Model Card – Helio Yajna: Rooftop Solar Panel Detection System

Team Name: Helio Yajna

Challenge: EcoInnovators Ideathon 2026 (College Edition)

Model Type: YOLO-based Instance Segmentation

Version: v12

Date: 4th January 2026

Problem Statement:

Accurate rooftop solar detection is challenging due to small object size, roof variability, occlusions, shadows, and hard negatives such as roads and rooftop equipment.

1. Model Overview

Helio Yajna is an end-to-end computer vision system designed to detect, segment, and verify rooftop solar panels from satellite imagery. The system combines a deep learning segmentation model with spatial verification logic to produce explainable outputs.

The solution directly addresses the **PM Surya Ghar: Muft Bijli Yojana** verification challenge by reducing dependence on physical inspections while maintaining transparency, traceability, and accuracy.

Primary Task:

- Instance-level detection and segmentation of rooftop solar panels

Secondary Tasks:

- Site-level solar presence classification

- Solar panel area estimation

- Capacity estimation

2. Intended Use:

Primary Use Case

- Remote verification of rooftop solar installations for government subsidy disbursal.
- Audit-friendly evidence generation for DISCOMs and state agencies.

Target Users

- Government auditors and scheme administrators
- DISCOM verification teams
- Urban energy planners and policymakers

3. Data Description

Positive Samples

- Rooftop solar PV panels captured across **multiple roof types** including residential, commercial, and industrial buildings.
- Visual diversity in **tilt, orientation, panel density, and layout**, reflecting real-world installations.
- Inclusion of **shadows, partial occlusions, and varying roof materials** to improve robustness.

Hard Negative Samples (Critical Design Choice)

- Aerial rooftop imagery without solar installations to reduce rooftop-based false positives.
- Roads, highways, and parking lots included due to visual similarity with panel grid patterns.
- Industrial sheds and warehouses without PV, often misclassified because of reflective metal roofing.

Data Sources (with attribution)

- Alfred Weber Institute – Rooftop PV (Roboflow)
- LSGI547 Project – Urban & Industrial scenes (Roboflow)
- Piscinas y Tenistable – High-variance aerial imagery (Roboflow)

Annotation type: Instance segmentation masks.

Single class: solar_panel.

Pre-processing:

- Resolution: 1280×1280 pixels, zoom 20, scale 2.
- Contrast enhancement (CLAHE)
- Augmentations: flip, brightness/contrast jitter

4. Model Architecture & Training

YOLO-based instance segmentation model trained using Roboflow.

Reported metrics:

mAP@50	**88.0%**
Precision	**81.3%**
Recall	**82.6%**
Detection F1	**81.94%**

Visual Explainability Strategy

- **Yellow Circle:** 1200 sq.ft reference zone
- **White Circle:** 2400 sq.ft reference zone
- **Green Masks:** Panels whose centroid lies within valid buffer zone
- **Red Masks:** Panels detected outside valid buffer zone

This ensures auditors can visually confirm *why* a decision was made.

5. Inference Pipeline

- Primary YOLO segmentation

- Buffer verification using 1200 sq.ft (primary) and 2400 sq.ft (secondary)

- Image enhancement fallback

- SAHI fallback

- Final green/red classification

6. Area & Distance Estimation

Area is estimated using mask pixel count and GSD.

Euclidean distance from image center is computed.

Capacity assumption: 1 kW ≈ 5 m^2.

7. Outputs

Annotated images with buffer circles and colored masks.

JSON outputs with confidence, area, buffer used, and QC status.

8. Evaluation Metrics

Image-level has_solar **F1: 91.49%**

MAE (Area m^2): 287.977

RMSE (Capacity kW): 167.048

9. Complexity

Time: O(N)

Space: O(1) per image

10. Ethics & Limitations

Uses public imagery only.

Not intended for enforcement or billing.

11. License & Usage

- Code: MIT License
- Models: For research & governance use under Ideathon guidelines

12. Conclusion

Helio Yajna provides a scalable, explainable, and policy-ready solution for rooftop solar detection.