Exploring the Potential of Freely Available Satellite Data for Energy Applications

Sentinel-2 in the Energy Sector

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1. Introduction

The growing demand for sustainable energy solutions has highlighted the importance of advanced data-driven decision-making in energy research. Satellite remote sensing offers a transformative opportunity to address this need. Freely accessible satellite datasets, such as those from the Sentinel-2 mission under the Copernicus program, provide immense capabilities for monitoring Earth's surface with high spatial, spectral, and temporal resolutions [1]. Designed for environmental monitoring, Sentinel-2 data enable diverse applications, including renewable energy planning, infrastructure siting, and environmental impact assessments [2].

Sentinel-2 satellite images have 10-meter spatial resolution and five-day revisit time making it particularly well suited for dynamic monitoring tasks. The data is open access and could be used efficiently in the energy sector which is increasingly relying on remote sensing to meet climate targets, such as achieving net-zero emissions. Satellite data can map resource availability and monitor CO_2 emissions and land-use changes, all critical for sustainable energy transitions. This abstract explores the applications, advantages, and limitations of freely available satellite data, focusing on Sentinel-2, to promote innovative energy solutions for a sustainable future.

2. Applications

We provide in the following subsections, some background work that forms the basis of our contribution.

2.1. Sentinel-2 for Ground-Mounted Photovoltaic Detection

Using Sentinel-2 data is particularly valuable for detecting ground-mounted photovoltaic (PV) installations because it offers the perfect balance between coverage and detail, enabling efficient large-scale monitoring without compromising the ability to distinguish solar panels from surrounding features like vegetation and urban [3],[4]. Deep learning models can be trained to extract various information about PVs, such as geocoordinates, areas, power generation. This valuable information is used for planning purposes and would allow a more accurate and sustainable development of solar integration into the grid [5]. An example of a PV segmentation is shown in Figure 1. The complexity lies in deducing an accurate delineation of PVs. This challenge can be solved by using synthetic data such as generating super resolution images.

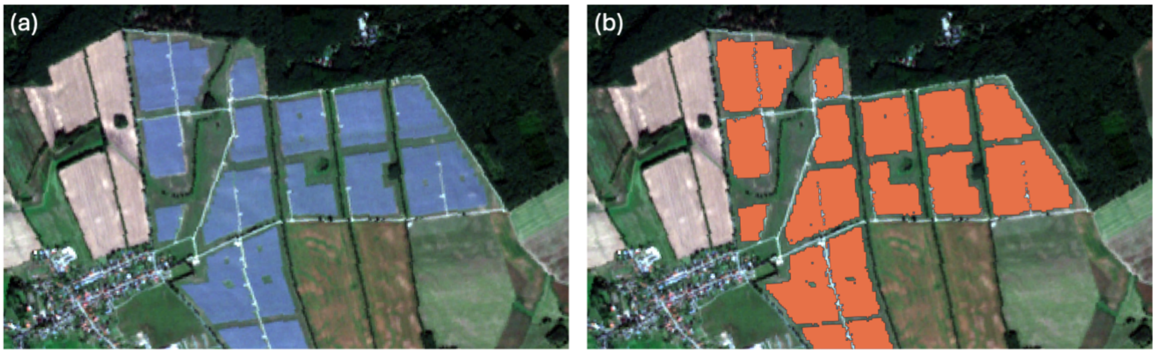

Figure 1. Ground-mounted PV as seen (a) in RGB from space and (b) the corresponding segmentation.

2.2. Synthetic Data Generation

Synthetic data generation is increasingly recognized as a solution to the limitations of existing real-world datasets, such as incomplete coverage, noise, and high acquisition costs. By simulating satellite imagery or augmenting existing datasets, synthetic data fills gaps in remote sensing applications for energy research.

For Sentinel-2, synthetic data can be generated using methods like Generative Adversarial Networks (GANs) or physics-based models. Synthetic data can be applied to train and validate detection algorithms for renewable energy installations, improving model generalizability across diverse geographies. Moreover, synthetic data generation facilitates transfer learning, where models pre-trained on synthetic datasets are fine-tuned with real-world data to enhance accuracy. This approach reduces reliance on extensive labelled datasets, accelerating the development of robust applications for energy infrastructure monitoring and resource assessment. The resolution of 10 m which could be challenging for detecting rooftop PVs could be improved by generating super resolution images improving the accuracy of detection.

3. Proposed Tool Concept

We developed a tool to automate ground-mounted PV detection from space based on the Sentinel-2 images. The tool is called *SpaR (Satellite Pattern Analysis for Renewables)*. It allows users to select any region desired globally and segment the PV installations available in that specific location. The tool provides publicly accessible PV location and size data for research purposes, aligning with our vision of making data on ground-mounted PV systems available worldwide in the future.

In the case of Germany, the tool also compares segmentations to officially registered data from *MaStR (Marktstammdatenregister)* and allows validation and update of the dataset. Figure 2 shows the interface, including the different features integrated within.

How It Works

- Input: The user inputs values of longitude and latitude for the desired location, then the tool calls the closest raster from the Sentinel-2 API.

- Sampling: The user could choose to sample data points from the raster or train the model using pre-sampled datapoints (meaning: solar farms or not solar farms).
- Training: The model is a fully connected neural network (FCNN) having as input the bands of a single pixel and trained using gradient descent [6]. The user trains the model to get the predictions and could select to use specific spectral bands from Sentinel-2 (with the possibility to train using all the bands).

Figure 2. A screenshot of the UI developed for automating PV segmentation using Sentinel-2 images using FCNN.

- Predictions: After training, predictions are visualized on top of the raster (in seconds).
- Evaluation And Update of *MaStR* Data: If PV located in Germany, a comparison between the predictions and the PVs registered geographic coordinates and covered areas in *MaStR* is listed in the output table.

Overall, the tool enables an overview, analysis, and comparison of registered official solar data and the creation of registries unavailable for many locations.

Data availability statement

The data supporting the findings of this study are based on Sentinel-2 satellite imagery, which is publicly available through the Copernicus Open Access Hub (https://dataspace.copernicus.eu). Sentinel-2 imagery is provided by the European Space Agency (ESA) under the Copernicus program and adheres to FAIR principles, ensuring free and open access for research and analysis. Further information on data access and usage policies can be found on the Copernicus website.

Author contributions

Conceptualization, Methodology, Writing: J.M. ; Reviewing and Editing: M.D.

Competing interests

The authors declare that they have no competing interests.

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