



The Role of Batteries in Energy Storage

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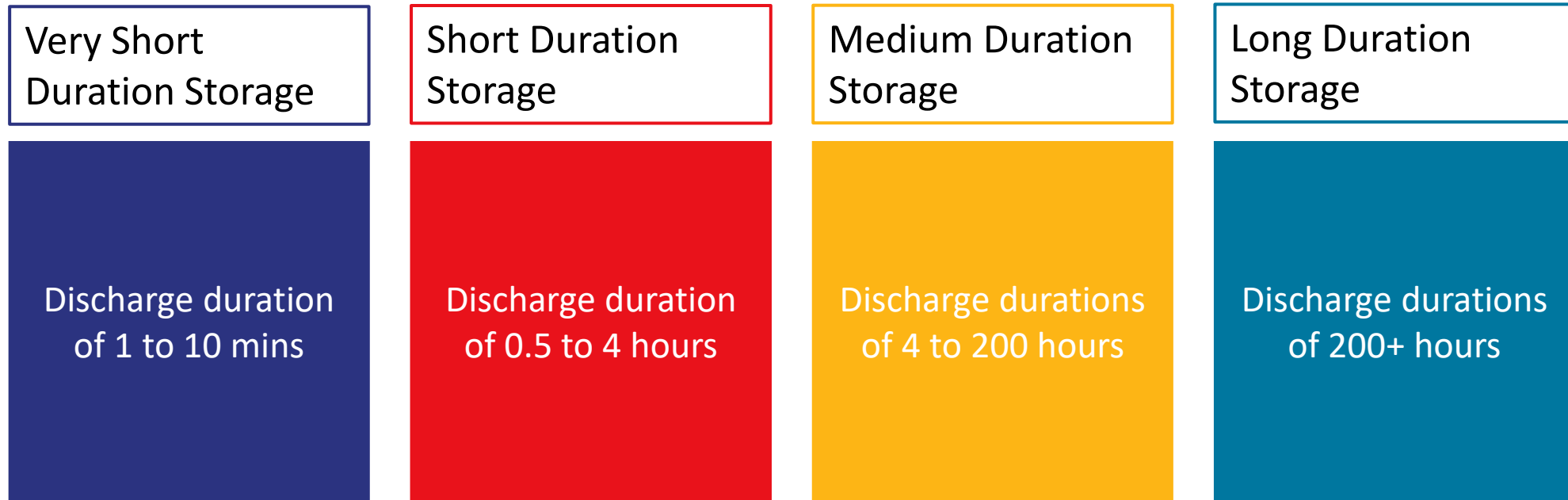
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The role of batteries in energy storage



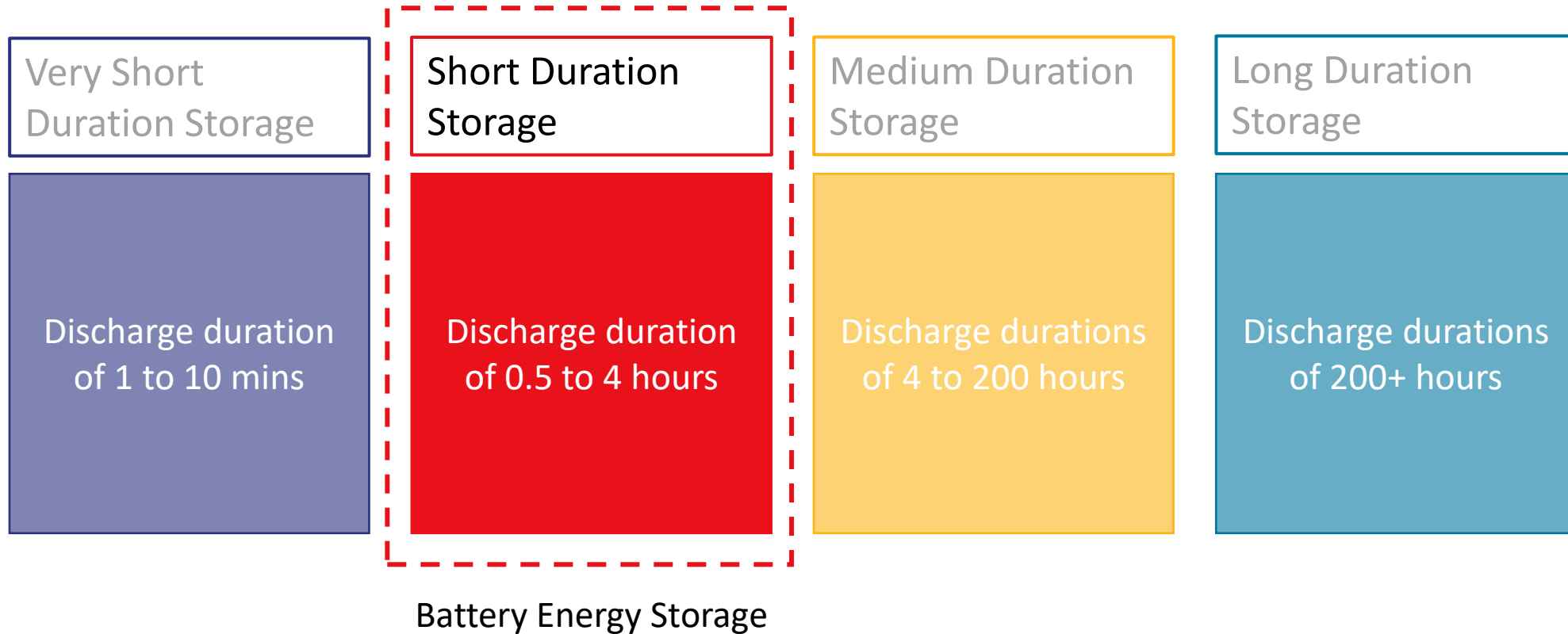
Where do batteries fit in?



