# The SRS Document for Solar Vision Pro

## Note

This document was produced with the assistance of ChatGPT-4.

Other documents used include:

https://pvlib-python.readthedocs.io/en/stable/index.html

## Table of Contents

## Definitions and Acronyms

PV (Photovoltaic) Systems: Technology that converts sunlight into electrical energy.

SaaS (Software as a Service): A software distribution model in which a third-party provider hosts applications and makes them available to customers over the Internet.

API (Application Programming Interface): A set of protocols, routines, and tools for building software and applications.

BIPV (Building-Integrated Photovoltaics): PV materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades.

ROI (Return on Investment): A performance measure used to evaluate the efficiency or profitability of an investment.

# 1. Introduction

## 1.1 Purpose

This document provides a comprehensive, detailed, and technically descriptive overview of Solar Vision Pro, a state-of-the-art B2B SaaS solution designed for modelling photovoltaic (PV) systems. The document outlines the software's capabilities, architecture, functional requirements, and user interactions, aiming to guide development, implementation, and usage.

## 1.2 Scope

Solar Vision Pro is engineered to revolutionize the way small residential to large-scale PV system modelling is conducted on various terrains including roofs, lands, and water bodies. It leverages advanced machine learning through the Solar Vision API for satellite image segmentation to predict optimal surfaces for PV installation, accounting for physical obstacles. Utilizing the pvlib Python library, it supports an array of solar energy calculations and simulations, streamlining the process of photovoltaic system design and optimization for enhanced energy production and financial returns. This capability aligns with the overall business goals to provide a versatile, efficient, and user-friendly tool for solar energy professionals, ensuring Solar Vision Pro's relevance and indispensability in the renewable energy sector. Solar Vision Pro is engineered for small residential and large-scale PV system modelling on roofs, land, and water bodies. It integrates advanced machine learning through the Solar Vision API for satellite image segmentation, predicting optimal surfaces for PV installation while accounting for obstacles. Additionally, it utilizes the pvlib Python library for in-depth PV system modelling, supporting various solar energy calculations and simulations.

## 1.3 Product Value

Solar Vision Pro addresses a critical need in the renewable energy market by simplifying and enhancing the accuracy of PV system modelling. Its importance lies in its ability to democratize access to advanced solar system design tools, enabling professionals to make informed decisions that optimize energy production and financial returns. By integrating cutting-edge technologies like machine learning for image analysis and comprehensive solar energy simulations, Solar Vision Pro solves complex modelling challenges, offering significant value to its users in terms of time savings, accuracy, and project viability assessment.

## 1.4 Intended Audience

The ideal audience for Solar Vision Pro includes solar energy consultants, engineering firms, and renewable energy project developers who specialize in designing and implementing photovoltaic systems. These professionals demand high accuracy, flexibility, and efficiency in solar system modelling tools to ensure optimal design and implementation of solar projects. Solar Vision Pro is tailored to meet these requirements, providing a robust platform that supports a wide range of PV system types and scales.

### 1.4.1 Intended Use

Solar Vision Pro is envisioned to be utilized in a variety of ways depending on the role of the user:

Solar Energy Consultants: can leverage the software to conduct preliminary assessments and feasibility studies for potential PV installations, optimizing system layout and energy output.

Engineering Firms: may use it for detailed design and simulation of PV systems, including electrical and structural analysis, to ensure compliance with industry standards and best practices.

Project Developers: could utilize the tool for project planning and management, including financial modeling and return on investment calculations.

Use cases include:

A solar energy consultant evaluating the potential of a commercial rooftop for solar installation, using Solar Vision Pro to model system performance and financial returns.

An engineering firm designing a utility-scale solar plant, utilizing the software to simulate various configurations and their impact on energy production.

1.4.2 Supported PV System Types

Solar Vision Pro is engineered to offer unparalleled flexibility, catering to the diverse landscape of photovoltaic (PV) system modelling. To meet the comprehensive needs of our users, Solar Vision Pro supports a comprehensive range of PV systems, categorized into three main groups: residential, commercial, and utility-scale plants. This categorization ensures a broad coverage across various application scenarios, from individual homes to large-scale power generation facilities.

Residential PV Systems

These systems are primarily small-scale and are designed for individual homes. They are predominantly installed on rooftops but can also be placed on residential plots. Residential systems can be static or equipped with sun-tracking capabilities to maximize energy production.

Commercial PV Systems

This category includes both ground-mounted solar farms and rooftop installations for businesses and industrial applications. Ground-mounted systems are often deployed on land not suitable for agriculture or other commercial uses, offering the flexibility to install a wide range of solar panel capacities. Rooftop systems, on the other hand, can be utilized for a variety of commercial buildings, including offices and industrial sites, providing benefits such as reduced energy costs, energy independence, and a positive environmental impact. Commercial systems can range from small-scale rooftop installations to larger power stations with capacities up to 5 MW, covering areas from 300 $m^2$ to 10 hectares.

Ground-Mounted Solar PV Farms

Utilized by industrial enterprises to generate significant power, potentially for revenue through electricity sales. These installations allow for any required power capacity, making them ideal for backup power stations or utilizing otherwise non-arable land.

Rooftop Solar PV Power Plants

Serve a dual purpose for business and industry, enabling energy cost reductions, fixed electricity costs for decades, and the potential for complete or partial energy independence. The return on investment for these installations is notably high, with low maintenance costs and the possibility of selling excess green electricity to the grid.

BIPV and Facade-Mounted Systems

Building-integrated photovoltaics (BIPV) merge the generation of electricity with architectural aesthetics, acting as both power sources and elements of the building envelope. This integration is poised for significant growth, offering a modern approach to incorporating renewable energy solutions into new and existing buildings.

Solar Canopies, Charging Stations, and Parking Lots

These installations provide multiple benefits, including protection and comfort for vehicles and users, while generating green energy. They can be integrated with electric vehicle charging stations, enhancing functionality, and contributing to a sustainable energy ecosystem.

Utility-Scale Solar Plants

Designed for large-scale solar power production, these plants are a cornerstone of renewable energy infrastructure. They can generate extensive amounts of green electricity and utilize various photovoltaic technologies, including tracking systems to optimize sun exposure. In addition to traditional ground-mounted installations, utility-scale solar plants can also be deployed on water bodies, such as lakes, utilizing floating solar panel technologies. This innovative approach allows for the efficient use of water surfaces to generate solar power, reducing land use and potentially cooling the solar panels to improve their efficiency.

Each PV system type shall be supported by Solar Vision Pro's comprehensive modelling capabilities, ensuring users can accurately simulate and plan PV installations tailored to specific requirements, from optimizing energy production and financial returns to enhancing sustainability impacts. This inclusive approach will solidify Solar Vision Pro's position as a versatile tool for the planning and implementation of PV projects across the spectrum of scale and application.

## 2. Functional and Non-Functional Requirements

### 2.1. Software as a Service (SaaS) Deployment – PS SaaS application

Solar Vision Pro's deployment as a Software as a Service (SaaS) platform is specifically designed to cater to organizations of all sizes, offering a scalable, accessible, and user-friendly solution for photovoltaic (PV) system modelling. This organizational-centric approach ensures that Solar Vision Pro seamlessly integrates into the business processes of its users, promoting efficient project management and collaboration.

