



Aalto University
School of Electrical
Engineering

ELEC-E8423 - Smart Grid

Battery Energy Storage Systems

Ella Asikainen

Maximilian Björkstam

25.04.2022

Introduction

BESS = Battery energy storage systems

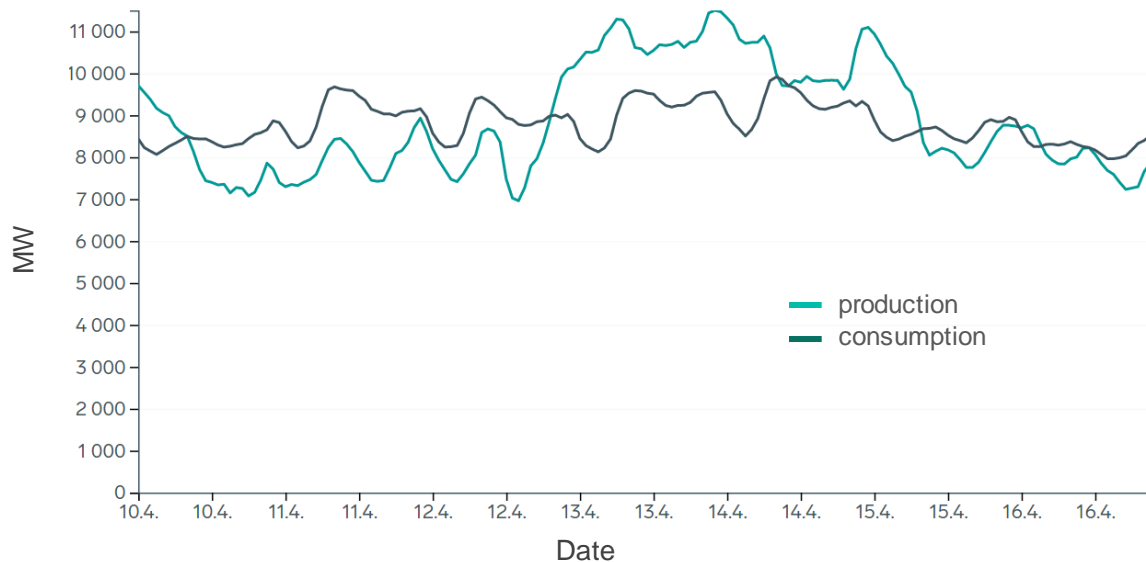
Structure:

- 1. Why we need energy storage**
- 2. Types of BESS**
- 3. BESS in the grid**
- 4. BESS architecture**
- 5. Development in BESS**
- 6. Projects in Finland**

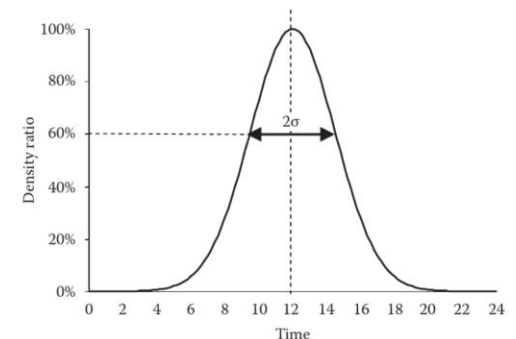
Why is storage needed?

- Increasing share of wind and solar, which are intermittent and hard to predict
- Mismatch of renewable production and consumption

Electricity production and consumption in Finland, 10.-17.4.2023 (Fingrid)



