltaic energy prediction, and intelligent energy management systems. Proper forecasting of solar power generation is critical in optimization of solar installations, enhancement of energy planning, and facilitation of effective incorporation of renewable energy in power systems.

The initial studies in solar forecasting were mainly concerned with the analysis of solar radiation and weather conditions to determine the amount of photovoltaic power that could be produced. Perez et al. confirmed short and medium term solar radiation forecasting models and showed the significance of proper solar radiation forecasting to operational energy planning [2]. In the same way, Reikard explored time-series forecasting methods to predict solar radiation and compared various statistical models to enhance prediction accuracy [7].

A number of studies have given detailed reviews of photovoltaic forecasting methods. Antonanzas et al. provided a comprehensive overview of photovoltaic power forecasting techniques and divided them into statistical, physical, and hybrid forecasting techniques [3]. Their research indicated the importance of considering both solar irradiance and weather parameters in order to predict energy more precisely. Yang et al. also reviewed several

solar irradiance prediction models and explained their use in renewable energy systems [16].

As artificial intelligence has developed, machine learning approaches have been used more and more in the prediction of solar energy. Mellit and Kalogirou examined applications of artificial intelligence methods including artificial neural networks, fuzzy logic and hybrid models in photovoltaic applications [9]. These methods have been effective in the modelling of nonlinear relationships between the solar radiation, weather conditions and the power output. Voyant et al. also examined machine learning methods of solar radiation forecasting and found that hybrid models improved the forecasting performance [4]. In a similar way, Dolara et al. examined hybrid machine learning approaches to solar power prediction and showed better prediction accuracy than the conventional models [17].

There have also been studies on incorporating solar prediction systems into smart energy management systems. Wan et al. examined photovoltaic power prediction in the context of smart grids and highlighted its significance in effective energy management and grid stability [8]. Moreover, photovoltaic system-sizing optimization models have been introduced to identify appropriate solar designs to meet given energy needs and environmental factors [5].

Although there has been a great advancement in the area of solar forecasting, much of the available solutions are either technical in nature or are very much dependent on intricate modelling tools. Furthermore, the majority of the current literature is devoted to the solar radiation forecasting instead of offering the integrated platforms that are capable of integrating solar prediction, financial analysis, and convenient visualisation. To overcome these drawbacks, the system that is proposed in the current study combines solar generation forecasting, consumption-based financial calculations, and artificial intelligence-based insights into a convenient web-based platform.

The proposed Solar Energy Generation Prediction System with the assistance of AI is based on the current studies on photovoltaic prediction and intelligent energy systems, integrating solar prediction APIs, integration of weather data, and AI-generated insights to offer an intuitive decision-support system to users contemplating the adoption of solar energy.

3. System Overview

The AI-Assisted Solar Energy Generation Prediction System is an internet-based application that can be used to estimate the production of solar energy in particular geographic areas and analyse the viability of solar photovoltaic (PV) systems. The system combines solar prediction models, weather data analysis, financial calculations, and artificial intelligence-based insights to give the user a full solar feasibility analysis tool.

The system architecture will be developed in such a way that it will provide efficient data processing, modular implementation, and easy interaction with the users. It is a web-based frontend interface with a backend processing engine that interacts with several external APIs to produce solar energy predictions and analysis.

3.1. System Architecture

The proposed system follows a **modular full-stack architecture** consisting of three primary layers: the

presentation layer, the application layer, and the service layer.

The **presentation layer** is responsible for user interaction and visualization. It is implemented using **HTML, CSS, and JS**, and provides a user interface where users can select their city, input electricity consumption, and view solar prediction results. Interactive charts and data visualizations are generated using the **Chart.js** library, while geographic visualization is provided through **Leaflet.js** with OpenStreetMap integration.

The **application layer** is implemented using the **Flask** web framework in **Python**. This layer is responsible for handling user requests, managing communication between the frontend and backend services, and supervises the overall workflow of the system.

The **service layer** consists of modules that are responsible for handling external API communication, performing solar energy calculations, and generating AI-based insights. These services include weather data retrieval, photovoltaic power prediction, solar system calculations, and AI-based recommendation generation.

