

- ADVANCING
RENEWABLE ENERGY
TECHNOLOGY

Optimizing solar panel placement using geospatial analytics

SOLAR SCAPE ANALYTICS





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INTRODUCTION

Renewable energy is any energy that is primarily derived from natural replenishment at a faster rate than consumption, including the sun and wind. It is important to reduce the effects of greenhouse gas emissions and develop sustainably.

Types of Renewable Energy

There are primary types of renewable energy: solar, wind, hydro, biomass, and geothermal.

Solar Energy

Solar energy is primarily focused on turning the sun's energy into usable electricity. It is clean and abundant.



PREDICTION CHALLENGES IN PHOTOVOLTAIC POWER GENERATION

Weather Variability

- Varied weather conditions lead to fluctuations in predicted power generation.

Efficiency Fluctuations

- Changes in efficiency affect the accuracy of power generation estimations.

Maintenance Costs Influence

- Maintenance expenses directly impact the overall cost predictions.



MACHINE LEARNING IN PHOTOVOLTAIC POWER PREDICTION

Machine learning (ML) leverages historical data to predict future solar power output, enhancing decision-making for installation planning and energy management.

Key Machine Learning Techniques:

- Time Series
- Correlation Analysis

Advantages of Machine Learning:

- Accuracy
- Adaptability



PROJECT AIM: SIMULATING PHOTOVOLTAIC PERFORMANCE

Objective

- **Goal:** Simulate photovoltaic (PV) performance across various locations, focusing on the impact of weather conditions on energy output.

Significance of Weather

- **Impact:** Weather significantly influences PV efficiency, with variables like sunlight intensity and temperature playing key roles.
- **Predictive Modeling:** Utilizes weather data to forecast solar panel performance using advanced machine learning techniques.

Project Outcomes

- **Optimization:** Aims to enhance PV system design and placement for maximum efficiency.
- **Decision Making:** Provides critical data to support investment and development decisions in solar infrastructure.



LEVERAGING NIST DATA FOR SOLAR PREDICTIONS

NIST's detailed environmental metrics to select optimal locations for solar panels based on environmental performance.

Source: <https://pvdata.nist.gov/>





Description:

For environmental factors:

AmbTemp_C_Avg: Average ambient temperature.

WindSpeedAve_ms: Average wind speed.

WindDirAve_deg: Average wind direction.

Pyra1_Wm2_Avg: Average solar irradiance measured by pyranometer 1.

Pyra2_Wm2_Avg: Average solar irradiance measured by pyranometer 2.

SEWSAmbientTemp_C_Avg: Average ambient temperature measured by SEWS.

SEWSPOAIrrad_Wm2_Avg: Average plane of array irradiance measured by SEWS.

WindHeatStateID_Avg: Average wind heater state identifier (if applicable, to account for potential temperature variations due to heating).

For power output:

- InvPAC_kW_Avg: Average inverter AC power output.

PROJECT EXECUTION OVERVIEW

Data Collection and Cleaning

- **Process:** Gathered NIST data on environmental metrics and solar panel performance.
- **Cleaning:** Addressed missing values, outliers, and inconsistencies to ensure data quality and reliability.

Exploratory Data Analysis (EDA)

- **Objective:** Analyzed the data to uncover patterns, trends, and relationships that inform the model's development.
- **Tools Used:** Utilized statistical tools and visualization libraries to examine data distributions and correlations

Machine Learning

- **Approach:** Developed predictive models to estimate optimal solar panel placement based on historical data.
- **Gradient Boosted Trees:** Chosen for their robustness and effectiveness in handling varied and complex data structures.

Pipeline Technique

- **Implementation:** Created a streamlined process using pipeline techniques to automate the flow of data through various preprocessing and modeling steps.
- **Benefits:** Ensured consistency in data handling and model application, enhancing reproducibility and efficiency.



Exploratory Data Analysis (EDA)

Time Series Analysis

- Objective: Investigate seasonal and temporal trends in solar power generation.
- Findings: Identified patterns that show variations in power output across different times of the year and day.