For this purpose, we must practically distinct two separate application. One is PS SaaS imagined as white label application for SaaS deployment and management. And another one is the Solar Vision Pro which will be deployed through PS SaaS

Subscriptions, payments and users

PS SaaS introduces an organizational subscription model, where subscriptions are made at the organization level. This model is crafted to accommodate the varied needs of different organizations, from small teams to large enterprises. Subscription plans are differentiated by the number of projects, storage capacity, and access to advanced features, ensuring that each organization can find a plan that best suits its needs. To facilitate the evaluation process, Solar Vision Pro includes a free trial period through PS SaaS, granting organizations full access to the software's features for a limited time before committing to a subscription.

Payment and billing system will also be implemented through the PS SaaS application. And it will include:

Secure Payment Gateway: Integrating a secure and reliable payment gateway to process subscriptions and renewals, supporting major credit cards, PayPal, and other widely used payment methods.

Automated Billing and Renewals: Automatic billing cycles and notifications for upcoming renewals or payment issues, ensuring organizations enjoy uninterrupted service for users.

Custom Quotes for Enterprises: For larger teams or organizations requiring custom solutions, Solar Vision Pro will offer personalized quotes and plans to meet specific requirements.

User and team management will also be done through the PS SaaS app. The initial step involves a user registering their organization. Following registration, the user, now designated as the organization administrator, can add team members to the organization, facilitating collaborative project management and design efforts in Solar Vision Pro. Subscriptions and billing are managed at the organization level in PS SaaS. Role-Based Access Control (RBAC) will be implemented through organizational roles: organization administrators and team members. Organization Administrators can manage organization settings, invite, or remove members, and oversee subscription and project management at the organizational level. Team Members access the software's features based on the organization's subscription plan but cannot alter organization settings or manage memberships.

Multi-Tenancy Architecture

The multi-tenancy architecture of PS SaaS is built with a focus on both security and efficiency. It ensures that each organization's data and projects are securely isolated from others, which not only guarantees privacy and security but also facilitates efficient resource sharing and management across the platform's infrastructure. This isolation is key to maintaining the integrity and confidentiality of each organization's information.

Simultaneously, the infrastructure underpinning PS SaaS is designed to be inherently scalable. It dynamically adjusts in response to changes in the number of users and the workload, ensuring that the performance and availability of the platform are maintained at optimal levels. This scalability is crucial for supporting growth and varying demands, allowing the platform to seamlessly accommodate an increasing volume of data and user activity without compromising on service quality or user experience.

Upon new registration in the PS SaaS application, a streamlined and automated process kicks off to provision a new instance of Solar Vision Pro specifically for the newly registered organization. This process is facilitated through the PS SaaS backend's "providers" module, which is designed with Django REST Framework (DRF) to interact seamlessly with various cloud providers like AWS, Azure, IBM, and Google Cloud through their respective APIs. When an organization registers on PS SaaS, the application identifies the preferred cloud provider based on the organization's selection or predefined criteria that could include factors like cost, region, or specific cloud features. The "providers" module then uses the selected cloud provider's API to initiate the provisioning of a new cloud environment. This involves setting up the necessary infrastructure, such as virtual machines, storage, and networking resources, tailored to the needs and scale required by the Solar Vision Pro instance.

The dynamic scaling capabilities of the cloud provider's API are particularly critical in this process. They ensure that as the organization's usage of Solar Vision Pro grows, the infrastructure can scale accordingly to maintain optimal performance without manual intervention. Automated scalability is essential for handling varying loads, from data processing requirements to user access patterns.

Furthermore, the PS SaaS application manages the entire lifecycle of the Solar Vision Pro instance for each organization. From the initial provisioning to ongoing maintenance, including security patches, software updates, and scaling operations, all are conducted through direct interactions with the cloud provider's API, ensuring that the organization always has access to a secure, up-to-date, and responsive Solar Vision Pro instance. This architecture not only simplifies the deployment and management of Solar Vision Pro for various organizations but also ensures that PS SaaS can be adapted to manage other projects with similar cloud infrastructure needs. By abstracting the complexities of cloud resource management into the "providers" module and leveraging cloud APIs for automated actions, PS SaaS offers a robust, flexible platform for SaaS deployment across multiple cloud environments.

PS SaaS application backend will be written on Python and Django REST Framework. In the structure of such a project we will place module/folder named “providers” in which we can write py scripts containing interfaces for cloud infrastructure provisioning and management. Each cloud provider can have its own .py file in which service classes are defined utilizing the provider’s API for infrastructure provisioning and management.

Compliance and Security

In the realm of compliance and security, PS SaaS commits to the highest standards to safeguard user data and ensure the integrity of its services. Adhering to global data protection regulations, PS SaaS will implement stringent security measures that encompass encryption, regular security audits, and obtaining necessary compliance certifications. This comprehensive approach to data protection is designed to shield user data from unauthorized access and breaches, instilling confidence among users regarding the safety of their information.

Moreover, the adoption of the SaaS model by PS SaaS facilitates the continuous delivery of software updates seamlessly to all users. This ensures that users consistently have access to the latest features, security enhancements, and bug fixes without requiring any manual intervention on their part. This approach not only streamlines the maintenance and upgrading process but also ensures that the software remains on the cutting edge of technology, providing a robust, secure, and efficient platform for users.

## 2.2. Solar Vision Pro Key Features

Solar Vision Pro harnesses the power of the Solar Vision API and the pvlib library to deliver an all-encompassing suite of tools for photovoltaic (PV) system design and sales. This innovative platform is designed to streamline the process of PV system modeling from initial site selection to the final stages of customer engagement. Key features include:

Optimal Site Selection: Utilizing advanced machine learning (ML) algorithms for satellite image analysis, Solar Vision Pro identifies the most suitable locations for PV installations. This process not only considers the physical layout and orientation of potential sites but also integrates environmental factors to predict the optimal placement of PV systems, ensuring maximum efficiency and energy output.

Detailed Modeling of PV Systems: At the core of Solar Vision Pro's capabilities is the detailed modeling of PV systems. By leveraging the comprehensive functions of the pvlib library, the software meticulously simulates various aspects of PV system performance, including but not limited to solar irradiance, module temperature, and system shading. This allows for the accurate prediction of energy production, considering both environmental and physical factors that influence system efficiency. Solar Vision Pro will be designed to allow users to utilize pre-made data or import new data for different physical parameters such as PV panel characteristics, inverter specifications, and weather time series. This capability is aligned with the types of data and functionalities found in the pvlib's data folder, ensuring that users have access to a wide range of parameters necessary for detailed modeling of PV systems .

Drawing Automatically Single-Line Diagram (SLD): Enables users to automatically generate single-line diagrams for PV systems. This tool simplifies the design process, providing a clear and efficient representation of the electrical connections and components within the PV installation. It's an essential resource for planning, installation, and documentation, ensuring accuracy and compliance with electrical standards.

Web Page Creation and Configuration: A unique feature of Solar Vision Pro is its ability to create and configure embeddable or standalone web pages designed specifically for the promotion and sales of PV system projects or complete PV system implementations. This tool empowers businesses to effectively showcase their PV solutions to potential customers, facilitating the selection of system parameters and simplifying the process of ordering PV projects or implementations. Whether for residential, commercial, or utility-scale applications, these customizable web pages serve as a dynamic interface between PV system providers and end-users, enhancing the customer experience and streamlining sales processes.

