Co-funded by the European Union

Battery storage and smart grid applications

Structure and FAQ

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1.1. Course description

Electric power systems are required to be increasingly flexible due to the growing penetration of intermittent renewable energy sources and increased variability in electricity use, such as the emergent presence of electric vehicles. Energy storage is an efficient, cost-effective, and sustainable approach to tackle this issue. Adding to that, energy storage is assisting in the decarbonisation of the electricity system. Stationary storage systems, in particular, can be implemented at different levels of the electricity value chain, such as the transmission, distribution, and consumer levels.

The Battery Storage and Smart Grid Applications course, allows learners to explore the exciting topic of smart grid applications of battery storage. Through real cases and interaction with topic specialists, learners will be able to identify steps and decisions you could translate to your organisation to achieve a flexible business model in the emerging market of battery storage.

1.2. Learning outcomes

This course empowers learners to:

- Identify the challenges faced by the EU electricity industry and situate battery energy storage as part of the solution
- Develop an understanding of the energy and battery storage market
- Understand the services, drivers, and barriers for battery storage applications behind-the-meter and front-of-the-meter
- Develop knowledge to determine the main risks and challenges when investing in such applications
- Grasp the link between electric vehicles and stationary storage systems
- Identify emerging players, broaden your business perspective and exploit new market openings

1.3. Target audience

This course is particularly beneficial for:

- Professionals and industry managers interested to understand battery storage as a strong part of the new energy system
- Energy consultants and engineers interested to learn about smart grid battery storage applications and business opportunities
- Energy analysts and strategists
- Investors interested in sustainable future investments

1.4. What qualifications does a learner need to join to the Battery storage and smart grid applications course?

In order to be able to follow and benefit from the Battery storage and smart grid applications course learners would need to have a general understanding of the electricity system and a very basic understanding of battery storage applications..

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

The required time investment is around 2 hours/week on average for the online part and around 13 hours for the face-to-face or virtual activity. Below appears a suggested timeline (***Figure 2***).

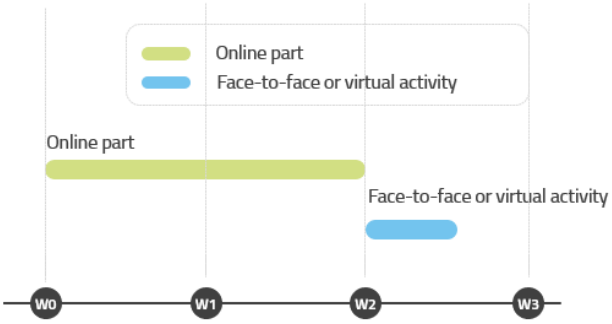

Figure 2: Suggested timeline for the Battery storage and smart grid applications course

1.6. Course structure and content

Battery storage and smart grid applications is a blended online course that consists of and online part, a face-to-face or virtual activity (***Figure 1***) and optionally a follow-up by a topic specialist. The learners will have the possibility to share their opinion and thoughts on relevant topics via the discussion elements throughout the course.

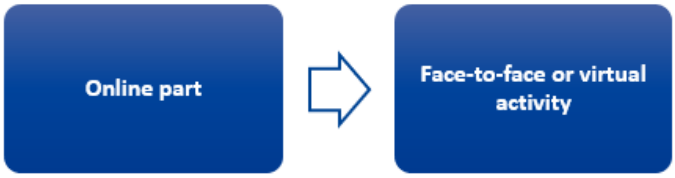

Figure 1: *Structure of Battery storage and smart grid applications course*

The online part consists of fifteen online lessons and is structured as follows:

- Lesson 1: Flexibility needs and the role of battery storage
- Lesson 2: Energy storage applications
- Lesson 3: Market development in Europe
- Lesson 4: Grid-scale storage application
- Lesson 5: The Gotland case study: Contextualisation
- Lesson 6: The Gotland case study: Today scenario
- Lesson 7: The Gotland case study: Reaching 1GW of wind power generation
- Lesson 8: The Gotland case study: Who should own the battery?
- Lesson 9: Behind-the-meter storage application
- Lesson 10: Behind the meter storage in apartments and villas
- Lesson 11: Behind the meter storage impacts in network operators
- Lesson 12: Battery storage application in mobility
- Lesson 13: Business models and regulation behind charging stations
- Lesson 14: Urban transformation: the impact of electrifying public transport
- Lesson 15: Battery storage at off-grid

At the end of the online part, learners will come together with experts (trainers) and peers at a face-to-face or virtual activity. During this activity, the learners can consolidate and deepen the knowledge they received during the online part.

