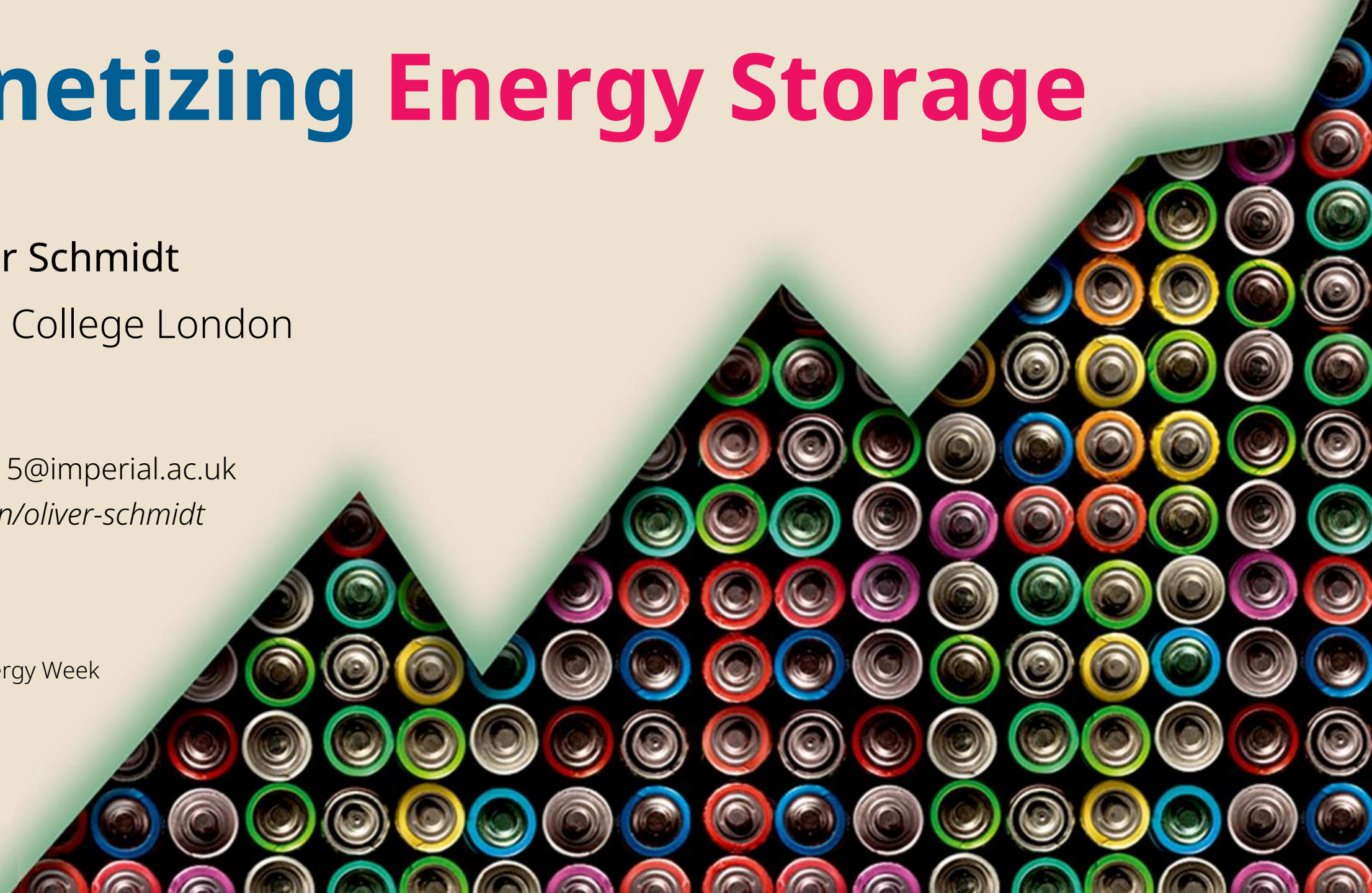
Monetizing Energy Storage

Dr Oliver Schmidt

Imperial College London

o.schmidt15@imperial.ac.uk

.com/in/oliver-schmidt

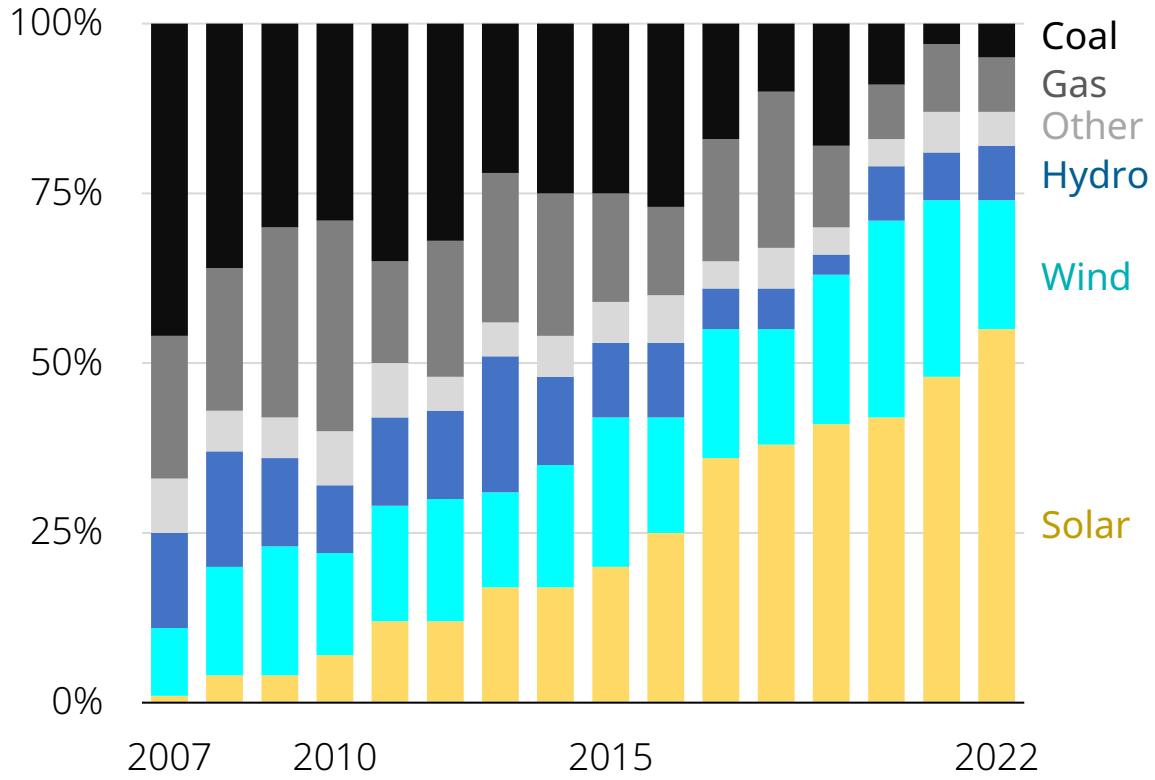


Australian Energy Week
Melbourne
June 13, 2024

The electricity sector is transforming rapidly

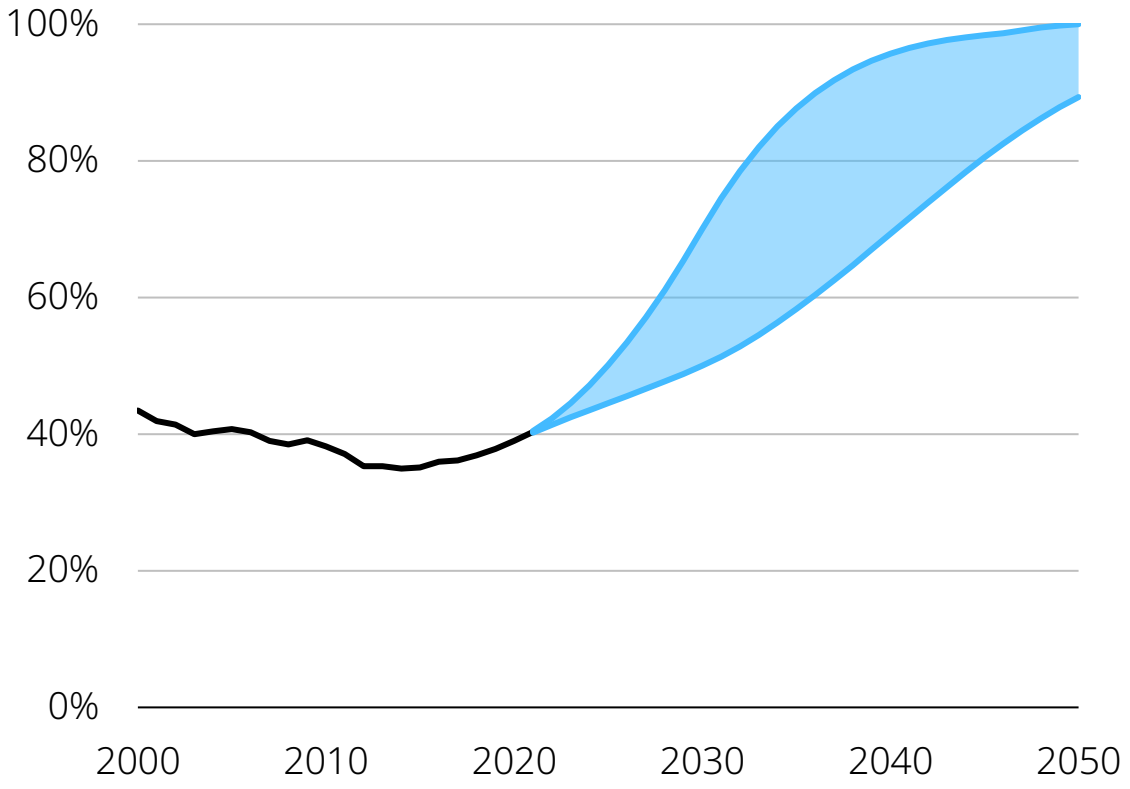
What is already happening:

