Project Documentation – Solar Panel Defect Detection

# 1. Problem Statement

Solar energy is a crucial renewable resource, but the accumulation of dust, snow, bird droppings, and physical/electrical damage on solar panels reduces their efficiency. While manual monitoring is time-consuming and expensive, automated detection can help improve efficiency and reduce maintenance costs.  
  
This project aims to develop deep learning models for both classification and object detection to accurately identify and localize different types of obstructions or damages on solar panels.

# 2. Business Use Cases

1. Automated Solar Panel Inspection – AI-based system to classify and detect issues, reducing manual inspections.

2. Optimized Maintenance Scheduling – Identify panels requiring immediate cleaning/repair.

3. Efficiency Monitoring – Track efficiency loss due to obstructions.

4. Smart Solar Farms – AI-integrated solar farms that auto-trigger cleaning/repair alerts.

# 3. Project Objectives

## a. Classification Task – Identifying Solar Panel Conditions

• Categories: Clean, Dusty, Bird-Drop, Electrical-Damage, Physical-Damage, Snow-Covered.  
• Input: Raw solar panel images.  
• Output: Predicted category label.  
• Use Cases: Automating inspection, prioritizing maintenance, improving efficiency.

## b. Object Detection Task – Localizing Issues on Solar Panels (Optional)

• Classes: Dust, Bird-Drop, Electrical-Damage, Physical-Damage.  
• Input: Annotated images with bounding boxes.  
• Output: Bounding boxes with class labels.  
• Use Cases: Targeted cleaning/repair, robotic cleaning integration.

# 4. Exploratory Data Analysis (EDA)

• Dataset Description – Images collected/annotated for multiple defect types.  
• Preprocessing Steps – Image resizing, augmentation, normalization.  
• Visualizations – Class distribution, sample images per class, bounding box visualizations.  
• Insights – Identification of dataset imbalance, common defect patterns, seasonal variations.

# 5. Approach & Methodology

## a. Data Preprocessing & Annotation

• Image augmentation for class balancing.  
• Resizing to model-suitable dimensions.  
• Bounding box annotation for object detection.  
• Pixel normalization for better training stability.

## b. Model Training

• Classification Models: ResNet, EfficientNet, MobileNet.  
• Object Detection Models: YOLOv8.

## c. Model Evaluation

• Classification Metrics: Accuracy, Precision, Recall, F1-Score.  
• Object Detection Metrics: mAP (Mean Average Precision), IoU (Intersection over Union).

# 6. Results

• High accuracy classification of panel conditions.  
• Effective object detection with bounding box localization.  
• Actionable insights for solar farm maintenance.

# 7. Deployment – Streamlit App

• Upload panel images.  
• View classification results.  
• (Optional) View bounding box detection outputs.  
• Maintenance recommendation system.

# 8. Expected Results & Outcomes

1. Predictive Modeling – Accurate classification & detection of defects.  
2. Actionable Insights – Recommendations for cleaning, repair, and efficiency improvement.  
3. Streamlit Application – User-friendly interface for real-time defect detection and decision-making.