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Wind Energy Technology Institute

# Power Prediction and Energy Arbitrage Modeling for Wind Farms Using ML

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# Overview



1 Introduction

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3 Data & Preprocessing

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6 Hydrogen Storage Concept

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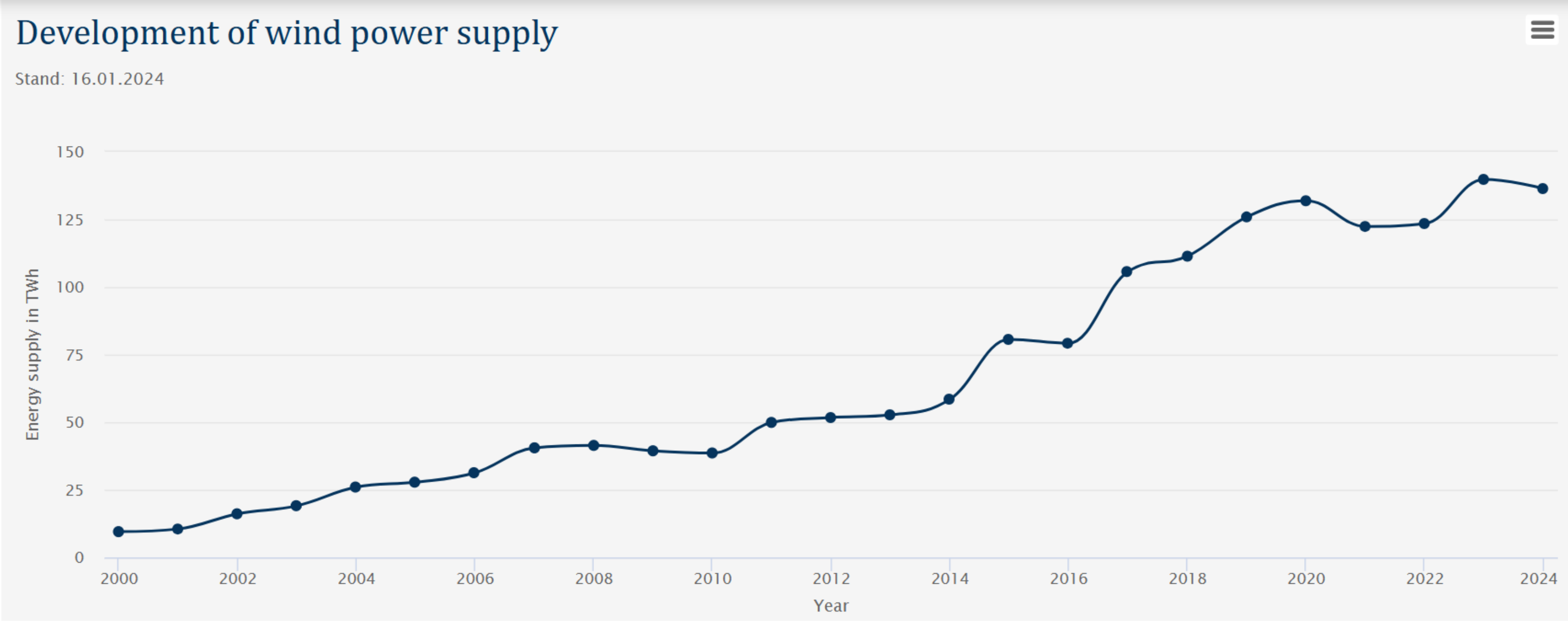
# 1. Introduction

- **Wind Energy:** One of the fastest-growing (Germany)
- Wind power (variable) → wind speeds (change)
- Electricity markets (fluctuate) → Wind production (high)
- Modern energy systems increasingly use **data** and **machine learning:**
  - improve forecasting
  - operational decisions




Reference: Statistics Germany | BWE e.V.

# 2. Problem Statements

- Wind power output changes every hour → difficult to predict
- Electricity prices fluctuate strongly → revenue is uncertain