By integrating these key functionalities, Solar Vision Pro positions itself as a comprehensive solution for the PV industry, catering to the needs of system designers, installers, and end-users alike. By using cutting-edge technology and user-centric design, Solar Vision Pro aims to revolutionize the way PV systems are planned, modeled, and marketed, setting a new standard for efficiency and accessibility in the renewable energy sector. Solar Vision Pro will have capability to generate a complete engineering project, design, and sales proposal from just an electric bill and an address/coordinate.

## 2.3. Optimal Site Selection

The Optimal Site Selection feature in Solar Vision Pro harnesses the power of advanced machine learning (ML) algorithms to analyze satellite images for identifying the most suitable locations for photovoltaic (PV) installations. This innovative process goes beyond merely assessing the physical layout and orientation of potential sites; it meticulously incorporates environmental factors to ascertain the optimal placement of PV systems. By doing so, Solar Vision Pro ensures that the selected sites are primed for maximum efficiency and energy output, thereby optimizing the performance of the PV installations.

When a user is ready to find an optimal site, they can simply enter an address, provide coordinates, or pinpoint a location directly on the integrated map within Solar Vision Pro. This input triggers a query to the Solar Vision API, which processes the request and returns a GeoJSON response. This response includes polygons that mark surfaces deemed optimal for PV system installation based on the comprehensive analysis conducted by the ML algorithms. These polygons are then displayed on the map, providing a visual representation of the areas recommended for PV installations.

Users have the flexibility to interact with these polygons by editing, removing, or moving them to tailor the site selection to their specific requirements. Furthermore, the Solar Vision API provides valuable information on the optimal azimuth for each highlighted surface. This azimuth information is crucial as it indicates the best angle for installing solar panels to maximize sunlight exposure and, consequently, energy production. In addition to providing optimal azimuth information, the Solar Vision API further enhances the Optimal Site Selection feature by suggesting the ideal inclination, which refers to the roof tilt or terrain angle, for each proposed installation site. This crucial piece of information allows for a more nuanced and precise approach to planning PV installations, ensuring that both the direction and angle of the solar panels are optimized for the highest possible solar energy capture. ML algorithms should offer most optimal approximation for selected surface, azimuth and inclination/tilt, but these should be customizable by the user.

Once the user is satisfied with the selected surfaces and their corresponding azimuths and inclinations, they can confirm their choices. This confirmation marks a pivotal step in the process, as it initiates the creation of a new PV system project within Solar Vision Pro. This seamless integration of satellite image analysis, ML-powered site selection, and user interaction culminates in a highly efficient and user-friendly process for identifying the best locations for PV installations, thereby simplifying, and enhancing the planning phase of solar energy projects.

Note: It would be highly recommended and very useful to provide high-definition satellite imagery for the purpose of training and consuming the Solar Vision API. Exploring sources like planet.com, Airbus and such would be beneficial. High-def imager by demand can come into play if it can be calculated into the business model.

### 2.4. Detailed Modeling of PV Systems

Solar Vision Pro aims to enable PV professionals to effectively and seamlessly model future PV projects. For that purpose, pvlib-python library is selected to be core engine of the Solar Vision Pro software. As the most advanced and most supported open-source backend library for the purpose. To work out “Detailed Modeling of PV Systems” features we must introduce some basic facts about pvlib-python and its paradigms. Because user experience and overall usage of the modeling features will be based on top of the pvlib-python library.

Pvlib-python is a community developed toolbox that provides a set of functions and classes for simulating the performance of photovoltaic energy systems and accomplishing related tasks. The core mission of pvlib-python is to provide open, reliable, interoperable, and benchmark implementations of PV system models. Pvlib-python started out as a Python translation of the PVLIB MATLAB toolbox (developed by the PVPMC at Sandia National Laboratories) in 2013 and has grown substantially since then. Today it contains code contributions from over a hundred individuals worldwide and is maintained by a core group of PV modelers from a variety institutions. pvlib has been supported directly and indirectly by DOE, NumFOCUS, and Google Summer of Code funding, university research projects, companies that allow their employees to contribute, and from personal time. Pvlib-python is published under BSD 3-clause license which permits redistribution of the code and its usage.

There are at least as many opinions about how to model PV systems as there are modelers of PV systems, so pvlib-python provides several modeling paradigms: functions, the Location/PVSystem classes, and the ModelChain class.

The PVSystem represents one inverter and the PV modules that supply DC power to the inverter. A PV system may be on fixed mounting or single axis trackers. The PVSystem is supported by the Array which represents the PV modules in the PVSystem. An instance of PVSystem has a single inverter, but can have multiple instances of Array. An instance of the Array class represents a group of modules with the same orientation and module type. Different instances of Array can have different tilt, orientation, and number or type of modules, where the orientation is defined by the Array's mount (a FixedMount, SingleAxisTrackerMount, or other). The PVSystem class methods wrap many of the functions in the pvsystem module. Similarly, the Mount classes and Array wrap several functions with their class methods. Methods that wrap functions have similar names as the wrapped functions. This practice simplifies the API for PVSystem and Array methods by eliminating the need to specify arguments that are stored as attributes of these classes, such as module and inverter properties. Using PVSystem is not better or worse than using the functions it wraps – it is an alternative way of organizing your data and calculations. The PVSystem class allows modelers to easily separate the data that represents a PV system (e.g. tilt angle or module parameters) from the data that influences the PV system (e.g. the weather). The data that represents the PV system is intrinsic. The data that influences the PV system is extrinsic. Intrinsic data is stored in object attributes.

The ModelChain class provides a high-level interface for standardized PV modeling. The class aims to automate much of the modeling process while providing flexibility and remaining extensible. A ModelChain has three components:

a PVSystem object, representing a collection of modules and inverters

a Location object, representing a location on the planet values for attributes that specify the model to be used for each step in the PV modeling process.

Modeling with a ModelChain typically involves 3 steps:

creating an instance of ModelChain,

executing a ModelChain.run_model method with weather data as input. See Running for a list of run_model methods.

Examining the model results that are stored in the ModelChain's ModelChain.results attribute

A ModelChain object is defined by the properties of its PVSystem and Location objects and the keyword arguments passed to it at construction. ModelChain uses the keyword arguments passed to it to determine the models for the simulation. The documentation describes the allowed values for each keyword argument. If a keyword argument is not supplied, ModelChain will attempt to infer the correct set of models by inspecting the Location and PVSystem attributes.

It is highly recommended to make yourself very familiar with the pvlib-python and its documentation here: https://pvlib-python.readthedocs.io/en/stable/user_guide/introtutorial.html.

2.4.1. The (Not) User Story of PV modeling

Continuing from Section 2.3, the confirmation of the selected site by the user initiates the creation of a PV System project in Solar Vision Pro. This project is designed to encapsulate all the essential details required for a comprehensive understanding and management of the PV installation project. It includes fields for the title, description, information on who created and modified the project, timestamps for creation and modification, site's centroid coordinates, and a relational field linking to project collaborators within the user's organization. Once the editable information is populated and saved, the user transitions to a detailed view of the project, enriched with the site image and form fields for modifying project details.

