**Hochschule Flensburg**

University of Applied Science

**Wind Energy Technology Institude**

Research on wind Energy

# Power Prediction and Energy Arbitrage Modelling for Wind Farms Using Machine Learning

**Market Integration and Commercial Optimization, WiSe 2025/26**

Master's degree in Wind Engineering, Flensburg, Germany

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# 1. Abstract

Objective, methodology, and key findings

Highlight ML approach and arbitrage results

# 2. Introduction

Wind energy is one of the fastest-growing renewable industries in Germany. It plays a critical role in reducing carbon emissions and achieving sustainability targets. [1] However, wind power generation is variable because wind speeds fluctuate continuously, making it difficult to predict power output accurately. This variability creates significant challenges for electricity markets, where prices also fluctuate strongly. Wind production is high during low-price periods, selling electricity immediately can reduce profits for wind-farm operators. (Add reference at here) Storing energy for later sale may increase revenue, but deciding when to store or sell is complex.

Machine Learning (ML) is good suited for improve forecasting and operational decisions. [2] ML models can capture nonlinear patterns in wind speed and power output, enabling more accurate predictions compared to traditional statistical methods. Forecasting is essential not only for grid stability but also for implementing energy arbitrage strategies, which allow operators to maximize profits during price fluctuations. [3] However, uncertainty in electricity prices and wind power output makes revenue prediction challenging. Selling at the wrong time or storing energy unnecessarily can lead to financial losses.

This report investigates two critical research questions:

1. Can machine-learning models accurately predict wind-farm power output and identify the optimal hours to STORE or SELL energy?
2. If low-price energy is stored as hydrogen, can the hybrid wind-hydrogen system remain economically profitable?

The primary objectives of this study are to develop and evaluate ML-based models for wind power forecasting and to assess the economic evaluation of hydrogen-based energy storage in arbitrage scenarios.

# 3. Literature Review

## 3.1 Wind Power Prediction

Traditional methods (physical models, statistical)

## 3.2 Energy Arbitrage

Market-based strategies, storage integration

## 3.3 Machine Learning in Wind Energy

Common algorithms (Regression, Neural Networks, Ensemble)

## 3.4 Gap Analysis

What existing studies lack and how your work addresses it

# 4. Data and Preprocessing

Data sources (wind speed, power output, market prices)

Data cleaning and normalization

Feature selection and engineering

# 5. ML Models

- Algorithms used (e.g., Random Forest, LSTM, XGBoost)
- Why chosen (advantages for time-series prediction)
- Evaluation metrics (RMSE, MAE, $R^2$)

# 6. Hydrogen Storage concept

- Role of hydrogen in energy storage
- Integration with wind energy and arbitrage
- Benefits and limitations

# 7. Results

# 8. Discussion

- Interpretation of results.
- Limitations of the study.
- Practical implications for wind farm operators.

# 9. Conclusion

- Summary of findings.
- Future work (e.g., real-time prediction, hybrid models).

# 10. References

- All cited papers, datasets, and tools.

# 11. Appendices

- Additional graphs, tables, or code snippets.

## GitHub Link

On our GitHub homepage, we have attached our report, presentation, land leasing contract, and economic calculation Excel file. If you want to gain more knowledge about the topic, please check out our GitHub.