Integration of Battery Storage into Distribution Networks

Based on content from Cigre WG C6.30

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Introduction

WHY is there interest in installing battery energy storage systems (BESS)?

WHEN is the growth of BESS in distribution networks likely to take place?

WHAT is being installed?

HOW are BESS being considered in the planning and operation of networks?

WHERE is seeing the highest uptake of BESS?

WHY is there interest in installing BESS?

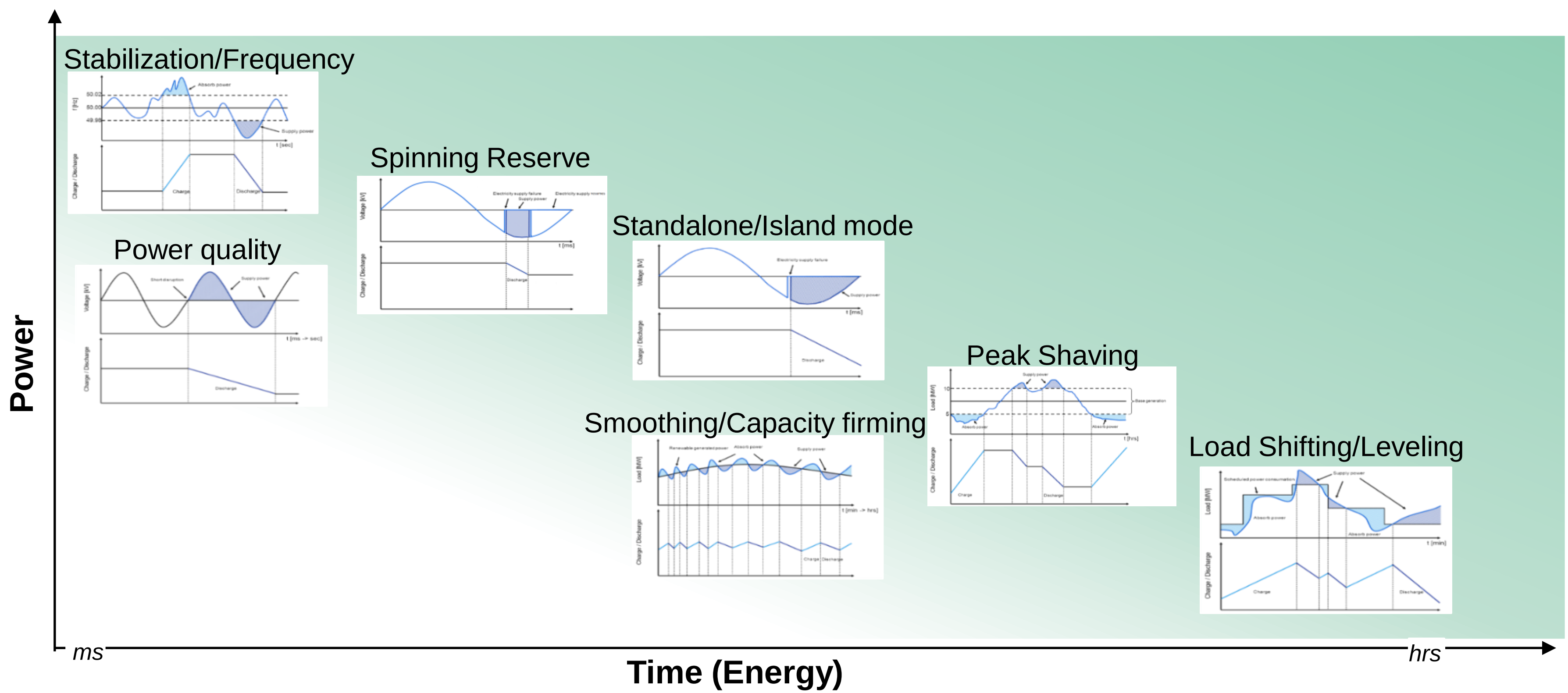
Why?

The flexible characteristics of BESS enable a range of benefits

Load levelling and peak shaving	Benefits are related to averaging out feeder loading which can be used for deferring or avoiding distribution network upgrades, and transmission capacity increase
Ancillary services	Benefits in the form of frequency regulation, power quality, spinning reserve, voltage regulation and power system oscillation damping
Balancing renewable energy	Benefits associated with balancing and firming-up renewable energy outputs, which can be considered across a range of time-scales and purposes
Energy Arbitrage	Benefits from purchasing electricity at a lower cost and selling at a higher cost, where electricity market conditions provide such opportunities
Resiliency	Benefits related to blackout ride-through and serving loads during outages, including back-up power to critical loads and enabling islanded operation

Why?

Benefits relate to both power and energy functions

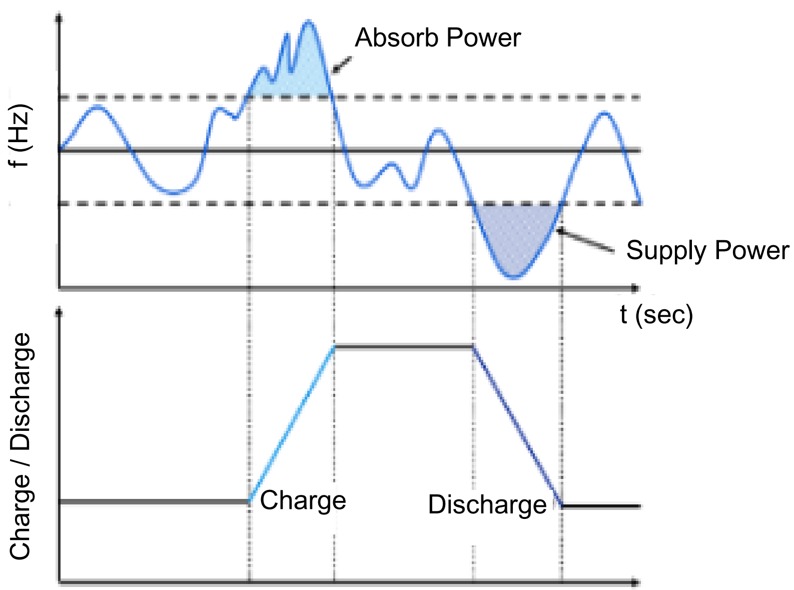


Source: ABB

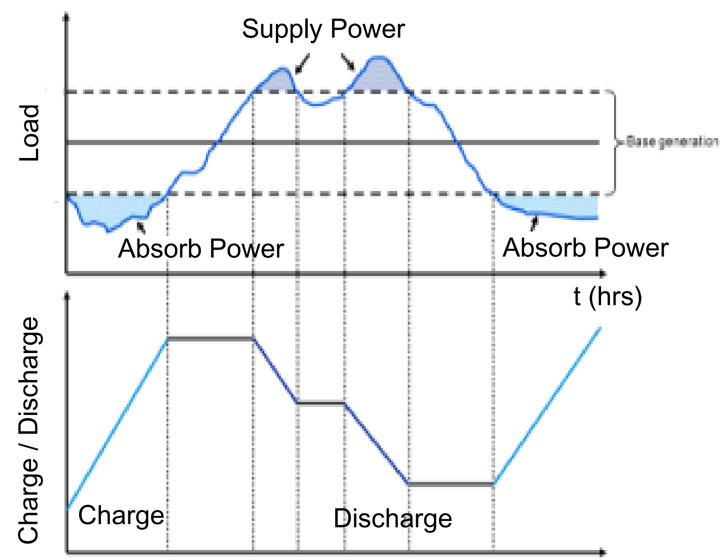
Why?