UX engineer should design a solution to user's journey through entering PV System details. This includes defining one or multiple Arrays and selecting an appropriate inverter for the system from a pre-populated database containing a variety of inverters and PV module types along with their parameters.

The PV System should contain one Array or multiple Arrays and one inverter. One Array contains PV modules of one type. Inverters and PV module type,s with their parameters are chosen from the database of those. In the next section 2.3.2 management of module and inverter databases will be explained.

Parameters of the PV System corresponding to the projects are:

Array(s)

Inverter

racking_model (string, default 'open_rack') – Valid strings are 'open_rack', 'close_mount', and 'insulated_back'. Used to identify a parameter set for the SAPM cell temperature model.

losses_parameters (dict or Series, optional) – Losses parameters as defined by PVWatts or other.

name (string, optional) –

For each Array it is possible to define following parameters:

mount (FixedMount, SingleAxisTrackerMount, or other) – Mounting for the array, either on fixed-tilt racking or horizontal single axis tracker. Mounting is used to determine module orientation. If not provided, a FixedMount with zero tilt is used.

albedo (float, optional) – Ground surface albedo. If not supplied, then surface_type is used to look up a value in irradiance.SURFACE_ALBEDOS. If surface_type is also not supplied then a ground surface albedo of 0.25 is used.

surface_type (string, optional) – The ground surface type. See irradiance.SURFACE_ALBEDOS for valid values.

module (string, optional) – The model name of the modules. May be used to look up the module_parameters dictionary via some other method.

module_type (string, optional) – Describes the module's construction. Valid strings are 'glass_polymer' and 'glass_glass'. Used for cell and module temperature calculations.

module_parameters (dict or Series, optional) – Parameters for the module model, e.g., SAPM, CEC, or other.

temperature_model_parameters (dict or Series, optional) – Parameters for the module temperature model, e.g., SAPM, Pvsyst, or other.

modules_per_string (int, default 1) – Number of modules per string in the array.

strings (int, default 1) – Number of parallel strings in the array.

array_losses_parameters (dict or Series, optional) – Supported keys are 'dc_ohmic_percent'.

name (str, optional) – Name of Array instance.

https://pvlib-python.readthedocs.io/en/stable/reference/generated/pvlib.pvsystem.Array.html

This intricate array parameterization is to be presented intuitively in the user interface, making the process of specifying these details as straightforward as possible for the user.

Upon completing the data entry through the UI, the user can run the model using the ModelChain class. ModelChain provides a high-level interface for simulating PV power from weather inputs, supporting various starting points depending on the available data. The results from the ModelChain, alongside additional simulations covering the entire spectrum of modeling capabilities listed in the pvlib-python documentation, such as Solar Position, Clear sky models, Irradiance models, and PV temperature models, are displayed to provide a comprehensive overview of the system's performance under various conditions.

https://pvlib-python.readthedocs.io/en/stable/reference/modelchain.html

After displaying data from the ModelChain, the software should do other through available modeling for the system and the location and to display results from that modeling, all sections from here https://pvlib-python.readthedocs.io/en/stable/reference/ should be covered and that includes listed:

Solar Position

Clear sky

Airmass and atmospheric models

Irradiance (Transposition, DNI estimation, Clearness index)

Incident angle modifiers

PV temperature models

Single diode models

DC to AC conversion models

Effect on PV System Output (Loss models, Snow, Soiling, Shading, Spectrum)

Wavelet Variability model etc.

Finally, the software expands to include modeling for bifacial PV modules, utilizing pvlib-python functions for calculating front and back surface irradiance. This addition underscores the software's capability to accommodate advanced PV technologies, offering users the tools to explore the benefits of bifacial modules in enhancing energy production.

https://pvlib-python.readthedocs.io/en/stable/reference/bifacial.html

By covering all these aspects, Solar Vision Pro aims to offer a complete, user-friendly solution for modeling PV systems, from the initial site selection and system configuration to detailed performance analysis, incorporating the latest advancements in PV technology.

## 2.5. PV Parameters Database

To ensure accurate predictions and calculations within Solar Vision Pro, it is crucial to utilize specific parameters for particular PV modules and inverters. These parameters, which significantly influence the performance modeling of PV systems, are meticulously detailed in the SANDIA and CEC (California Energy Commission) databases. These comprehensive repositories include a wide array of data on PV modules and inverters, facilitating precise and reliable system modeling. To seamlessly integrate this vital data into Solar Vision Pro, the platform will feature a dedicated interface for managing PV modules data and inverter data, ensuring users can effortlessly access and utilize this information.

Interface Design for Data Management

For efficient management of these databases, two main views within the user interface (UI) are proposed:

PV Modules Data Management View: This view is specifically designed for the importation, update, and management of data related to PV modules from the SANDIA and CEC databases. It allows users to search for specific module types, view their detailed parameters, and select them for use in their PV system models. The UI will enable filtering and sorting options to quickly find modules based on key characteristics such as efficiency, power output, or manufacturer.

Inverter Data Management View: Similarly, this view focuses on managing inverter data from the CEC database. Users can explore inverter options, understand their specifications, and choose the most suitable inverters for their projects. The interface will provide functionalities to compare different inverter models based on efficiency, power rating, and compatibility with selected PV modules.

Data Import and Update Mechanism

To populate and keep the databases up-to-date, Solar Vision Pro will implement a robust data import and update mechanism. This mechanism will include:

Automated Data Fetching: Periodically, Solar Vision Pro will automatically fetch the latest data from the SANDIA and CEC databases. This ensures that the platform's database contains the most current information, reflecting any new additions or updates to module and inverter specifications.

Manual Data Import: Users with administrative privileges can manually import data into Solar Vision Pro. This feature is particularly useful for adding proprietary or custom module and inverter data that may not be available in the SANDIA or CEC databases.

Data Validation and Integrity Checks: Before importing data into the system, Solar Vision Pro will perform validation and integrity checks to ensure the accuracy and completeness of the data. This step minimizes errors and inconsistencies in the performance modeling of PV systems.

User Notification on Updates: Users will be notified of any significant updates to the PV modules or inverters data that might affect their ongoing or planned projects. This notification system ensures that users can make informed decisions based on the latest data.

User Interaction with Database Data

Users will interact with the imported data through intuitive forms and selectors embedded within the project creation and modeling views. When specifying the components for a new PV system project, users can select PV modules and inverters from dropdown menus populated with data from the databases. Detailed information about each component will be readily available, including graphical representations of performance characteristics, to assist users in making the best choices for their specific project requirements.

By integrating the SANDIA and CEC databases into Solar Vision Pro's UI for easy management and access, the platform empowers users to build more accurate and efficient PV system models. This approach not only enhances the user experience but also elevates the quality and reliability of PV system designs generated through Solar Vision Pro.

## 2.6. Drawing Automatically Single-Line Diagram (SLD)

The Single-Line Diagram (SLD) feature in Solar Vision Pro is an innovative tool designed to automate the generation of single-line diagrams for photovoltaic (PV) systems. This functionality is pivotal in streamlining the design process by offering users a precise and straightforward graphical representation of the electrical connections and components integral to the PV installation. As an indispensable resource for planning, installation, and documentation phases, the SLD tool guarantees the accuracy of designs and adherence to prevailing electrical standards.