The role of batteries in energy storage



Where do batteries fit in?



Talk Overview

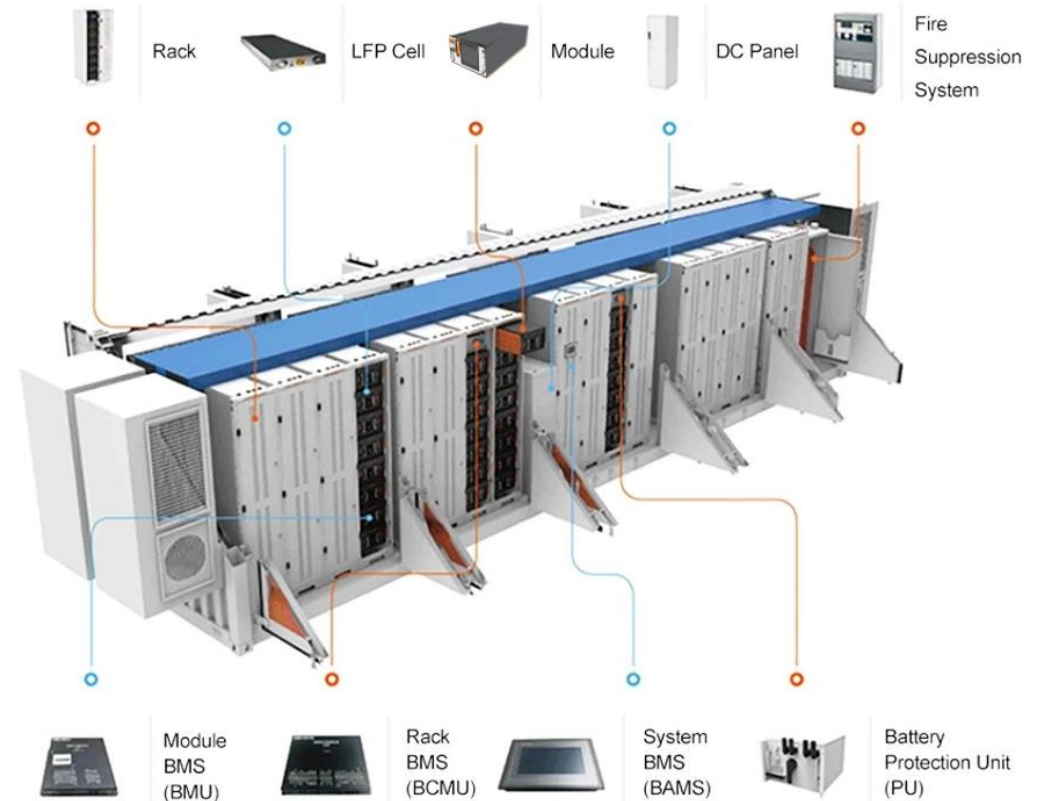


- How are batteries used as energy storage devices?
- What are the key applications of battery energy storage on the grid?
 - Utility scale
 - Behind-the-meter
 - Co-location
- How will these applications change between now and 2030?
- What technologies are used for battery energy storage?

An overview of battery energy storage systems (BESS)



- A battery energy storage system allows electricity from the grid, or from renewable energy sources, to be stored and used later.
- BESS are comprised of:
 - Battery system (battery cells)
 - Battery management system (at the module, rack and system level).
 - Power conversion system
 - Cooling systems
 - Fire suppression systems
- Different battery chemistries may be installed depending on the use.