Benefits enabled through ability to both supply and absorb power

Frequency Response



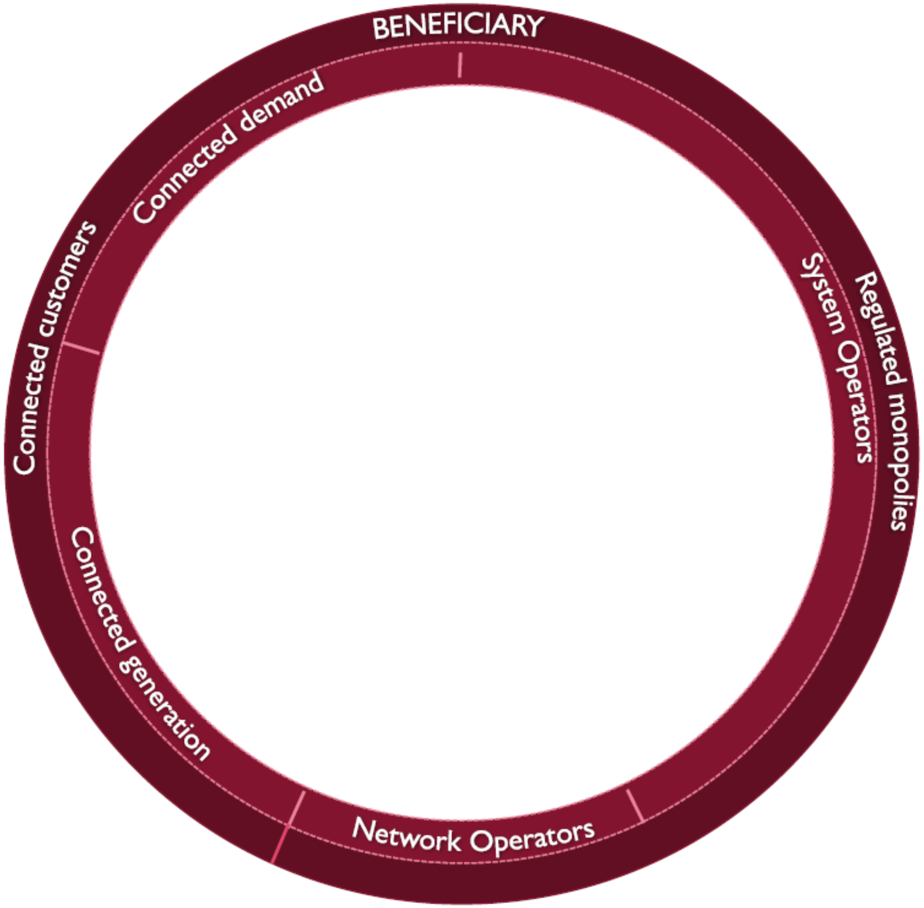
Peak Shaving



Source: Modified from ABB

Why?

Benefits can accrue to a range of stakeholders



Source: Everoze

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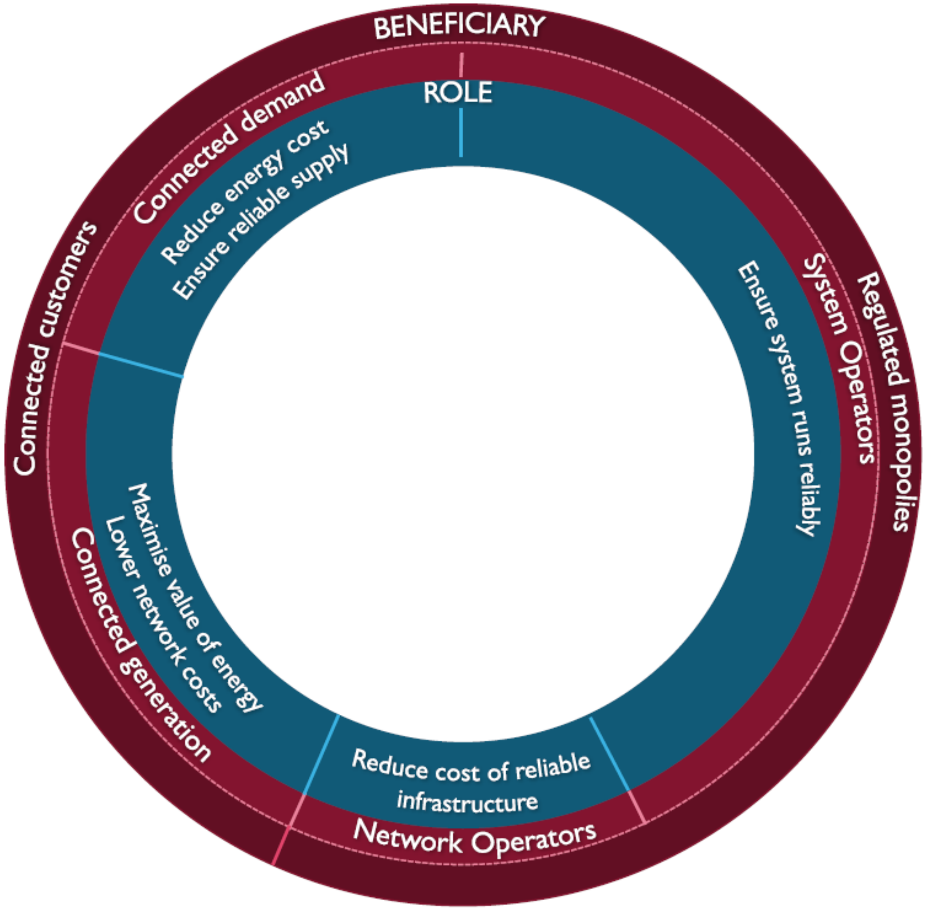
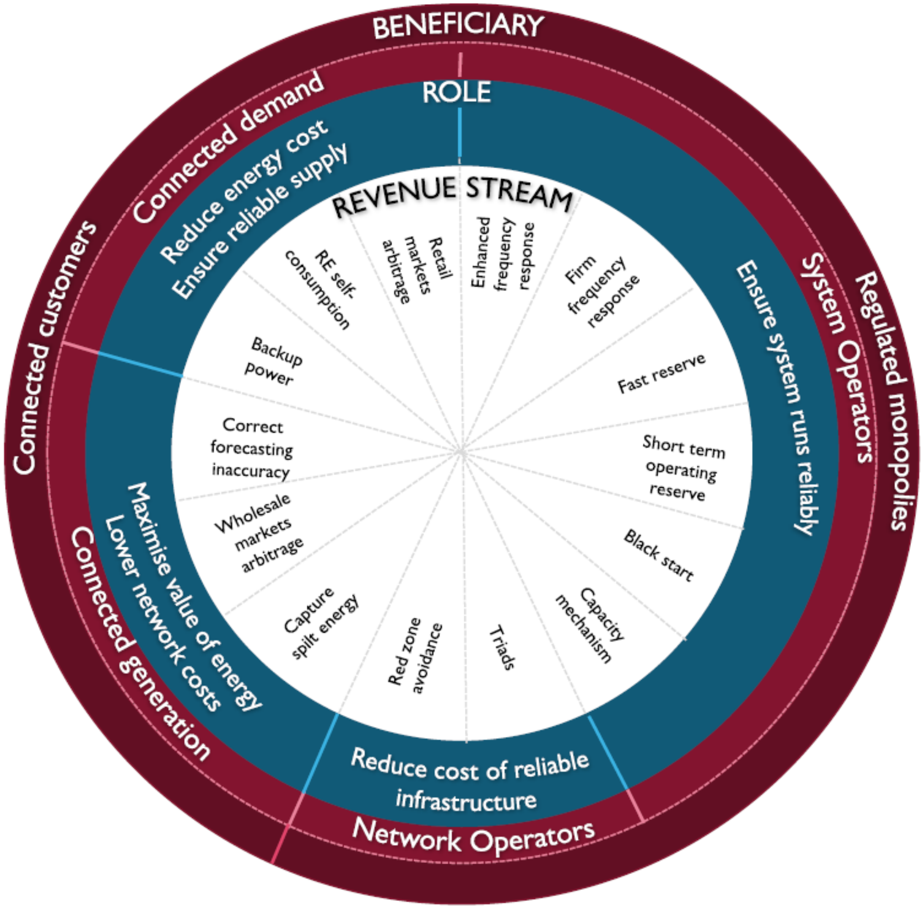