Global capacity additions



What will be needed:

Electricity generation from low-carbon sources

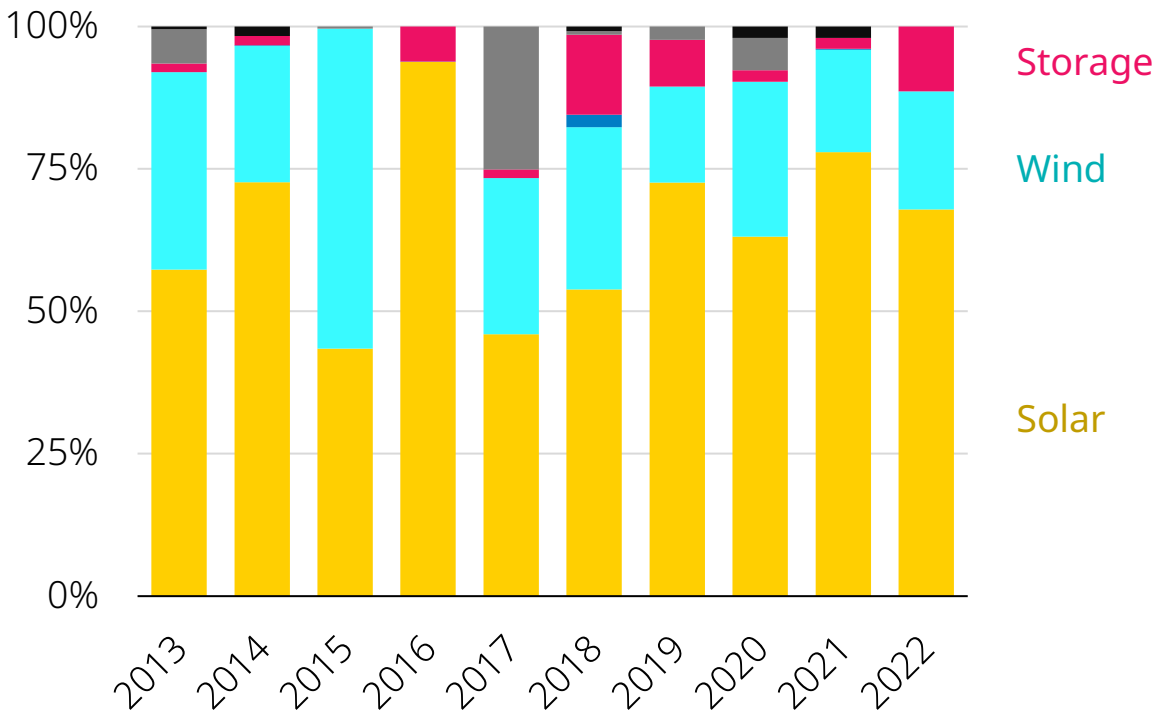


Source: BloombergNEF (2023), IPCC 6th Assessment Report (2021)

Australia is leading this transformation!

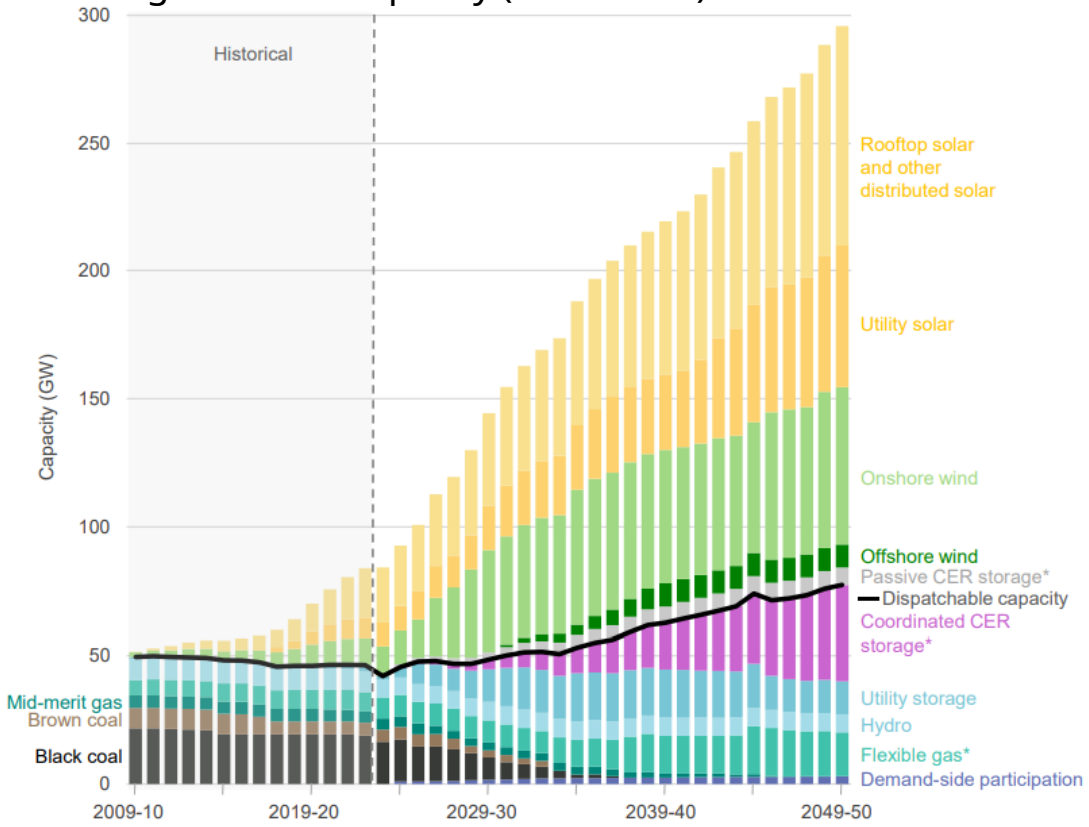
What is already happening:

NEM capacity additions



What is likely to happen:

NEM generation capacity (2010-2050):



Source: Annual Market Performance Review 2022 (AEMC, 2022); Integrated System Plan for the National Electricity Market (AEMO, 2024)

There are many concepts and technologies for storing energy

Liquid air

- Sensible heat
- Latent heat
- Thermochemical heat

- Gravitation
- Compression
- Motion

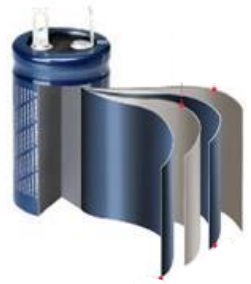
Pumped hydro

Electrolysis

- Hydrogen
- Ammonia
- Alcohols
- Hydrocarbons

- Capacitance
- Inductance

Supercapacitor



Redox flow

- Sealed batteries
- Flow batteries

Lithium ion

Lifetime cost is *the* metric for comparing these technologies

Levelised Cost Of Storage

$$\textbf{LCOS}\left[\frac{\text{US\$}}{\text{MWh}}\right] = \frac{\textit{Costs}: \text{Investment} + \text{O\&M} + \text{Charging} + \text{End of life}}{\textit{Output}: \text{Energy capacity} \cdot \text{Cycles per year} \cdot \text{Lifetime}}$$

(all costs and energy output are discounted over the lifetime)

- Accounts for all cost components required to serve specific application (e.g. power conversion to enable fast response)
- Includes replacement cost to account for degradation

Cost to operate, insure and periodically service technology components

- Reflects round-trip efficiency, because more energy is purchased than discharged (respective power price depends on application)
- Also accounts for auxiliary energy (e.g. air conditioning)

Can be a cost or a value depending on the reusability or recyclability of the technology, its components and raw materials

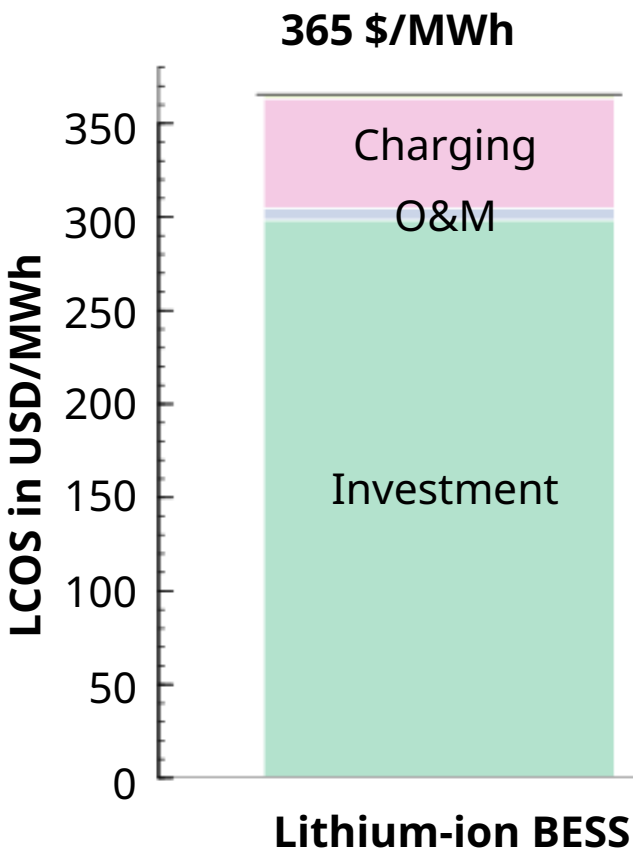
- Electricity that is discharged each cycle; should include annual degradation
- If it refers to electricity charged (against common practice), round-trip efficiency and DoD must be accounted for here

