RZESZOW UNIVERSITY OF TECHNOLOGY

THE FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING, AND ARCHITECTURE
RZESZOW UNIVERSITY OF TECHNOLOGY

Co-funded by the European Union

Forecasting of PV Energy Production Using Machine Learning Methods

Paweł Kut, Katarzyna Pietrucha-Urbanik

Rzeszow University of Technology

Poland

International Conference „European Green Dimensions", June 5-7, 2025, Mykolaiv, Ukraine

Introduction

- ***Energy production from photovoltaic systems*** - an important area of research in the context of energy transformation and integration of renewable energy sources.
- ***Short-term PV production forecasts*** - crucial for effective management of energy consumption in households and optimization of self-consumption.
- ***Predictive model*** - based on meteorological data and actual measurements of energy production from a photovoltaic installation.
- ***Main goal of the study*** - development of a method enabling forecasting of PV energy production for the next day with high accuracy and using weather data.

RZESZOW UNIVERSITY OF TECHNOLOGY

Goal of the analysis

THE FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING, AND ARCHITECTURE
RZESZOW UNIVERSITY OF TECHNOLOGY

- Forecasting daily PV energy production based on meteorological data and actual energy measurements
- Comparison of the effectiveness of prediction models: linear regression, XGBoost and random forest in the context of forecast accuracy.
- Assessment of the usefulness of forecasts for increasing self-consumption in prosumer systems.

Methodology

Characteristics of the PV installation

- A flat roof installation with a capacity of 38.25 kWp
- consisting of 85 photovoltaic modules with a capacity of 450 Wp each
- 40 kW inverter - conversion of direct current (DC) to alternating current (AC) and real-time monitoring of energy production
- A ballast construction that minimizes the impact on the building's insulation
- An installation without energy storage

Methodology

Meteorological data

- Actual data from a weather station located in the immediate vicinity of the PV installation, collected at 5-minute intervals.
- Weather forecasts for the next day for the city of Rzeszów
- Actual data were used to train the predictive model, while weather forecasts for the Rzeszow location were used to improve the quality of predictions for the next day.

Methodology

Predictive Models

- **Linear Regression**
  The model assumes a simple relationship between weather and PV energy production.
- **Random Forest**
  The model creates multiple independent decision trees and combines their results into an average forecast.
- **XGBoost**
  The model builds successive trees that correct the errors of the previous ones, increasing the accuracy of the forecast.

Model evaluation metrics

- **MAE (Mean Absolute Error)**
  The mean absolute difference between actual and forecasted values.
- **RMSE (Root Mean Square Error)**
  A measure of error that highlights larger differences between actual and forecasted values.
- **MAPE (Mean Absolute Percentage Error)**
  The mean percentage error of the forecast relative to actual values.
- **R^2 (Coefficient of Determination)**
  A measure of model fit, indicating how well the forecasts explain the variability of the actual data.

Results and analysis

Random Forest

- A much better fit - the model explains a significant part of the variability of the data.
- Prediction errors are smaller than in linear regression, but the relative error (MAPE) is on the border of acceptability.
- It can be used as a supporting model, but requires further optimization.

Linear Regression

- The model is characterized by a very poor fit - it practically does not explain the variability of the data.
- High forecast errors make it impossible to use it in practice to predict PV energy production.

XGBoost

- The best fit among the tested models - very high R^2 and the lowest forecast errors.
- A low relative error (MAPE <20%) allows precise planning of PV energy production.
- A model resistant to data variability, suitable for forecasts in real conditions.

Potential applications of energy production forecasts

- Optimization of self-consumption of energy in prosumer households
- Planning of electricity consumption during peak PV production hours
- Reduction of energy costs by better matching production to demand
- Support for home energy management systems (HEMS) without the need for energy storage
- Facilitation of settlements in net-billing systems by more accurate production forecasting.

Conclusion

- The analysis confirmed the feasibility of short-term forecasting of PV energy production based on meteorological data and actual measurements from a real installation.
- Among the tested models, XGBoost demonstrated the highest prediction accuracy and stability in real-world conditions.
- Random Forest showed intermediate performance, while linear regression failed to provide acceptable forecasts.
- Weather forecasts were effectively used to improve the accuracy of next-day predictions.
- The developed forecasting models have the potential to optimize energy self-consumption in prosumer households and support energy management systems without the need for energy storage.

RZESZOW UNIVERSITY OF TECHNOLOGY

THE FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING, AND ARCHITECTURE
RZESZOW UNIVERSITY OF TECHNOLOGY

Thank You for Your Attention

International Conference «European Green Dimensions», June 5-7, 2025, Mykolaiv, Ukraine

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.