### User Interface (UI) Design for SLD Generation

The UI for the SLD feature is crafted to be intuitive, facilitating a seamless user experience from the conceptual phase to the detailed design of a PV system. Key aspects of the UI design include:

Project Input Panel: At the outset, users are presented with a form to input essential details of the PV system, such as the number of arrays, types of inverters, and any additional electrical components. This panel serves as the preliminary step to guide the automated SLD generation process.

Interactive Diagram Area: Following the initial input, the core of the UI is the interactive diagram area where the single-line diagram is dynamically generated and displayed. This workspace allows users to view the SLD in real-time, with the ability to zoom in/out and pan across different sections for detailed inspection.

Component Toolbox: A sidebar or toolbox within the UI contains a library of electrical symbols and components that can be added to the SLD. Users can drag and drop items such as disconnects, combiner boxes, and meters from the toolbox into the diagram area, where they automatically snap into the correct position in the circuit layout.

Properties and Settings Panel: When a component within the SLD is selected, a properties panel appears, offering detailed information and customization options for that component. This includes electrical specifications, model numbers, and any relevant notes or warnings. Users can adjust settings such as wire sizes, conduit types, and protection devices to ensure the system design meets specific requirements.

Validation and Compliance Checks: Integrated validation tools automatically check the SLD against relevant electrical codes and standards. Discrepancies or potential issues are highlighted directly on the diagram, prompting users to make necessary adjustments.

Automated Drawing Mechanism

The automated drawing mechanism underlying the SLD feature operates on sophisticated algorithms that interpret the user inputs and electrical rules to construct an accurate diagram. This process involves:

Layout Generation: Based on the project details provided, the system automatically generates a layout that logically arranges components and connections, optimizing for both electrical efficiency and visual clarity.

Symbol Representation: Each component in the PV system is represented by standardized electrical symbols, ensuring the diagram is universally understandable. The placement of symbols follows electrical engineering best practices, with clear labels for easy identification.

Connection Routing: Electrical connections between components are intelligently routed to minimize crossings and ensure a clean, readable diagram. The routing algorithm takes into account the physical and electrical characteristics of the system to model realistic cable runs.

Dynamic Updates: As users modify the system configuration or add components through the UI, the SLD updates in real-time to reflect changes. This dynamic interaction encourages exploration and optimization of the PV system design.

By leveraging the Drawing Automatically Single-Line Diagram feature, Solar Vision Pro empowers users to efficiently create detailed and compliant electrical diagrams for PV installations. This tool not only enhances the design accuracy but also significantly reduces the time and effort required to move from conceptualization to completion of PV system projects.

## 2.7. Web Page Creation and Configuration

Solar Vision Pro introduces a groundbreaking feature with its Web Page Creation and Configuration tool, enabling users to effortlessly generate and customize web pages for the promotion and sales of photovoltaic (PV) system projects. This innovative functionality is designed to bridge the gap between PV system providers and potential customers, creating a seamless, interactive online experience that not only showcases PV solutions but also simplifies the decision-making and purchasing processes for users.

### Overview of Web Page Creation Tool

This tool allows for the creation of both embeddable web pages that can be integrated into existing websites and standalone web pages that can operate independently. The aim is to provide PV system providers with a versatile and powerful marketing and sales platform that can be tailored to target residential, commercial, or utility-scale applications effectively.

### Key Features and Functionalities

Intuitive Web Page Builder: At the heart of this feature is an easy-to-use web page builder interface, where users can drag and drop various elements to design their page. This includes text blocks, images, videos, and interactive elements like sliders and dropdown menus for selecting PV system parameters.

Customizable Templates: Solar Vision Pro offers a range of pre-designed templates that users can customize to match their branding and marketing strategy. These templates are optimized for both performance and aesthetics, ensuring that the created web pages are engaging and load efficiently on all devices.

Dynamic System Configuration: A standout feature of the web pages is the dynamic configuration tool, which allows end-users to customize their desired

PV system by selecting specific parameters such as system size, module types, and storage options. This interactive process is powered by real-time calculations that provide immediate feedback on energy production estimates and potential cost savings.

E-commerce Integration: To streamline the sales process, the web pages include e-commerce functionalities, enabling customers to place orders directly from the page. This includes integration with payment gateways, order management systems, and customer support chatbots, providing a comprehensive sales platform.

SEO and Analytics: Built with search engine optimization (SEO) in mind, these web pages are designed to rank well in search results, increasing visibility and attracting more potential customers. Additionally, integrated analytics tools allow businesses to track user engagement, conversion rates, and other key metrics, offering insights to refine their marketing strategies.

Implementation and Customization

Implementing and customizing web pages within Solar Vision Pro is a straightforward process:

Selection of Template: Users begin by selecting a template that best fits their project or brand.

Customization: Through the web page builder interface, users can customize the template by adding their content, images, and choosing colors and fonts.

Configuration of PV System Options: Users define the parameters that customers can select or customize, such as PV module types and system sizes.

Integration of Sales Tools: E-commerce functionalities are set up, including pricing details, payment options, and customer support features.

Publishing: Once the web page is complete, users can publish it as a standalone page or generate code to embed it into an existing website.

By offering the capability to create and configure web pages dedicated to the promotion and sales of PV systems, Solar Vision Pro empowers businesses to enhance their online presence, engage effectively with potential customers, and streamline their sales processes. This feature not only elevates the customer experience but also positions PV system providers for increased visibility and success in the competitive renewable energy market.

The Web Page Creation and Configuration feature in Solar Vision Pro not only serves as a powerful tool for the promotion and sales of PV system projects but also acts as a direct Business-to-Consumer (B2C) funnel. This innovative approach seamlessly connects the interactive, customer-facing web page with the backend project creation process within Solar Vision Pro, thereby streamlining the journey from customer interest to project initiation.

Connection between Web Page and PV System Project Creation

Upon visiting the custom web page created through Solar Vision Pro, potential customers are presented with an intuitive interface where they can specify their address or pinpoint a location on an integrated map. This user action triggers the Solar Vision API, which then analyzes satellite imagery to identify suitable roof or terrain surfaces for PV system installation at the specified location. This process mirrors the optimal site selection feature detailed in Section 2.3, ensuring that the recommended surfaces are primed for maximum solar energy generation.

The selection of a location and identification of potential installation surfaces automatically initiate the creation of a PV system project within Solar Vision Pro. This automated process includes several key steps:

Interactive Location Selection: The web page includes an interactive map or an address input field, enabling customers to specify the location for the proposed PV installation. This critical first step mirrors the customer's intent and interest in exploring solar energy solutions for their property.

Automatic Site Analysis: Leveraging the Solar Vision API, the platform automatically analyzes the provided location, identifying suitable roof or terrain surfaces for PV system installation. This process utilizes advanced algorithms and satellite imagery to determine optimal sites, ensuring that the proposed systems are both feasible and efficient.

PV System Project Initiation: Following the site analysis, a new PV system project is automatically initiated within Solar Vision Pro. This project inherits the customer's location data and the identified optimal surfaces, setting the foundation for detailed system modeling and design.