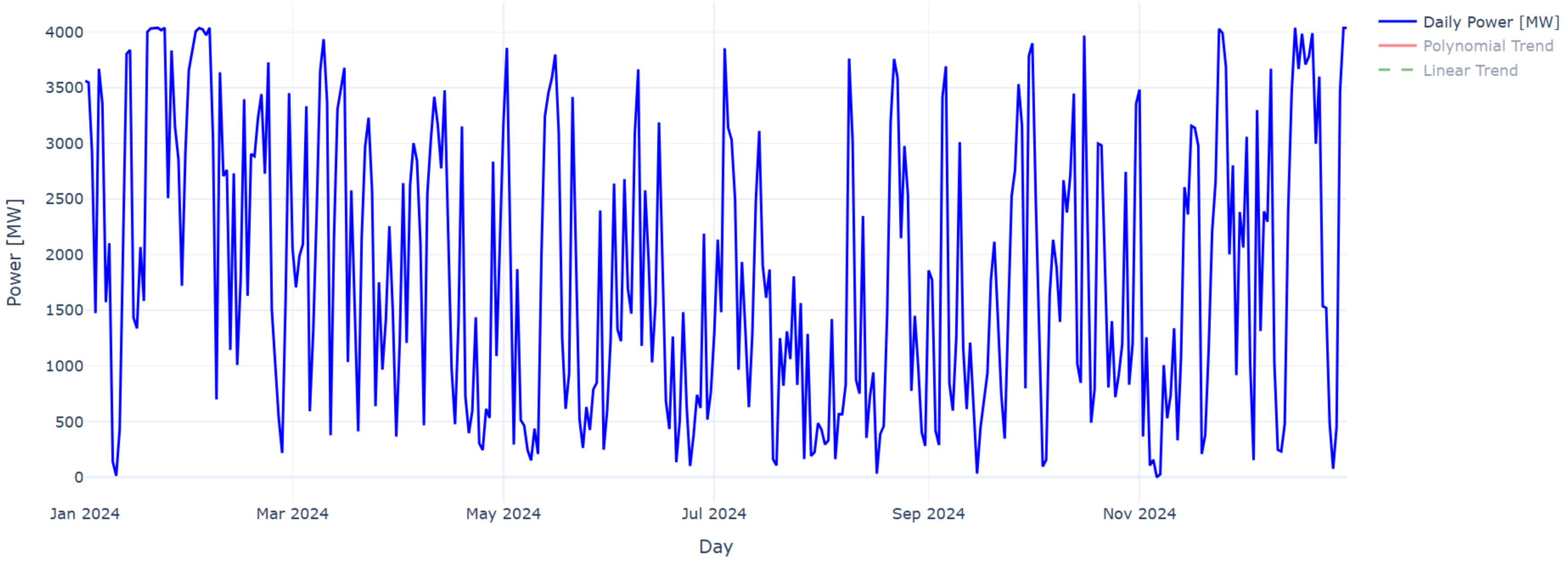



Fig 2.1: Day Vs Power generation (MW) (Own).

- Selling at the wrong time reduces profit for wind-farm operators
- Hard to know when storing energy will be more profitable than selling
- A **data-driven ML model** is needed to support STORE vs SELL decisions

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# 3. Data and Preprocessing

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## 1. Wind Data (ERA5):

- **Reference:**
- Used ERA5 reanalysis dataset for wind components (**u100**, **v100**)
- Calculated wind speed at **100m**
- Converted to a clean CSV file **(wind_speed.csv)**