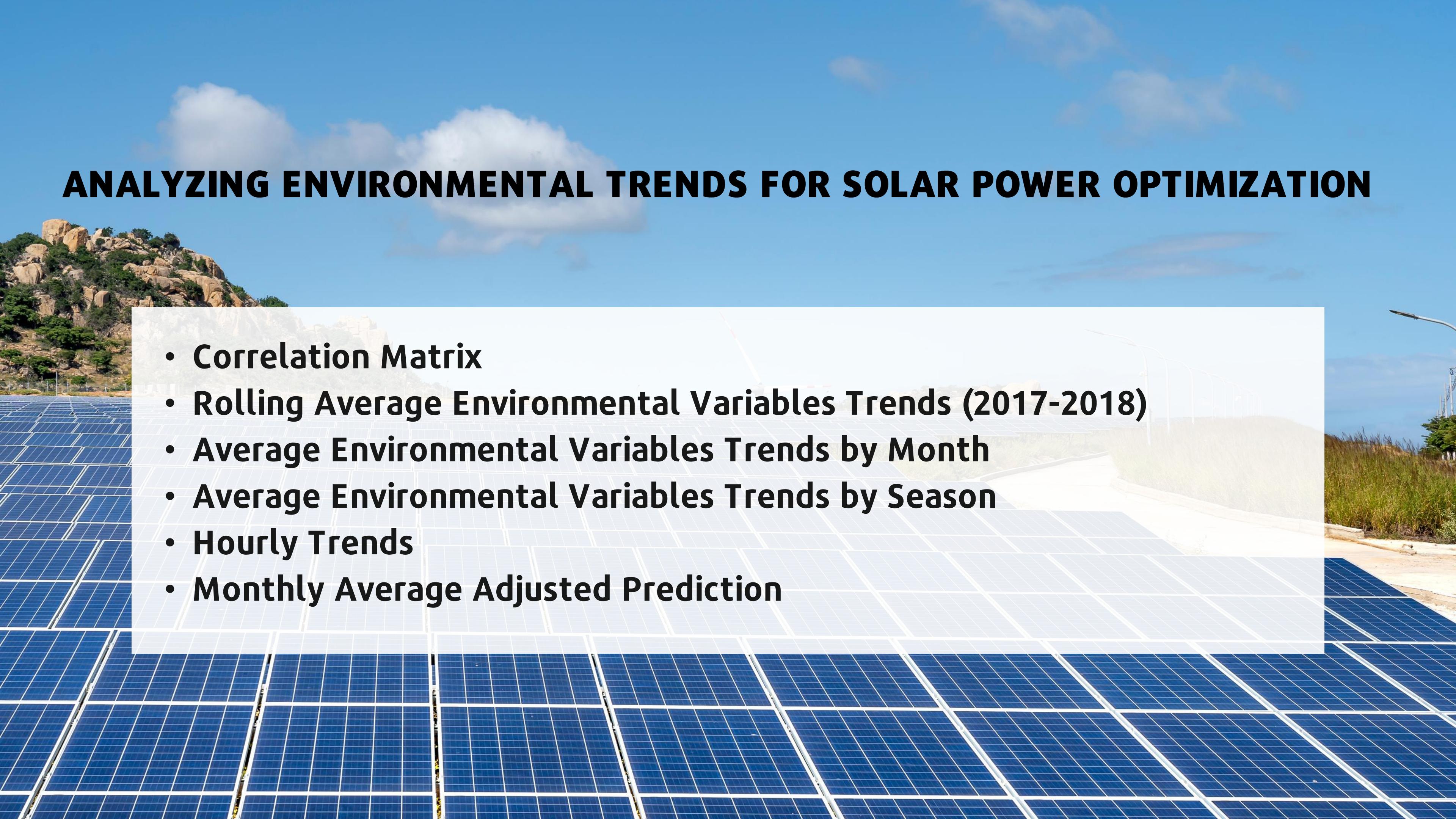


Correlation Study

- Purpose: Understand the relationship between weather conditions (like solar irradiance and temperature) and the power generated by solar panels.
- Results: Demonstrated strong correlations where higher temperatures and increased solar irradiance lead to greater energy production.