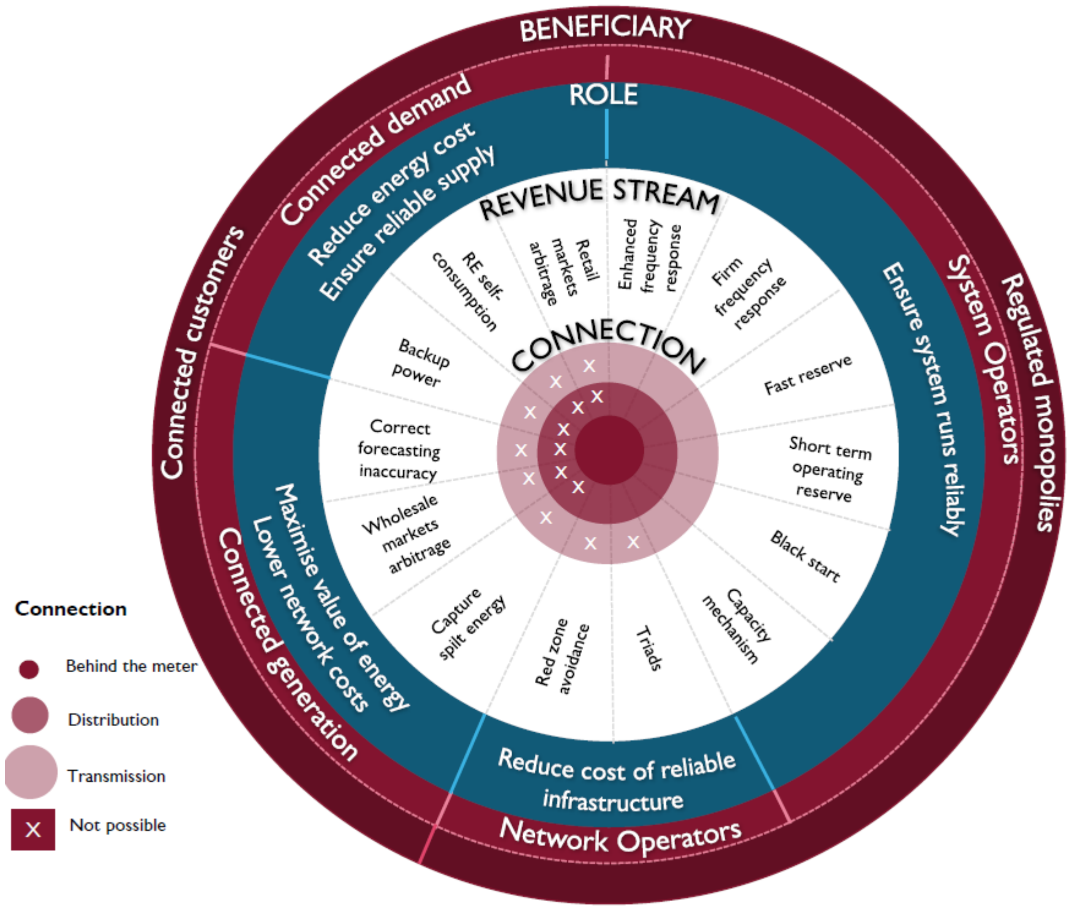
Source: Everoze

Benefits can accrue to a range of stakeholders, with some existing revenue streams



Source: Everoze

Provision of benefits and access to revenue streams affected by where connected



Source: Everoze

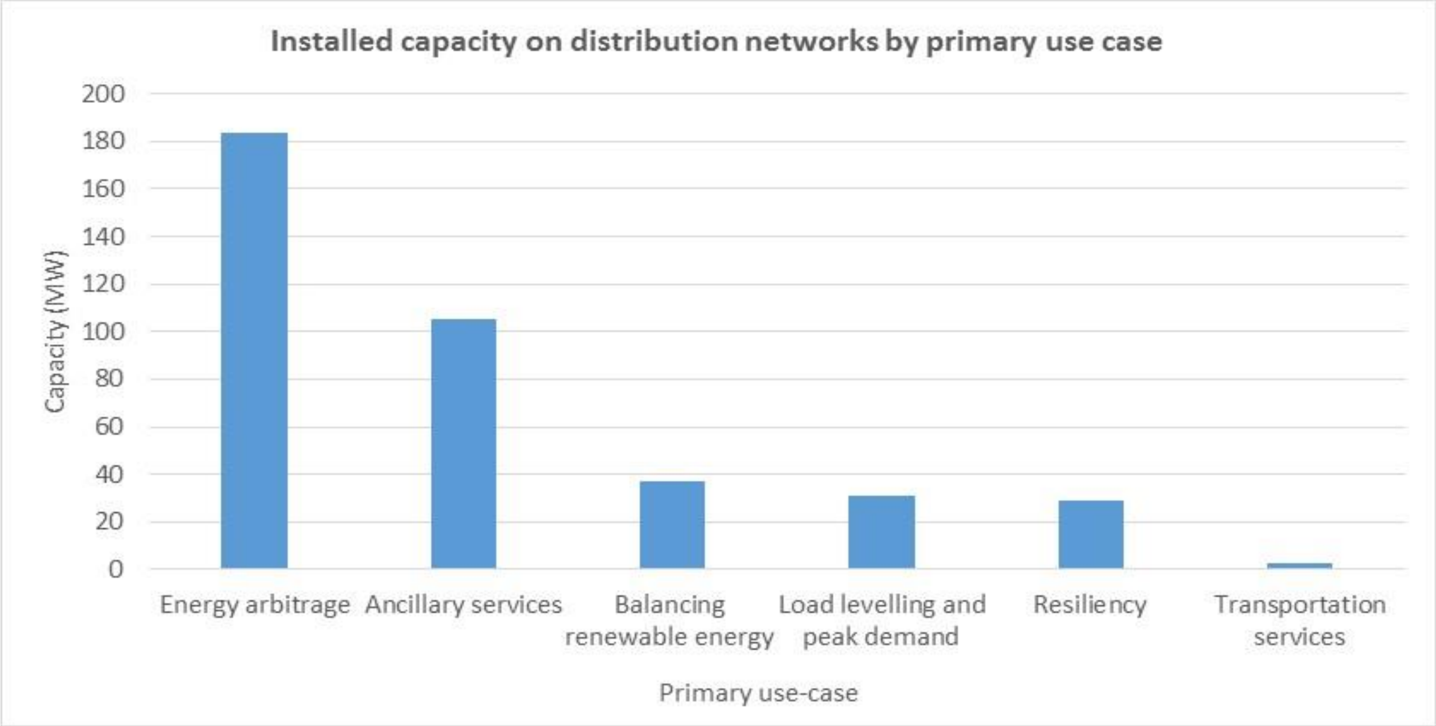
Business case development can be complex

Examples of complexity:

- Each installation is unique e.g. benefits dependant on owner, application and market
- Market and regulatory frameworks vary around the world
- Benefits without market revenue streams may be difficult to quantify e.g. value of resilience
- Available revenue streams may not capture all services which BESS can provide, however new opportunities may emerge over the life of the asset
- Size of revenue streams may change over time
- Size of BESS affects the applications which can be provided and the asset cost
- Stacking of revenues is often required with complexity around optimisation and compatibility
- Duty cycle to deliver applications has impact on life of asset
- Charging and discharging incurs losses which should be considered in calculations

Why?

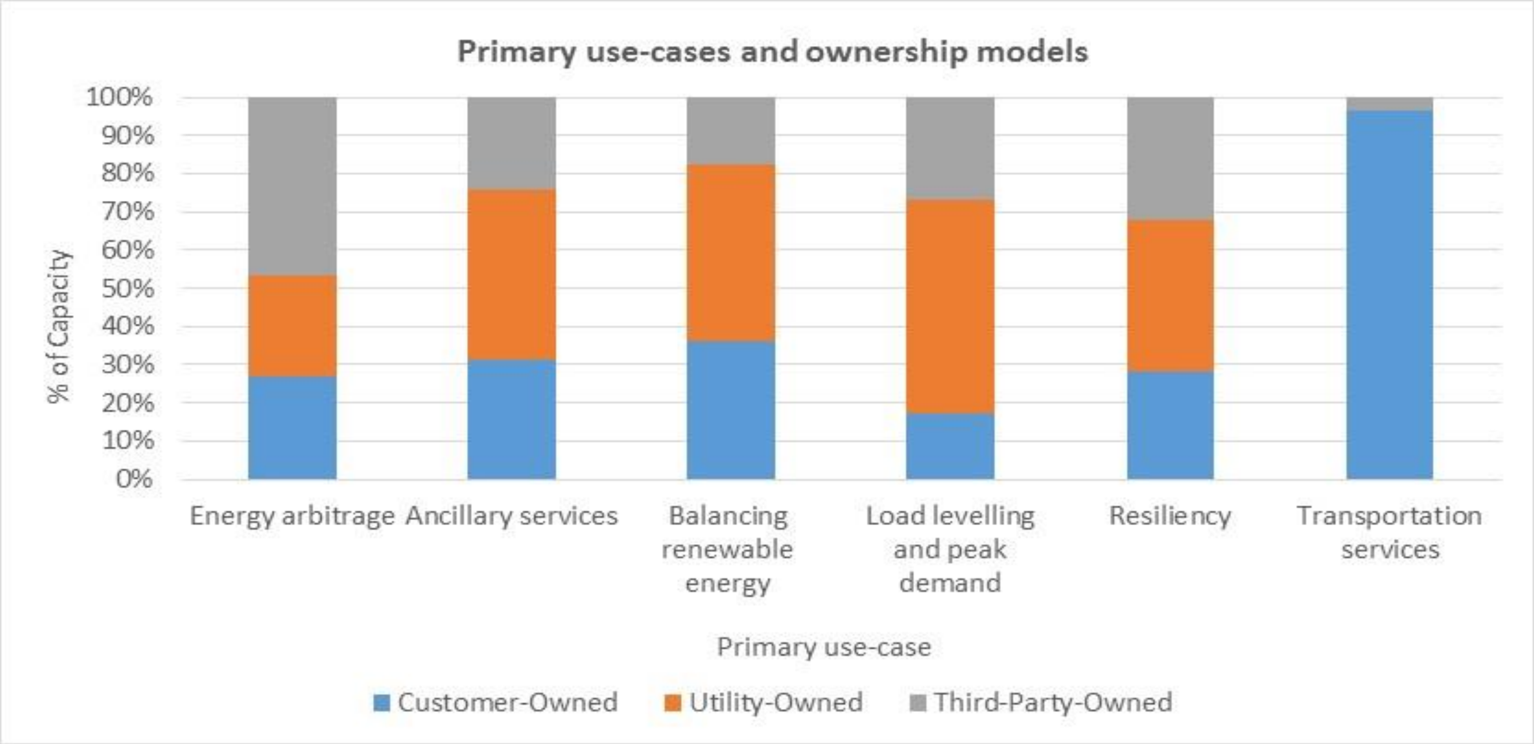
International experience indicates energy arbitrage and ancillary services are the main primary use cases for BESS connected to MV distribution networks



Source: WG C6-30 – Analysis of DOE database , July 2016

Why?