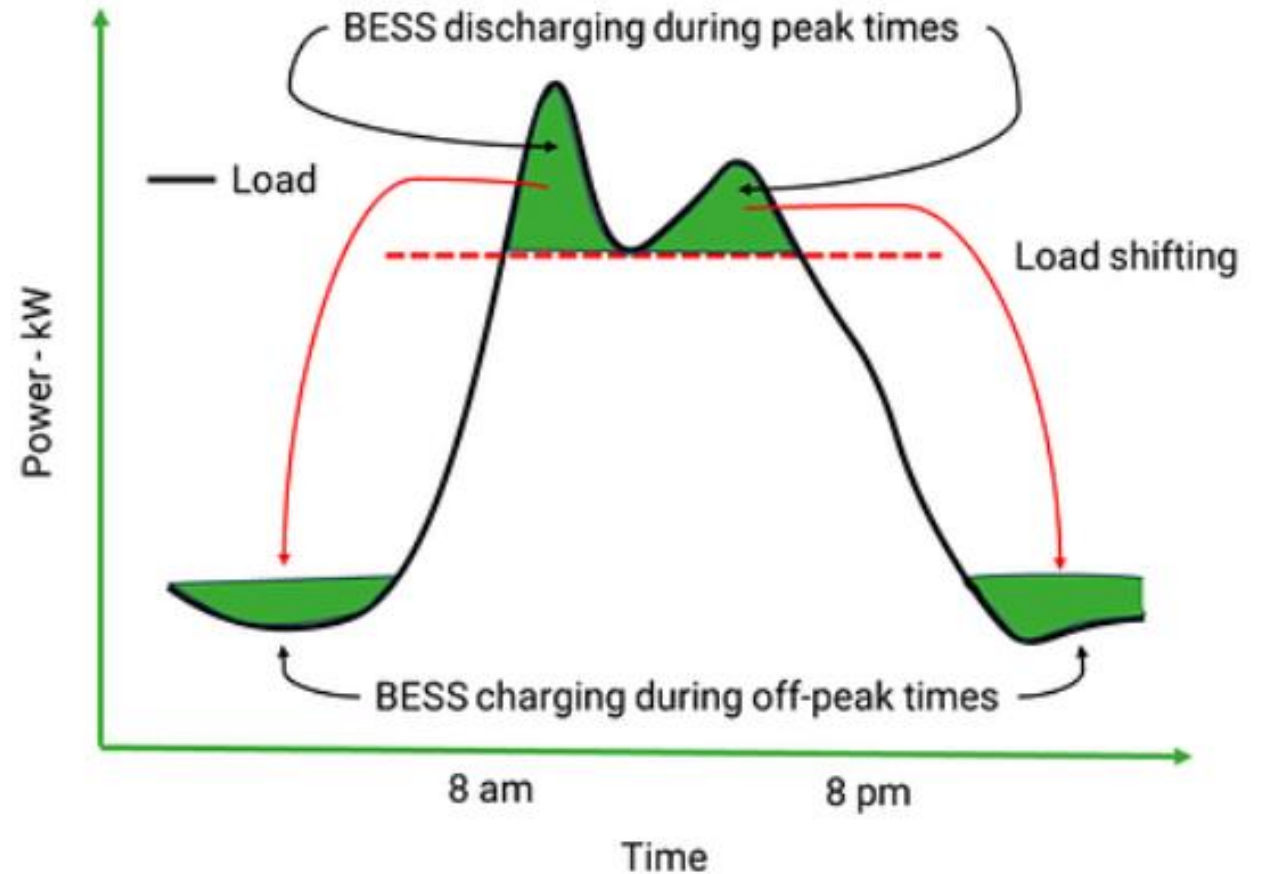


Applications of BESS – Utility scale



Energy shifting

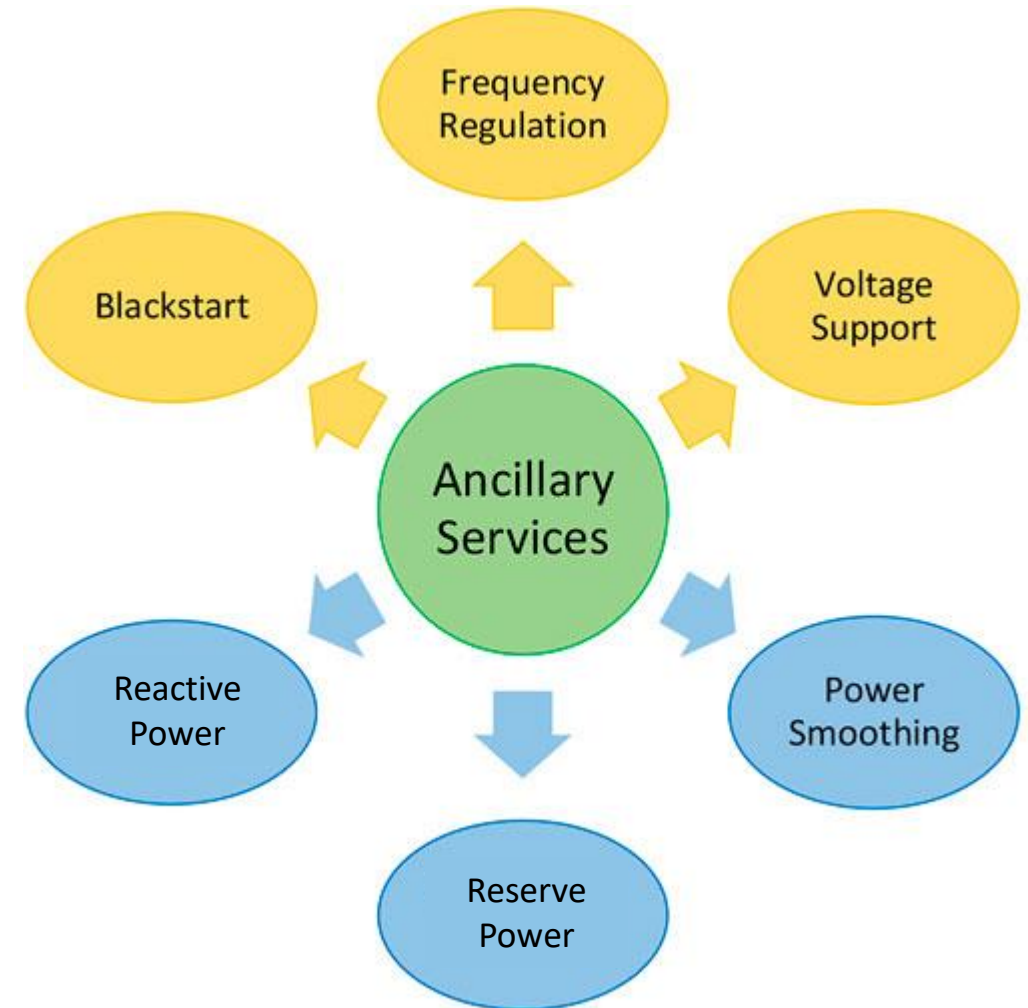
- Energy supply applications for energy storage provide electricity to the grid to help meet demand.
- BESS are charged during periods of low electricity demand, or with excess generation from renewables (energy arbitrage).
- This energy is then supplied back to the electricity grid in periods of peak demand.





