46040 - Introduction to energy analytics F25

Assignment 1: Bidding strategy of a battery system and prosumer analytics
Deadline: Tuesday, March 11, 2025 at 23.59 hrs.

The goal of Assignment 1 is to become more familiar with the analysis of electricity spot prices and with employing optimization models. You will use two datasets: ProsumerHourly and ElspotpricesEA csv files.

We will use exclusively local time in all tasks.

Logistics for the submission of your report:

1. Maximum length of the report: **6 pages, excluding the frontpage**
2. Upload one report per group as a .pdf in Assignment 1 at DTU Learn.
3. Please **mention how you shared the workload**, either on the frontpage or at the end. If an allocation is missing, it will be assumed that work was shared equally.
4. You must provide **running-code**, i.e., the user should be able to press run in your **Main.py** file and obtain answers to all the following questions.
5. Upload all your code files in a single zip file.
6. You need to upload your report and code on DTU Learn the latest by **Tuesday, March 11, 2025, at 23:59 hrs**.

Expectations and assessment:

- Please use short and clear comments in the code to indicate what each part of the code does. We should be able to follow your thought process and understand what you are doing.
- Do not use any absolute paths. One should be able to run **Main.py** and obtain all answers without any code adjustments.
- Do not use printscreens but actual figures/tables.
- Your figures must be clear and easy to read/interpret.
- Provide short but clear answers to the questions, justified by your data analysis.
- You can find the DTU rules regarding assignments and use of generative AI tools **here**.
- The first task accounts for 20%, the second 30% and the third 40% of the grade. Overall quality and presentation of your work accounts for 10%.

Tasks description

Task 1: Statistical analysis of historical prices for DK2

1.1 Use the spot price data from years 2019, 2020, 2021, 2022 and 2023. You can find the data in the ElspotpricesEA csv file. Find the average price for each year in area DK2. Present your results in a single figure or table, expressing prices in DKK/MWh, and discuss your findings (evolution of prices over the years).

1.2 Calculate and plot the average spot price per hour of day for each of the 5 considered years (24x5 values) in DK2; discuss the results. Based on these results, which year seems more attractive financially for using a battery for arbitrage? Why?

Task 2: Battery arbitrage problem

You are using a battery only to profit from spot price variations with the following considerations:

- You are located in DK2.
- The battery's state of charge can vary between 10% and 100%.
- The battery energy storage system has a power capacity of 5 kW and an energy capacity of 10 kWh.
- Your charging and discharging efficiency is equal to 95%, i.e., $\eta_c = \eta_d = 0.95$.
- Each day you optimize the schedule of the battery at 00:00 for the next 24 hours, assuming you have perfect knowledge of the prices.
- The battery state of charge at the start and end of your daily optimization will be set to 50% of the energy capacity.
- You buy and sell energy at the spot price.

2.1 Optimize the operation of your battery for each day of the five years (2019, 2020, 2021, 2022 and 2023). Present your results on an aggregated yearly basis. Which year is more profitable? Can you provide a possible explanation? What do you expect to happen to profits if you optimize for each year in one problem, instead of optimizing each day separately?

2.2 Do you see any correlation between **the profits of each day** and any spot price metric of the corresponding day? Remember you have 1826 data points to consider in this task. Which metric (min price of the day, max price, etc.) do you think is the best predictor of the daily profit? Discuss the result and what conclusion you can make.

2.3 Do you think it's a good idea to set the battery state of charge at 50% at the start and end of each day? Can you think of a better strategy judging from the price results of 1.2? You can test your hypothesis and explain which strategy you would use and why. The strategy should be very simple:

  - The starting and ending state of charge has the same value (respecting the battery's energy limits...)
  - You keep the same value for all days and all 5 years you investigate.

Task 3: Prosumer analytics

We now consider a prosumer, again located in DK2. Hourly PV generation and consumption values are given by the ProsumerHourly csv file. Consider only years 2022 and 2023. The prosumer buys energy at the *Buy* price and sells at the *Sell* price at each hour; you have calculated these prices in a previous hands-on (refer to the previous hands-on exercises). The prosumer is subject to hourly net metering, i.e., at each hour the prosumer pays for the energy import or receives money for the energy export.

3.1 For this question consider only consumption and neglect PV generation. Calculate the total costs of the user for each of the two years (the customer buys energy at the *Buy* price).

Next, do a rough calculation for comparison. Calculate costs by multiplying the total consumption of each year with the corresponding average *Buy* price. Is there a substantial difference? What is your conclusion?

3.2 Calculate the yearly benefit of the PV system. You can do that by comparing the total costs without PV generation (which you calculated in 3.1) with the costs of the prosumer under **net metering** when owning the PV. Calculate the benefit on a yearly basis and discuss the results.

Do you think the PV is a good investment over a 20-year period? You will need some assumptions to answer the question. You can look up online for the approximate cost of a 5 kW PV system.

3.3 Now assume that the prosumer buys the battery described in Task 2. Optimize the operation of the battery for every day of 2022 and 2023, with the goal of minimizing prosumer costs under net metering. Use the same setup as in Task 2: every day at 00:00, you optimize for the following day with a 50% starting and ending state of charge. What is the benefit that the **battery** brings to the prosumer on a yearly basis? The comparison should be made between the case where the prosumer owns only the PV and the case where both the PV and a battery are present.

3.4 Based on the two years of data and your analysis, which investment option do you think is more attractive financially?

(a) Installing only a PV system

(b) Installing a combined PV/Battery system

(c) Installing only a battery

You can find an indicative cost online for each of these options online. Justify your answer based on the cost assumptions you make. Tip: You can calculate the only-battery benefit as in task 3.3 with the same code, by simply using zero as the PV production input.