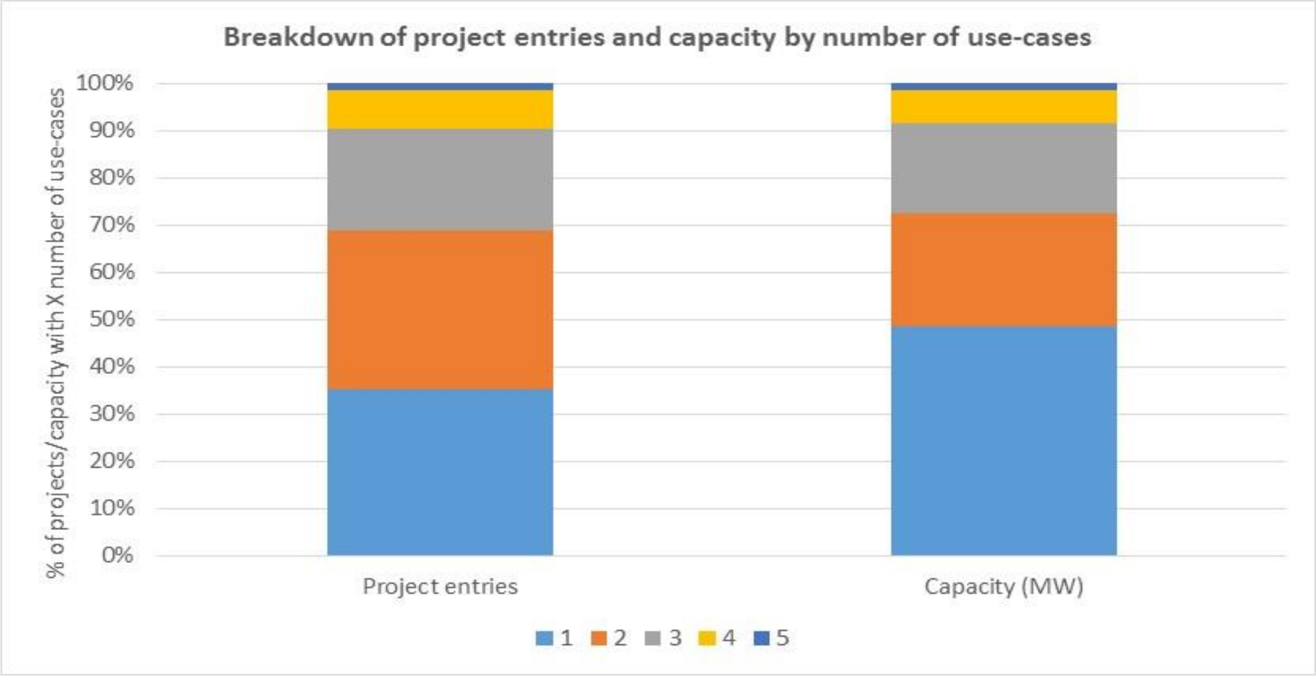
In general all ownership models can support the primary use cases. Utility-owned storage tends to be more focussed on load levelling and peak demand



Source: WG C6-30 – Analysis of DOE database , July 2016

Why?

Many installations provide more than one application

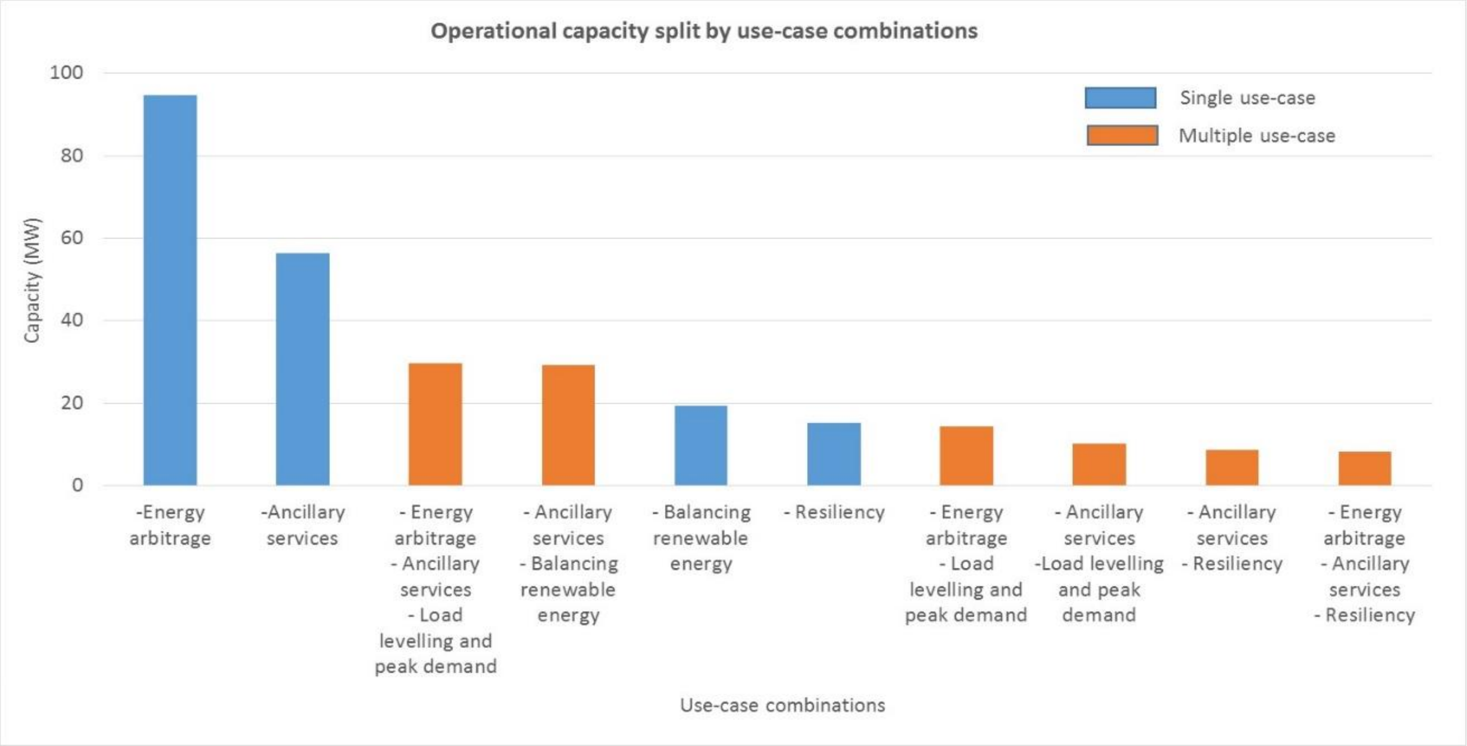


65% of project entries (51% of capacity) had more than one use-case assigned but this does not necessarily mean they are multiple-use applications. Use-cases referred to may not necessarily have associated revenue, and the use-cases selected and initially envisioned for the project may be shown to not be suitable in the case of trial projects.

Source: WG C6-30 – Analysis of DOE database , July 2016

Why?

The most used combinations are energy arbitrage and ancillary services as single use-cases. These also appear in the multiple use-case combinations in the top 10



Source: WG C6-30 – Analysis of DOE database , July 2016

Why?

In the UK, the provision of frequency response has been a key application

- 2015 Enhanced Frequency Response (EFR) tender created tremendous interest in energy storage, with DNOs receiving thousands of connection requests. Contracts were however awarded to 8 utility-scale installations.
- Firm Frequency Response (FFR) has been a key revenue stream for distribution connected storage. Capacity Market (CM) has also been source of a revenue. Aggregators have provided access to these markets for batteries which do not meet minimum size requirements.
- Rising non-commodity costs has increased interest in industrial behind-the-meter installations.