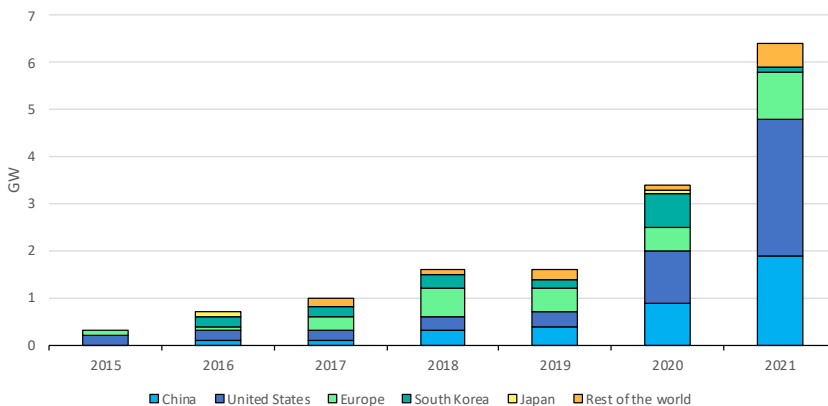
Typical solar production profile



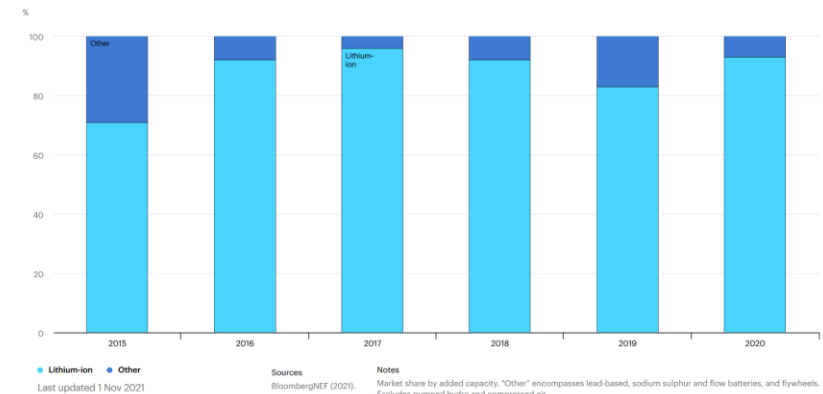
Different types of BESS: Li-ion battery

- Lithium-ion is most common: great efficiency (78-98%) and energy density (75-250 Wh/kg), cost dependent on critical mineral costs
- Total installed grid-scale BESS amounted to 16 GW by the end of 2021
- The installed technology mix remained largely the same in 2021 compared to 2020 (Li-ion as the most used)

Annual grid-scale battery storage additions, 2016-2021



Energy storage technology mix, 2015-2020



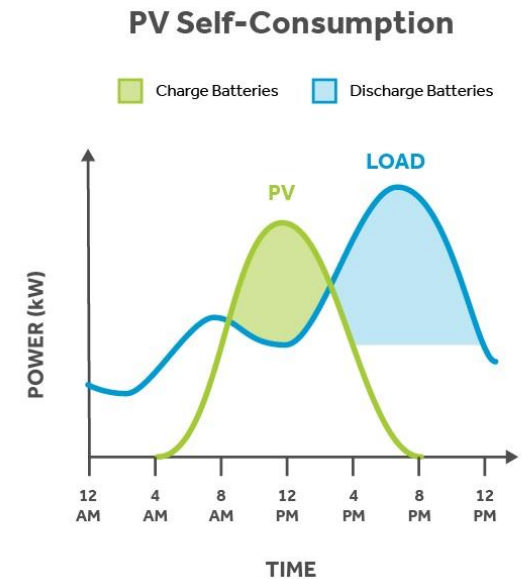
Different types of BESS: Other types

- There are many any other types of batteries, such as lead acid, zinc-ion and sodium-ion batteries
- Flow batteries (vanadium redox flow)
 - Advantages: less degradation over time, than in li-ion batteries, more cycles
 - Disadvantages: high investment cost, lower efficiency, large quantity of liquid electrolyte needed, availability and price volatility of vanadium
 - Largest project: 100 MW/ 400 MWh in China (opened in 2022)



BESS in the grid

- **Load shifting**
 - Hourly or daily balancing
 - Charge when overproduction – discharge when load needed, but not enough production
- **Emergency backup**
- **Voltage and frequency control (response times < 1 s)**



BESS architecture

- **Battery Packs**

- Chemical energy is converted into electrical energy.
- Cells in modules that form battery packs.

- **Battery Management System (BMS)**

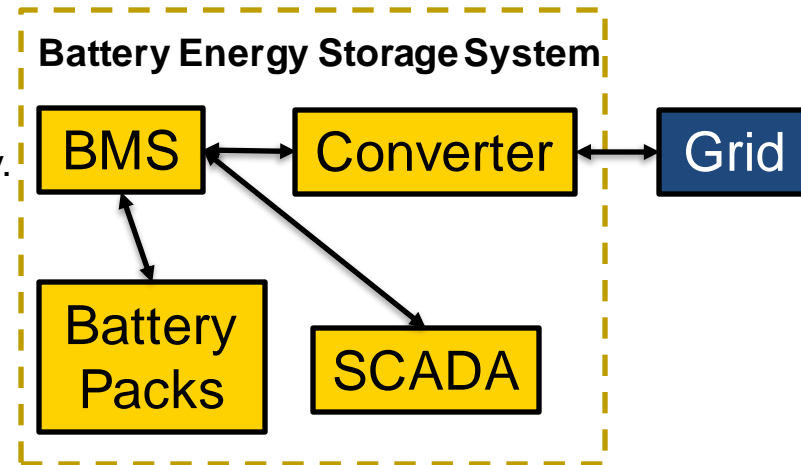
- Protects cells from harmful operation and hazards.
- Monitors the condition of the battery cells.