Ancillary services

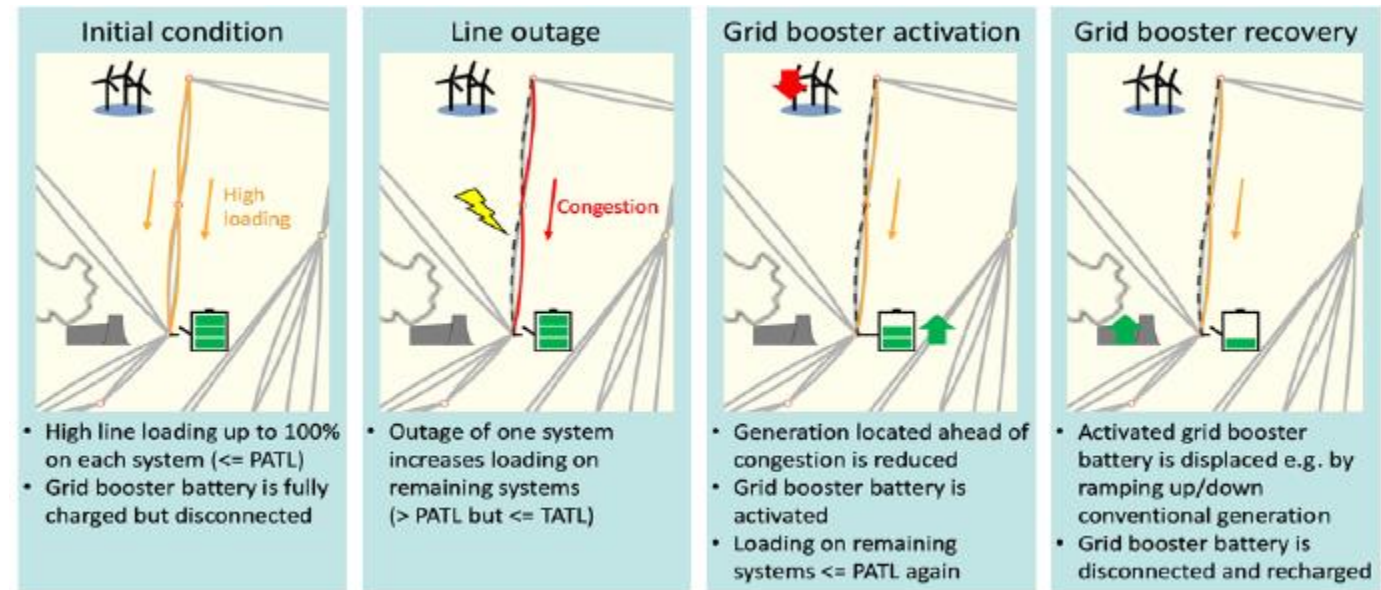
- Refers to a **broad array of services** keeping the electricity grid within its operational frequency requirements and **ensure system stability**.
- Batteries are particularly well suited to frequency regulation applications due to fast response times.
- BESS are being investigated to **provide synthetic inertia** to the grid, as well as providing **black-start capabilities**.





Congestion Relief

- Providing **local flexibility** aims to **alleviate and manage grid constraints** on the transmission and distribution networks.
- These are required when the electricity grid is unable to transmit power due to thermal constraints (or others).
- BESS provides an alternative to these solutions by shifting electricity usage from peak to off-peak periods.



Applications of BESS – co-location and BTM



Co-location

- BESS can be co-located with renewable energy generation to help smooth power output and reduce curtailment.

Residential & Commercial

- Improve the resilience of consumers.
- Increase consumption of on-site renewable energy generation.
- Provide grid connection upgrade deferrals.