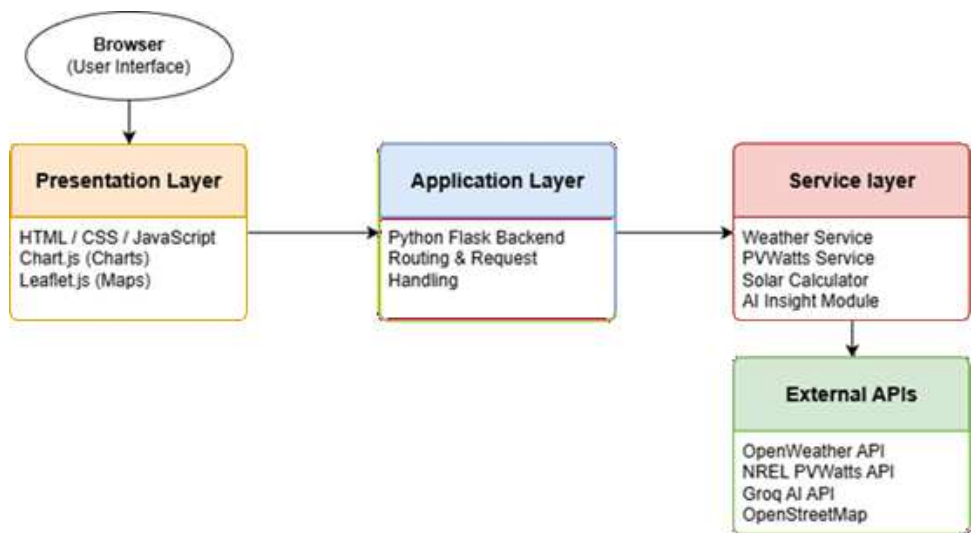


Fig 1. System architecture of the proposed model

The overall architecture of the proposed system is illustrated in **Figure 1**. The system follows a layered architecture consisting of a presentation layer, application layer, and service layer that interact with external APIs to generate solar predictions.

3.2. User Interaction Flow

The system is created with easy and user-friendly workflow to enable users to assess solar potential in their location in a short time. The user starts by choosing a city after which a list of Indian cities has been preset and typing in their average monthly electric usage.

After the user enters this data, the application interprets the input and starts the workflow of solar prediction. The system obtains the geographic coordinates of the city of interest and relies on these coordinates to retrieve solar generation predictions using external APIs.

These findings are then presented in a set of visual elements such as system comparison tables, solar production charts and financial analysis cards. Users may compare the sizes of various photovoltaic systems interactively and see the effect that each system has on energy production, financial savings, and environmental impact.

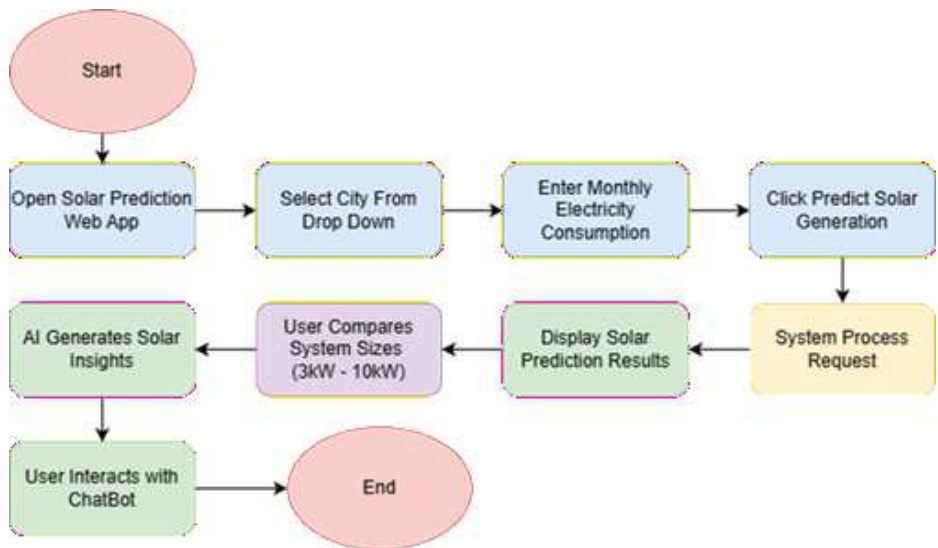


Fig 2. User interaction flow of the proposed model

The interaction between the user and the system is illustrated in Figure X. The workflow begins with user input and progresses through solar prediction processing before displaying visualizations and AI-generated insights.