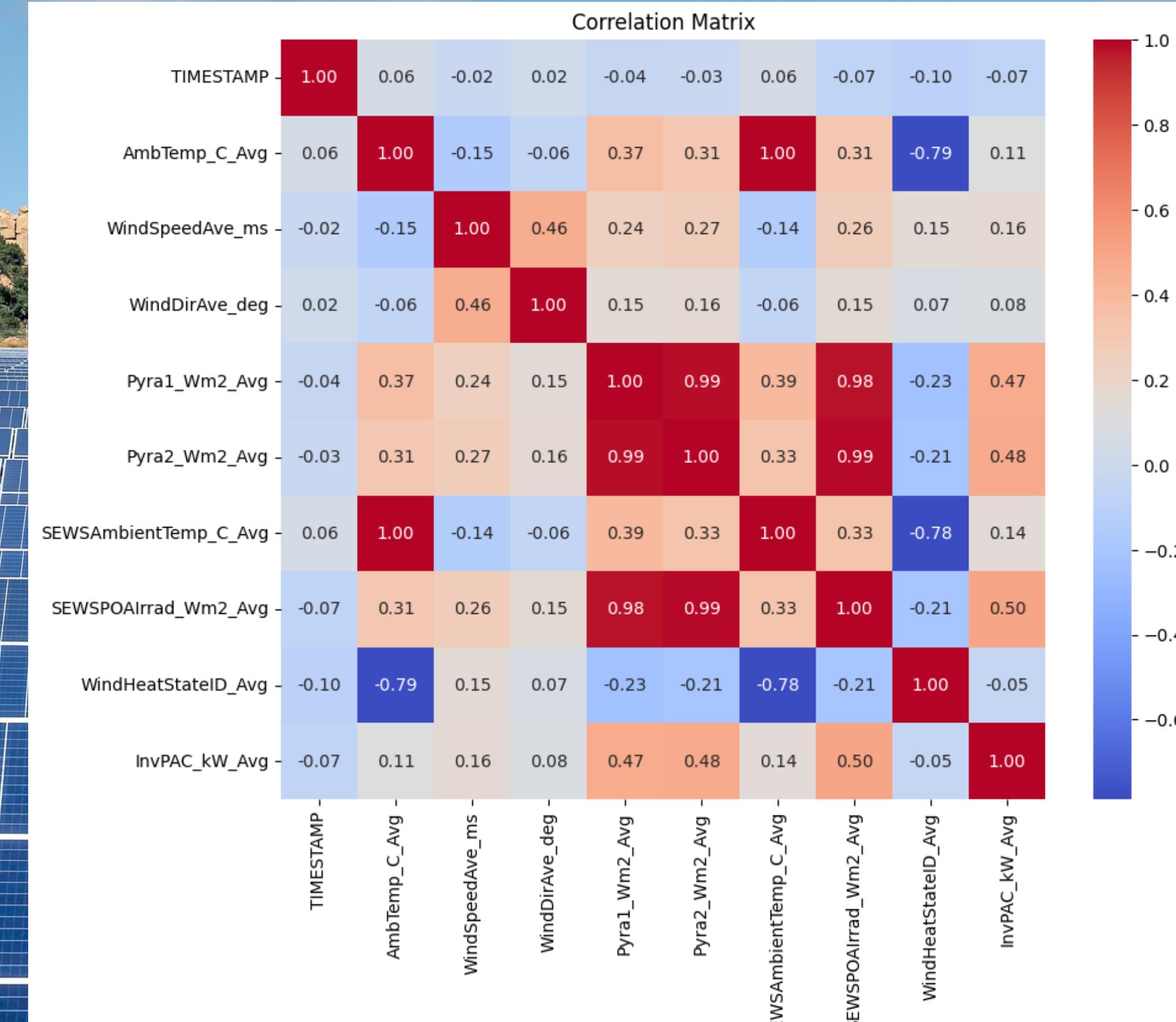


ANALYZING ENVIRONMENTAL TRENDS FOR SOLAR POWER OPTIMIZATION

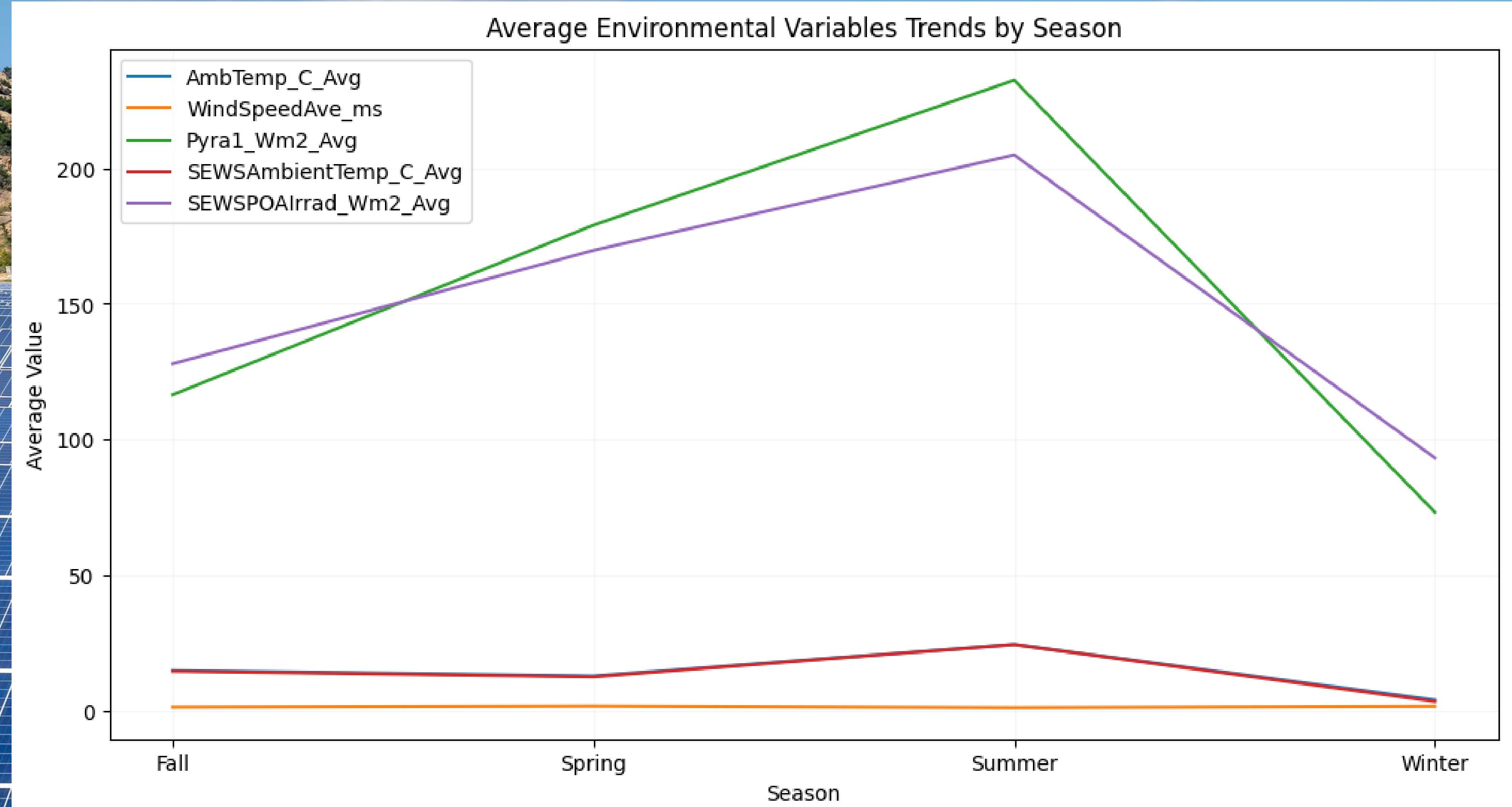
A wide-angle photograph of a massive solar farm. In the foreground, numerous blue solar panels are arranged in long rows. Behind them, a road leads towards a range of mountains. The sky is a clear, vibrant blue with scattered white clouds.

- Correlation Matrix
- Rolling Average Environmental Variables Trends (2017-2018)
- Average Environmental Variables Trends by Month
- Average Environmental Variables Trends by Season
- Hourly Trends
- Monthly Average Adjusted Prediction

