Battery Storage Systems

Battery Storage Expert Programme – Face-to-face activity

Structure and FAQ

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1.1. Course description

At the end of the Battery Storage Expert programme, learners will come together with experts (trainers) and peers at an immersive activity (face-to-face or virtual) focusing on specific areas that appear across the programme. During this activity, the learners can consolidate and deepen their knowledge and analyse the relevance to their business. This activity consists of a series of interactive sessions and lab sessions where learners can actively participate.

The **Battery storage systems** course will provide you with a chance to understand what aspects to consider for a battery installation. You will explore how a battery is made, but also understand the importance of testing and the management of the battery. You will learn to identify the challenges and opportunities while considering which battery system would be more suitable for your various projects.

1.2. Learning outcomes

This course empowers learners to:

- Explore the different battery storage technologies
- Understand what affects the choice of a battery storage solution.
- Grasp what the role of a battery management system is
- Understand the importance of battery testing, how to test a lithium-ion battery cell, and the relevant tools for initial evaluation of testing results
- Understand how a battery cell is made

1.3. Target audience

This course is particularly beneficial for:

- Energy engineers
- Quality and R&D engineers
- Technical managers
- Entrepreneurs entering the battery storage field

1.4. What qualifications does a learner need to join to the Battery storage systems course?

In order to be able to follow and benefit from the Battery storage systems course learners would need to go through the online contents of the Battery Storage Expert Programme. Therefore, the learners wound need to have a general understanding of battery cells, battery system components, and their working principles.

1.5. What is the expected time investment by each learner?

The required time investment is 13 (virtual) to 16 hours (face-to-face). Below appears a suggested timeline (*Figure 1*).

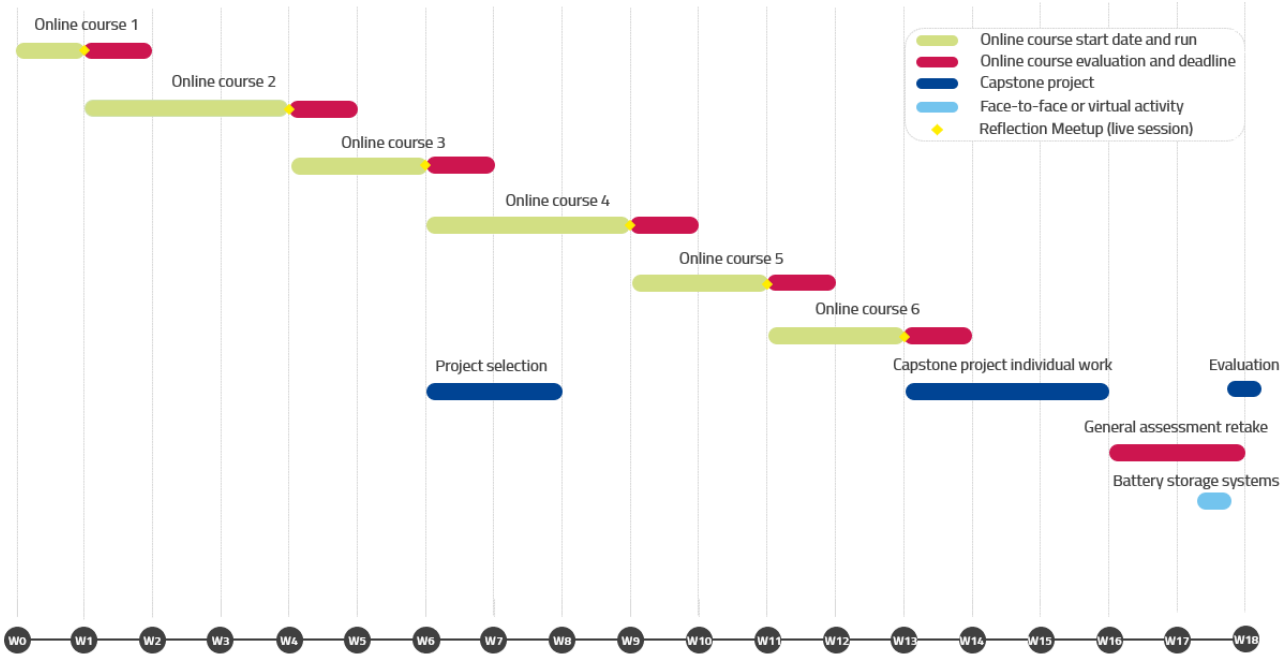

Figure 1: *Suggested timeline for the Battery storage systems course as part of the Battery Storage Expert Programme*

If the activity is delivered face-to-face, it is proposed to be delivered in two consecutive days. If it is delivered in a virtual environment, it is proposed to be delivered in three or four consecutive days.

