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**Pengembangan Model Prediksi Produksi Energi PLTS Atap Gedung SGLC Berbasis Data NASA POWER dan BMKG**
Arkananta Firjatullah Ariza, Ir. Avrin Nur Widiastuti, S.T., M.Eng., IPM. ; Dr. Ir. I Wayan Mustika, S.T., M.Eng.
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# ABSTRAK

Sistem Pembangkit Listrik Tenaga Surya (PLTS) atap Gedung Smart Green Learning Center (SGLC) Fakultas Teknik Universitas Gadjah Mada memiliki kapasitas 62,4 kWp dengan produksi energi harian yang berubah mengikuti radiasi matahari, kondisi atmosfer, operasi sistem, dan kualitas data *monitoring*. Pada 315 hari target valid, produksi memiliki rata-rata 177,89 kWh/hari, standar deviasi 46,09 kWh, dan *Coefficient of Variation* 25,91%. Penelitian ini mengembangkan dan mengevaluasi *Long Short-Term Memory* (LSTM), *Extreme Gradient Boosting* (XGBoost), dan *Persistence Model* untuk memprediksi produksi energi PLTS SGLC sekaligus menilai informasi prediktif yang diberikan oleh data meteorologi BMKG dan NASA POWER.

Jalur NASA POWER mencakup 392 hari kalender pada 16 April 2025–12 Mei 2026, dengan 315 hari target valid dan 309 sekuens harian setelah penerapan *lookback*. Masukan model mencakup energi historis, fitur kalender, *lag*, statistik bergulir, serta parameter meteorologi. NASA POWER menyediakan tambahan parameter radiasi global, langit cerah, langsung, difus, aktif fotosintesis, dan luar atmosfer. Evaluasi dilakukan menggunakan MAPE, sMAPE, WAPE, dan koefisien determinasi ($R^2$) pada skenario *direct daily*, per jam, agregasi per jam menjadi harian, dan kontrol *PLTS-only* tanpa fitur meteorologi eksternal.

Pada jalur utama *direct daily* NASA POWER, XGBoost menghasilkan performa uji terbaik dengan MAPE 12,75%, sMAPE 12,83%, WAPE 12,3341%, dan $R^2 = 0,6159$, sedangkan Persistence menghasilkan WAPE 17,92%. Pada pendekatan BMKG tahap awal, hasil terbaik diperoleh *Rolling* XGBoost dengan MAPE 15,13% dan $R^2 = 0,4101$. Kontrol LSTM *PLTS-only* memperoleh WAPE 12,5380%, tetapi memiliki $R^2 = -0,1992$ sehingga kemampuan menjelaskan variasi hariannya masih terbatas. Agregasi prediksi per jam menghasilkan hasil pendukung terbaik pada LSTM dengan WAPE 9,0636% dan $R^2 = 0,8398$. Evaluasi operasional 1 Mei–28 Juni 2026 menunjukkan seri gabungan LSTM menghasilkan MAE 23,51 kWh/hari, MAPE 15,59%, dan WAPE 15,05%.

Hasil penelitian menunjukkan bahwa XGBoost NASA POWER paling sesuai untuk jalur utama prediksi harian langsung, sedangkan LSTM berpotensi untuk merepresentasikan pola intrahari dan memberikan hasil lebih baik pada evaluasi operasional Mei–Juni. NASA POWER bernilai penting karena menyediakan informasi radiasi langsung dan analisis per jam, bukan karena selalu mengungguli seluruh alternatif. Prediksi yang dihasilkan layak digunakan sebagai informasi pendukung estimasi suplai dan pemantauan performa PLTS, tetapi belum sebagai dasar tunggal kontrol otomatis. Perbandingan *PLTS-only*, BMKG, dan NASA POWER tetap diposisikan sebagai komparasi empiris terarah karena periode uji dan protokolnya belum sepenuhnya identik.

**Kata kunci**: energi fotovoltaik, *forecasting*, NASA POWER, BMKG, XGBoost, LSTM, sistem manajemen energi bangunan

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# ABSTRACT

*The Smart Green Learning Center (SGLC) at the Faculty of Engineering, Universitas Gadjah Mada, operates a 62.4 kWp rooftop photovoltaic (PV) system whose daily energy production varies with solar radiation, atmospheric conditions, system operation, and monitoring-data quality. Across 315 valid target days, the system produced an average of 177.89 kWh/day, with a standard deviation of 46.09 kWh and a coefficient of variation of 25.91%. This study develops and evaluates Long Short-Term Memory (LSTM), Extreme Gradient Boosting (XGBoost), and Persistence models for forecasting SGLC PV energy production and examines the predictive information provided by BMKG and NASA POWER meteorological data.*

*The NASA POWER pipeline covers 392 calendar days from 16 April 2025 to 12 May 2026, including 315 valid target days and 309 daily sequences after applying the lookback window. The models use historical energy, calendar variables, lag and rolling features, and meteorological predictors. NASA POWER additionally provides global, clear-sky, direct, diffuse, photosynthetically active, and top-of-atmosphere radiation parameters. Model performance is evaluated using MAPE, sMAPE, WAPE, and the coefficient of determination ($R^2$). The study evaluates direct daily forecasting, hourly forecasting, daily aggregation of hourly forecasts, and a PLTS-only control without external meteorological features.*

*In the main direct-daily NASA POWER experiment, XGBoost achieved the best holdout performance with a MAPE of 12.75%, an sMAPE of 12.83%, a WAPE of 12.3341%, and an $R^2$ of 0.6159, compared with a Persistence WAPE of 17.92%. The initial BMKG-based experiment produced its best result using Rolling XGBoost, with a MAPE of 15.13% and an $R^2$ of 0.4101. The PLTS-only LSTM control achieved a WAPE of 12.5380%, but its negative $R^2$ of -0.1992 indicated limited ability to explain daily variation. Hourly forecasts aggregated into daily totals yielded a supporting LSTM WAPE of 9.0636% and an $R^2$ of 0.8398. An additional operational evaluation for 1 May–28 June 2026 showed that the combined LSTM forecast series achieved an MAE of 23.51 kWh/day, a MAPE of 15.59%, and a WAPE of 15.05%.*

*The results indicate that XGBoost with NASA POWER is the most suitable model for the main direct-daily forecasting path, while LSTM is promising for intraday representation and performed better in the May–June operational evaluation. NASA POWER is valuable because it provides direct radiation information and enables hourly analysis, rather than because it consistently outperforms every alternative. The forecasts are therefore appropriate as decision-support information for PV supply estimation and performance monitoring, but not as the sole input for automatic building control. Comparisons among PLTS-only, BMKG, and NASA POWER remain directed empirical comparisons because their test periods and protocols are not fully identical.*

**Keywords**: photovoltaic energy, forecasting, NASA POWER, BMKG, XGBoost, LSTM, building energy management system