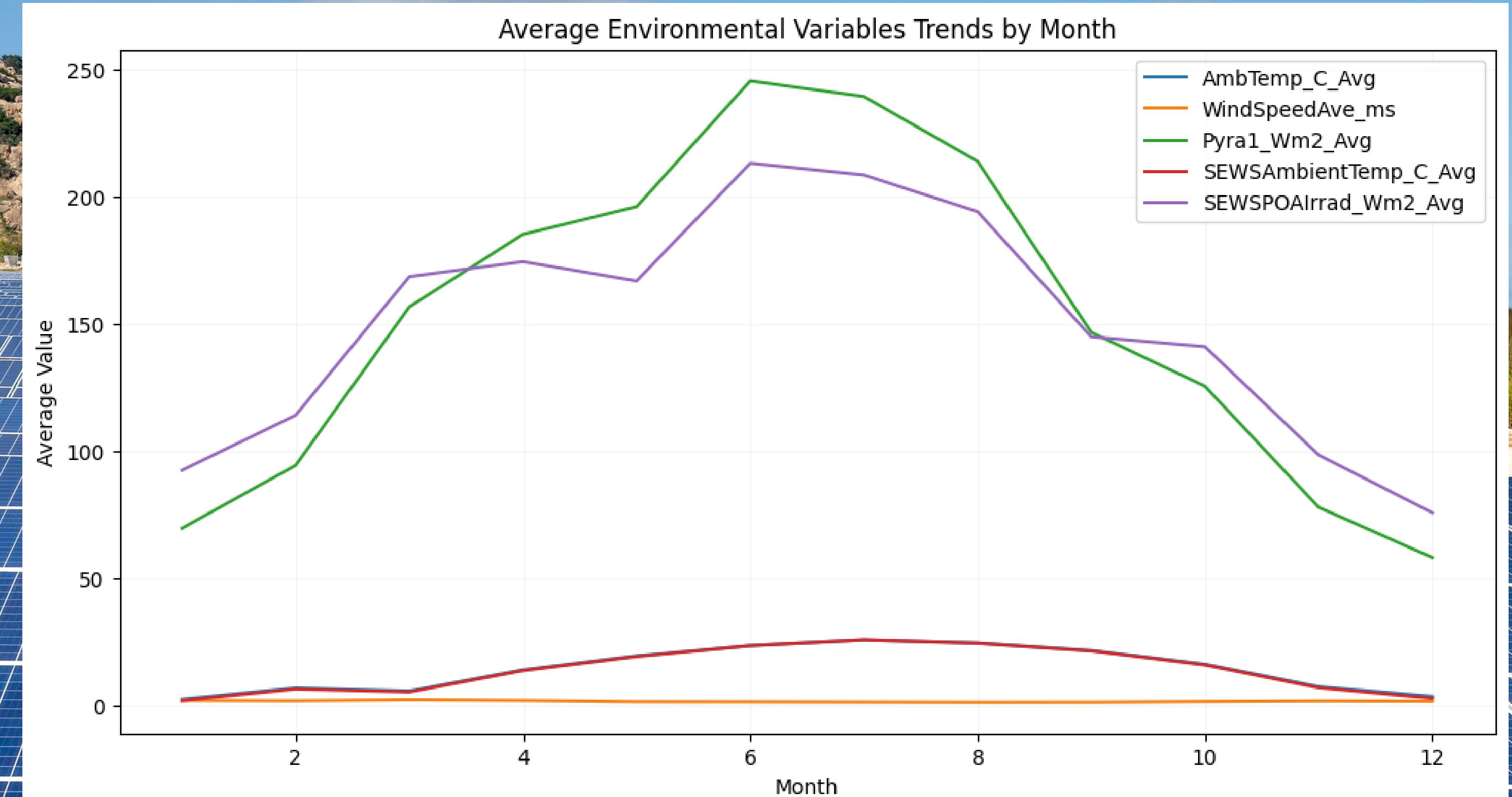
- Strong positive correlations between solar irradiance measurements and ambient temperature suggest that these factors jointly influence power output.
- Wind speed shows less correlation with solar power output, indicating it may not be as significant a factor in predicting solar energy production.