## 2. Electricity Price Data:

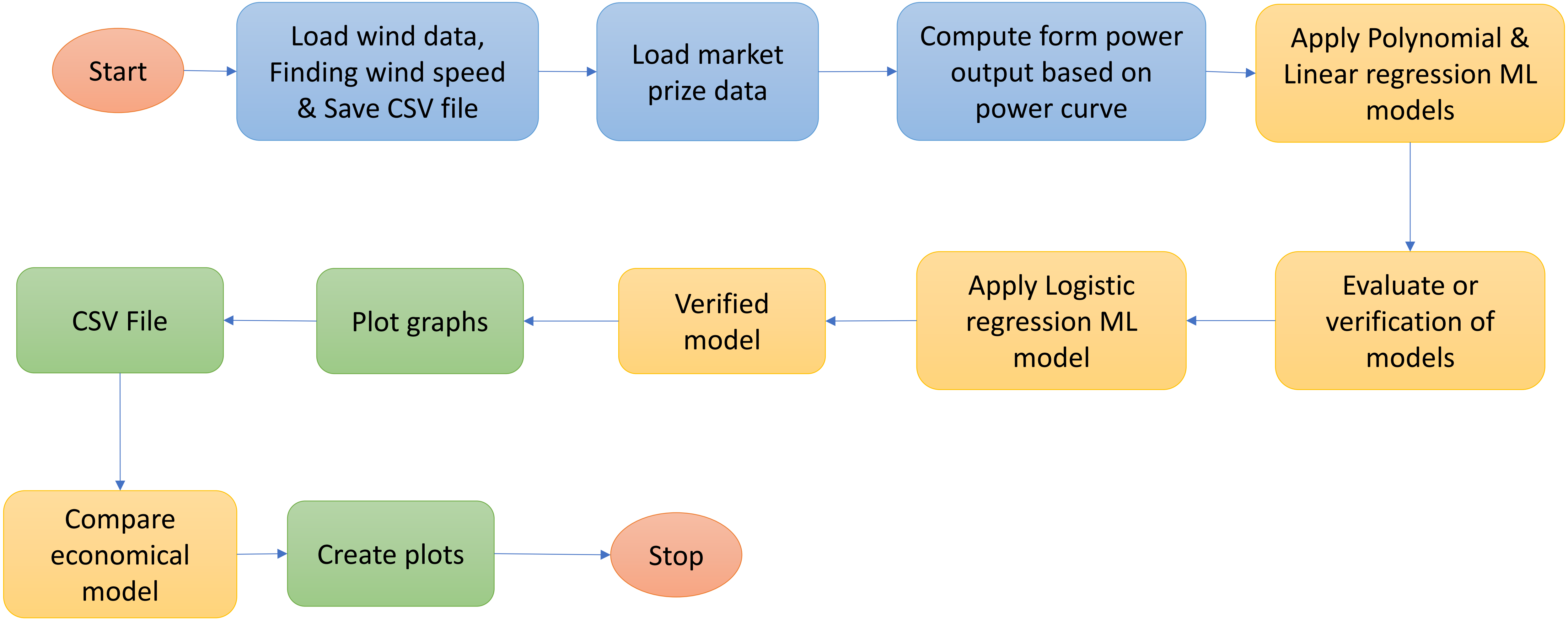
- **Reference:**
- Imported **sport market prices** (EUR/MW)
- Cleaned timestamps and extracted **hour** and **month**

## 3. Power Curve Processing:

- Location: **Reusenkoog, Germany**
- Scaled for **51 turbines** (total farm capacity) **(1)**
- Used **Vestas V112-3.3 MW** turbine power curve **(2)**
- Converted wind speed → power output

# 4. Flowchart




Start
Load wind data, Finding wind speed & Save CSV file
Load market prize data
Compute form power output based on power curve
Apply Polynomial & Linear regression ML models
Evaluate or verification of models
Apply Logistic regression ML model
Verified model
Plot graphs
CSV File
Compare economical model
Create plots
Stop

# 5. Machine Learning Models

## Why ML?

1 Fast growing and widely used field

2 ML helps automate STORE vs SELL decisions

3 Gives a more mathematical and accurate solution

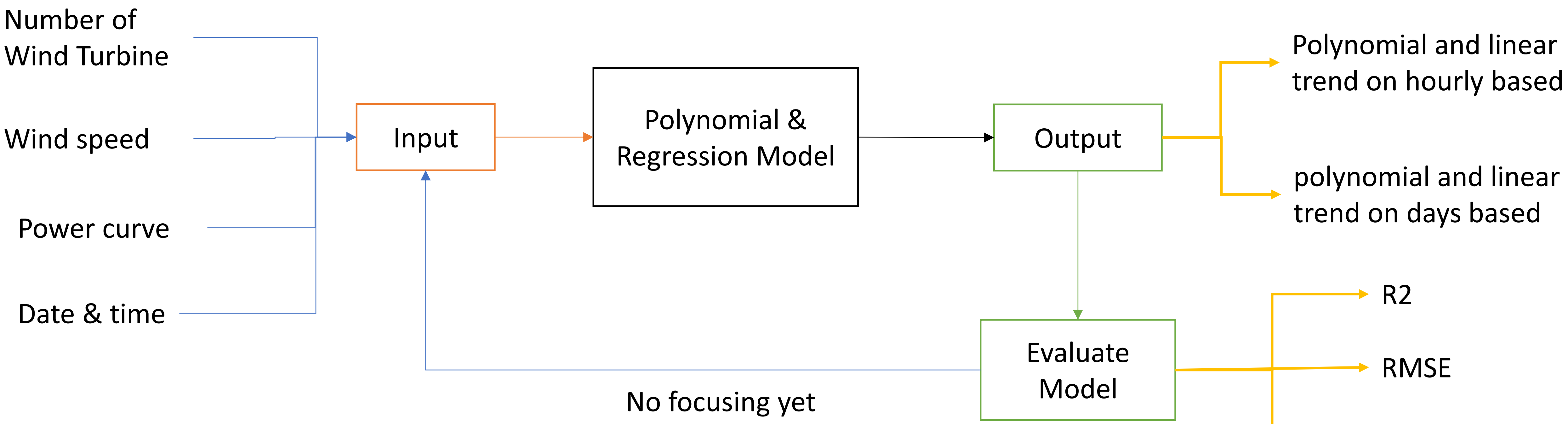
4 Patterns are **non-linear** and difficult to capture manually