Customer Engagement and Customization: Customers are then guided through a series of customizable options for their PV system, such as selecting system size, module types, and other preferences. This interactive engagement not only educates customers about their choices but also refines the project details for more accurate modeling and estimation.

Seamless Transition to Consultation or Purchase: After specifying their preferences, customers can submit their inquiries or proceed directly to purchase or consultation stages. This seamless transition from an interactive web page to actionable steps toward system installation underscores the web page's role as a comprehensive B2C funnel.

Key Benefits and Features

Streamlined Customer Journey: From initial interest to project initiation, the process is designed to be intuitive and engaging, significantly enhancing the customer experience.

Increased Engagement: The interactive web page serves as an engaging platform for customers to explore PV system possibilities, enhancing their experience and satisfaction.

Data-Driven Site Selection: By automating the site analysis using the Solar Vision API, the platform ensures that system recommendations are based on precise data, increasing the likelihood of customer satisfaction and system performance.

Efficient Project Kickoff: The automatic initiation of projects upon customer interaction significantly reduces the time and effort required to move from customer inquiry to project planning.

Direct Linkage to Sales Funnel: The integration of e-commerce functionalities means that customer interactions can directly translate into sales, improving the efficiency of the sales process.

Customization and Flexibility: Customers appreciate the ability to influence the design of their PV system, fostering a sense of ownership and satisfaction with the proposed solution.

Analytics and Optimization: By tracking customer interactions and choices, businesses can gather valuable insights to optimize their offerings and marketing strategies further. The integration provides valuable insights into customer preferences and behaviors, enabling businesses to tailor their offerings and marketing strategies more effectively.

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3. Specific requirements

The Specific Requirements section of the Software Specification Requirements Document for Solar Vision Pro delineates the detailed prerequisites essential for the development, implementation, and successful operation of the platform. These requirements, grounded in the overarching goal of creating a versatile and robust SaaS solution for photovoltaic (PV) system modeling and sales, are meticulously outlined to ensure that the platform not only meets but exceeds the expectations of its intended users. This section is structured to provide a clear and comprehensive overview of the architectural design, integration capabilities, user interface specifications, data management protocols, security measures, and compliance adherence necessary for Solar Vision Pro. By establishing these specific requirements, we lay the foundation for a highly modular, scalable, and user-centric platform. These guidelines are pivotal in steering the development process, guaranteeing the platform's adaptability to diverse languages and regions, ensuring seamless integration with critical external resources, and upholding the highest standards of data security and regulatory compliance. Ultimately, this section serves as the blueprint for creating a state-of-the-art PV modeling tool that empowers solar energy professionals to optimize energy production, streamline project planning, and enhance customer engagement through innovative technology solutions.

3.1. Architectural Requirements

The architecture of Solar Vision Pro is meticulously designed to ensure that the platform is not only robust and reliable but also flexible and adaptable to meet the evolving needs of its users. This section outlines the architectural requirements that form the cornerstone of Solar Vision Pro's development strategy, emphasizing modularity, scalability, internationalization, and localization.

Modularity and Scalability

Decoupled Software Architecture: Solar Vision Pro is structured around a decoupled software architecture, wherein the backend, frontend, and auxiliary services are developed and operated independently. This architectural choice is pivotal in fostering modularity across the platform, allowing each component to evolve, scale, and be maintained without impacting the others.

Ease of Updates and Maintenance: The modular nature of the architecture facilitates streamlined updates and maintenance procedures. By isolating changes to specific components, the platform can undergo enhancements and bug fixes with minimal downtime and reduced risk of introducing new issues.

Responsive Scaling: Scalability is a core architectural requirement, enabling Solar Vision Pro to efficiently manage fluctuations in user demand and data volume. The platform is designed to dynamically allocate resources, ensuring optimal performance during peak usage times and conserving resources during periods of lower demand.

Internationalization and Localization

Framework Integration: From its inception, Solar Vision Pro integrates comprehensive internationalization frameworks, laying the groundwork for a platform that truly caters to a global audience. This strategic integration ensures that the platform can be seamlessly adapted to different languages, enhancing its accessibility and user experience.

Content Translation and Regional Adaptations: A key aspect of making Solar Vision Pro globally usable is the capability to translate textual content into multiple languages. Beyond mere translation, the platform is also designed to accommodate regional variations in date formats, currencies, and units of measurement. This attention to localization details ensures that Solar Vision Pro can provide an intuitive and relevant experience to users worldwide.

Cultural Sensitivity and Compliance: Acknowledging the cultural and regulatory diversity across regions, Solar Vision Pro aims to respect local customs and comply with regional regulations through its internationalization and localization efforts. This includes adapting user interfaces, operational workflows, and data handling practices to meet the specific needs and expectations of users in different geographies.

3.2. Integration and Modeling Requirements

The effectiveness and accuracy of Solar Vision Pro as a state-of-the-art platform for photovoltaic (PV) system modeling and analysis hinge on its integration with key external resources and the utilization of sophisticated modeling libraries. This section details the specific requirements related to the integration of the Solar Vision API and the utilization of the pvlib-python library, both of which are crucial for the platform's capability to deliver precise and comprehensive PV system modeling.

Solar Vision API Integration

Seamless Connection: Solar Vision Pro is designed to establish a seamless integration with the Solar Vision API. This connection is vital for accessing advanced satellite imagery and analytical capabilities, enabling the platform to perform detailed analyses of geographical locations for potential PV installations.

Optimal Surface Identification: Through the integration with the Solar Vision API, Solar Vision Pro can accurately identify optimal surfaces for PV installations. This includes analyzing factors such as terrain orientation, shading patterns, and potential obstructions, ensuring that the selected sites offer the best possible conditions for solar energy production.

Real-time Data Processing: The platform's integration architecture must support real-time data processing to enable immediate feedback and updates based on satellite image analysis. This requirement ensures that users can make informed decisions swiftly, streamlining the site selection process for PV projects.

pvlib Library Utilization

Comprehensive Modeling Capabilities: Solar Vision Pro leverages the pvlib-python library to offer detailed modeling of PV systems. This integration enables the platform to simulate a wide array of PV system performance aspects, including but not limited to solar irradiance, module temperature variations, and overall energy output.

Support for Diverse Use Cases: The utilization of the pvlib-python library equips Solar Vision Pro with the flexibility to address a comprehensive range of use cases. From residential rooftop installations to large-scale utility projects, the platform can accurately model PV systems under various configurations and environmental conditions.

Accuracy and Reliability: Ensuring the accuracy and reliability of PV system modeling is a critical requirement. By integrating the pvlib-python library, Solar Vision Pro adopts validated models and methodologies that are widely recognized within the renewable energy sector. This commitment to precision underpins the platform's ability to deliver dependable projections and analyses.

Together, the seamless integration with the Solar Vision API and the strategic utilization of the pvlib-python library form the backbone of Solar Vision Pro's modeling capabilities. These integrations not only empower the platform to perform advanced analyses and precise system modeling but also ensure that Solar Vision Pro remains at the cutting edge of technology, offering valuable insights and tools to professionals in the solar energy industry.