3.3. Data Processing Pipeline

The system has a data processing pipeline that consists of a number of sequential steps. Upon getting the input of the user, the backend will retrieve weather data of the chosen location via the OpenWeather API. This data gives environmental conditions such as temperature, humidity, wind velocity, and cloud cover.

The system then requests the NREL PVWatts API to approximate solar power generation using the geographic coordinates and system capacity. The API gives a comprehensive solar production information such as monthly energy production, annual production, and solar radiation.

These values are then used by the backend processing module to do other calculations such as energy offset, system coverage percentage, annual savings and reduction in carbon dioxide. These calculations enable users to know the technical and financial aspects of installing solar panels.

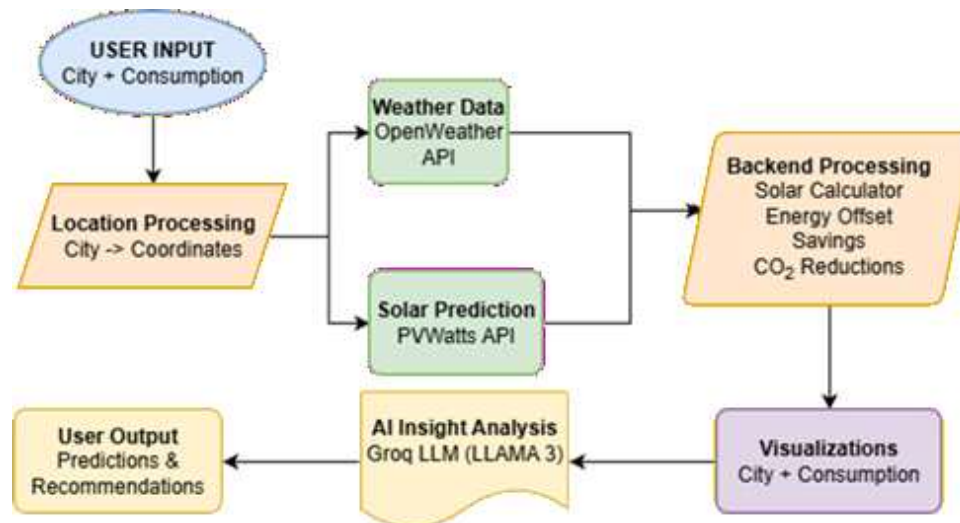


Fig 3. Data Processing Pipeline of the AI-Assisted Solar Energy Generation Prediction System

The overall data processing pipeline of the proposed system is illustrated in Figure 3. The system processes user input, retrieves solar and weather data from external APIs, performs solar generation calculations, and generates interactive visualizations and AI-based insights.

3.4. Prediction and Analysis Modules

The prediction and analysis part of the system assesses the production of solar energy in various photovoltaic systems sizes. The system compares four system capacities (3 kW, 5 kW, 7 kW, and 10 kW) to give the user comparative information on energy generation and savings.

Under every setup, the system computes the key performance indicators, which include annual solar generation, energy offset against the consumption of electricity, financial saving in terms of electricity tariffs and environmental benefits in terms of carbon dioxide emission reduction.

Besides numerical analysis, the system incorporates a natural language explanation module that produces natural language descriptions of the prediction output. The AI element processes the data generated and gives suggestions on the size of the system, anticipated financial gains, and the environmental effects.

This predictive modelling, financial analysis, and AI-driven interpretation allow the system to serve as a smart decision-support tool to people who consider installing solar energy.