5 ML learns from historical data and improves decision accuracy


Reference: https://www.vecteezy.com/free-photos/machine-learning

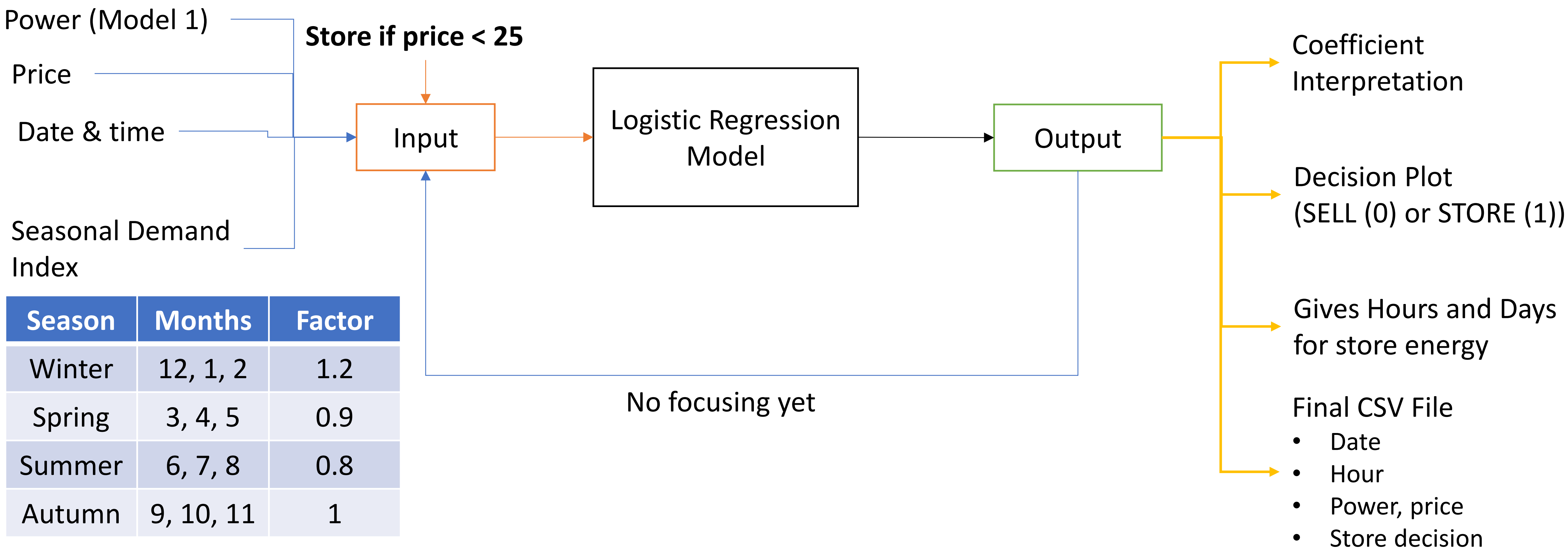
# 5. Machine Learning Models

## Block Diagram of Wind Farm Model:



# 5. Machine Learning Models

## Decision Arbitrage Model:




| Season | Months | Factor |
|---|---|---|
| Winter | 12, 1, 2 | 1.2 |
| Spring | 3, 4, 5 | 0.9 |
| Summer | 6, 7, 8 | 0.8 |
| Autumn | 9, 10, 11 | 1 |

# 6. Hydrogen Storage Concept

# 7. Economic analysis

# 8. Results

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# 9. Conclusion

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# 10. Future Tasks



- Add more feature of wind (air density, wind direction, turbulence)
- Improve power curve for better outputs
- Try higher order polynomial regression
- Use some other ML models
- Improve data cleaning
- Possible to use more years of data
- Add more economic features (forecasted prices, market demand, so on)
- Optimize the decision threshold
- Use real seasonal power demands data

Reference: Wind Farm Layout Design at NAYXA || We´re Wind Energy Experts

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# References

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1. https://www.nsenergybusiness.com/projects/reusenkoge-wind-farm-expansion/?cf-view
2. https://en.wind-turbine-models.com/turbines/693-vestas-v112-3.3