### 3.3. User Interface and Experience

Creating an intuitive and efficient user interface (UI) is fundamental to the success of Solar Vision Pro, enabling users from diverse backgrounds to effectively utilize the platform's extensive features. This section outlines the specific UI and user experience (UX) requirements for both the system modeling interface and the web page builder, ensuring that Solar Vision Pro offers a seamless and productive experience to its users.

System Modeling Interface

Intuitive Design: The system modeling interface must be designed with intuitiveness in mind, allowing users to easily navigate through various modeling features without extensive prior training. Icons, tooltips, and guided workflows should be employed to assist users in understanding the functionality available to them.

Efficient Configuration: Users should be able to input and configure their PV system designs effortlessly. This includes selecting PV modules and inverters, defining system layout, and inputting site-specific parameters. Dropdown menus, sliders, and input fields must be logically organized to streamline the configuration process.

Real-time Analysis and Feedback: The interface should provide real-time analysis and visual feedback as users configure their PV systems. This could include dynamic charts, graphs, and visualizations that update immediately to reflect changes in system design, helping users understand the impact of their configurations on system performance.

Collaborative Features: Incorporating collaborative tools within the system modeling interface will enable multiple users to work on a single project simultaneously. Features like comment sections, change tracking, and version control can facilitate teamwork and improve project outcomes.

Web Page Builder

Drag-and-Drop Functionality: The web page builder should offer drag-and-drop functionality, allowing users to easily add, remove, and rearrange elements on their custom web pages. This approach enables users to design visually appealing and effective web pages without needing to write code.

Template Library: A library of customizable templates tailored to different PV system types and marketing goals should be available to users. These templates will serve as starting points, which users can then personalize with their branding, color schemes, and content.

Dynamic Content Integration: Users should be able to integrate dynamic content related to their PV systems, such as interactive calculators for potential energy savings, system configuration tools, and live chat support. This content enhances the web pages' interactivity and engagement potential.

E-commerce Integration: The web page builder must include e-commerce integration capabilities, allowing users to add shopping carts, payment processing, and order management features directly to their web pages. This facilitates a smooth transition from customer interest to purchase, directly within the platform.

SEO and Analytics Tools: Built-in search engine optimization (SEO) tools and analytics will help users optimize their web pages for search engines and track visitor interactions. This data is invaluable for refining marketing strategies and improving web page effectiveness.

By prioritizing these UI and UX requirements, Solar Vision Pro aims to provide a user interface that is not only aesthetically pleasing but also highly functional, enabling users to maximize the platform's capabilities for PV system modeling and online promotion.

### 3.4. Data Management

At the core of Solar Vision Pro's functionality is the precision in PV system modelling, heavily reliant on the accurate and up-to-date parameters of PV modules and inverters. Recognizing this, the platform incorporates a sophisticated data management system designed to handle the complexities of component database management effectively. This system ensures that users have access to the latest, most accurate data necessary for designing optimal PV systems.

#### Component Database Management

The cornerstone of Solar Vision Pro's data management capabilities lies in its handling of component databases, specifically those concerning PV modules and inverters. These components are critical to the accurate simulation and analysis of PV system performance, making the management of their parameters a priority.

A crucial aspect of Solar Vision Pro's functionality and its ability to deliver precise PV system modeling is the platform's sophisticated data management system. This system not only facilitates the integration with well-known SANDIA and CEC databases but also underscores the platform's capability to incorporate data from a variety of other sources. This flexibility is essential for catering to the diverse needs of Solar Vision Pro users, enabling the design of PV systems that accurately reflect a wide range of components and conditions.

While the integration with the SANDIA and CEC databases provides a solid foundation for accessing reliable PV module and inverter parameters, Solar Vision Pro's data management capabilities extend far beyond these sources. This inclusive approach ensures that users have access to the most comprehensive and up-to-date information available for their PV system modeling needs:

Broad Data Source Integration: Beyond SANDIA and CEC, Solar Vision Pro is designed to accommodate data from an array of other reputable sources. This might include proprietary databases from manufacturers, research institutions, or industry consortia that offer specialized or more current data than what is available in the traditional databases.

Data Importing Capabilities: Users can import data directly into Solar Vision Pro, allowing for the inclusion of custom or proprietary component parameters that may not be available in the SANDIA and CEC databases. This feature supports the platform's flexibility and adaptability to specific user needs.

Automated Data Updates: To maintain the accuracy and relevance of component data, Solar Vision Pro implements automated update mechanisms. These mechanisms periodically refresh the platform's internal databases with the latest information from SANDIA, CEC, and other trusted sources. This ensures that users are always working with the most current data available.

User-Friendly Data Utilization: Solar Vision Pro provides an intuitive interface for users to search, view, and select component parameters when modeling PV systems. Advanced search filters and categorization features allow users to quickly find the components that best match their project requirements.

Data Integrity and Validation: Before integrating new data into the platform, Solar Vision Pro performs comprehensive integrity checks and validation processes. These checks ensure that the imported data is complete, accurate, and free from errors, thereby safeguarding the reliability of PV system simulations conducted on the platform.

Customization and Configuration: Recognizing that each PV project may have unique requirements, Solar Vision Pro allows users to customize and configure component parameters. This customization can include adjusting values to reflect specific environmental conditions or performance characteristics, providing a tailored approach to system modeling.

By prioritizing efficient and accurate component database management, Solar Vision Pro enables users to leverage critical data for the design and analysis of PV systems. This approach not only enhances the platform's modeling capabilities but also ensures that users can confidently rely on Solar Vision Pro for their PV system design and optimization needs.

3.5. Security and Compliance

In the rapidly evolving landscape of digital solutions for renewable energy, the significance of security and compliance cannot be overstated. Solar Vision Pro is committed to upholding the highest standards of data security and regulatory compliance, recognizing these as foundational to the trust and reliability placed in the platform by its users. This section delineates the stringent security protocols and compliance measures Solar Vision Pro adheres to, ensuring the safeguarding of user data and adherence to international standards.

Security Protocols

Robust Authentication and Authorization: Solar Vision Pro employs advanced authentication mechanisms to verify the identity of users, coupled with comprehensive authorization strategies to ensure users have appropriate access levels. Multi-factor authentication (MFA) and role-based access control (RBAC) are integral components of this approach, providing a layered security model that protects against unauthorized access.

Data Encryption: To protect sensitive information, all data in transit between the user's device and Solar Vision Pro servers, as well as data at rest stored on the platform, is encrypted using industry-standard encryption protocols. This ensures that even in the unlikely event of data interception or unauthorized access, the information remains secure and unreadable.

Regular Security Audits: To continually assess and enhance the platform's security posture, Solar Vision Pro undergoes regular security audits conducted by external experts. These audits help identify potential vulnerabilities and ensure that all security measures are current with best practices and emerging threats.

Regulatory Compliance

International Data Protection Regulations: Solar Vision Pro is designed to comply with global data protection standards, such as the General Data Protection Regulation (GDPR) in Europe, among others. This commitment involves implementing rigorous data handling practices, ensuring user consent where required, and providing users with control over their personal data.

Compliance with Energy Regulation Standards: The platform also adheres to international and local energy regulation standards relevant to PV system modeling and implementation. This includes compliance with standards for system design, safety, and performance, ensuring that PV systems modeled and deployed through Solar Vision Pro meet all regulatory requirements.