1.6. Course structure and content

Battery storage systems is part of the blended Battery Storage Expert Programme and represents final face-to-face or virtual activity (***Figure 2***).

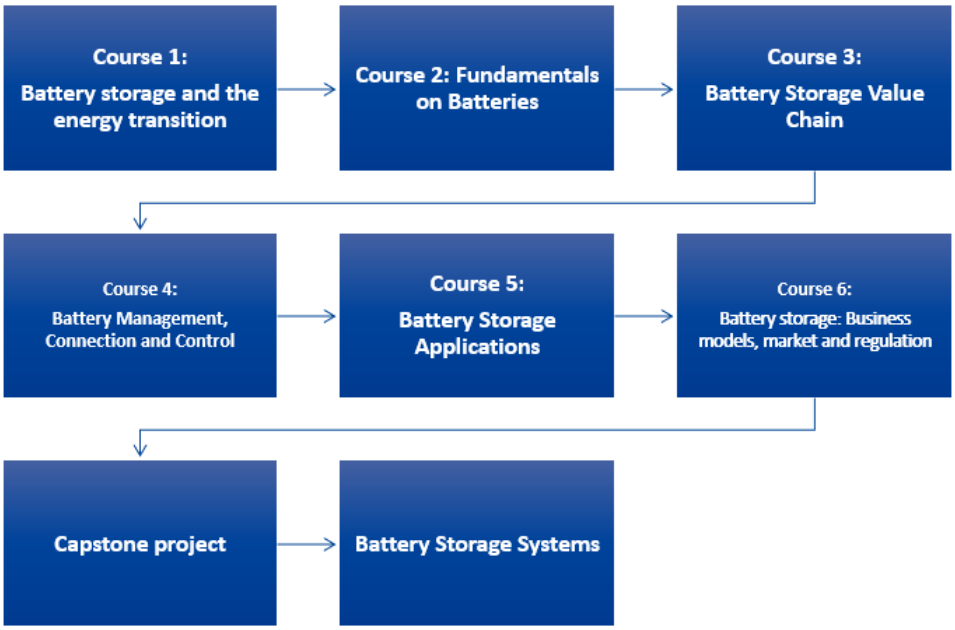

Figure 2: *Structure of the Battery Storage Expert Programme*

This activity consists of the following teaching and learning activities:

- **Interactive sessions in form of presentation delivered by a group of trainers (usually one trainer per session):** Depending on the familiarity from the expert, multiple tools can be used. As basis a simple PowerPoint slide deck can be used or a Prezi presentation. During the presentation the trainers should open the floor for questions and ask the learners to interact. It is recommended to split the presentation time in parts so to allow interaction throughout the session. Certain tools can be used here such as polls or mentimeter.
- **Group work:** This initiates interaction between the learners and help them see a problem or a solution from another perspective. The trainer can separate the learners in groups (usually 3-4 learners per group). In a virtual environment the different groups can be sent to separate breakout rooms. Following, the trainer can provide a number of short case studies to review or a particular problem and ask the learners to discuss and respond to a number of questions or come up with a solution. After regrouping, the learners can discuss their answers or solutions with the rest of the groups to initiate further discussions or to provide/receive feedback. Ensuring that all learners are participating actively is important.
- **Group discussions being led by the trainer(s):** Here the trainer(s) can take two different approaches. A) Ask a question to the learners to hear their perspective and assess their understanding of the topic in question. B) Present a short case or example and open the floor to questions from the learners. Both can lead to a brainstorming or debate, depending on the question in focus or the case/example. Ensuring that all learners are participating actively is important.
- **Pre-readings:** The trainers can provide pre-readings if they find appropriate to avoid any lengthy introductions to basic elements. That can even be a simple glossary.

The activity follows the below structure (***Table 1***). A further detailed structure is provided at 1.8.

