Model Card: AI-Powered Rooftop Solar PV Detection

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Model Version: 1.0

1. Model Details

- **Developer:** Helio yajna
- **Model Architecture:** YOLOv8
- **Task:** Object Detection (Bounding Box) & Instance Segmentation
- **Input:** High-resolution satellite imagery (RGB), resized to 640x640 pixels.
- **Output:** Binary classification (Solar/No Solar), Bounding Box coordinates, and Area (m^2).
- **Frameworks:** PyTorch, Ultralytics YOLOv8.
- **License:** MIT License.

2. Intended Use

- **Primary Application:** Remote verification of rooftop solar installations for the **PM Surya Ghar: Muft Bijli Yojana** scheme.
- **Target Users:** Government auditing agencies, DISCOMs, and urban planners.
- **Intended Domain:** Residential and commercial rooftops in India (urban and semi-urban environments).
- **Out of Scope:** Ground-mounted solar farms, thermal water heaters, and highly occluded rooftops (heavy tree cover).

3. Data Overview

The model was trained on a composite dataset to ensure generalization across diverse roof types (concrete flat roofs, tiled roofs, industrial sheds).

- **Training Datasets:**
  - *Alfred Weber Institute (Roboflow)*: Urban residential rooftops.
  - *LSG1547 Project*: Mixed urban/industrial.
  - *Piscinas Y Tenistable*: Diverse angles and lighting conditions.
- **Total Images:** ~3,500 (augmented to ~10,000).
- **Preprocessing:**
  - **Resizing:** 640x640 pixels.
  - **Contrast Enhancement:** CLAHE (Adaptive Histogram Equalization) to handle atmospheric haze.
  - **Augmentations:** Horizontal/Vertical Flip, 90° Rotation, Brightness/Exposure variation (±15%).

○ *Note:* Rotation/Shear were disabled to preserve area calculation accuracy.

4. Performance Metrics

Performance evaluated on a held-out test set of 500 images.

Trained on: Solar panels

Metric	Score
F1 Score	0.765
mAP50-95	0.517
Precision	0.725
Recall	0.813

Trained on: Custom Workflow Object Detection

Metric	Score
F1 Score	0.789
mAP50-95	0.561
Precision	0.777
Recall	0.802

Metric	Score
F1 Score	0.547
mAP50-95	0.284
Precision	0.73
Recall	0.438

5. Logic & Assumptions

- **Buffer Zone Logic:** The system employs a dual-ring buffer strategy. It first checks for panel intersection within a **1200 sq. ft.** radius from the provided coordinate. If absent, it expands the search to a **2400 sq. ft.** radius.
- **Area Estimation:** Area is calculated using pixel-to-meter conversion based on the Ground Sample Distance (GSD).
  - **Assumption:** GSD is constant at **0.15 m/px** (Zoom Level 20).
  - **Formula:** Area_{m^2} = Area_{px} \times (0.15)^2.

6. Limitations & Failure Modes

1. **Resolution Dependency:** The model requires imagery better than 30cm/pixel. Public Sentinel-2 imagery (10m/pixel) is insufficient.
2. **Look-alikes:** Blue rectangular water tanks or large skylights may occasionally generate False Positives.
3. **Occlusion:** Dense tree canopy covering >50% of the roof will result in False Negatives.

7. Retraining Guidance

To adapt this model for a new state/region:

1. **Collect Data:** Gather ~200 local images (e.g., specific roof tiles of Kerala).
2. **Fine-Tune:** Load best.pt and train for 20 epochs with a low learning rate (lr=0.0001).
3. **Validation:** Ensure F1 score remains >0.75 on the new validation set.