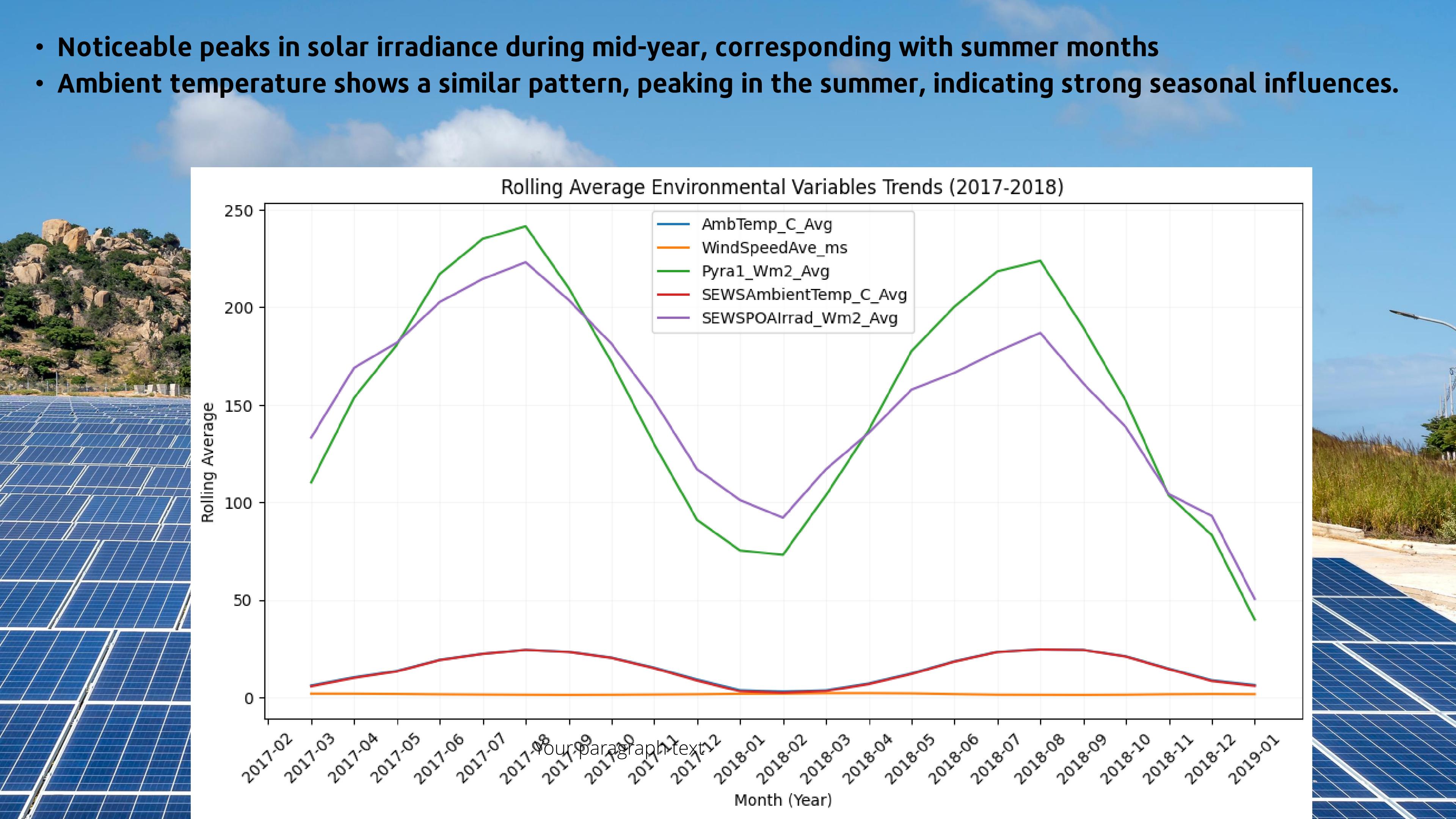
- Both solar irradiance and ambient temperatures are highest in summer, lowest in winter, indicating potential optimization strategies for solar panel efficiency based on seasonal adjustments.