- Determined by application served by the storage system
- Can have significant impact on degradation and overall lifetime as cycle life is limiting factor for most technologies

- Option 1 - Technical: Number of years after which energy capacity degraded to e.g. 80%
- Option 2 - Economic: Pre-defined number of years, e.g. secured revenue

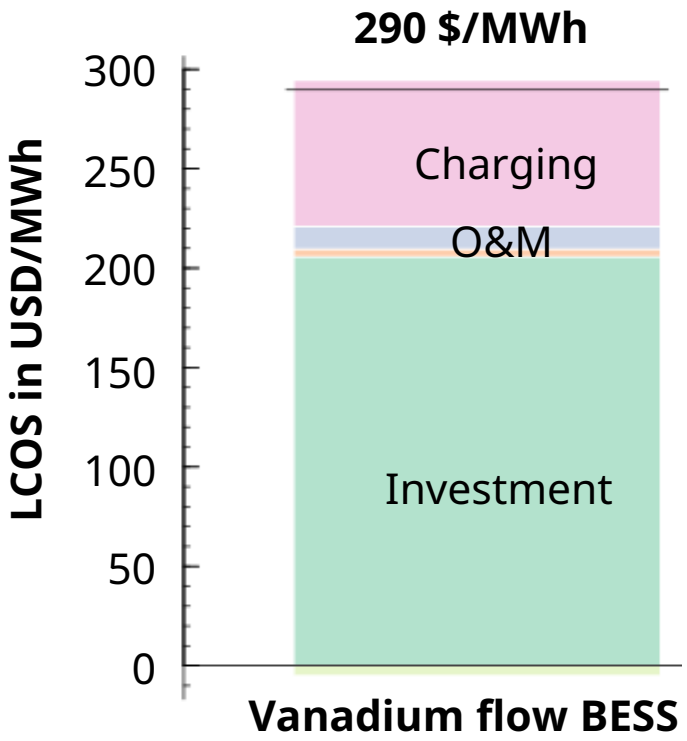
Example: For peak capacity, flow batteries beat lithium-ion

Peak capacity: 10 MW capacity, 300 cycles per year x 4 hours per cycle



Specifications

- $14.6 m
- 86% efficiency
- 3,500 cycles



Specifications

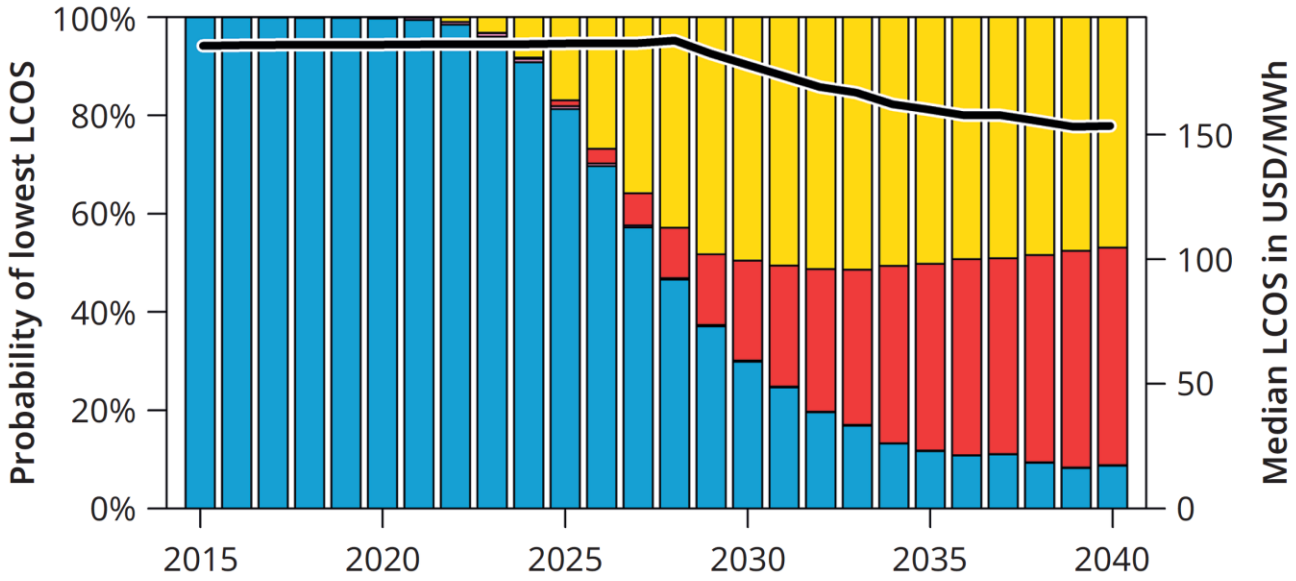
- $25 m
- 68% efficiency
- 20,000 cycles

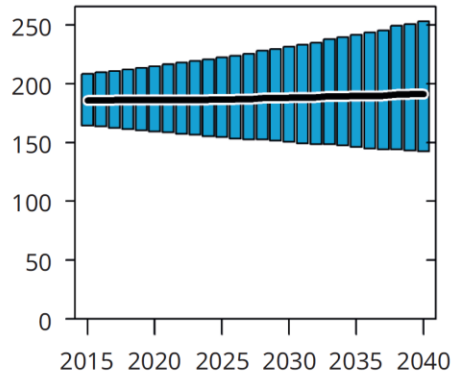
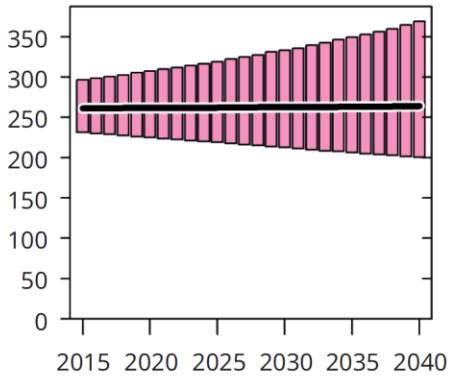
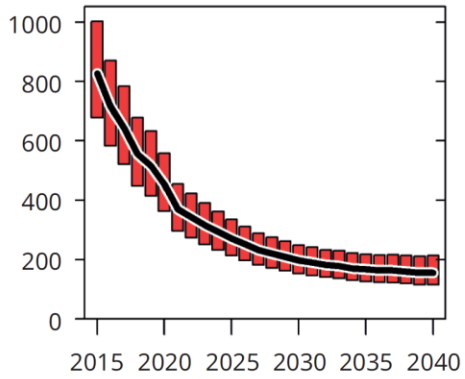
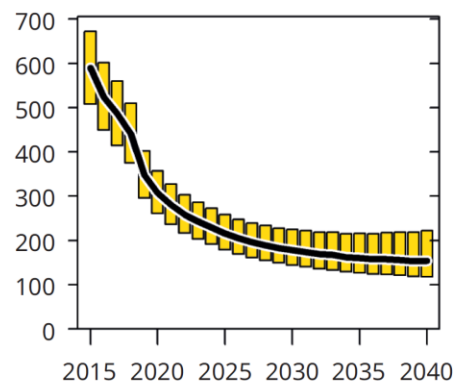
Source: Graph generated on www.EnergyStorage.ninja