Table 1: Face-to-face (or virtual) activity structure

Session focus	Duration	Teaching and learning activities	Suggested tools
Battery storage technologies and applications	2 hours incl. 5 min break	Interactive session – presentation Group discussion (~40 min)	PowerPoint/Prezi Polls/Mentimeter
How battery materials are fabricated	1.5 hours incl. 15 min break	Interactive session – presentation Group discussion (~30 min)	PowerPoint/Prezi Polls/Mentimeter
Battery preparation and assembly	2.5 hours incl. 10 min break	Interactive session – presentation Lab session including discussion (~2 hours)	PowerPoint/Prezi Relevant lab equipment/software
Battery selection and price effects	2 hours	Interactive session – presentation Group work (~20 min) Group discussion (~20 min)	PowerPoint/Prezi Whiteboard Mural

Efficiency and power conversion in battery applications	2.5 hours incl. 10 min break	Interactive session – presentation Lab session including discussion (~1.5 hours)	PowerPoint/Prezi Relevant lab equipment/software
Battery management systems	2.5 hours incl. 10 min break	Interactive session – presentation Lab session (~1 hour)	PowerPoint/Prezi Relevant lab equipment/software
Battery testing	2.5 hours	Interactive session – presentation Lab session including discussion (~2 hours)	PowerPoint/Prezi Relevant lab equipment/software

1.7. Trainer profiles

Each session needs to be delivered by a trainer that has the right profile and experience in the topic of each session. The trainer profiles are (note the same trainer might cover more than one trainer profiles):

- **Trainer 1**: Experience in the energy or power sector (renewables, distributed generation of electricity, smart grids, etc.) with knowledge on battery storage applications and integration in smart grids predominantly from a business perspective. Preferred to have also a technical understanding of the main applications of battery storage. Good presentation skills. Preferred to have also pedagogical experience.
- **Trainer 2**: Research/industrial experience on battery raw and active materials, and battery cell manufacturing (lab or large-scale setting) from mainly a technical perspective. Experience with battery cell manufacturing (coin and/or pouch), and relevant safety aspects at a battery lab setting. Specific competences required for the lab are listed in the dedicated lab description. Good presentation skills. Preferred to have also pedagogical experience.
- **Trainer 3**: Research or industrial experience with battery systems components and factors affecting the system's operation and optimisation. Good presentation skills. Preferred to have also pedagogical experience.
- **Trainer 4**: Research or industrial experience with power conversion and power electronic interfaces for battery storage applications. Experience with experiments for determining efficiency of battery systems (e.g., AC coupled home battery system). and relevant safety aspects at a lab setting. Specific competences required for the lab are listed in the dedicated lab description. Good presentation skills. Preferred to have also pedagogical experience.
- **Trainer 5**: Research or industrial experience with battery systems components and operation, battery management systems, and battery testing. Experience with battery components, battery testing protocols, and relevant safety aspects at a battery lab setting. Specific competences required for the lab are listed in the dedicated lab description. Good presentation skills. Preferred to have also pedagogical experience.

1.8. Detailed structure of the face-to-face (or virtual) activity

Here is the detailed proposed structure of each session:

- **Session 1: Battery storage technologies and applications**
  - Main types of current battery storage technologies and emerging technologies

        - Brief list of advantages and disadvantages (e.g. discharge time, response time, lifetime, efficiency, maturity, scalability, safety, cost, etc.)
    - Main applications that each technology is most suitable (include explanations based on certain parameters)
        - Ancillary services
        - Energy arbitrage
        - Self-consumption maximisation
        - Peak shaving
        - Backup power
        - Time-of-use shift
        - Frequency regulation
        - Reserve capacity
        - Voltage support
        - Transmission & distribution deferral
        - Congestion relief
        - Black start…
        - Value stacking
    - Group discussion: What applications do the learners believe will drive the market in the next 5 years? – They should be able to argue their opinion based on elements they have seen in the online contents preceding this activity.
- Session 2: How battery materials are fabricated
    - What kind of materials are used in batteries?
        - Main battery materials used for the battery storage technologies described before.
        - Cell materials as part of the battery back cost
    - Where do critical battery materials come from?
        - Brief explanation of the resources and reserves of critical battery raw materials.
    - How are they fabricated? What are the synthesis routes used to fabricate them?
        - List of solution based routes to tune materials
        - Material synthesis by chemical solution routes (aqueous sol-gel, non-hydrolytic sol-gel, combustion, precipitation, thermal decomposition etc.)
        - Aspects of material fabrication that needs careful consideration
        - Impact of synthesis to the material properties
    - Case study e.g., synthesis of NMC cathode materials
    - Group discussion: Raw materials requirements for lithium-ion batteries
        - Environmental and social impact of battery raw materials extraction
        - Recycling of batteries and recovery of materials
- Session 3: Battery preparation and assembly
    - Cell types and geometries explanation
    - Step by step explanation of the cell preparation (slurry preparation and mixing, electrode coating, drying, calendering, electrode cutting and stacking different possibilities, crimping/tab welding, pouch sealing and electrolyte filling, formation cycles, gas release, pouch final sealing, finished cell)
        - Lab session: Coin cell making - If access to pilot line facility we recommend doing so while performing each step in the pilot line.