4. Methodology

This section describes the methodology used to design and implement the **AI-Assisted Solar Energy Generation Prediction System**. The system combines solar prediction by location, weather data retrieval, energy consumption analysis, and artificial intelligence to generate valuable insights of photovoltaic systems. The methodology is focused on the prediction system workflow, data sources, the system architecture, and the technologies applied in implementation.

4.1. Proposed Algorithm / Workflow

The suggested system adheres to a systematic workflow to produce solar energy forecasts and financial analysis. The workflow commences with user input and follows several steps of data retrieval, processing, and visualisation.

First, the user is asked to choose a city among the list of supported locations and to input the average amount of electricity they use every month in kilowatt-hours (kWh). The system retrieves the geographic coordinates of the chosen city and employs the coordinates to start the solar prediction calculations. The system then asks the OpenWeather API to supply environmental data, which gives up-to-date weather conditions like temperature, humidity, wind speed, and cloud cover. These parameters give contextual environmental information that assists users to know the conditions related to the production of solar energy.

Once the necessary location data is collected, the system submits a request to the NREL PVWatts API to compute solar energy production at various photovoltaic system sizes. The PVWatts API takes solar irradiance data and system configuration parameters to calculate monthly and annual electricity generation. The backend processing module then carries out a set of calculations to calculate key performance indicators like annual energy generation, energy offset of the electricity used by the user, financial savings, number of required solar panels and reduction in carbon dioxide emission.

The findings are sent to the frontend interface where they are presented in interactive charts and comparison tables. Lastly, an artificial intelligence module interprets the results of the prediction and produces natural language insights explaining the performance of the chosen solar system and giving recommendations to the user.

The simplified workflow of the proposed system can be represented as follows:

User Input → Location Processing → Weather Data Retrieval → Solar Prediction via PVWatts API → Energy and Financial Calculations → Visualization of Results → AI Insight Generation.

4.2. Data Sources

The proposed system utilizes multiple external data sources to perform solar prediction and analysis. These data sources provide accurate and reliable information necessary for energy estimation and environmental analysis.

The primary solar generation data is obtained from the **NREL PVWatts API**, which is widely used for estimating photovoltaic system performance. This API calculates solar energy production based on parameters such as geographic location, system capacity, panel orientation, and system losses. Weather information is retrieved from the **OpenWeather API**, which provides real-time environmental data including temperature, humidity, wind speed, and cloud cover. Although weather data does not directly determine solar generation in the PVWatts model, it provides useful contextual information for understanding solar performance conditions.

Geographic visualization of selected locations is provided through **OpenStreetMap**, integrated using the Leaflet.js library. This allows users to view the selected city and its coordinates on an interactive map interface. The system also integrates the **Groq API**, which provides access to a large language model used for generating AI-powered insights and chatbot responses related to solar energy predictions. section.

4.3. System Architecture

The architecture of the proposed system follows a modular and layered design that separates user interaction, backend processing, and external service communication. This design improves maintainability, scalability, and overall system efficiency.

The **frontend layer** is responsible for managing user interaction and visualization. It includes the web interface built using HTML, CSS, and JavaScript. This layer handles form input, displays prediction results, renders charts, and provides an interactive chatbot interface.

The **backend layer** is implemented using the Flask framework in Python. This layer processes user requests, communicates with external APIs, performs solar generation calculations, and generates prediction results.

The **service layer** contains specialized modules responsible for performing specific tasks. These modules include weather data retrieval, photovoltaic generation prediction using the PVWatts API, solar energy calculations such as energy offset and savings estimation, and AI insight generation using the Groq API.

This layered architecture ensures clear separation of responsibilities and allows each module to operate independently while contributing to the overall functionality of the system.

4.4. Technology Stack

The implementation of the proposed system utilizes a combination of modern web technologies, programming frameworks, and external APIs to ensure efficient data processing and user interaction.

The frontend of the application is developed using **HTML5, CSS3, and JavaScript**, which provide the structure, styling, and interactive behavior of the user interface. Data visualizations such as solar production charts and system comparison graphs are implemented using the **Chart.js** library. Geographic visualization and map functionality are implemented using **Leaflet.js** in combination with **OpenStreetMap** tiles.

