Guidelines for EMS Algorithm Competition (TechArena 2025_Phase_I)

1. Overview of the Competition

This competition challenges participants to develop an Energy Management System (EMS) algorithm for optimizing the operation of a utility-scale Battery Energy Storage System (BESS) connected to the electric grid and trading on multiple electricity markets. The EMS algorithm will need to optimize the battery's charge and discharge strategy based on wholesale electricity market prices and participation in ancillary service markets, such as Frequency Containment Reserve (FCR) and automatic Frequency Restoration Reserve (aFRR).

2. Objective

The competition consists of three main optimization challenges:

1. **Operation Optimization**: Maximize revenue by determining the optimal charge/discharge strategy for a BESS based on market prices and participation in ancillary services.
2. **Investment Optimization**: Identify the best European countries to achieve the highest return on investment (ROI) over a 10-year period by installing a utility-scale BESS, with a detailed results analysis considering the country's weighted average cost of capital and inflation rate.
3. **Configuration Optimization**: Getting the optimal battery configuration and identify as well as analyze the effect of the battery parameter configuration, including the C-rate and the daily number of cycles.

3. Problem statement and requirements

3.1 Operation Optimization

- Problem Statement. Participants will develop an EMS algorithm that optimizes the operation of a utility-scale BESS with a 15-minute resolution. The BESS optimal operation should consider the arbitrage on day-ahead electricity market and capacity bids on FCR and aFRR capacity markets. The goal is to maximize revenue by determining the optimal charge and discharge strategy considering market conditions and operational constraints.

  Participants will use one year of data (e.g., 2024) for running their optimal operation problem.

- Algorithm and model inputs. Input data includes electricity market prices, summarized in **Table 1**, as well as battery data, reported in battery datasheet/catalogue.

Table 1. Overview of available market data, with time resolution during TechArena.

Market data	Resolution & availability
Day-ahead electricity market price	15-minute resolution, available on the day ahead (day *d*-1) of time of delivery
FCR accepted capacity bids	4-hour resolution, available on day *d*-1
aFRR accepted capacity bids	4-hour resolution, available on day *d*-1

- Constraints. These include BESS and market technical operational constraints. Physical battery operation parameters should be considered, such as battery capacity, maximum charge/discharge power and daily number of cycles.
- Objective. The objective of the optimization is to maximize the revenue from participating in all selected markets simultaneously.
- Evaluation Criteria (50%). Participants will be evaluated based on:
    - **Revenue maximization**. Here the evaluation will consider how well the algorithm maximizes revenue based on market prices. A linear scaling formula will be used to map all submission values between the minimum and maximum observed

3.2 Investment Optimization

- Problem Statement. Participants are tasked with identifying the best European country to install a BESS based on the current market situation. The goal is to select the country that provides the highest potential return on investment (ROI) over a 10-year project horizon, assuming the BESS was installed in 2023 considering investment cost of 200 EUR/kWh. Selected countries include Germany (DE), Austria (AT), Switzerland (CH), Hungary (HU), and Czech Republic (CZ).

  Future developments of electricity markets, as well as electricity market prices, are beyond the scope of the challenge, and the analysis will be purely based on differences in current electricity prices and market regulations.
- Algorithm, model inputs, and constraints. Input data includes (1) the current electricity market mechanisms and related prices for all selected countries, (2) the weighted-average cost of capital and the country-dependent inflation rate, and (3) the operational data and constraints specified in Section 3.1.
- Objective. The objective of the analysis is the maximum ROI, achieved by selecting the optimal country for installing the BESS. This can be done for all configurations considered in 3.3 to obtain a multi-dimensional assessment of optimal operation and configuration across multiple countries.

3. Evaluation Criteria (20%). Participants will be evaluated based on the obtained ROI after 10 years of operation. This will evaluate the assessment of optimal investment locations and markets. The evaluation will consider the following criteria and weights.

Getting result for all 5 countries	0-5%
Correct calculation methodology for ROI considering the optimal operation and battery configuration.	0-5%
Results analysis of major differences across countries	0-10%

3.3 Configuration Optimization

Problem Statement. Getting the optimal battery configuration and identify as well as analyze the effect of the battery parameter configuration, including C-rate and daily number of cycles. For simplicity consider the number of full cycle equivalent (FCE) is calculated as follows

$$\mathrm{FCE}(t) = \frac{1}{E_{\mathrm{nominal}}} \sum_{i=1}^{t} E_{\mathrm{dis},i}$$

where:

- $E_{\mathrm{dis},i}$ = discharged energy during interval i.
- E_{nominal} = nominal capacity of the battery

- Algorithm, model inputs, and constraints. Input data and technical constraints include:
  - Configuration data and constraints, namely the C-rate and the daily number of cycles.
  - Operational Data and constraints specified in Section in 3.1.
- Objective. The objective of the assessment is to identify the optimal configuration that maximizes the performance and longevity of the BESS.
- Evaluation Criteria (20%).

  The evaluation will focus on the assessment of the most relevant configuration parameters on BESS revenue. The following criteria and weights are considered.

Getting the results for all C-rate	0-5%
Getting the results for all number of cycles per day	0-5%
Result analysis: Comparison of configurations, identification of the most profitable, and justification.	0-10%

5. Data and Inputs

All teams will be provided with historical market prices for 2024 (see **Table 1**) for all selected countries, as well as BESS specifications for all selected configurations, to be used for simulation and optimization purposes.

Participants are expected to model the battery operation in compliance with the 2024 regulation in the countries of interest.

6. Submission Requirements

Participants must submit the following items.

1. Code and Documentation. More specifically:
    - A Python code implementing and running the EMS algorithm. The code must take as inputs the data provided and must return: (1) the optimal operation strategy in 15-minute resolution in an .xlsx file, and (2) the values of the objective function for all the analyses of interest (e.g., countries, configurations, …)
    - Clear documentation explaining the methodology and optimization approach.
2. Simulation Results. More specifically, the following must be provided:
    - The **total revenue** achieved over the simulation period (2024) for all considered countries and configurations.
    - The **ROI over a 10-year period** for all selected countries and configurations with installation in 2023 considering investment cost of 200 EUR/kWh.
    - A .csv or .xlsx file with **charge/discharge decisions and SOC values** of the battery over the simulation period (2024).

7. Evaluation Criteria

Submissions will be evaluated based on the following criteria

1. **Revenue maximization (50%).** This will evaluate how well the algorithm maximizes revenue based on market prices. A linear scaling formula will be used to map all submission values between the minimum and maximum observed
2. **Investment optimization (20%).** This will evaluate the assessment of optimal investment locations and markets. The evaluation will consider
3. **Configuration optimization (20%).** This will evaluate the assessment of the most relevant configuration parameters on BESS revenue.
4. **Code Quality and Documentation (10%).** This will evaluate the clarity and structure of the code.

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