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 so 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 1.9.

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

Session focus	Duration	Teaching and learning activities	Suggested tools
Overview on the European energy storage market	2 hours incl. 10 min break	Interactive session – presentation Group discussion (~30 min)	PowerPoint/Prezi Polls/Mentimeter
Battery energy storage at the behind-the-meter level	2.5 hours incl. 15 min break	Interactive session – presentation Group work (~1 hour incl. discussion)	PowerPoint/Prezi Polls/Mentimeter Value proposition canvas
Battery energy storage for grid management	2.5 hours incl. 15 min break	Interactive session – presentation Group work (~1 hour incl. discussion)	PowerPoint/Prezi Polls/Mentimeter Mural

Value stacking and revenue streams	2 hours incl. 10 min break	Interactive session – presentation Group discussion (~30 min)	PowerPoint/Prezi Polls/Mentimeter Whiteboard
Electric vehicles and stationary energy storage	2 hours incl. 10 min break	Interactive session – presentation Group discussion (~30 min)	PowerPoint/Prezi Polls/Mentimeter Whiteboard - Debate
Focusing on a case study	2 hours incl. 10 min break	Interactive session – presentation Group work (~40 min) Group discussion (~40 min)	PowerPoint/Prezi Polls/Mentimeter Business model canvas

1.7. Who are the experts in the online part of the course?

This course was developed in collaboration with experts from the EIT InnoEnergy ecosystem, authorities in sustainable energy from the worlds of research and industry. Faculty for this course are:

Anna Darmani

Energy system analyst at InnoEnergy, Anna is responsible for several EU projects in the area of energy technology innovation and research. She is engaged in the road-mapping of high-potential energy technologies in the future European energy market.

Bo Normark

Industrial Strategy Executive and core member of European Battery Alliance at EIT InnoEnergy, Bo has more than 35 years of industrial experience in ABB in development, design, project management, and global management of the Power Systems business

Julian Jansen

Research and Analysis Manager at IHS Markit Technology, leading the global research on energy storage and provides insight into the value drivers and emerging business models driving storage deployment across Europe and N. America.

Johan Driesen

Full professor at the Faculty of Engineering and Science head of Subdivisie EnergyVille Electa - Driesen with years of experience in distributed generation of electricity, renewable energy, power electronics, electrical drives, electric vehicles, and smart grids.

Peter Van Den Heede

Head of Sales Council – Electrification Benelux at ABB, working at ABB for more than 10 years in the fields of smart grids, electrification, and business development.

1.8. Trainer profiles

It is recommended that during the online part has a dedicated course leader (topic specialist). The course leader shall optionally be available for a (suggested) total of one hour throughout the online part run to answer asynchronous questions via the learning platform or other means. This is recommended to take place in a forum where all learners have access and can benefit from the answers or any discussion.

The course leader's profile is expected as follows: Experience and knowledge in the integration of storage in smart grids, not only at a grid level but also at a residential level, and the integration of electric vehicles, primarily from a business perspective.

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. Additionally, EU-wide view of the electricity and energy storage market within the field. 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: Industrial experience with residential storage predominantly from a business perspective but also a certain knowledge of relevant technical aspects. Knowledge of behind-the-meter storage services in smart grids, trends, possible opportunities, and relevant business models. Good presentation skills. Preferred to have also pedagogical experience.
- Trainer 3: Industrial experience with grid scale storage predominantly from a business perspective but also a certain knowledge of relevant technical aspects. Knowledge of in-front-of-the-meter storage services in smart grids, trends, possible opportunities, and relevant business models. Good presentation skills. Preferred to have also pedagogical experience.
- Trainer 4: Knowledge/experience with different battery storage applications, relevant services in smart grids, and revenue streams, and experience with value stacking and relevant tools. Good presentation skills. Preferred to have also pedagogical experience.
- Trainer 5: Knowledge/experience with electric vehicles predominantly from a business perspective but also a certain knowledge of relevant technical aspects. Knowledge of, relevant trends, possible opportunities and business models in smart grids, but also second life of electric vehicles' batteries. Good presentation skills. Preferred to have also pedagogical experience.