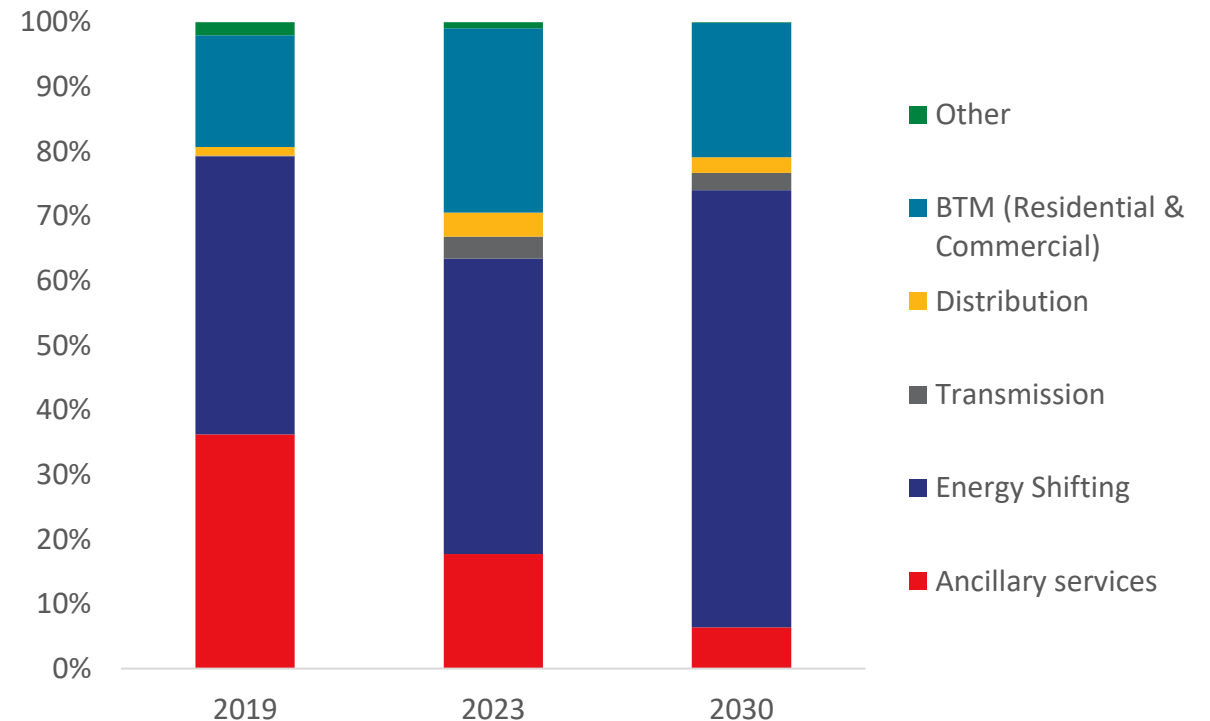


Applications of BESS in the UK – Breakdown of use cases



- BESS are used for multiple applications at once (also known as revenue stacking).
- Initial uses of BESS were focused on ancillary services (requires 0.5 to 1 hour BESS).
- As ancillary service markets become saturated, new revenue opportunities have emerged such as energy shifting (requires 2hours+ BESS).
- This will lead to an increase in the average discharge duration of installed BESS, increasing from ~1.5 hours to +2.5 hours towards 2030.

Breakdown of applications for UK energy storage installations between 2019 and 2030.



Data from BNEF, 2023.

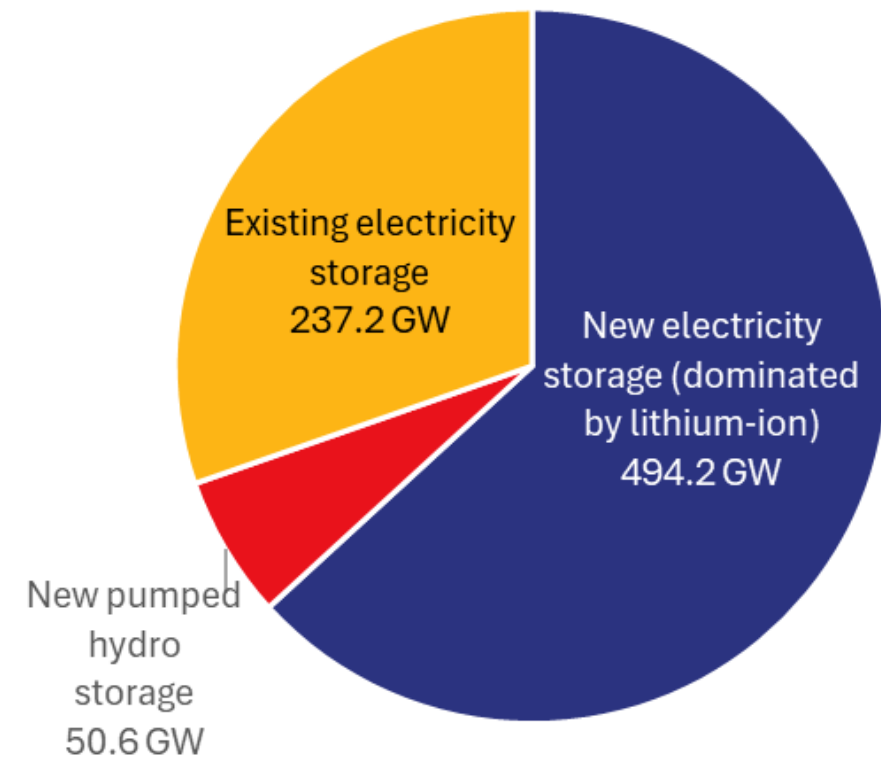
UK BESS Demand and Technologies



Current technologies: Lithium-ion

- UK BESS capacity sits at:
 - In 2024, 3.5GW / 5GWh.
 - By 2030, ~30 GW / 60GWh.
 - By 2050, ~50GW / 100 GWh.
- In 2030, lithium-ion BESS will be the most widely installed energy storage technology globally.
- Lithium-ion batteries are in high demand as:
 - Lithium-ion can be deployed quicker than other storage technologies
 - Lithium-ion batteries are higher performing than other battery chemistries
 - Lithium-ion batteries have benefitted from rapid technological innovation.

Global energy storage capacity landscape in 2030.



Data from CNESA, BNEF, and IEA.