The competitiveness of technologies will change over time

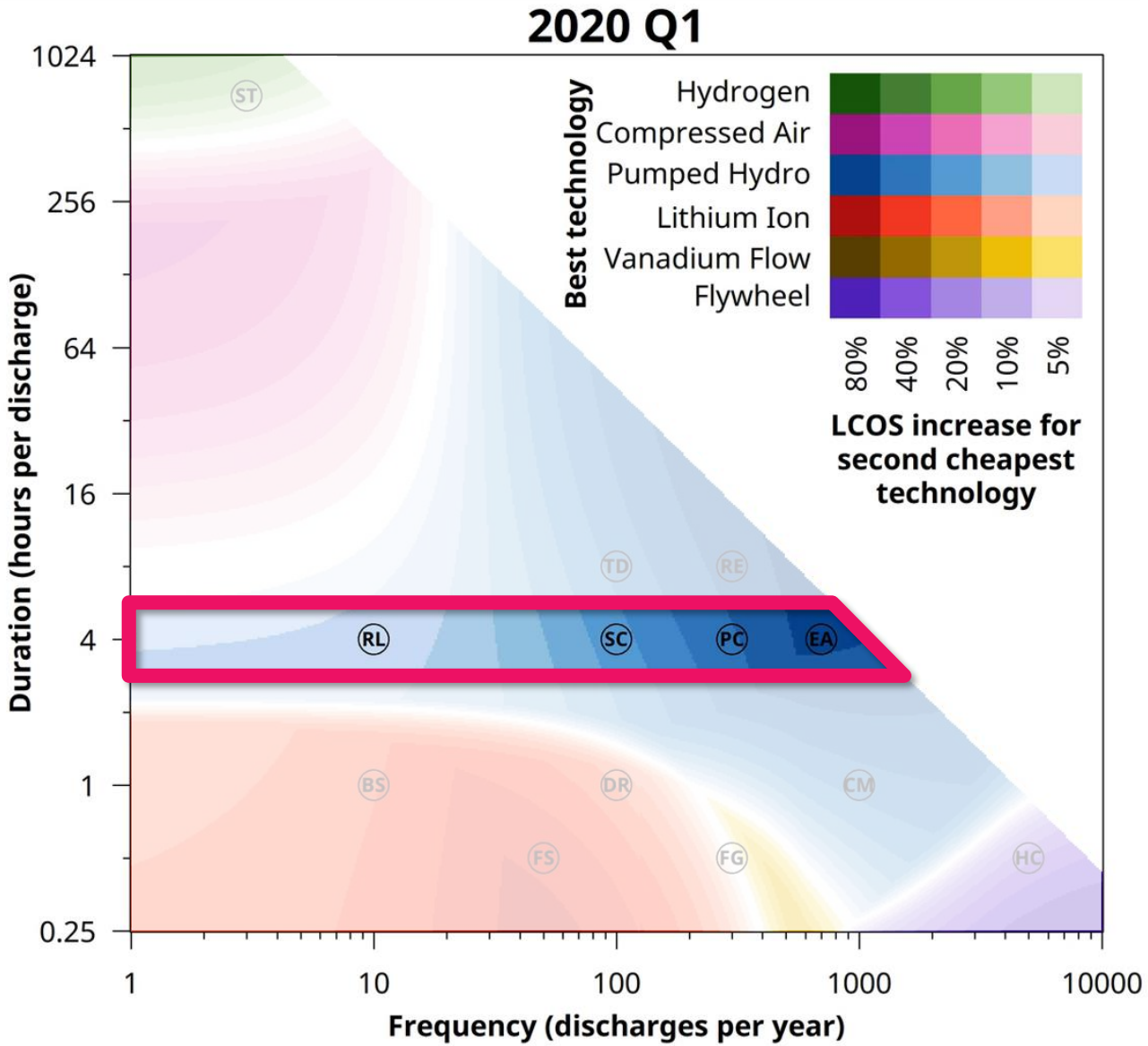
PC Peak capacity

Power capacity	10 MW
Discharge duration	4 hours
Annual cycles	300
Response time	>10 seconds
Electricity price	50 USD/MWh



	Pumped hydro	Compressed air	Lithium ion	Vanadium redox flow
Median and range of LCOS in USD/MWh				

There are dominant technologies for different requirements



Circles denote typical power system applications:

- (ST) Inter-seasonal storage
- (RL) Power reliability
- (TD) Transmission & distribution investment deferral
- (RE) Renewables integration
- (SC) Increasing self-consumption
- (PC) Peaking capacity
- (EA) Energy arbitrage
- (BS) Black start
- (DR) Demand charge reduction
- (CM) Congestion management
- (FS) Frequency response (ramping / inertia)
- (FG) Frequency regulation (power quality)
- (HC) High cycle

Source: Graph generated on www.EnergyStorage.ninja

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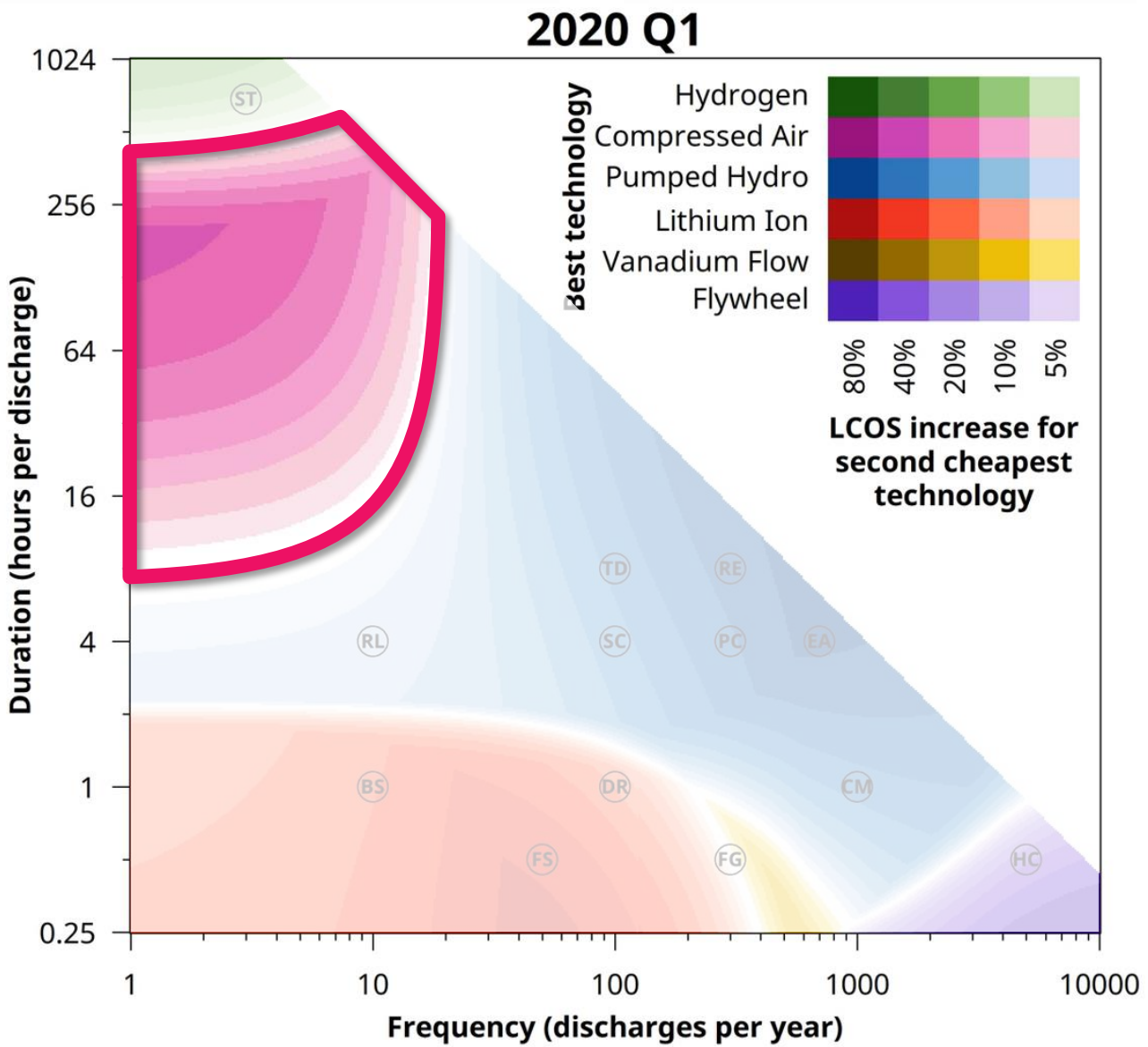

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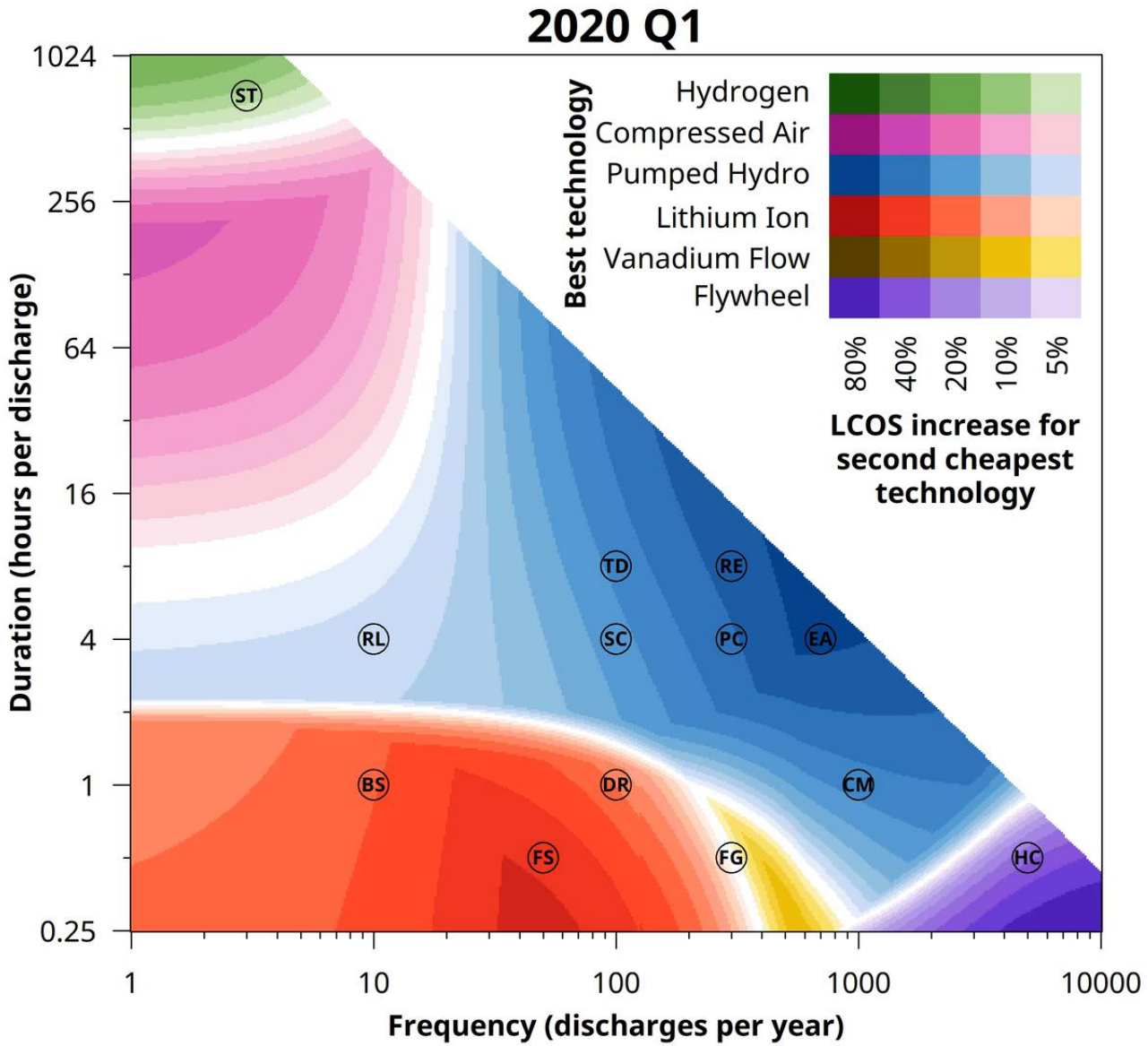