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

Here is the detailed proposed structure of each session:

- Session 1: Overview on the European energy storage market
  - What makes a power grid "smart"?
    - Rapid change of the power systems
    - Traditional vs smart grid
    - Characteristics of a smart grid, key technologies, and functionalities
  - What is the role of energy and battery storage technologies?

        - Relevant battery storage applications (power rating, discharge time etc.), services and benefits for a smart grid
            - Grid scale storage – Load shifting, energy management, frequency and power quality etc.
            - Behind-the-meter storage – optimising self consumption, peak shaving, balancing services, emergency power support etc.
        - How has the market evolved in the last few years?
        - Relevant parameters to take into account for a positive business case
    - What is the role of electric vehicles?
        - Understanding the current EV penetration and effects (driving range, cost, charging infrastructure, charging time, safety etc.)
        - Impact of electric vehicles in the grid – examples (e.g. Norway, UK)
        - Brief explanation of vehicle-to-grid business model
        - What are the main benefits of combining battery storage with smart grids? - Group discussion while looking at a few examples. For example:
            - 22MW battery at Vattenfall´s Pen y Cymoedd Wind Farm in South Wales. It was one of eight projects
            - 182.5 MW battery Tesla PG&E Megapack
- Session 2: Battery energy storage at the behind-the-meter level
    - Energy system challenges at a behind-the-meter level
    - Trends that can affect future business models
    - Behind-the-meter battery storage system for a smart home
    - Innovation in behind-the-meter storage (technologies, market design, operation and business models)
    - Building-level services and opportunities (what is it, benefits, challenges, technical complexity, business case)
        - Optimising self consumption
        - Energy arbitrage
        - Demand charge reduction
        - Effect of EV charging and vehicle-to-grid
    - Services for various stakeholders (what is it, benefits, challenges, technical complexity, business case)
        - Ancillary services
        - Frequency regulation
        - Virtual battery
        - Platform for flexibility aggregation and activation of services
        - Aggregation of behind-the-meter assets
    - Short introduction to value stacking (as there is a dedicated session)
    - Short introduction on the value proposition canvas (if necessary, although a pre-reading is suggested)
    - Group work: One existing example to each group with a target to fill in the value proposition canvas (Annex). The information provided to the learners should be enough to allow them to fill in the canvas. Possible examples:
        - 6MWh behind-the-meter storage at Poway Unified School district in California
        - 1MWh behind-the-meter storage by STEM at customer sites in Hawaii

    - 500kW/1000kWh Tesla Powerpack batteries by AMS at Morgan Stanley
    - Sonnen community
- Session 3: Battery energy storage for grid management
    - Energy storage in liberised energy markets – A well-functioning electricity grid (cost-efficient, reliable, future proof)
        - Short introduction to how the market works today, how power exchanges work, day-ahead market, balancing supply/demand
        - Cost-efficient: Liberalisation and unbundling of electricity markets
        - Reliable: Avoidance of blackouts, balanced portfolios via Balance Responsible Parties, liquid wholesale markets etc.
        - Future proof: Security of supply, decarbonisation, need for flexibility
    - Energy storage applications for grid management (what is it, benefits, challenges, technical complexity, business case)
        - Ancillary services
        - Congestion relief
        - Price arbitrage
        - Reducing renewables shaping and ibalance risk
        - Renewable plus storage
        - Back up power…
    - Short introduction to value stacking (as there is a dedicated session)
    - Levelised cost of storage (LCOS)
        - A short intro to relevant financial terms (possible to provide as a preparatory handout)
        - Explaining the concept and how it is calculated
        - Caveats of LCOS
        - Few examples of calculated LCOS for real or fictious examples. Assumptions should be clearly stated. For example:
            - Lifetime of X years for simplicity
            - No sales taxes or grid tariffs are taken into account
            - CAPEX (X EUR/MWh)/OPEX (X% of CAPEX/year) assumptions
            - Round trip efficiency X%
            - Degradation/year: X%
    - Group work: One real life or fictious example to each group (Case 1: Renewables plus storage, Case 2: Ancillary services, Case 3: Congestion relief, Case 4: Price arbitrage in the wholesale markets) with a target to discuss and answer the following questions:
        - What are the market segments suited for this business model?
        - What is the value proposition for each market segment?
        - What market conditions favour the business model?
        - What market conditions hinder this business model?
- Session 4: Value stacking and revenue streams
    - Intro to energy storage value and how we can stack it
        - What is considered as ''value''?
        - What is value stacking and how does it work?
        - What are the benefits and challenges of value stacking? - Examples of existing or possible value stacking