Current technologies: Lithium-ion

- The BESS landscape is dominated by lithium-ion (specifically, LFP batteries).
- **In 2030, lithium-ion BESS will be the most widely installed energy storage technology globally.**
- Lithium-ion batteries are in high demand as:
 - **Lithium-ion can be deployed quicker than other storage technologies**
 - **Lithium-ion batteries are higher performing than other battery chemistries**
 - **Lithium-ion batteries have benefitted from rapid technological innovation.**

Next-generation battery chemistries

- Sodium-ion batteries:
 - Could cost 20-30% less than lithium-ion
 - Will compete with lithium-ion in short duration storage applications.
- Redox flow batteries:
 - Vanadium-flow already in use. Many other chemistries under development.
 - Targeting longer discharge duration applications (~4-8 hours).
- Metal-air batteries:
 - Theoretically very cheap to produce, but low power density and efficiency.
 - Targeting 100 hours discharge durations (Form Energy, US based company).

Concluding Remarks



BESS are well suited to short duration energy storage

- Lithium-ion (in the form of BESS) are the fastest growing energy storage technology today.
- BESS will be used for energy shifting applications on the grid but are also important for ensuring grid stability through ancillary services.
- The average discharge duration of BESS will increase towards 2030 as larger BESS are installed.

Lithium-ion is the technology of choice for BESS towards 2030

- Lithium-ion technology is the driver behind the demand for energy storage globally.
- Lithium-ion batteries are characterised by high power densities and high round-trip efficiencies.
- The cost of lithium-ion cells has fallen dramatically over the past decade, ensuring their use beyond electric vehicles.

New battery technologies are aimed at medium duration storage

- Next generation battery technologies are aiming to reduce the costs of BESS.
- Sodium-ion has the most potential to compete with the lithium-ion batteries of today.
- Redox-flow batteries and metal-air batteries are aiming for medium duration storage.



Thank you



Sodium-ion batteries

- Cons: Lower energy density, but overall similar performance for lower cost.
- Pros: Could cost 20-30% less than lithium-ion (at the cell level).
- Will be used for similar applications to lithium-ion.
- Has the most potential to compete with lithium-ion for market share.
- Sodium-ion BESS were installed in China in 2024.

Redox-flow batteries

- Cons: Very low energy density and lower efficiency.
- Pros: No self-discharge, can decouple power output and energy storage volume.
- Targeting longer discharge duration applications than lithium-ion (~4-8 hours).
- Vanadium-flow batteries are already in commercial use.
- However, many other chemistries are under development in a bid to reduce costs.

Metal-air batteries

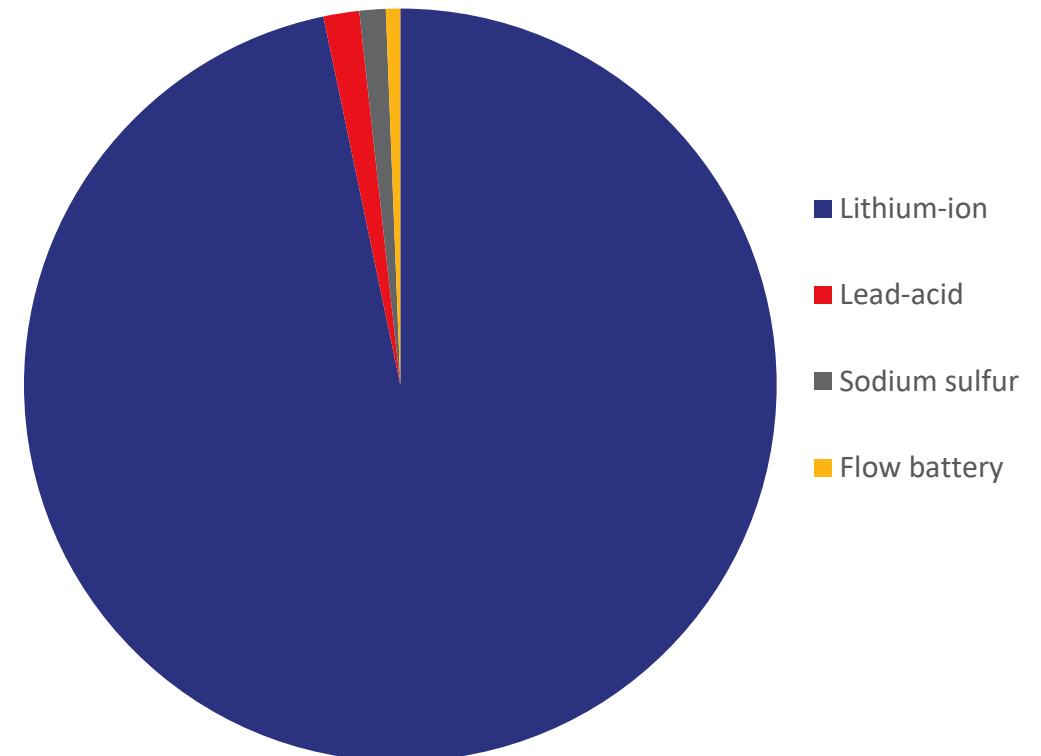
- Cons: Very low energy, power density and efficiency.
- Pros: Theoretically very cheap to produce.
- Targeting 100 hours discharge durations at a tenth of the cost of lithium-ion.
- Most advanced company in this space is US Form Energy.

Why is lithium-ion so good?