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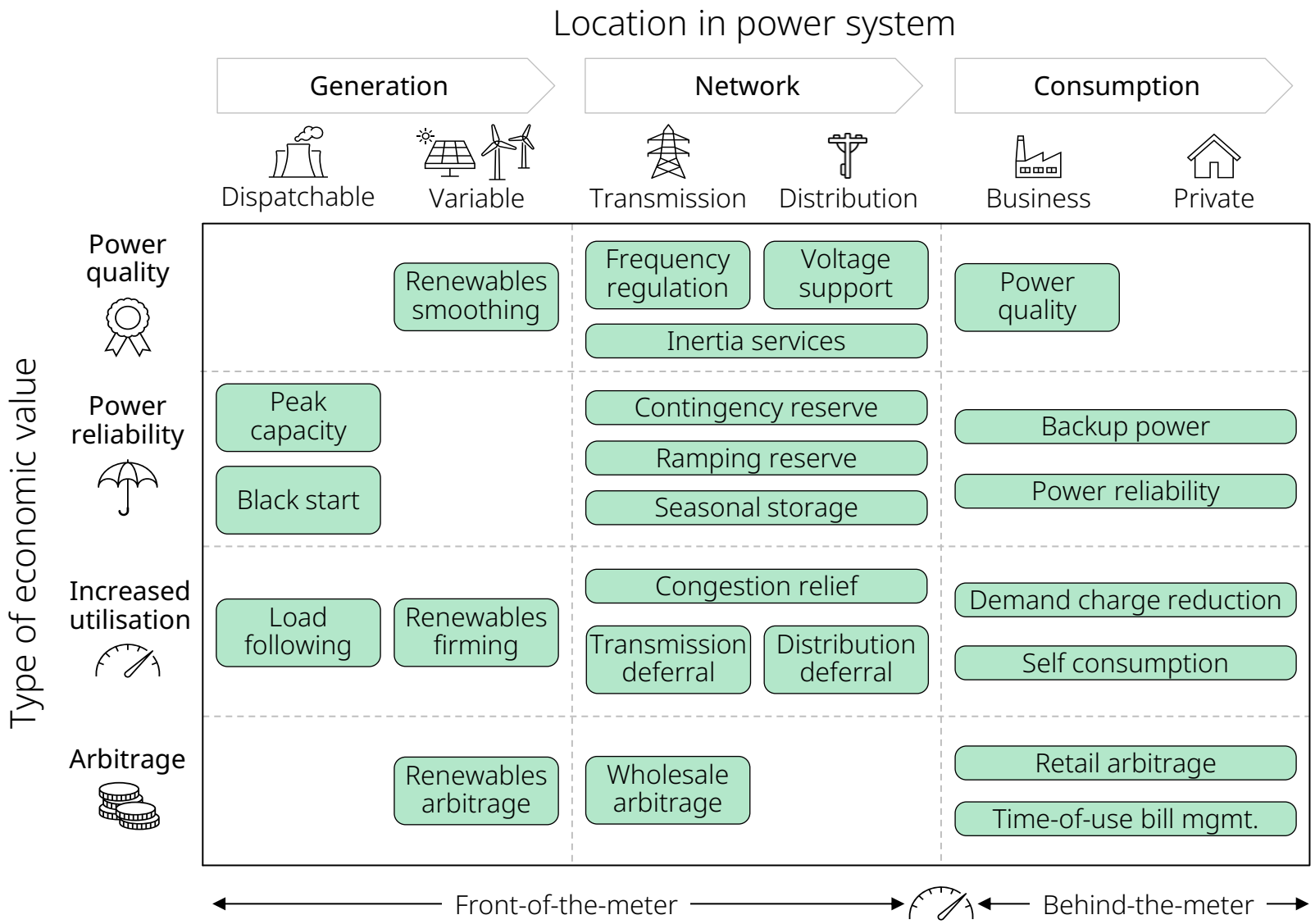
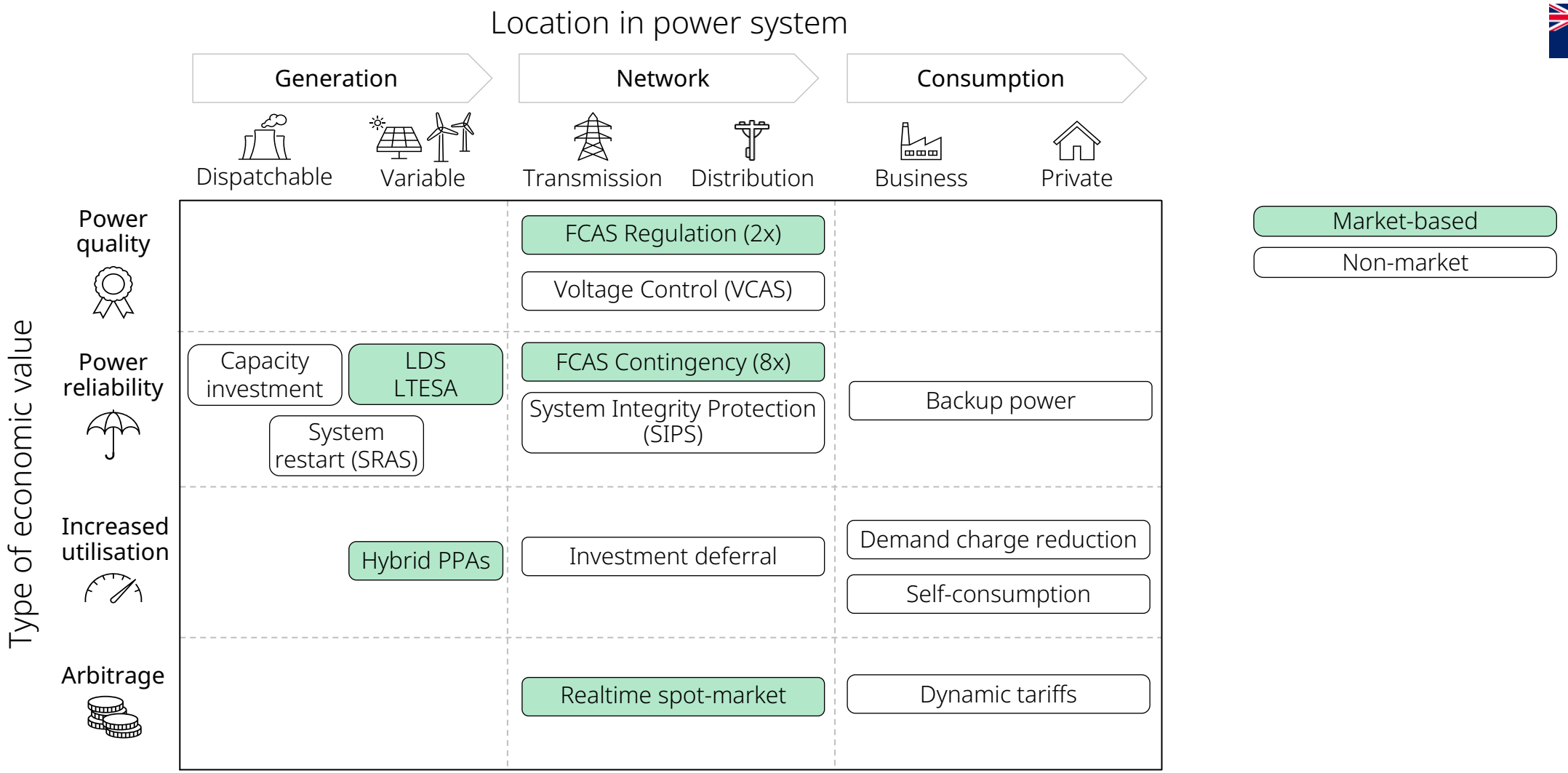
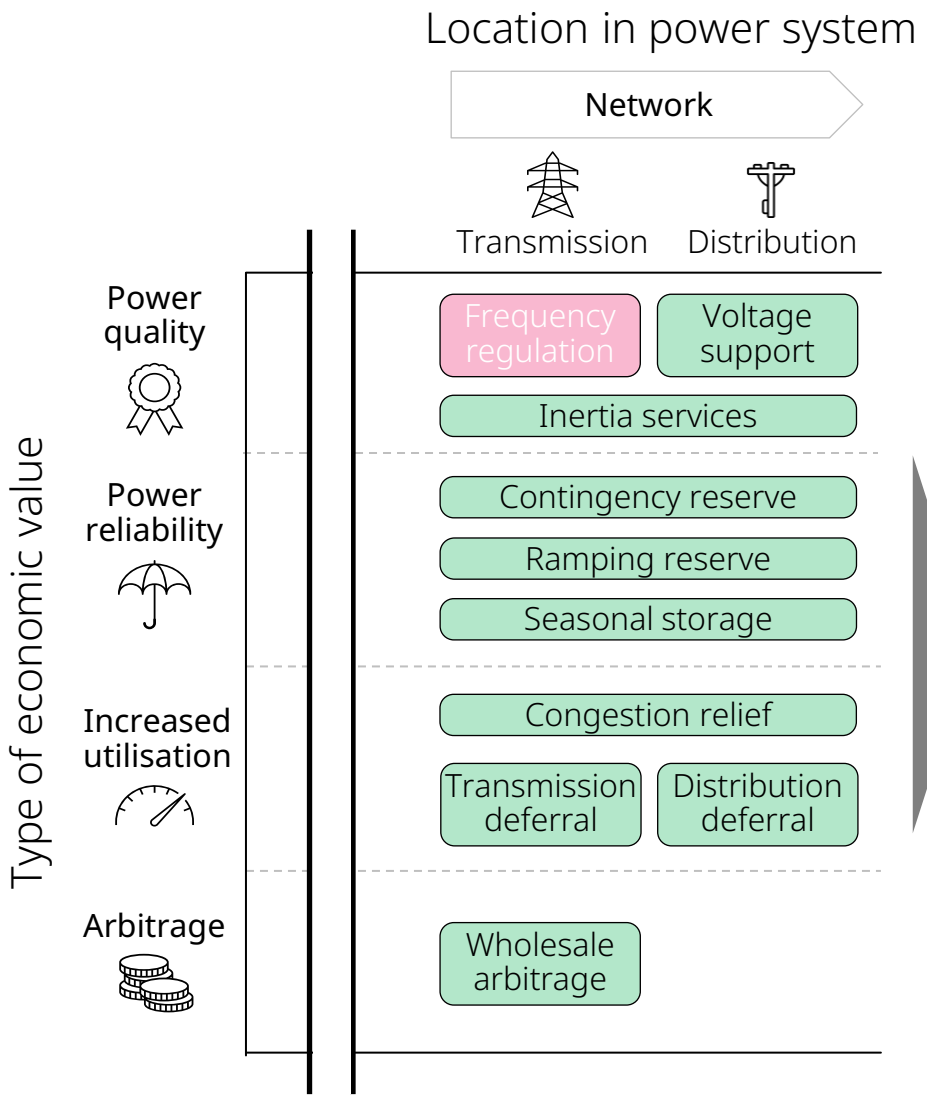
Like with technologies, there is a wide range of applications