The backend of the application is implemented using **Python** with the **Flask web framework**, which manages routing, API communication, and backend processing. External data and intelligence are obtained through integration with several APIs including the **NREL PVWatts API for solar prediction**, **OpenWeather API for weather information**, and the **Groq API for artificial intelligence-based insights and chatbot interaction**.

The integration of these technologies enables the system to provide accurate solar predictions, interactive visualizations, and intelligent recommendations within a unified web-based platform.

5. Results & Analysis

The **AI-Assisted Solar Energy Generation Prediction System** was experimented with various city locations and electricity consumption values to assess its capacity to produce precise solar forecasts and give valuable information to the planning of photovoltaic systems. The system is able to combine various APIs and calculation modules to generate solar generation estimates, financial analysis, and environmental impact analysis.

The system computes solar energy production of four photovoltaic system sizes, namely, **3 kW, 5 kW, 7 kW, and 10 kW**, per user request. The outcomes are the forecasted annual solar output, energy savings compared to the energy used by the user, number of solar panels required, financial savings, and reduction of carbon dioxide emissions. These findings enable users to compare various solar system setups and choose the most suitable system size depending on their energy needs and financial ambitions.

The findings show that bigger photovoltaic systems tend to generate more annual solar energy and more financial savings. But the system also takes into consideration the idea of **energy offset** whereby financial savings are restricted to the quantity of electricity used by the user. This method will make the calculated savings realistic and will represent realistic energy usage situations.

The system also produces **monthly data on solar production**, which assists users to learn about seasonal changes in solar energy production. Areas with increased solar irradiance have high monthly production, especially during summer when the sun is the strongest.

Besides numerical analysis, artificial intelligence allows the system to produce contextual explanations and recommendations. The AI module interprets the results of the prediction and gives information about the suitability of the system, the possible financial gains, and the environmental impact. This aspect makes the results more interpretable and makes the users more aware of the implications of solar installation.

Altogether, the experimental assessment shows that the offered system offers a stable and convenient platform to estimate the solar energy potential and help the users make the right decisions concerning the installation of photovoltaic systems.

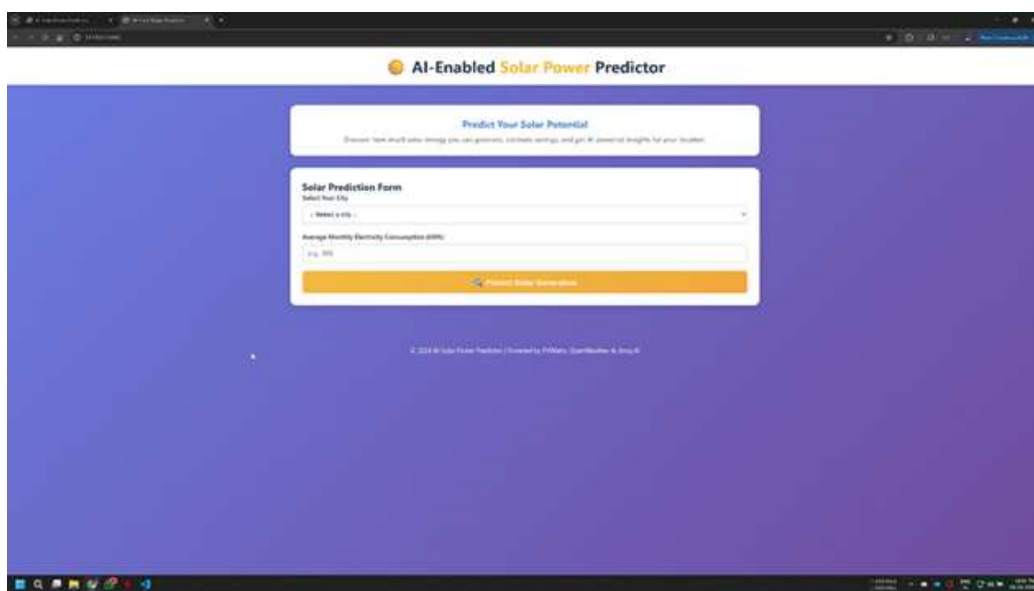


Fig 4. Start-up Page of the AI-Assisted Solar Energy Generation Prediction System

The Start-up Page of the proposed system is shown in Figure 4. The system ask the user to select the city from the drop down menu and enter the estimated monthly consumption.