Continuous Monitoring and Adaptation: Recognizing that regulatory landscapes are subject to change, Solar Vision Pro maintains a proactive stance on compliance, continuously monitoring regulatory developments and adapting its practices accordingly. This ensures ongoing compliance with both current and future regulations.

### 3.6. Dependencies

The development, operation, and maintenance of Solar Vision Pro are underpinned by its reliance on a set of critical external resources and software requirements. These dependencies are integral to ensuring that the platform functions as intended, offering precise and reliable PV system modeling capabilities. Understanding these dependencies is crucial for both the development team and the end-users to ensure seamless integration and optimal performance.

#### External Dependencies

Solar Vision API: For advanced satellite image analysis and optimal PV installation site identification, Solar Vision Pro integrates with the Solar Vision API. This dependency is crucial for accessing detailed geospatial data and leveraging machine learning algorithms for site selection.

pvlib Library: At the core of Solar Vision Pro's system modeling functionality is the pvlib-python library. This open-source library provides a comprehensive suite of tools for simulating PV system performance, making it an indispensable resource for the platform.

Component Databases: For accurate component specification, Solar Vision Pro depends on external databases, notably SANDIA and CEC, for PV module and inverter parameters. The platform may also integrate with other databases and proprietary data sources to enhance its component selection capabilities.

#### Software Requirements

Python 3 Compatibility: Solar Vision Pro and the pvlib-python library are compatible with Python 3, requiring users and developers to ensure that their systems can run Python 3 applications.

Core Dependencies: The operation of pvlib-python, and by extension, Solar Vision Pro, depends on several key Python packages:

Pandas: For data manipulation and analysis.

Numpy: Essential for numerical computations.

SciPy: Used for scientific computing and technical computing.

The minimum version requirements for these packages are specified in the pvlib-python setup.py file and are typically versions released several years ago.

Optional Packages: Certain features of pvlib-python require additional packages, installed separately via pip or conda:

statsmodels: Needed for parameter fitting.

numba: Offers the fastest calculations for solar positions.

pyephem: Used for solar positions calculations via an astronomical library.

These optional dependencies enhance the functionality and performance of Solar Vision Pro's modeling capabilities.

Alternatively, users may install all optional dependencies using>

pip install pvlib[optional] # on Mac: pip install "pvlib[optional]"

NREL SPA algorithm

pvlib-python is distributed with several validated, high-precision, and high-performance solar position calculators. We strongly recommend using the built-in solar position calculators.

pvlib-python also includes unsupported wrappers for the official NREL SPA algorithm. NREL's license does not allow redistribution of the source code, so you must jump through some hoops to use it with pvlib. You will need a C compiler to use this code.

To install the NREL SPA algorithm for use with pvlib:

Download the pvlib repository (as described in [Obtain the source code])

Download the [SPA files from NREL]

Copy the SPA files into pvlib-python/pvlib/spa_c_files

From the pvlib-python directory, run pip uninstall pvlib followed by pip install .

https://pvlib-python.readthedocs.io/en/stable/user_guide/installation.html#nrel-spa-algorithm

3.7. Risks and Assumptions

The deployment and ongoing development of Solar Vision Pro are contingent upon carefully navigating a landscape of potential risks and making key operational assumptions. This proactive approach to risk management and acknowledgment of assumptions is crucial for maintaining the platform's reliability, user satisfaction, and operational integrity.

Risk Management

In developing a platform as complex and data-intensive as Solar Vision Pro, several risks must be meticulously managed:

Inaccuracies in Satellite Image Analysis: The core functionality of Solar Vision Pro relies on advanced satellite imagery for site analysis. However, there's an inherent risk of inaccuracies due to cloud cover, shadowing, or outdated images, which could lead to suboptimal site selection. Mitigation strategies include integrating multiple data sources, employing machine learning algorithms to discern patterns over time, and providing users with the ability to manually adjust or validate suggested sites.

Dependency on External Data Sources: Solar Vision Pro's effectiveness in modeling PV systems is significantly influenced by the accuracy and currency of external databases for component parameters. Any discrepancies, outdated information, or unavailability of these databases pose a risk to the platform's accuracy. To mitigate this, Solar Vision Pro plans to establish agreements with multiple data providers, implement rigorous data validation processes, and encourage user feedback for continuous improvement.

Operational Assumptions

For Solar Vision Pro to operate seamlessly, several assumptions about the operational environment and user base are made:

Basic User Knowledge of PV Systems: It is assumed that users of Solar Vision Pro possess a foundational understanding of PV systems and their components. This assumption influences the platform's design, aiming to strike a balance between usability for non-experts and the depth of information for professionals. To support users, Solar Vision Pro will offer educational resources, tutorials, and responsive customer support.

Reliable Internet Connectivity: Given that Solar Vision Pro is a Software as a Service (SaaS) platform, continuous and reliable internet connectivity is assumed for optimal operation. This connectivity is essential for accessing up-to-date satellite imagery, component databases, and performing cloud-based calculations. Awareness campaigns and guidance on minimum connectivity requirements will be provided to ensure users are equipped for the best possible experience.

By identifying these risks and assumptions, Solar Vision Pro can implement strategies to mitigate potential issues while ensuring the platform is designed and operated in a manner that aligns with user needs and operational realities. This holistic approach to risk management and operational planning is integral to the platform's mission to provide a reliable, accurate, and user-friendly tool for PV system modeling and project planning.

3.8. Exclusions

In the development and deployment of Solar Vision Pro, a clear definition of the platform's scope is essential to align expectations and streamline focus on its core functionalities. While Solar Vision Pro is designed to be a comprehensive tool for photovoltaic (PV) system modeling, sales, and project planning, it is important to acknowledge certain exclusions from its scope. These exclusions help delineate the boundaries of the platform's capabilities, ensuring that resources are optimally allocated to areas where Solar Vision Pro can provide the most value to its users. Below are the key exclusions from the scope of Solar Vision Pro:

Scope Limitations

Modeling Non-PV Renewable Energy Systems: Solar Vision Pro is specifically tailored for the modeling, analysis, and optimization of PV systems. As such, the platform does not support the modeling of other types of renewable energy systems, such as wind turbines, hydroelectric power stations, or biomass energy plants. This focus allows Solar Vision Pro to specialize and excel in the PV domain, offering detailed and precise modeling capabilities that cater exclusively to the needs of solar energy professionals.

Direct Control or Real-Time Monitoring of PV Installations: While Solar Vision Pro facilitates the detailed planning and modeling of PV systems, it does not extend to the direct control of actual PV installations or provide real-time monitoring functionalities. The platform is designed as a pre-installation tool that aids in the conceptualization, design, and analysis phases of PV projects. Users looking to control or monitor their PV systems in real-time should integrate Solar Vision Pro's outputs with dedicated monitoring and control solutions specifically designed for operational PV installations.

These exclusions are integral to understanding the intended use and limitations of Solar Vision Pro. By focusing on its strengths in PV system modeling and project planning, the platform ensures that it delivers exceptional value within its designated scope. Users of Solar Vision Pro can leverage its sophisticated modeling capabilities to design optimized PV systems, while also recognizing the need for complementary tools and solutions for aspects of renewable energy projects that fall outside of Solar Vision Pro's purview.