In Australia, storage can monetize at least 14 applications

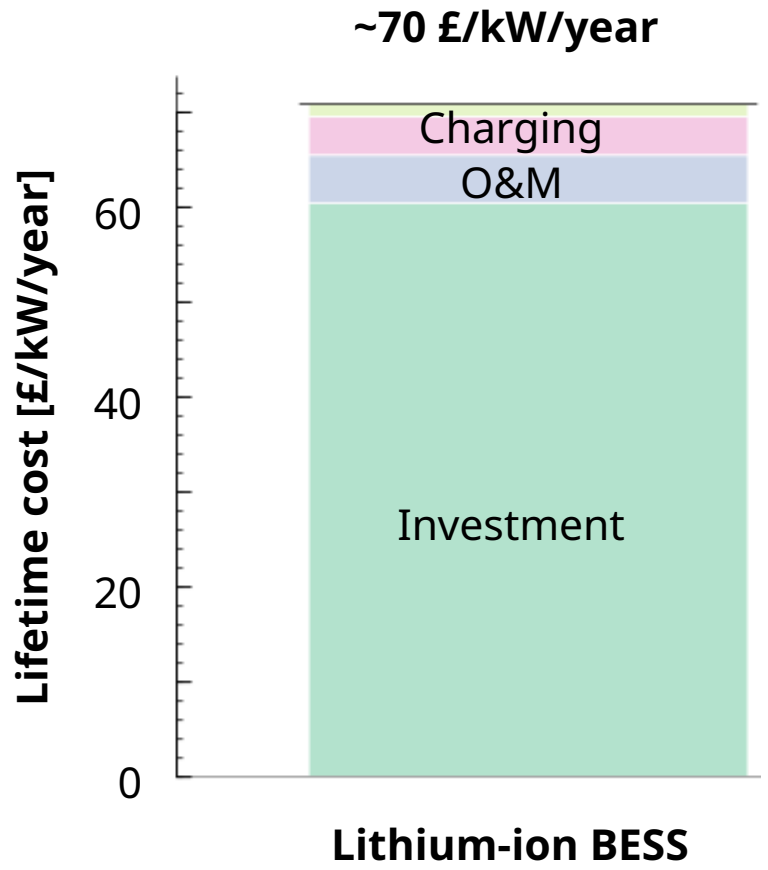


Frequency response can be provided at a cost of ~70 £/kW/yr



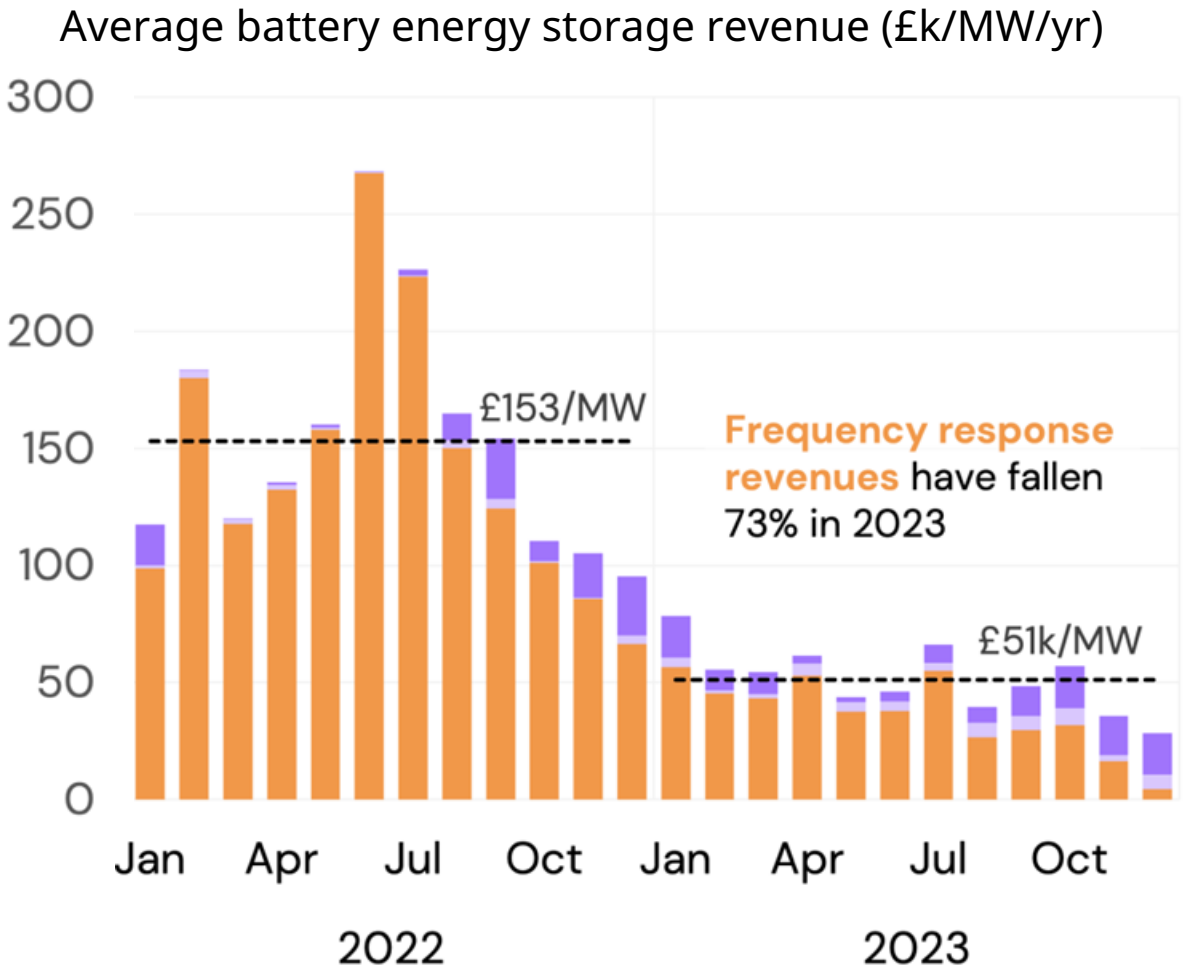
Battery specs

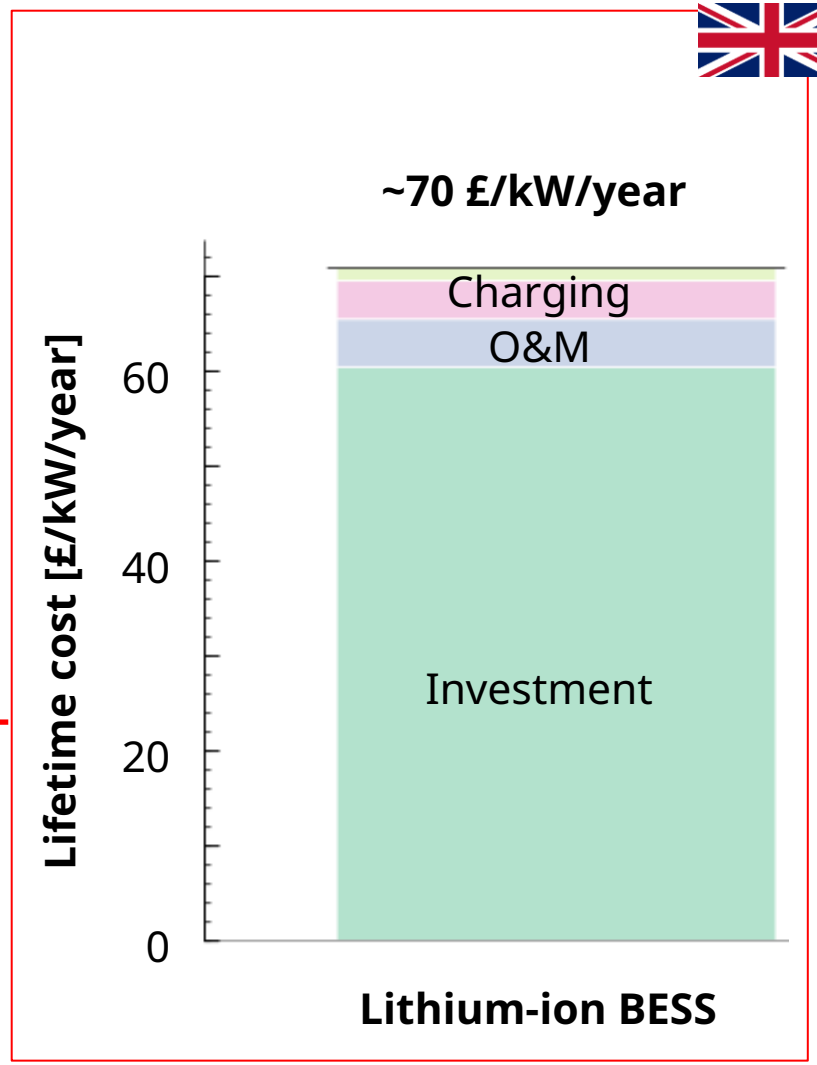
- 10 MW / 5 MWh
- £4 m capex
- 85% efficiency
- 10 years lifetime
- 8% discount rate



