MODEL CARD: ROOFTOP SOLAR PV DETECTION & QUANTIFICATION

1. MODEL OVERVIEW

Model Name: Rooftop Solar PV Detection Pipeline

Primary Task: Detection and quantification of rooftop solar photovoltaic (PV) panels from satellite imagery

Model Type: Hybrid Deep Learning Pipeline (CNN + Object Detection)

This system is designed to automatically identify whether rooftop solar panels are present in a given satellite image, and if present, estimate panel count and approximate covered area with explainable outputs.

2. INTENDED USE

Primary Intended Uses:

- Automated rooftop solar adoption assessment
- Renewable energy planning and analytics
- Urban sustainability studies
- Policy and research support

Out-of-Scope Uses:

- Legal or regulatory enforcement
- Real-time monitoring
- Individual household decision-making
- Financial valuation or billing
- The model is not intended to replace on-site inspections.

3. DATA USED

3.1 Training Dataset

Dataset Name: Custom Workflow Object Detection – Solar Panels

Source: Roboflow Universe

Dataset Author: Alfred Weber Institute of Economics

Total Images: 10,000(approximately)

Annotations: Bounding boxes for solar panels

Split: Predefined Train / Validation / Test

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Dataset URL: https://universe.roboflow.com/alfred-weber-institute-of-economics/custom-workflow-object-detection-tgnqc

3.2 Imagery Source (Inference)

Provider: Mapbox Satellite

Type: Public satellite imagery

Resolution: Varies by location

Attribution: Map imagery © Mapbox © OpenStreetMap contributors

4. MODEL ARCHITECTURE & LOGIC

4.1 Classification Stage (ResNet50)

Architecture: ResNet50 (Convolutional Neural Network)

Pretrained on ImageNet

Fine-tuned for binary classification:

Solar Present

Solar Not Present

Output: Probability score indicating presence of solar PV

This stage acts as a filter, reducing unnecessary object detection computations.

4.2 Detection Stage (YOLOv8)

Architecture: YOLOv8 Object Detector

Input: Satellite image

Output:

Bounding boxes for solar panels

Confidence scores

Bounding boxes are used for:

Panel counting

Area estimation

Explainability artifacts

5. ASSUMPTIONS

- Solar panels are visually distinguishable in satellite imagery
- Rooftops are not fully occluded
- Satellite images are recent and sufficiently high-resolution

- Bounding box area correlates with actual PV surface area
- Panel orientation and tilt are not estimated
- Capacity (kW) estimation is not included in this version.

6. OUTPUT & EXPLAINABILITY

Outputs Produced:

Binary solar presence classification

Confidence score

Bounding box coordinates

Estimated PV area (pixel-based)

Quality Control (QC) Status

QC Status Definitions

VERIFIABLE: Clear visual evidence of solar panels

NOT_VERIFIABLE: Insufficient evidence due to low image quality, shadows, clouds, or occlusion

Audit images with bounding boxes are generated to support human verification.

7. KNOWN LIMITATIONS & BIASES

7.1 Data Biases

Bias toward regions with clear rooftop visibility

Limited representation of:

- Rural rooftops
- Informal housing
- Snow-covered or desert environments

7.2 Technical Limitations

Pixel-based area estimation is approximate

Cannot detect panels fully hidden by:

- Trees
- Water tanks
- Heavy shadows
- Performance depends heavily on satellite image quality

8. FAILURE MODES

The model may fail or produce unreliable outputs in cases such as:

Cloud cover or haze

Low-resolution imagery

Strong rooftop shadows

Non-standard panel shapes or colors

Reflective rooftops causing false positives

In such cases, the QC status is marked as NOT_VERIFIABLE.

9. ETHICAL CONSIDERATIONS

- Uses only publicly available imagery
- No personally identifiable information (PII) processed
- Attribution provided for all datasets and imagery
- Designed for analysis at scale, not individual profiling

10. RETRAINING & MAINTENANCE GUIDANCE

When to Retrain

- Expansion to new geographic regions
- Significant change in satellite imagery source
- Performance degradation observed
- Inclusion of new rooftop styles or panel types
- Retraining Steps
- Collect additional annotated satellite images
- Ensure license compatibility and attribution
- Fine-tune ResNet50 and YOLOv8 models
- Validate on region-specific test data
- Update confidence thresholds if needed

11. VERSIONING & UPDATES

Current Version: v1.0

Future versions may include:

Segmentation-based area estimation

Capacity (kW) estimation

Multi-class rooftop object detection

12. License & Attribution

Code License: MIT License

Dataset License: CC BY 4.0

Dataset Credit: Alfred Weber Institute of Economics