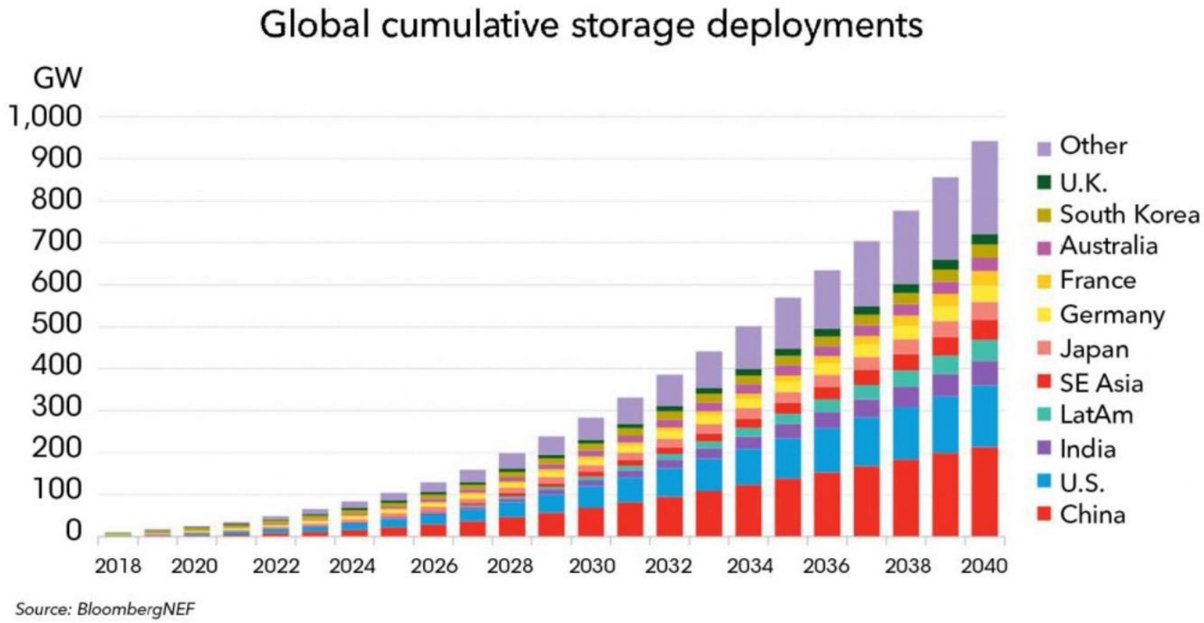
Existing revenue streams are however declining, with new opportunities emerging

- Existing revenue streams declining:
  - FFR prices fallen due to competition
  - CM suspended
  - Proposed changes to network charging – reduced opportunity for non-commodity cost reduction
- New opportunities emerging:
  - Energy arbitrage could become a more important revenue stream
  - Enhanced frequency control capability trial
  - Introduction of DNO flexibility markets
  - Wider use of time-of-use tariffs

WHEN is the growth of BESS in distribution networks likely to take place?

When?

Significant global growth in energy storage expected for all connection levels



- BNEF forecast that the majority of storage capacity will be utility scale until the mid-30s when behind-the-meter applications will overtake.
- Approx. 22GW of energy storage is forecast to be installed in the UK by 2040

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UK battery storage market has already seen signs of growth

2018 Figures:

0.6GW installed

4.8GW planned

10,000 home batteries

c. 0.5GW distribution connected

RenewableUK database launched in Nov 2018 quoted 3.3GW operational storage capacity. Value included pumped hydro which is understood to be c. 2.7GW.

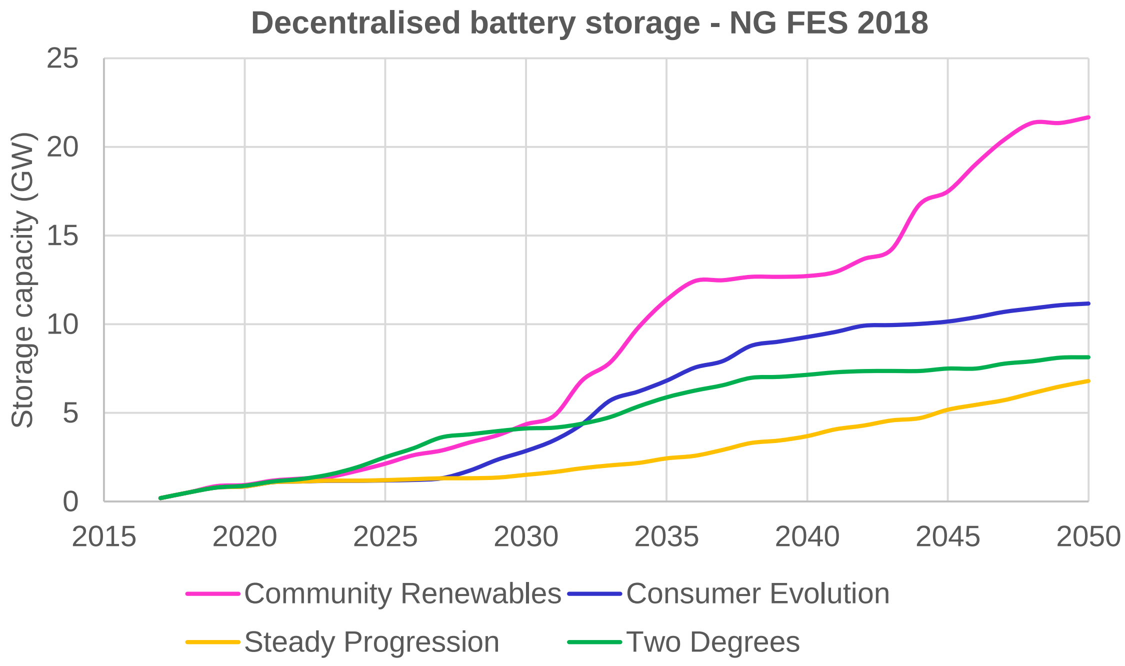
NG FES assumed c. 660MW for 2018, with 514MW being distribution connected

RenewableUK database – Nov 18

Guardian article – June 2018
https://www.theguardian.com/environment/2018/jun/27/uk-home-solar-power-subsidies-costs-battery-technology

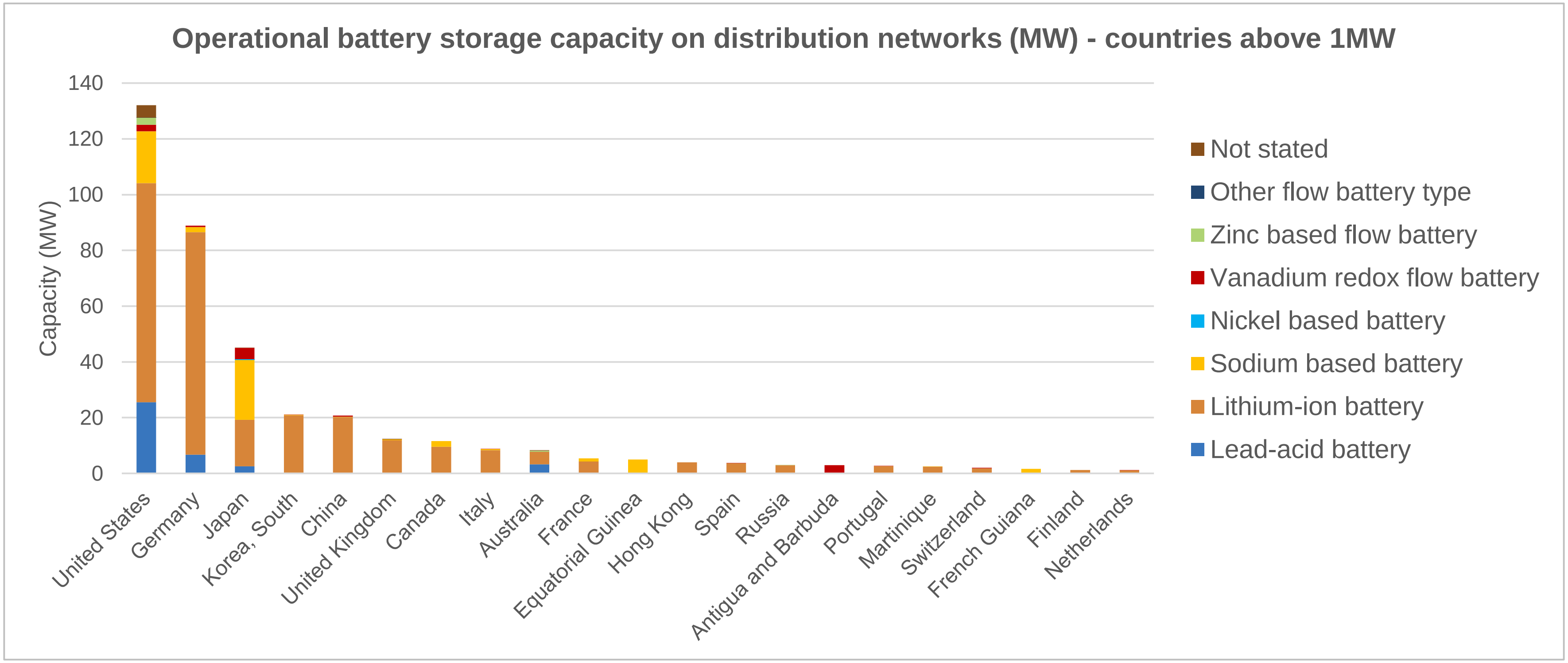
When?

Even in National Grid’s more conservative scenario, distribution connected storage could triple by 2030, and at least triple again by 2045



WHAT is being installed?