- **Power Conversion System (Converter)**

- Converts power flow between the grid and the battery (AC/DC)

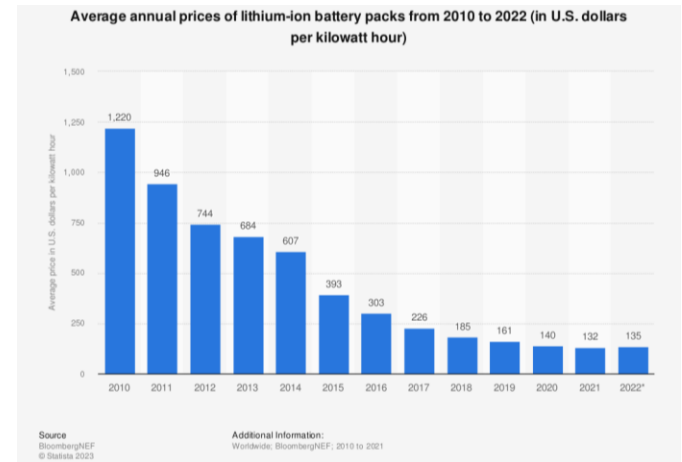
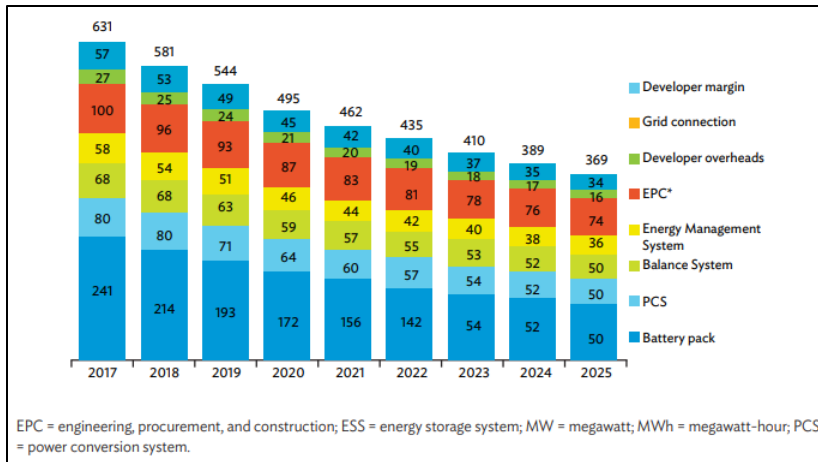
- **Supervisory Control and Data Acquisition (SCADA)**

- Collects and analyzes energy data.
- Coordinates the components.



Development in BESS

- Expansion in manufacturing capacity of lithium-ion batteries.
- Almost 90% decrease in the prices of Li-ion battery prices since 2010
- Price stabilization suggested due to insufficient raw materials
- Estimated CAGR of around 16% for the BESS market during 2022-2029
- The war in Ukraine → Anode and cathode materials increase



Projects in Finland

- Pohjolan Voima 35 MW lithium ion battery project to increase system security and increase regulating power flexibility (N/A)
- Taaleri Energia/ Merus Power, Lempäälä 30 MW/36 MWh to balance wind power production (2024)
- Helen Oy 5 MW/10 MWh capacity BESS system that is going to be connected to the 86 MW new wind farm Lakiakangas 3 (2022)
- 20 MW BESS at Sinebrychoffs brewery in Kerava (2021)
- Neoen's 30 MW/30 MWh capacity Ylikkälä Power Reserve One (in operation since 2020)



Conclusions

- **BESS can help overcoming the challenge of volatility of renewable generation.**
- **BESS is very useful for load balancing and has fast response times.**
- **Second biggest storage technology after pumped hydro storage.**
- **Lithium-ion is currently the main technology for BESS.**
- **BESS systems are becoming more economically viable options.**
- **There are problems in availability and recycling of materials.**

