Energy Markets, AAE-E3006

December 2023

Exam question

The intermittent nature of renewable energy sources brings about an imbalance in energy generation and consumption. Energy storage technologies have been utilised to mitigate the imbalance and provide system flexibility. One of the applications of energy storages is to provide primary response to the power systems, meaning correcting continuous and sudden frequency and voltage changes across the network by charging or discharging the storage.

The objective is to calculate **LCOS** of a Lithium-ion (Li-ion) storage, which is suitable for primary response application. LCOS in €/MWh for an electricity storage can be formulated as follows:

$$LCOS = \frac{Discounted\ sum\ of\ all\ costs\ (€)}{discounted\ sum\ of\ discharged\ electricity\ (MWh)}$$

Table 1 summarises the assumptions and technical characteristics of the studied Li-ion storage.

Table1. Assumptions and technical characteristics of the storage

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Characteristics	Value	Unit

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Capital investment		€/kW
Fixed operation cost		€/kW, year
Variable operation cost		€/MWh, year
Capacity of storage		kW
Nameplate discharged electricity		MWh/year
Degradation rate		
Round trip efficiency		
Buying price of electricity		€/MWh
Discount rate		
Lifetime		Years

Following simplifying assumption are made:

1. Investment cost (capital investment) of the storage is made as a **one-time deal** on **year zero**
2. The storage is **operational from year 1** (all costs except capital investment cost should be considered from year 1)
3. Operation costs of the storage (both fixed and variable) are paid when the storage is in operation (**from year 1**) **on an annual basis**
4. Yearly variable operation cost is calculated based on the **input electricity**
5. Round-trip efficiency of the energy storage device is the ratio of the nameplate discharged electricity to the energy used to charge the storage (input)
6. Buying price of electricity is **constant for each year** over the lifetime of the storage
7. Input electricity of the storage **is not** subject to degradation. **A constant input** is assumed for each year
8. Discharged electricity of the storage is subjected to degradation from **the first operational year (year 1).**

Hint 1: You should derive a new formula for degraded discharged electricity based on this assumption (like the formula explained in the exercise session, but with the difference that this time degradation is considered from year 1).

Hint 2: To derive the formula, assume the nominal discharged electricity of year zero equal to the nameplate discharged electricity given in the table and calculate the degraded discharged electricity for the subsequent years. (Assuming the nameplate discharged electricity for year zero does not mean any production in that year, i.e., the storage is operational from year 1).

9. Do not consider and calculate any revenue (just consider all the costs while calculating LCOS)

Calculate the following parameters (Total 6 points)

Note that in all parts, just write the final answer without any decimals (You can do this manually or using TRUNC function of excel. Also do not round up/down the answer. For example, if the final answer is 199.70, write in the box 199.

Note that, only cut the decimals when you want to write the final answer in the box for each part. DO NOT use truncated results from one part in the calculation of other parts.

Pay attention to the units.

1. Yearly investment cost when it is amortized over the lifetime of the storage in **euro (€)** (1 points)

2. Yearly operation cost in **euro (€)** (1 points)

3. Yearly cash flow with the amortized investment cost in **euro (€)** (1 points)

Hint: Just consider all costs (including amortized investment cost) in a year with positive signs when calculating cash flow (Do not calculate revenue)

4. Sum of discounted costs over the lifetime of the storage in **euro (€)** (1 point)

5. Sum of discounted discharged electricity considering degradation over the lifetime of the storage **in MWh** (1 point)

6. Levelized cost of storage (LCOS) in **€/MWh**? (1 point)

Answer the following power market related questions:

a) Why might a wind power plant with an LCOE of 40 €/MWh be profitable in a market where a solar power plant with an LCOE of 30 €/MWh is not? **(1p)**

b) On a wintery day in 2024, there's an outage in a Nordic nuclear power plant. However, wind generation in that bidding zone is two gigawatts above seasonal average on that day. Is the net impact bullish or bearish for power price in that bidding zone, and why? **(1p)**

c) What is water value? Describe the expected impact of the following on the water values of a bidding zone: a) An autumn with higher rainfall than the seasonal average, b) An outage in a nuclear power plant in the same bidding zone. **(1p)**

d) Let's assume that the transmission capacities between all Nordic bidding zones would be infinite. How would power prices differ in Nordic bidding zones? Also, let's assume that in addition, there's an infinitely large electricity storage located in Finland. How would power price profiles look like in Nordic bidding zones? **(1p)**

e) Using yesterday's (11 Dec) closing prices, what is the spread between Finnish and German power futures for year 2024? **(1p)**

You are a famous energy market expert. Finnish district heating (DH) companies have invited you to give advice for their long-term strategies (up to 30 years ahead). You don't have to worry about cartel issues when discussing with them.

a) Would you recommend investing in new CHP DH plants to replace the retiring ones? Why? Justify your answer with two issues. **(1p)**

b) Give a counterargument to your recommendation in (a) and explain the problem. **(1p)**

c) How would you advise the Finnish DH companies to prepare for the expected electricity market related changes? Concentrate on two most essential issues for the DH companies and justify them. **(1p)**

d) What kind of DH companies in Finland have probably had the least problems during the past two years of European energy crisis? Justify your answer with two issues. **(1p)**

Your home participates in a large electricity demand management program. You have hourly spot pricing on your electricity consumption and an aggregator is managing the electricity consumption of 100 000 homes in Finland (including yours). Who benefits when this consumption is moved away from peak demand times? Remember to mention all parties who benefit. **6 correct answers give you full points. Each wrong point gives -0,5 point (3p)**

Evaluate the positive and negative aspects of Finland now relying more on LNG than on long-term pipeline contract? Mention 4 essential aspects. **(2 p)**

You are CEO of a start-up company that wants to build a nuclear power plant somewhere in the EU. List 8 market and policy issues that you need to consider when making the choice of location country. **(2p)**

Finland witnessed unprecedented power price volatility during week 47 this year. Explain what happened and what caused the weird events. **(2p)**