## Question 1

The increasing share of variable renewable energy sources in the electricity system leads to an increasing interest in different electricity storage options. The Levelised Cost of Storage (LCOS), similar to the widely used Levelised Cost of Electricity (LCOE), allows for simple verification of the economic viability of certain storage technologies in a given electricity market.

The objective is to calculate **LCOS** of a sodium-sulfur (NaS) battery, which is suitable for stationary energy storage applications. The application of the studied storage is in energy arbitrage, meaning purchasing power in low-price and selling it in high-price periods on wholesale or retail market. 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 storage.

Table1. Assumptions and technical characteristics of the storage (battery)

| Characteristics | Value | Unit |
|---|---|---|
| Capital investment | 630 | €/kW |
| Operation cost | 10 | €/kW, year |
| Capacity of storage | 30 | kW |
| Nameplate discharged electricity (per year) | 11 | MWh/year |
| Degradation rate | 0,9% | |
| Round trip efficiency | 82% | |
| Buying price of electricity | 50 | €/MWh |
| Discount rate | 6% | |
| Lifetime | 14 | Years |

The following simplifying assumption are made:

- Investment cost (capital investment) of the storage is made as a **one-time deal** on **year zero.**

- The storage is **operational from year 1** (all costs except capital investment cost should be considered from year 1).
- Operation cost of the storage is paid when the storage is in operation (**from year 1**) **on an annual basis.**
- The energy output (discharged electricity) of the storage system is the energy input reduced by the **round-trip efficiency.** In other words, round-trip efficiency of the energy storage device is the ratio of the discharged electricity to the energy used to charge the device (input).
- Buying price of electricity (50 €/MWh) is **constant for each year** over the lifetime of the storage.
- Input electricity of the storage is **not subject** to degradation. **A constant** input is assumed for each year.
- Discharged electricity (output) of the storage in **year 1** is assumed to be the **nameplate discharged electricity** given in the table, while from subsequent years it is subjected to **degradation.**
- Do not consider and calculate any revenue (just consider all the costs while calculating LCOS).

**Calculate the following parameters. (Total 7 points)**

*Note that in all parts, just write the final answer without any decimal (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 199.10, write in the box 199.*

A. Calculate the **annual** input electricity of the storage in **MWh.** (1p)

B. Calculate the electricity purchase cost of the storage in **year 1** in **euros (€).** (1p)

C. Sum of all costs (including the capital investment) over the lifetime of the storage in **thousands of euros (1000 €) without discounting.** (1p)

D. **Discounted** sum of all costs (including the capital investment) over the lifetime of the storage in **thousands of euros (1000 €).** (1p)

E. Total discharged electricity over the lifetime of the storage in **MWh (including degradation).** (1p)

F. **Discounted** sum of discharged electricity over the lifetime of the storage in **MWh (Including degradation).** (1p)

G. Levelised cost of storage (LCOS) in **€/MWh.** (1p)

## Question 2

You can return your Excel sheet here, if you wish. No text, just drag your file into the return box.

## Question 3

You are a famous energy market expert. Finnish district heating (DH) companies have invited you to give advice for their near term strategies (1–10 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)

## Question 4

Finnish TSO Fingrid wants to contribute to solving the DH challenges and expand their business by installing and operating wind power in Vaasa region and electric boilers (using power produced by Fingrid's wind turbines) to supply heat in the DH network of Helsinki. Electric boilers operate with high conversion efficiency and have low investment cost. Evaluate if this is feasible and why? (2p)

## Question 5

You are an experienced gas analyst. Your team is responsible for procuring a long-term gas contract to purchase LNG shipped to the floating terminal located in Finland. Briefly answer the following questions, keeping in mind the local and current market conditions.

a) What key terms that must be agreed in the contract? (1p)

b) What kind of price indices are most likely, and which one would you recommend as a starting point? (1p)

c) Reconsider question (b) with the additional information that the gas will be consumed by a DH CHP power plant. What are the relevant changing factors, and do you change your recommendation? (1p)

d) Your team has ordered a power price forecast for the next two years. What details in the forecast especially affect your contracting goals? (1p)

## Question 6

Answer the following power market related questions:

a) LCOE is a useful indicator when comparing production costs of different technologies. However, what should be taken into account when comparing the LCOEs of for example nuclear and wind power? **(0,5p)**

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? **(0,5p)**

c) What is water value? How do water values impact power price formation in Finland? Which bidding zones' water values do you think have the highest impact on the Finnish power price? **(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 last Friday's (13 Oct) closing prices, what is the spread between Finnish and German power futures for year 2024? **(1p)**

## Question 7

This question is related to the independent video assignment about Texas power freeze.

a) What caused the Texas grid failure based on the videos? Elaborate on both the immediate causes, and the deeper systematic causes. (**1p**)

b) Could the Texas power outage have been avoided? Give two justified aspects. (**1p**)

c) Could this happen in Finland? Justify this both from technical and market point of view. Provide two arguments either for or against this utilising both technical and market aspects. (**1p**)