Source material used

- Datta U, Kalam A, Shi J. A review of key functionalities of battery energy storage system in renewable energy integrated power systems. *Energy Storage*. 2021;3:e224. <https://doi.org/10.1002/est2.224>.
- IEA: Energy Storage Tracking Report (November 2021). Available online: <https://www.iea.org/reports/energy-storage>.
- IEA: Grid-scale storage (September 2022). Available online: <https://www.iea.org/reports/grid-scale-storage> (24.4.2023)
- Kebede A A, Kalogiannis T, Van Mierlo J, Berecibar M. A comprehensive review of stationary energy storage devices for large scale renewable energy sources grid integration. *Renewable and Sustainable Energy Reviews*, Vol. 159 (2022). ISSN 1364-0321. <https://doi.org/10.1016/j.rser.2022.112213>.
- Koohi-Fayegh S, Rosen M.A, A review of energy storage types, applications and recent developments. <https://doi.org/10.1016/j.est.2019.101047>
- Badeda J, Fler J, Zurmühlen S, Meyer J, Stenzel P, Hake J and Sauer D. 11th International Renewable Energy Storage Conference. Price development and bidding strategies for battery storage systems on the primary control reserve market. <https://doi.org/10.1016/j.egypro.2017.09.497>
- Cranney J, Davidson M, Townsend C and Summers T.J. 2018 7th International Conference on Renewable Energy Research and Applications. Decentralised Energy Market for Implementation into the Intergrid Concept - Part 2: Integrated System. DOI: 10.1109/ICRERA.2018.8566719
- Fortune Business Insights. 2022. Battery Energy Storage Market. Available online: <https://www.fortunebusinessinsights.com/industry-reports/battery-energy-storage-market-100489>
- Pohjolan Voima. 2021. Pohjolan Voima is planning a battery hybrid solution that ranks as one of the largest in Europe. Available online: <https://www.pohjolanvoima.fi/en/pohjolan-voima-is-planning-a-battery-hybrid-solution-that-ranks-as-one-of-the-largest-in-europe/>
- Neoen Ylikkälä battery energy storage: <https://neoen.com/en/news/2020/neoen-builds-in-finland-the-nordics-largest-battery-storage-unit/>
- Kauppalehti. 2022. Keravalta löytyy nyt puoli jalkapallokentällistä akkuja – näin Siemens ja Sinebrychoff tasapainottavat Suomen sähköverkkoa. Available online: <https://www.kauppalehti.fi/kumppanisallot/siemens/keravalta-loytyy-nyt-puoli-jalkapallokentallista-akkuja-nain-siemens-ja-sinebrychoff-tasapainottavat-suomen-sahkoverkkoa/>
- Merus/Taaleri Lempäälä battery storage: <https://meruspower.com/news/merus-power-receives-20-million-euro-order-supply-large-battery-energy-storage-system-taaleri-energia/>

Image sources

- **Electricity consumption in Finland on a week:** <https://www.fingrid.fi/sahkomarkkinainformaatio/kulutus-ja-tuotanto/> (18.4.2023)
- **Typical solar production graph:** El-Sharkawi, Mohamed A. **Electric Energy, An Introduction (Third Edition)**. 2012. E-book ISBN 9781466504318. Publisher: Taylor & Francis Group. Page 102.
- **Energy storage technology mix:** Adapted from IEA. Original available online: <https://www.iea.org/data-and-statistics/charts/energy-storage-technology-mix-2015-2020>
- **IEA. 2022. Annual grid-scale battery storage additions, 2016-2021, Data from IEA, Paris.** Available online: <https://www.iea.org/data-and-statistics/charts/annual-grid-scale-battery-storage-additions-2016-2021>
- **Vanadium flow battery cell stacks, VRB Energy.** Accessed: <https://www.energy-storage.news/first-phase-of-800mwh-world-biggest-flow-battery-commissioned-in-china/> (18.4.2023)
- **PV Self consumption: Sustainable Solar Services.** Available online: <https://www.solarsponsoring.com.au/battery-storage-use-in-australia/>
- **Asian Development Bank. 2018. Handbook on battery energy storage system.** <https://www.adb.org/sites/default/files/publication/479891/handbook-battery-energy-storage-system.pdf>
- **BloombergNEF. (2022). Average annual prices of lithium-ion battery packs from 2010 to 2022.** Statista. Available online: <https://www.statista.com/statistics/1042486/india-lithium-ion-battery-packs-average-price/> (18.4.2023)
- **Helen. 2021. Helen investoi suurimpaan sähkövarastoonsa, joka auttaa turvaamaan koko pohjoismaiden energijärjestelmää.** Available online: <https://www.helen.fi/uutiset/2021/helen-investoi-suurimpaan-sahkovarastoonsa>
- **Utilities. Neon's 30MW/30MWh battery storage project in Finland to help stabilize grid.:** <https://www.utilities-me.com/news/15594-neons-30mw-30mwh-battery-storage-project-in-finland-to-help-stabilise-grid-in>
- **Merus battery storage Lempäälä:** <https://meruspower.com/news/merus-power-receives-20-million-euro-order-supply-large-battery-energy-storage-system-taaleri-energia/>

Thank you for your
attention!