Source: Graph generated on www.EnergyStorage.ninja

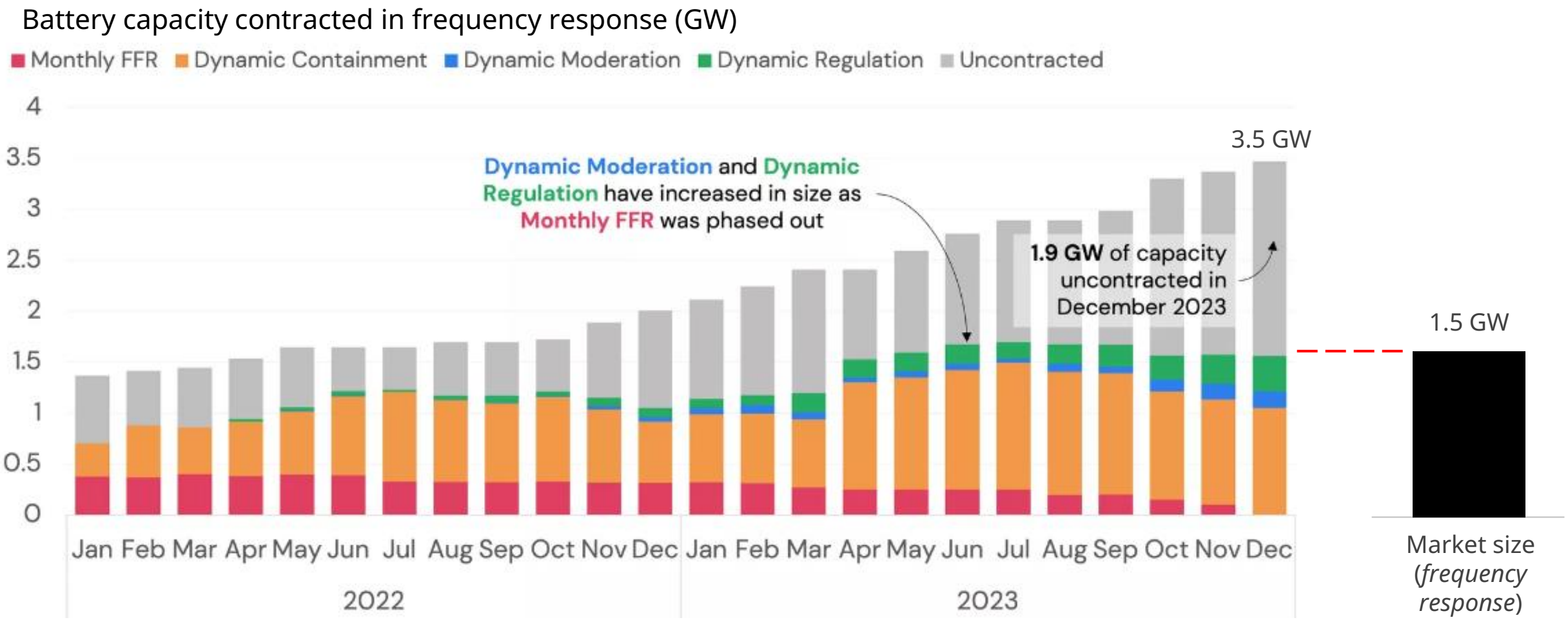
But, frequency response revenues have fallen below that





Source: Modo Energy (Jennings, 2023)

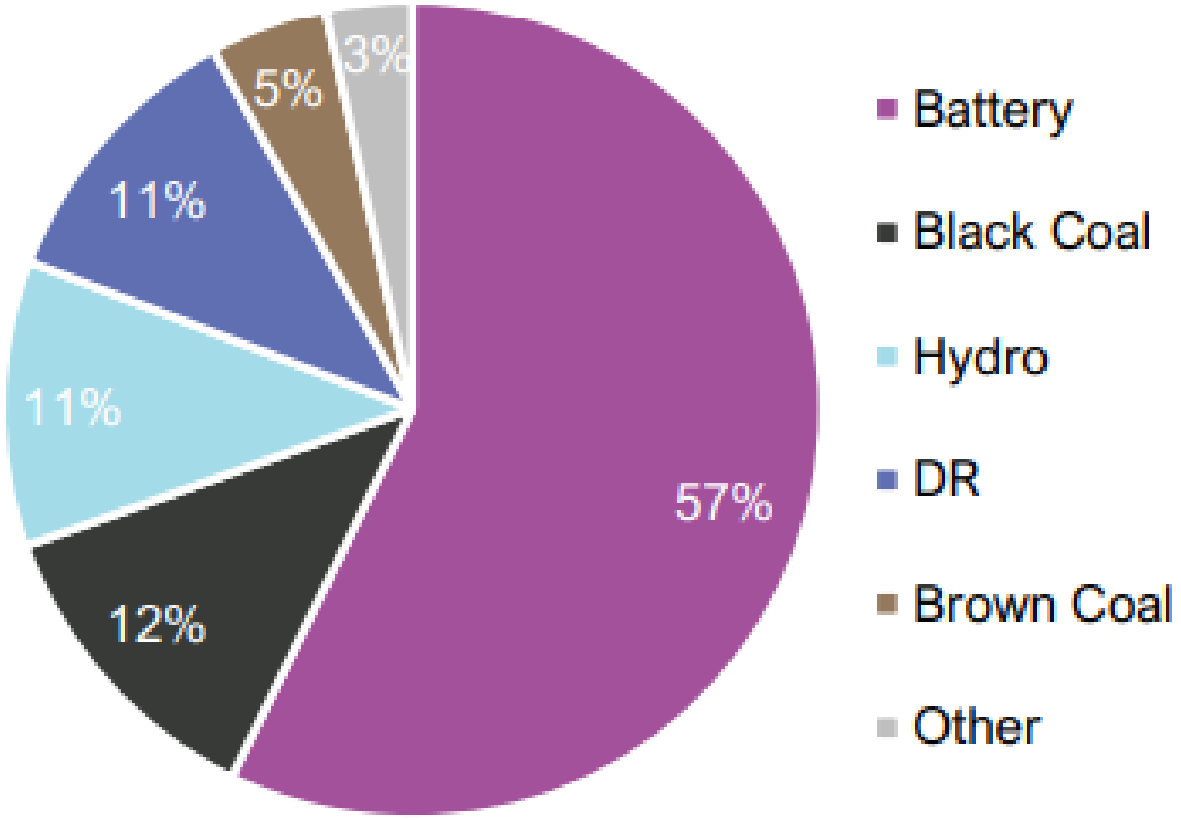
This is because frequency response markets are saturated



Source: Modo Energy (Middleton, 2023)