- Many legacy battery chemistries have been used in energy storage systems.
- However, the BESS landscape is dominated by lithium-ion (specifically, LFP batteries).
- There are three key reasons for this:
 1. **BESS are modular** and can be **deployed more quickly** than other storage technologies.
 2. **Lithium-ion batteries are higher performing** than other chemistries in key areas, notably **power density** and **efficiency**.
 3. Lithium-ion batteries have benefitted from **rapid technological innovation**.

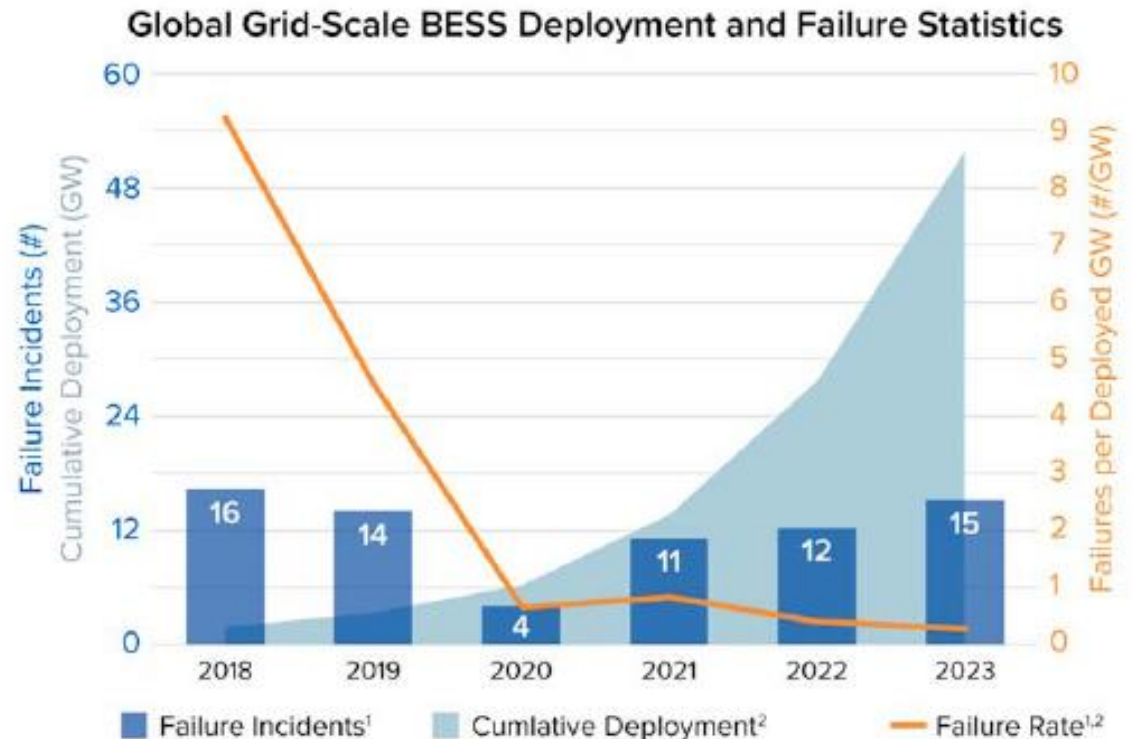
Breakdown of battery chemistries installed in energy storage applications in 2022.



Safety improvements of BESS



- **Safety** is a priority for batteries in energy storage applications.
- Safety concerns are prominent due to the rapid increase in demand for lithium-ion batteries, which has experienced several high-profile incidents in recent years.
- However, **global failure rates of BESS dropped 97% between 2018 and 2023.**
- This is thanks to **lessons learned** from previous incidents have been incorporated into **system designs and safety protocols**



Sources: (1) EPRI Failure Incident Database, (2) Wood Mackenzie. Data as of 12/31/23.

Source: EPRI - Insights from EPRI's Battery Energy Storage Systems (BESS) Failure Incident Database (2024).

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Evidence-based assessments of the market, economics, commercial potential, and capabilities for energy storage technologies and the transition to a fully electric UK.

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The Value of Modelling for Battery Development and Use

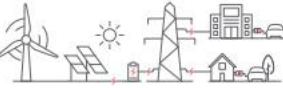


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Batteries are important enablers of clean energy and mobility, but improvements in performance, longevity, safety and sustainability are needed. Battery models used to design a product on a computer save time and reduce the number of expensive physical prototypes needed. Computer models at multiple scales consider not only the properties of materials, components and cells, but also the impacts on pack functionality and across the lifecycle. Model simulations are often the only practical way to predict battery performance or battery failure, ensuring their safe and efficient operation.

Introduction
Energy storage, in the form of batteries, is an important enabling technology for supporting the transition of the UK to a green economy.¹ The high power, energy density and rapid response times of batteries provide power for electric vehicles (EVs), as well as much-needed flexibility for buffering the intermittency of renewable energy sources in domestic and grid installations.

Figure 1: The role of batteries within the electricity and transport systems



Battery models lead to better batteries
Developing a new battery pack with a predefined and well understood operational performance (i.e., rate of battery degradation, temperature performance and control) requires

Image: Simulation of heat generation during discharge across an entire electric vehicle battery pack using Simulink.
¹ The Faraday Institute, www.faraday.ac.uk

Powering Britain's Battery Revolution

UK Research and Innovation

Faraday Insights - Issue 20: July 2024

THE FARADAY INSTITUTION

Developing a UK lithium-ion battery recycling industry



Jonathan Leong, Business Intelligence Manager, Faraday Institution

Establishing a battery recycling industry in the UK will enhance the security of the supply chain for the raw materials needed for EV battery production, while also ensuring the sustainable treatment and management of used materials. At present, recycling is a labour-intensive process, with costs heavily dependent on factors such as battery chemistry, commodity prices and recovery efficiency. Developing and implementing advanced recycling technologies and processes should increase efficiency, reduce costs and help foster a circular domestic battery economy.