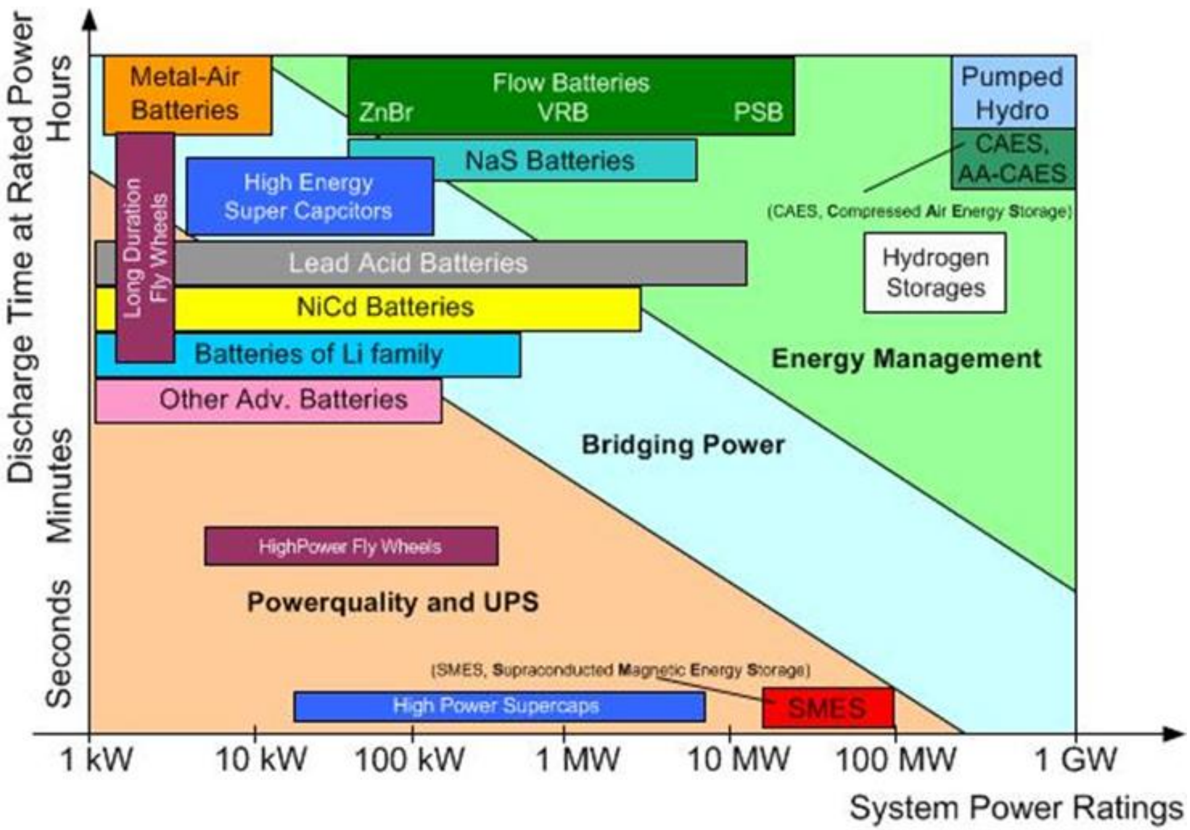
Lithium-ion is the dominant battery technology



- c. 70% of capacity is from Lithium-ion batteries (2016)

Source: WG C6-30 – Analysis of DOE database , July 2016

Different energy storage technologies are suited to different applications



Source: EPRI 2010

Range of other considerations may affect technology choice

Lithium-Ion

- Declining prices
- Relatively high energy density and good cycle life
- Some variants susceptible to thermal runaway

Lead-acid

- Well-established and relatively low cost
- Relatively low energy density and limited cycle life

Sodium-Sulphur (NaS)

- High energy and power density, cycle-life and efficiency
- Requires high temperature to operate, and careful management of safety risks

Nickel-Cadmium (NiCd)

- Well-established with a relatively simple management system
- Relatively low energy density and mid cost

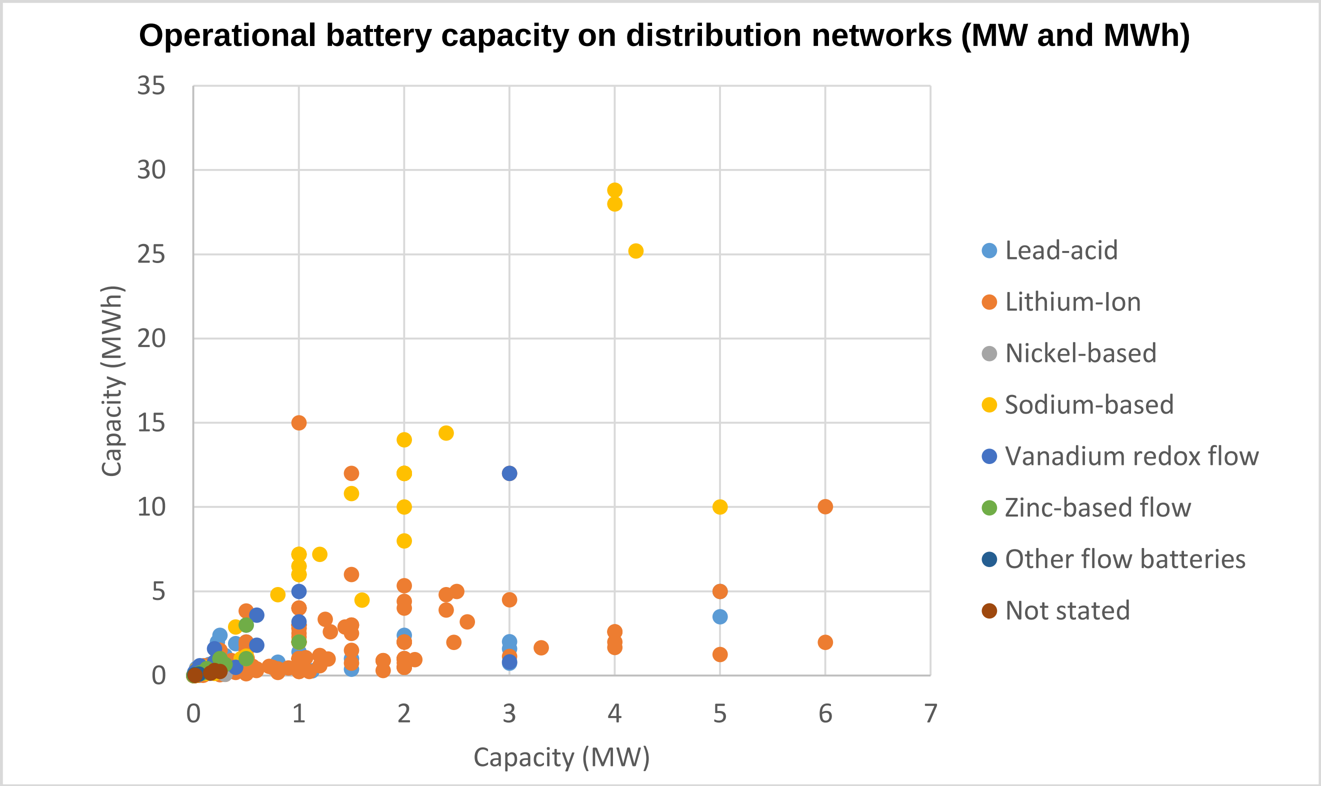
Flow Batteries

- Decoupled power and energy ratings
- Lack of capacity degradation
- High cycle life
- High cost, but can be cost-effective if life considered

Sodium-Ion

- In development - being researched as an alternative to lithium-ion due to accessibility and low cost of sodium. Performance challenges to overcome.