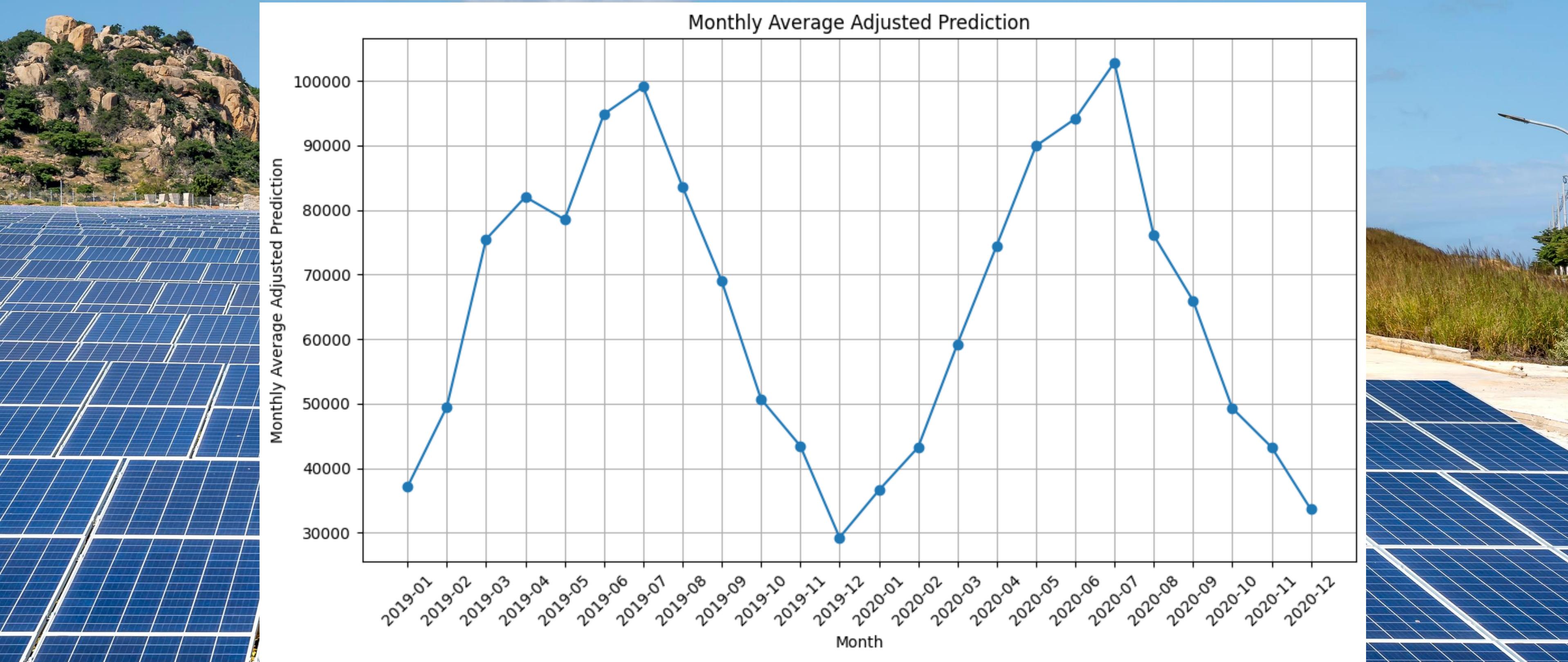
- Solar irradiance starts increasing significantly from April, peaking around July, then decreases towards December.
- Temperature trends follow a similar pattern but begin rising earlier in the year around March.



- Noticeable peaks in solar irradiance during mid-year, corresponding with summer months
- Ambient temperature shows a similar pattern, peaking in the summer, indicating strong seasonal influences.



- Predictions show high variability, peaking during mid-year which is consistent with the highest irradiance and temperature readings.
- Significant drops in predictions during the winter months align with lower solar irradiance and cooler temperatures.



Limitations:

1. Data Quality and Completeness: Handling missing or inconsistent data points within the environmental variables.
2. Seasonal Variability: Difficulties in modeling solar power output accurately due to significant seasonal fluctuations.
3. Model Complexity: Balancing the complexity of machine learning models to avoid overfitting while ensuring they are sufficiently robust to handle diverse data.

Conclusion

- **EDA and Visualizations:** Extensive exploratory data analysis revealed critical insights into how environmental variables influence solar power generation. Visualizations highlighted seasonal and hourly trends, demonstrating the significant impact of solar irradiance and ambient temperature on power output.

Machine Learning Integration

- **Model Performance:** Employed gradient boosted trees proved effective in capturing complex relationships between environmental factors and solar power output. The models were rigorously tuned and validated, showing high accuracy in predicting solar energy generation, particularly in relation to seasonal variations.

Key Insights

- **Environmental Impact:** Confirmed the strong correlation between higher solar irradiance, increased temperatures, and greater power output. These relationships are pivotal for optimizing solar panel placement and operational strategies.
- **Predictive Power:** The models' ability to adjust predictions based on monthly and seasonal data enhances the potential for proactive energy management and infrastructure planning.

Strategic Implications

- **Optimization Strategies:** The findings enable more informed decisions regarding the placement and utilization of solar panels, potentially increasing energy efficiency and reducing operational costs.
- **Policy and Planning:** Insights from the project can assist policymakers and energy companies in developing strategies that capitalize on predictable patterns of solar energy production.

Overall Impact

- **Advancing Renewable Energy Goals:** This project contributes to the broader goal of enhancing the efficiency and reliability of renewable energy sources, particularly solar power, which is crucial for meeting global energy needs sustainably.

Q&A