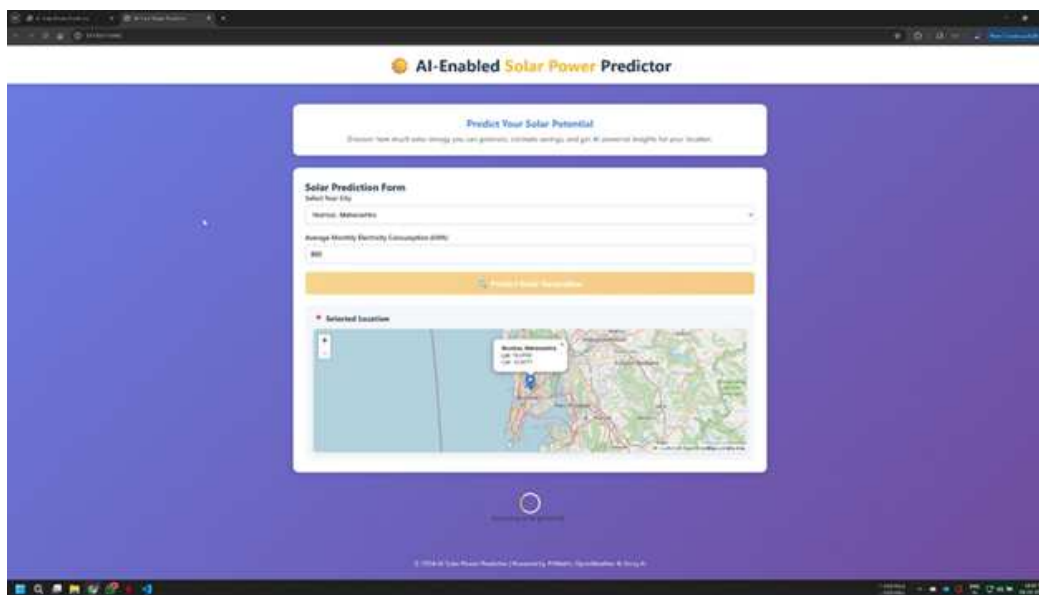


Fig 5. Location Processing to fetch the weather of the selected city.

The location Processing of the proposed system is shown in Figure 4. The system convert the selected city into coordinates to fetch weather data of that location.

