universität freiburg

INATECH

Python for Energy System and Sustainability Analysis

Capstone Project Assignment I – Explaining Price Formation in the aFRR Market

Summer Semester 2025

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Topics: Market Analysis, Regression, Model Interpretation

Instructions

- You will work in teams of **two students** to complete the analysis you started in class.
- Submit the following via ILIAS by **July 14, 2025**:
  - A **Python script or Jupyter Notebook** with all relevant code, explanations, and visualizations.
  - A **written report (maximum 2 pages, PDF)** summarizing your approach, findings, and reflections.
- The data can be accessed at: `https://nick-harder.github.io/AIES/lecture9/data/`
- You may reuse and adapt code from the lectures.

Background

The automatic Frequency Restoration Reserve (aFRR) market ensures frequency stability in the power grid. TSOs procure aFRR services through competitive auctions. Prices in this market are shaped by technical requirements, economic behavior, and real-time system conditions — including variable generation, load dynamics, and reserve activation.

As European balancing markets become more integrated, understanding how aFRR prices are formed is essential for market participants and policymakers.

Objective

The aim of this assignment is to analyze and explain the formation of market prices for both **positive and negative capacity procurement** in the aFRR balancing market. Your analysis should focus solely on the **capacity prices – not on energy activation or dispatch data**.

Using the datasets provided, you are expected to explore which factors influence aFRR capacity prices and to what extent. While you are encouraged to engineer new features from the raw data (e.g., aggregations, trends, lagged values), you must limit your approach to the set of techniques and models introduced in the course.

Note: This is not a forecasting competition. We are not evaluating your work based on predictive accuracy or full model explainability. Instead, the main goal is to demonstrate your understanding of a typical data-driven analysis pipeline:

- What steps are required from raw data to insights?
- How does each method work and when is it appropriate?
- What can we conclude from our modeling results?

You are expected to reason critically about your model choices, reflect on limitations, and interpret your results within the context of the energy market.

Assignment Tasks

Each team must complete the following steps:

1. **Problem Framing:**
    - Clearly define the research question: What explains variations in aFRR positive and negative capacity prices?
    - State your assumptions and rationale for the analysis.
2. **Data Preparation:**
    - Use the provided datasets as the basis of your analysis.
    - Perform appropriate cleaning and preprocessing.
    - Engineer additional features if relevant (e.g., time lags, aggregations).
3. **Modeling and Analysis:**
    - Apply regression or tree-based models as discussed in class (e.g., linear regression, decision trees, random forests).
    - Justify your model choices and describe your evaluation metrics.
    - Investigate both positive and negative capacity prices as separate or comparative targets.
4. **Interpretation:**
    - Identify which variables have the greatest influence on the target prices.
    - Explain in your words and using your domain knowledge why these identified variables have such impact on the price formation, and what conclusions can we draw from these insights.
    - Use visualizations and model outputs to support your interpretation.
    - Reflect on model limitations and the relevance of your findings.
5. **Submission:**
    - **Code:** A Python script or Jupyter Notebook including all code, documentation, and output plots.
    - **Report:** A 2-page PDF summarizing your:
        - Methodology
        - Key findings
        - Reflections on model use and project workflow

Data Provided

- aFRR market prices (positive and negative capacity)
- Day-Ahead electricity prices
- Time-series data for:
    - PV, Wind, Biomass, and other renewables
    - Conventional generation
    - Storage charge/discharge