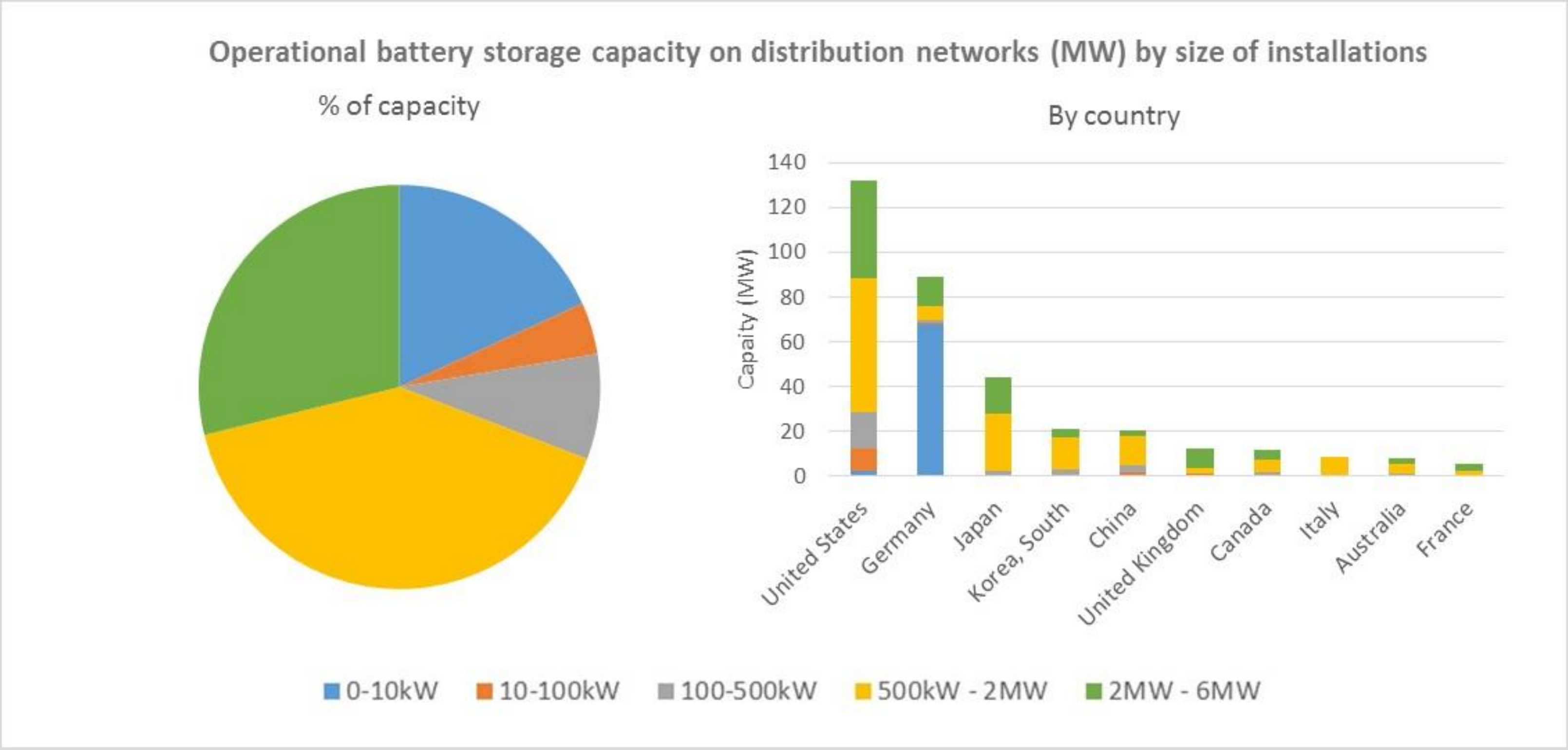
A range of battery sizes (power and energy) are installed



Source: WG C6-30 – Analysis of DOE database , July 2016

What?

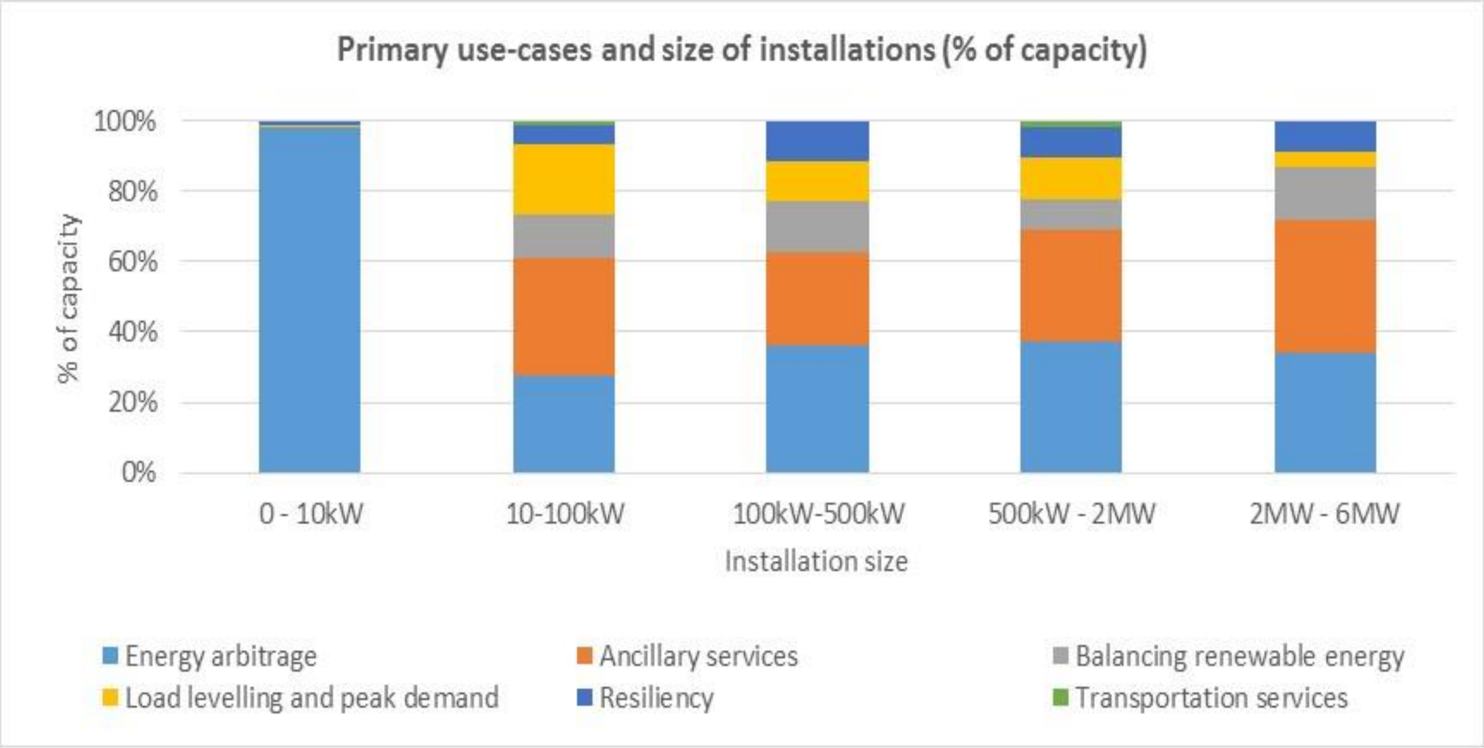
Medium installations (10kW – 2MW) make up around half of the installed capacity, with the breakdown of capacity by installation size varying by country



Source: WG C6-30 – Analysis of DOE database , July 2016

What?

Whilst size is a key design factor to be optimised, analysis suggested that in general most sizes are able to support all use-cases.



Source: WG C6-30 – Analysis of DOE database , July 2016

HOW are BESS being considered in the planning and operation of networks?

How?

Traditional static assessment methods are typically used to assess BESS connection requests and represent BESS in distribution planning models

- Planners may need to consider system impacts such as:
  - Thermal network constraints
  - Voltage (over and low voltages)
  - Effects on protection
- Traditional static assessment methods typically used based on a worst-case scenario. As BESS acts as a source and load need additional assessment beyond single instantaneous peak.
- Intended use may be taken into account in connection quotes

Type of storage use	Connection capability	Examples of services	Relative network cost/Impact
Response	Full import and export. Full power swings.	Enhanced / firm frequency response to NGET.*	£
Reserve	Full export, limited import capacity. Managed power swings.	STOR, capacity markets, DSO support (future)	£
Price and Time shift	Limited import and export capacity. Managed power swings.	Behind the meter, time of day trading, load shifting	£

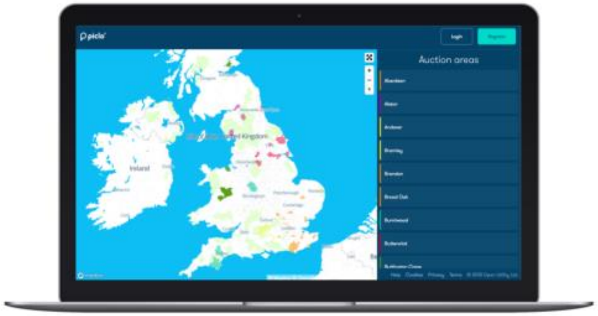
Source: ENA

- P2/7 will formally allow UK DNOs to recognise the contribution DER can make to security of supply
- Active distribution system planning methods being developed as a result of increased DER in general.

How?