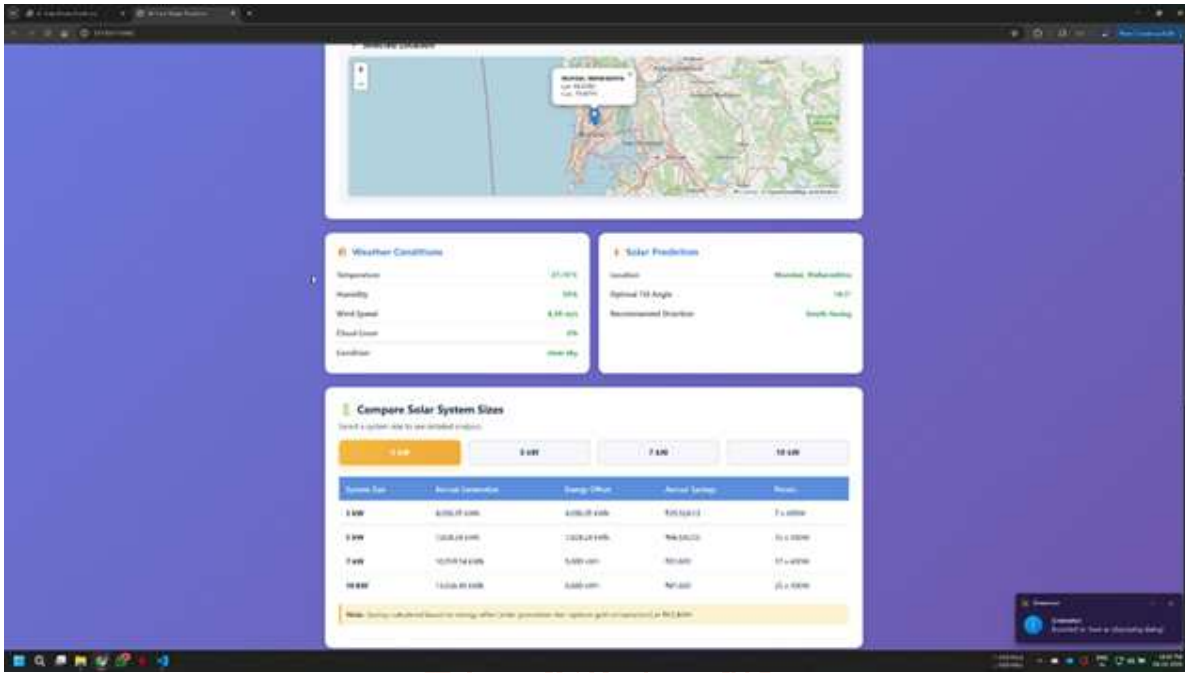


Fig 6. Predictions Presented to the user



Fig 7. Calculation show to the user and AI ChatBot

In Figure 6 & 7, it is shown how the user can interpret the calculations and better understand the impact of all four kind of systems according to their usage. Furthermore, AI insights help the user make decision for their own purposes as well as an AI ChatBot is also available for users to get a better understanding of the solar predictions.

6. Future Scope

Although the proposed system provides reliable solar prediction and analysis capabilities, several improvements can be implemented in future versions to enhance its functionality and usability.

One potential enhancement is the integration of **machine learning-based solar forecasting models** that utilize

historical solar radiation data to further improve prediction accuracy. Incorporating such models could enable more precise forecasting of solar generation under varying weather conditions. Another improvement would involve the inclusion of **battery storage analysis and energy storage optimization**, allowing users to evaluate the benefits of combining solar panels with battery systems for improved energy management.

The system could also be extended to include **installation cost estimation and return-on-investment (ROI) calculations**, which would provide users with a more complete financial assessment of solar installations. Additionally, support for **government incentives and subsidy information** could further assist users in evaluating

the economic feasibility of solar systems. Future developments may also include expanding the platform to support **international locations**, integrating **real-time solar monitoring data**, and developing a **mobile application** to improve accessibility and user engagement.

These enhancements would further strengthen the system's capabilities and expand its potential as a comprehensive platform for solar energy analysis and renewable energy decision support.

7. Conclusion

The **AI-Assisted Solar Energy Generation Prediction System** introduced in this study offers a holistic platform to assess the viability of solar photovoltaic systems. The system combines solar prediction models, weather data, financial analysis, and artificial intelligence to provide valuable information about solar energy production and its possible advantages.

The proposed system will allow users to estimate the production of solar energy of various sizes of photovoltaic systems depending on their geographic location and electricity consumption. The system uses trusted external data sources like the NREL PVWatts API and OpenWeather API to create precise estimates of solar production and display them in interactive visualisations and comparison tools. These characteristics enable the users to have a clearer picture of solar energy potential, system coverage and anticipated financial savings.

Besides numerical predictions, the system can be made more usable by integrating artificial intelligence that produces contextual insights and recommendations regarding the solar installation. The AI-based assistant assists users in simplifying the interpretation of technical results, which makes the system more accessible to users who do not have specialised knowledge of solar technologies.

On the whole, the created system shows that the combination of modern web technologies, data-driven prediction models, and artificial intelligence can be used to develop an effective decision-support tool to adopt renewable energy. The suggested platform offers a viable solution to those who would like to assess the opportunities of solar energy and promotes informed decision-making on sustainable energy investments.

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