        - In case the activity takes place at a virtual environment or facilities are not available, adaptation to the time of the session might be required, and the learning outcomes should be achieved through other means (e.g., presentation and discussion).
- Session 4: Battery selection and price effects
    - Components of a battery pack and cost structure (anode, cathode, separator, electrolyte, active materials, BMS, packaging etc.)
    - Parameters affecting battery selection (energy density, power density, cycle efficiency, self-discharge, lifetime etc. in connection to the Battery storage technologies and applications session)
    - Factors to be taken under consideration for appropriate battery sizing
    - Group work: One example of application (behind-the-meter, off-grid, grid) to each group, with a target to discuss and answer the following questions. Any assumptions should be clearly stated (load profile, location, etc.).
        - Which parameters affect most the battery size in this example?
        - Which battery would they choose and why? Which characteristics determined their choice?
    - Levelised cost of storage
        - A short intro to relevant financial terms (possible to provide as a preparatory handout)
        - Explaining the concept and how it is calculated
        - Few examples of calculated LCOS for real or fictious examples.
- Session 5: Efficiency and power conversion in battery applications
    - Reminder on the nominal capacity, energy and output voltage, and the need for power conversion for battery applications (examples USB power bank and home battery)
    - Power converter components and conversion losses
    - Lab session: Home battery experiment - determine the efficiency of an AC coupled home battery system for a scenario with a single charge/discharge cycle
        - Battery charged with 4kW for +/- 30 min
        - Battery discharged until empty with 4.5kW
    - Lab session: USB power bank experiment - Determine the efficiency of a USB power bank, for a scenario with a single charge/discharge cycle.
        - Battery charged with USB charger for +/- 30 min
        - Battery discharged until empty with 10 W
    - Lab session: USB charger experiment - determine the efficiency of a modern USB charger for different load currents at a constant USB voltage.
        - USB voltage: 5 V
        - Different load currents
    - In case the activity takes place at a virtual environment or facilities/equipment are not available, adaptation to the time of the session might be required, and the learning outcomes should be achieved through other means (e.g., presentation of the experiment and results, and discussion).
- Session 6: Battery management systems
    - Reminder on the need for a BMS
    - BMS types, topologies and connection

- BMS functionalities (recommended to show a demo/example e.g., balancing, state estimation)
- Lab session: Building a lithium-ion powerbank – step by step assembly
  - In case the activity takes place at a virtual environment or facilities/equipment are not available, adaptation to the time of the session might be required, and the learning outcomes should be achieved through other means (e.g., presentation of the assembly steps and discussion).

- Session 7: Battery testing
  - Battery testing standards reminder
  - Types of battery testing (Information that can be extracted, how certain parameters influence test results, how they correlate with each other, etc.)
  - Safety and risks during battery testing
  - Lab session: Basic battery testing protocols – basic battery testing examples
    - In case the activity takes place at a virtual environment or facilities/equipment are not available, adaptation to the time of the session might be required, and the learning outcomes should be achieved through other means (e.g., presentation of testing protocols, battery testing examples, results, and discussion).

1.9. Course evaluation

To succeed in the Battery storage systems course and receive a Certificate of Participation a learner needs to:

- complete successfully the online contents of the Battery Storage Expert Programme, and
- attend and actively participate at all face-to-face (or virtual) sessions.