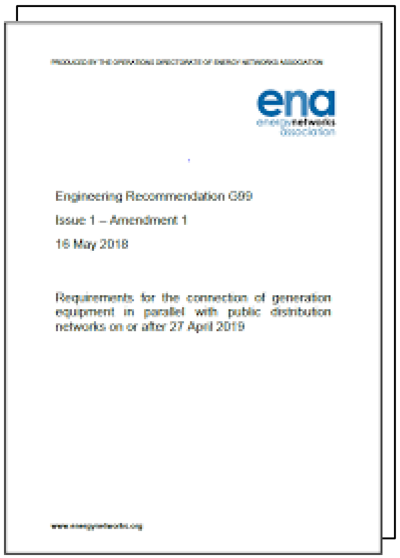
UK DNOs will not be able to operate BESS. Markets are being developed, which will allow DNOs to benefit from flexibility services including BESS

- From April 2019 DNOs will be prohibited from operating storage, unless captured by an exception
- DNOs are committed to opening up flexibility markets and to comparing relevant reinforcement and market flexibility solutions for all new projects of any significant value.
- Flexibility markets are technology agnostic, but storage is likely to be an important provider of services
- Progress to date mainly involves bilateral contracts, online platforms being trialled including PicloFlex



Source: Piclo

GB distribution connection standards have limited requirements for BESS


Engineering Recommendation G99

Issue 1 – Amendment 1

16 May 2018

Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019

Source: ENA

- In April 2019, G99 and G98 replace G59 and G83, incorporating European network code changes
- For BESS minimal change – loss of mains protection still required to prevent islanded operation
- New requirements have been placed on generation excluding storage (limited frequency sensitive mode). Fault ride through and reactive current injection during transmission fault is also required.
- European network codes may be changes to include storage, but changing European legislation could take around 5 years.

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How?

International standards exist which apply to BESS integration

IEC

- IEC 62933 standards – Electrical Energy Storage (EES) systems
  - Part 1: Vocabulary
  - Part 2-1: Unit parameters and testing methods – General Specification
  - Part 3-1: Planning and performance assessment of electrical energy storage systems – General specification
  - Part 4-1: Guidance on environmental issues – General Specification
  - Part 5-1: Safety considerations for grid-connected EES systems – General specification
- IEC 61850 – Substation automation
  - IEC 61850-90-9, Use of IEC 61850 for electrical storage systems

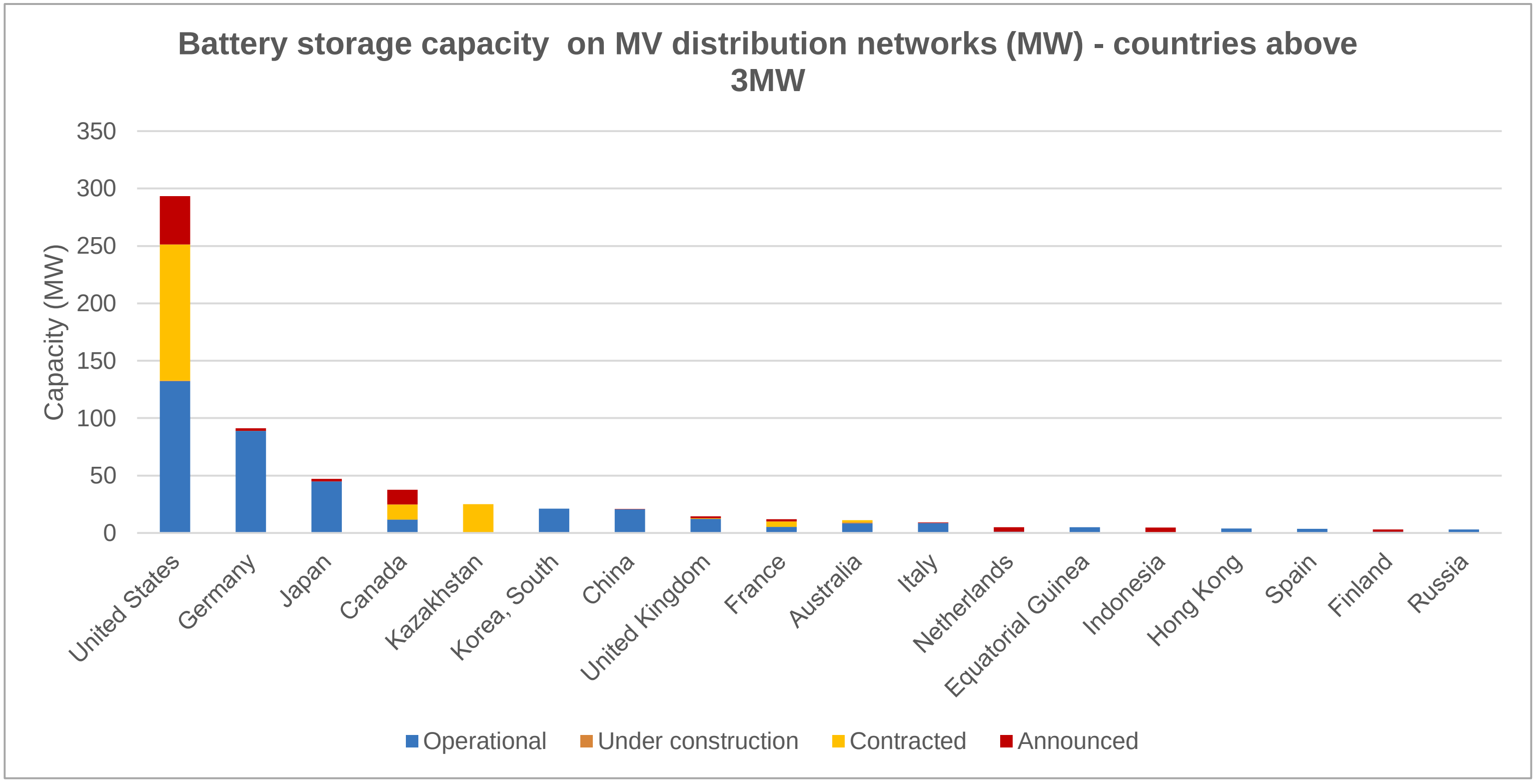
IEEE

- IEEE 1547 standards – DER integration
- IEEE 2030 standards – Smart grid
  - IEEE P2030.3 – Standard for Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications

WHERE is seeing the highest uptake of BESS?

Where?

BESS is being installed in distribution networks around the world



Source: WG C6-30 – Analysis of DOE database , July 2016

Where?

Range of drivers, support and challenges in some of the most active countries

United States

- Interest since 1970s oil crisis
- Federal initiatives such as SGDP helped to fund demos
- Growth driven at state level including through incentives and procurement targets
- Addressing regulatory barriers

Germany

- Ambitious energy transition - 80% renewables by 2050
- Funded research and demos
- Significant PV with grants and low interest loans for storage + PV, plus innovative residential business models

Japan

- Addressing energy challenges following Fukishima incident
- Aim for Japanese companies to gain 50% global battery market
- Strong government support with significant annual subsidies.
- Funding for large scale demos

South Korea

- Supporting ambitions to reduce dependence on imported energy, and become leader in green tech
- Significant investment incl. R+D
- Frequency regulation key market
- Vision to build nationwide smart grid by 2030

China

- Key for emission reduction and smart grid for economic growth
- Rapid growth of renewables led to high curtailment – addressing
- Rapid development + significant manufacturing capabilities
- Growing policy support

Australia

- Increased interest following widespread blackouts in 2016
- Debate around federal energy policy. State policy and initiatives driving growth, particularly in S.A.
- Significant domestic growth-high PV, high elec cost, incentives

In the UK storage is considered to be important in meeting climate change targets

United Kingdom

- Important technology in helping to meet climate change targets of reducing CO_2 emissions by 80% by 2050, by facilitating wide-spread distributed renewables and increasing system flexibility (Clean Growth Strategy)
- Investing in R+D considered to be opportunity for supporting UK economy (Industrial Strategy)
- Initiatives predominantly related to ensuring a level playing field and investing in research and innovation
- **Smart Systems and Flexibility Plan** important part of Clean Growth Strategy and Industrial Strategy
  - Addressing previous issues of storage being charged as both generation and demand – including in relation to charges for use of network, and final consumption levies
  - Work ongoing more broadly around clarity of treatment of storage
  - Innovation funding including Faraday Battery Challenge
  - Broader initiatives which affect business case for storage e.g. potential move to market-wide half-hourly settlement which could enable wider use of TOU tariffs, opening of flexibility markets, wider access to balancing services market.
- Other initiatives – tax break (5% VAT) for domestic storage if installed with a new PV system.

Summary

WHY is there interest in installing battery energy storage systems (BESS)?

Flexible characteristics of BESS can enable a range of benefits, accrued to a range of stakeholders

WHEN is the growth of BESS in distribution networks likely to take place?

Existing signs of growth, with significant growth expected. UK decentralised storage could triple by 2030

WHAT is being installed?

Lithium-ion is the dominant battery technology. Range of battery sizes (power and energy) being installed

HOW are BESS being considered in the planning and operation of networks?

Traditional planning methods used to assess BESS applications. Markets to be used to procure flexibility

WHERE is seeing the highest uptake of BESS?

Being installed around the world including US, Germany and Japan, with range of drivers and support

Thank-you

Members can access the report for free at:

https://e-cigre.org/publication/721-the-impact-of-battery-energy-storage-systems-on-distribution-networks

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