        - Frequency containment – Energy arbitrage
        - Frequency containment – Frequency regulation
        - Back up power – Peak shaving – Energy arbitrage
    - Importance of real-time control and optimisation for value stacking
    - Visualising possible value streams stacking and the ideal business model
        - Relevant stakeholders and barriers for value stacking
            - Regulators
            - Utilities / DSOs / TSOs
            - Distributed energy resources
            - Storage developers etc.
    - Some tools for value analysis (e.g. StorageVET, DER-VET, QuEst etc.)
    - Group discussion while looking at a few examples of value stacking (e.g. examples for utility scale storage projects, real life example of Tesla's BESS in Australia, Stafford Hill microgrid) with main questions:
        - What are the main values to be stacked?
        - What is the business case?
        - How can it be optimised?
        - What is a particular value stops?
- Session 5: Electric vehicles and stationary energy storage
    - How is the EV market in Europe developing and what potential does this offer
        - Overview of different ways for electric vehicles to contribute to smart grids (smart charging (V1G), bi-directional charging (V2G), second life of EV batteries)
    - What is V1G, V2H, V2G, V2B, V2X? How do they work?
    - What technology is required to utilize V2X?
        - On vehicle side – Batteries and battery degradation
        - On charger side – AC and DC chargers
        - Communication - ISO 15118
    - Smart charging (v1G) and impact for a household
    - Second life usage of EV batteries
        - When can an EV battery be reused?
        - Refurbishing and reusing – specifications and limitations
        - Group discussion and debate around recycling vs reuse of EV batteries
    - Some actual examples where EVs already are used for smart grid applications
        - Examples of V2G (e.g. France's *Grid motion* – Groupe PSA, Denmark's *Parker* – Nuvve, US's *INVENT* – Nuvve and UC San Diego)
    - 5-year outlook – when will V2G happen?
        - CHAdeMO standard
        - CCS standard
- Session 6: Focusing on a case study
    - Presentation and introduction to a case study (preferably real-life but fictional is also possible)
        - Company profile
        - Market status at the particular country
        - Problem the company tries to solve and current solution they provide

- Short introduction on the business model canvas (if necessary, although a pre-reading is suggested)
- Group work: Target is to fill in the business model canvas (Annex) for the current business model of the company. The information provided to the learners should be enough to allow them to fill in the canvas. A few points can be pre-filled as per the introduction of the case study.
  - Key partners
  - Key activities
  - Key resources
  - Value proposition
  - Customer relationships
  - Channels
  - Customer segments
  - Cost structure
  - Revenue streams
- Group discussion: It is important to provide feedback throughout this process and initiate discussion to ensure that all learners have the same level of understanding.
  - The trainer fills in the business model canvas as per input received by the learners.
  - Additional discussion on the following questions:
    - How can the business case be improved (e.g. value stacking)? Are there additional opportunities?
    - What are the main limitations/bottlenecks (e.g. technological, financial, or regulatory considerations)?

1.10. Course evaluation

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

- complete at least 80% of the online course contents, and
- attend and actively participate at all face-to-face (or virtual) sessions.