MODEL CARD

AI-Powered Rooftop PV Detection System

Model Version: 1.0.0

Date: November 30, 2025

Framework: Ultralytics YOLOv8 / PyTorch

This document provides a detailed overview of the model architecture, training methodology, intended use cases, and ethical considerations for the solution submitted to the EcoInnovators Ideathon 2026.

1. Model Details & Architecture

Overview

The EcoInnovators-SolarDetect-v1 is a computer vision model designed to identify and segment rooftop solar photovoltaic (PV) installations from high-resolution satellite imagery. It utilizes a deep convolutional neural network (CNN) architecture optimized for object detection.

Technical Specifications

- Architecture: YOLOv8-Medium (You Only Look Once).
- Backbone: CSPDarknet53 (Cross Stage Partial Network) for feature extraction.
- Neck: PANet (Path Aggregation Network) for feature fusion across scales.
- Head: Decoupled anchor-free head for separate objectness, class, and bounding box regression.
- Input Resolution: 640 x 640 pixels (RGB).
- Precision: FP16 (Half Precision) optimized for NVIDIA T4/A100 inference.

2. Intended Use Cases

Primary Application

Automated verification for the PM Surya Ghar: Muft Bijli Yojana. The model serves as a governance tool to audit beneficiary claims by validating the physical presence of solar panels at reported GPS coordinates.

Verification Logic (Buffer Zones)

To account for GPS inaccuracies, the model implements a two-stage geospatial buffer check:
1. Inner Ring (1200 sq.ft / ~6m radius): High-confidence verification zone.
2. Outer Ring (2400 sq.ft / ~8.4m radius): Secondary verification zone if the first check fails.
This logic ensures fairness in verification even if the geocoding is slightly off-center.

Out-of-Scope Use Cases

This model is NOT designed for:
- Real-time video surveillance.
- Large-scale utility solar farm inspection (airport/industrial grids).
- Defect detection (cracks or dust on panels).

3. Training Data & Methodology

The model was trained on a curated dataset of satellite imagery specifically labeled for solar panel detection.

Data Sources

- Source 1: Alfred Weber Institute of Economics (Roboflow)

- Source 2: LSG1547 Project (Roboflow)
- Source 3: Piscinas Y Tenistable (Roboflow)
Total Training Images: ~12,000 labeled instances.

Data Preprocessing

- Resizing: All images normalized to 640x640.
- Augmentation: Mosaic, MixUp, Random Brightness (±20%), and HSV augmentation were applied to simulate diverse weather conditions (haze, bright sun, slight cloud cover).

4. Quantitative Analysis

The model was evaluated on a held-out validation set comprising 10% of the total data.

Key Metrics

- mAP@50 (Mean Average Precision): >0.85
- Precision: High precision was prioritized to minimize False Positives (detecting a non-solar roof as solar).
- Recall: Tuned via a confidence threshold of 0.15 to ensure valid installations are not missed.

Area Estimation Accuracy

Area quantification is derived using latitude-dependent Ground Sample Distance (GSD). Evaluation against reference objects shows an area estimation error margin of <10% for standard installations.

5. Ethical & Operational Considerations

Bias and Fairness

The training data predominantly features urban and semi-urban Indian rooftops. Consequently, the model may exhibit lower confidence on rural thatched roofs or highly unconventional mounting structures. Human-in-the-loop verification is recommended for 'Low Confidence' flags.

Privacy

The system processes satellite imagery at a resolution (Zoom 19) sufficient for infrastructure detection but insufficient for facial recognition or reading license plates. No Personal Identifiable Information (PII) is stored within the model weights.

6. Deployment & Maintenance

The model is containerized using Docker for reproducible deployment. It requires a standard Python environment with PyTorch and OpenCV. For ongoing maintenance, we recommend retraining the model quarterly with fresh satellite data to account for seasonal vegetation changes that might occlude roofs.