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Validation of a Methodology for Post-Construction Energy Yield Assessment of an Operational Wind Farm

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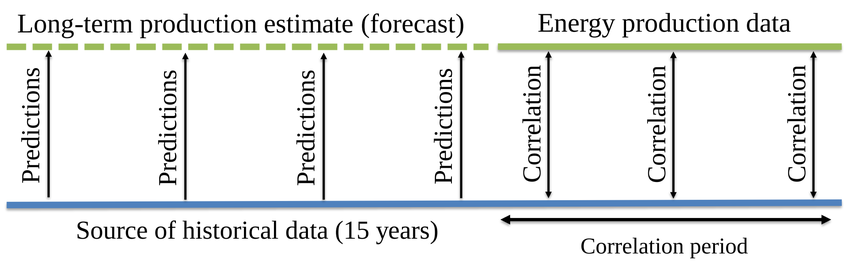
Motivation and Objectives

- Implementing a wind farm presents numerous challenges, from assessing its economic feasibility to securing funding. However, a crucial aspect involves the inherent uncertainty in the prospective Energy Yield Assessment (EYA), stemming from local measurements and limitations of wind models.
- The study aims to validate a straightforward methodology for the Post-Construction Energy Yield Assessment (EYA) of operational wind farms. This methodology leverages statistical methods to scrutinise the primary assumptions considered, ultimately reducing uncertainty and providing more reliable energy yield estimates essential for refinancing or selling wind farm projects.

Methodology

The *Measure-Correlate-Predict* Method

This approach correlates observed energy production data from the wind farms with a Long-Term historical wind database.



Operational wind farm data

The study utilizes monthly production data from 26 wind farms located in Portugal, Spain, Romania, and Canada. These wind farms have operational periods ranging from 4 to 15 years, providing a robust dataset for analysis.

Reanalysis data

MERRA-2 and ERA5 reanalysis series were selected for points close to each wind farm. These datasets provide comprehensive historical wind data necessary for accurate correlation.

Linear correlation

Linear correlations were established between the normalized production data (100% wind farm availability) and Long-Term wind data.

Statistical validation

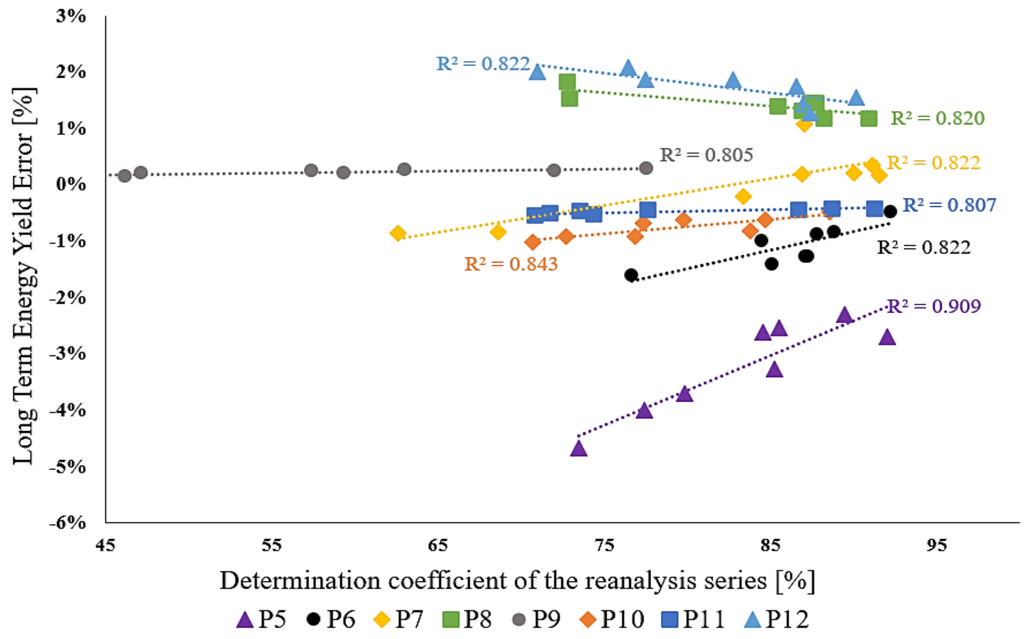
Validation of the methodology involved ensuring adherence to linear regression assumptions for the obtained correlation through statistical analyses, including:

- *ANOVA*: Analysis of variance was used to test the significance of the regression models, ensuring the linear relationship between variables is statistically robust [1] .
- *Shapiro-Wilk Test*: This test evaluated the normality of residuals, confirming that the residuals follow a normal distribution, which is crucial for the validity of regression models [2].
- *Durbin-Watson Test*: This test checked for autocorrelation in residuals, ensuring that the residuals are independent and the model assumptions hold [3].
- *Breusch-Pagan Test*: This test assessed the variability of residuals, verifying homoscedasticity [4].

Results

High correlation

The study found a strong linear relationship ($R^2 > 80\%$) between the determination coefficient of the reanalysis series and the Long-Term energy yield error, indicating the reliability of the selected data sources.



Statistically Robust Model

- ANOVA (A): linear regression model is statistically significant for all wind farms.
- The Shapiro-Wilk test (SW): residuals are normally distributed for all wind farms except P6 and P11.
- The Durbin-Watson test (DW): no autocorrelation (NAR) of residuals for the majority wind farms, except E7 and P2.
- The Breusch-Pagan test (BP): non-constant variances (NCV) in eight wind farms – E4, R1, P4, P5, P6, P8, P9 and P12.
- Although some wind farms violated assumptions of autocorrelation and constant variances, the methodology was generally validated.

Wind Farm	A	SW	DW	BP
E1	SS	ND	NAR	CV
E2	SS	ND	NAR	CV
E3	SS	ND	NAR	CV
E4	SS	ND	NAR	NCV
E5	SS	ND	NAR	CV
E6	SS	ND	NAR	CV
E7	SS	ND	AR	CV
E8	SS	ND	NAR	CV
E9	SS	ND	NAR	CV
E10	SS	ND	NAR	CV
E11	SS	ND	NAR	CV
R1	SS	ND	NAR	NCV
R2	SS	ND	NAR	CV
C1	SS	ND	NAR	CV
P1	SS	ND	NAR	CV
P2	SS	ND	AR	CV
P3	SS	ND	NAR	CV
P4	SS	ND	NAR	NCV
P5	SS	ND	NAR	NCV
P6	SS	NND	NAR	NCV
P7	SS	ND	NAR	CV
P8	SS	ND	NAR	NCV
P9	SS	ND	NAR	NCV
P10	SS	ND	NAR	CV
P11	SS	NND	NAR	CV
P12	SS	ND	NAR	NCV

Conclusions

- The analysis suggests that R^2 is a reliable indicator for selecting the best reanalysis series for energy production estimation.
- Statistical tests confirmed the methodology's validity. Despite a few exceptions, the methodology is overall reliable.

References

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