Introduction
The transition to electric vehicles (EVs) requires large amounts of raw materials, such as lithium, nickel, cobalt, copper and graphite, to manufacture the batteries that power them. When these batteries reach end-of-life (EOL), it is important that the materials they contain are appropriately managed and their value maintained.¹

The recycling industry will become a substantial global and UK economic opportunity in the 2030s as EV batteries manufactured in the early 2020s reach their EOL. Creating a circular battery economy through recycling in the UK would not only reduce the UK's dependency on importing critical materials, such as lithium, graphite and cobalt, but also reduce carbon emissions, environmental costs and the need for mining virgin raw materials around the world. As such, and as recognised in the UK Battery Strategy, recycling will be a vital part of the development of a more secure and resilient battery supply chain.² The need for this has been exposed by disruptions in global trade as a result of the pandemic and energy crisis. It is also an issue that the UK will find difficult to sidestep as battery recycling will be a necessary component of the EOL waste management of EVs.

Recycling is not the only possible option for EOL lithium-ion batteries but part of a waste management hierarchy (Figure 1) also involving re-use, re-purposing, recovery and disposal. Before recycling and the recovery of materials is undertaken, in many cases cells will be re-used or re-purposed. Re-use involves using the cell again for its initial purpose, such as an EV, after undergoing refurbishment or repair. It is often viewed as the preferred first option as it retains the prior processing value by utilising the cell in another automotive application. Re-purposing involves utilising the cell in an alternative, less demanding application, such as stationary storage, with minimal changes to the cell itself. A potential downside of this approach is that high-specification battery materials are used in lower-grade applications that they are neither needed for, nor best suited to (delaying recovery of materials that could be used for the remanufacture of future batteries). Disposal is the least attractive option, as ecological and environmental damage is of concern due to the potential leaching of toxic materials, as well as the loss of valuable minerals. Batteries are banned from being incinerated or dumped into landfill in the UK under the Waste Batteries and Accumulators Regulation 2009.

Image: Shredded battery feedback. Courtesy of R&I-B project, University of Birmingham.
Image: Leong, J. (2024) Recycled lithium-ion batteries from electric vehicles. Department for Business and Trade (2022). UK Battery Strategy.

Powering Britain's Battery Revolution

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THE FARADAY INSTITUTION

Improving the Safety of Lithium-ion Battery Cells



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Lithium-ion battery cells in electric vehicles are already safe and failure incidents are very rare. But with increasing use across automotive, stationary storage and other sectors, there is a need to make them even safer. Whilst lithium-ion cell fires are extremely infrequent, they can occur under conditions of mechanical, thermal or electrical stress or abuse. Building safer and more reliable lithium-ion battery packs, as well as improving the design and optimisation of safety systems, will help to decrease the risks associated with rising lithium-ion battery usage.

Introduction
Even with billions of lithium-ion cells in circulation, there are very few safety incidents involving them, which is a testament to how safe they are. Rates of catastrophic cell failure and associated battery fires involving lithium-ion cells remain extremely low, with some estimates suggesting that only one in 40 million cells suffers such a failure.¹ But with an increasing range of use cases for lithium-ion batteries (LiBs), spanning electric vehicles (EVs), heavy goods vehicles, aerospace, micromobility and consumer electronics, as well as in second-life applications, the potential for problems is increasing. There is, therefore, a pressing need to improve LiB safety still further.

As well as protecting end users, improving battery safety has economic benefits. Increasing the reliability of lithium-ion battery cells could allow EV automakers to reduce the complexity of their systems, saving space, weight, and system and warranty costs.

This insight looks at the routes to LiB failure, the different risks involved and the way fires in EVs differ to those in internal combustion engine (ICE) vehicles. It considers current mitigations in place and the additional mitigations that could

be implemented to further reduce these risks. It also sets out the work that the Faraday Institution SafeBat project is undertaking to develop safer LiBs.

Routes to Cell Failure
When LiB fires do infrequently occur, the cause is generally due to the following forms of stress or abuse:

- Mechanical** - An internal defect introduced during manufacture or damage caused to the cell by crushing or penetration (for example, from an EV collision or penetration by a sharp object) can lead to an internal short circuit. Shorting results in an excessive current flowing through the circuit, causing heating above safe limits, cell damage and, in some circumstances, may ignite a fire.
- Thermal** - Overheating the cell (for example, if exposed to an external fire) causes the cell components, such as the cathode and electrolyte, to break down. These processes are heat-generating (i.e. exothermic), resulting in a feedback loop where the cell temperature spirals upwards and eventually results in a fire. This is referred to as 'thermal runaway'. Overheating can also result in the softening or melting of the separator between the two electrodes (generally a polymer such as polypropylene), which can lead to an internal short circuit.

¹ Hill, Douglas and F.C. Bell, 'A General Discussion of Li-Ion Battery Safety', 2012 *Electronics Soc. London*, 21, 32.

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