In Australia, FCAS markets are saturated soon as well

FCAS volume market share by technology – Q1 2024



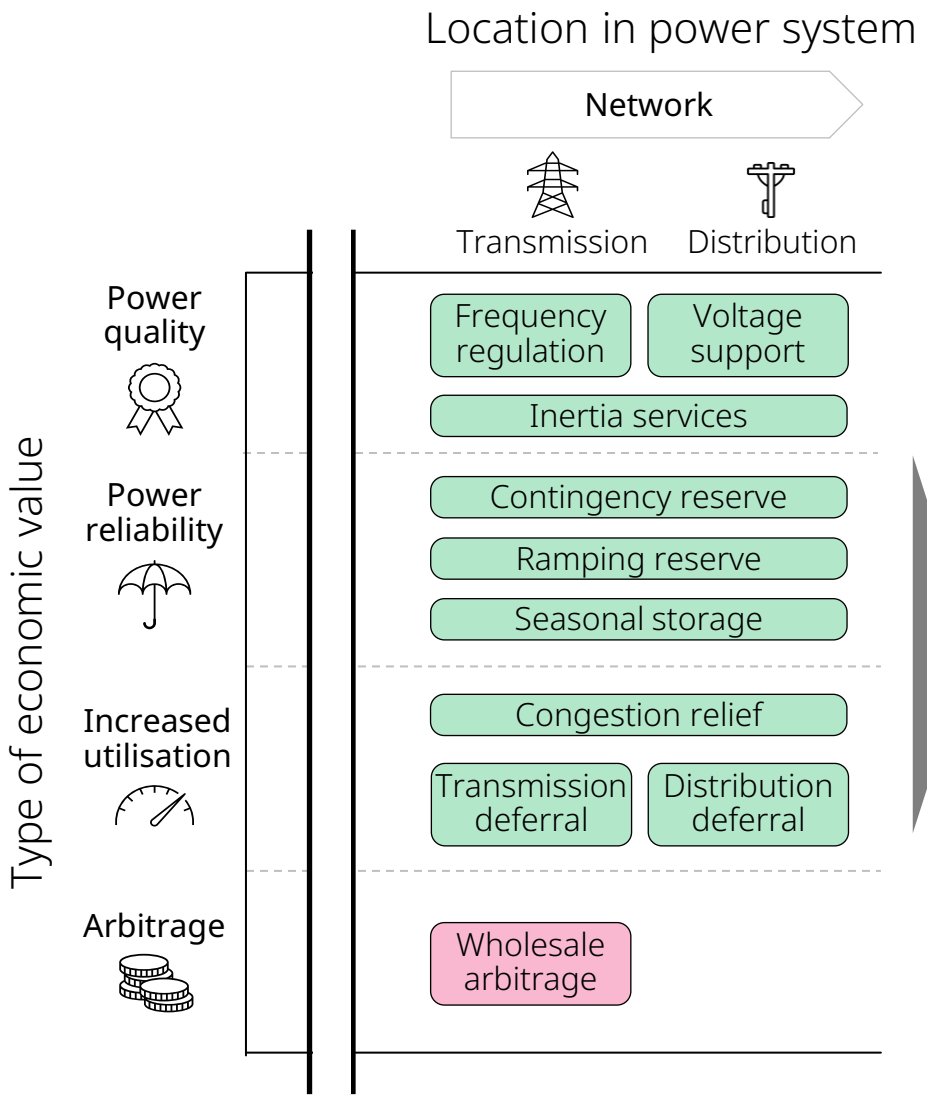
FCAS volume: ~500 MW

BESS capacity:

- Existing: 1.4 GW
- Committed: 1.2 GW
- Anticipated: 4.0 GW
- Proposed: 55.2 GW

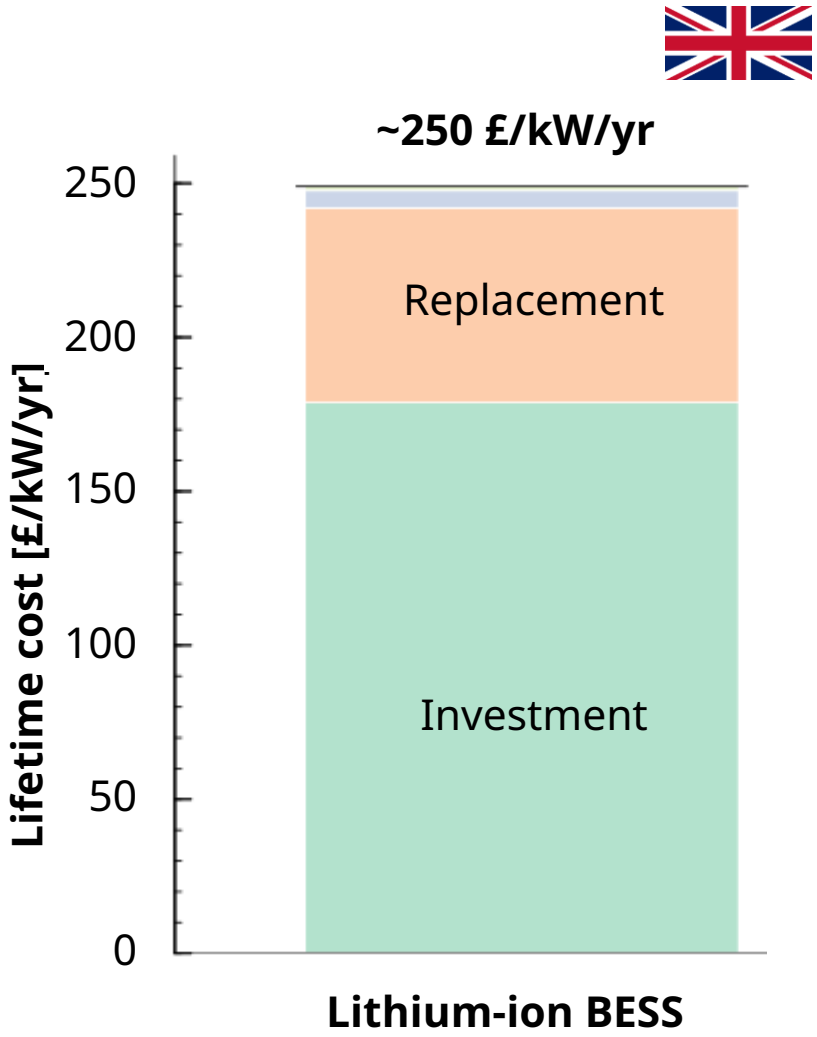
Source: Energy storage financeability in Australia (Nexa Advisory, 2024)

Power price arbitrage can be provided at ~250 £/kW/yr



Battery specs

- 10 MW / 40 MWh
- £12 m capex
- 85% efficiency
- 10 years lifetime
- 5-year replacement
- 8% discount rate



Source: Graph generated on www.EnergyStorage.ninja

But, arbitrage is not yet profitable, even at longer durations

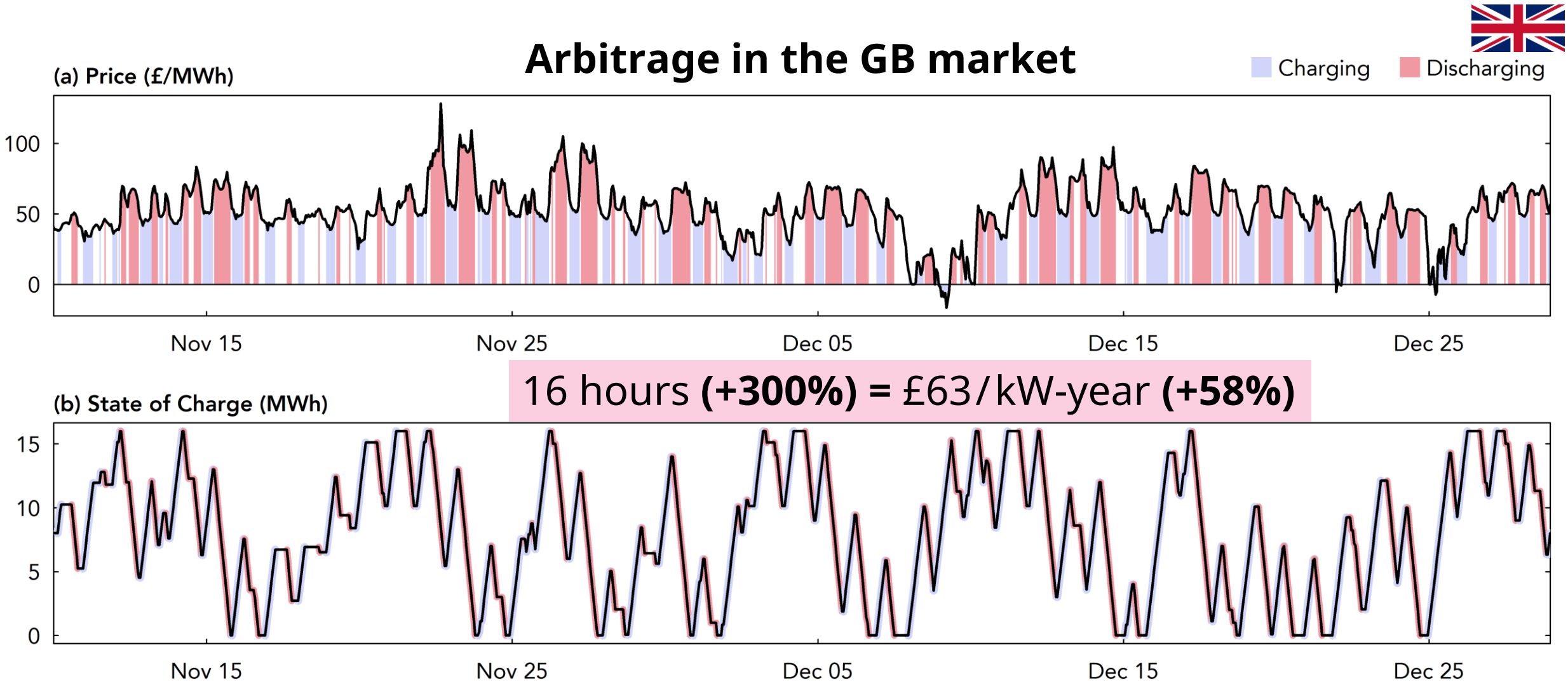
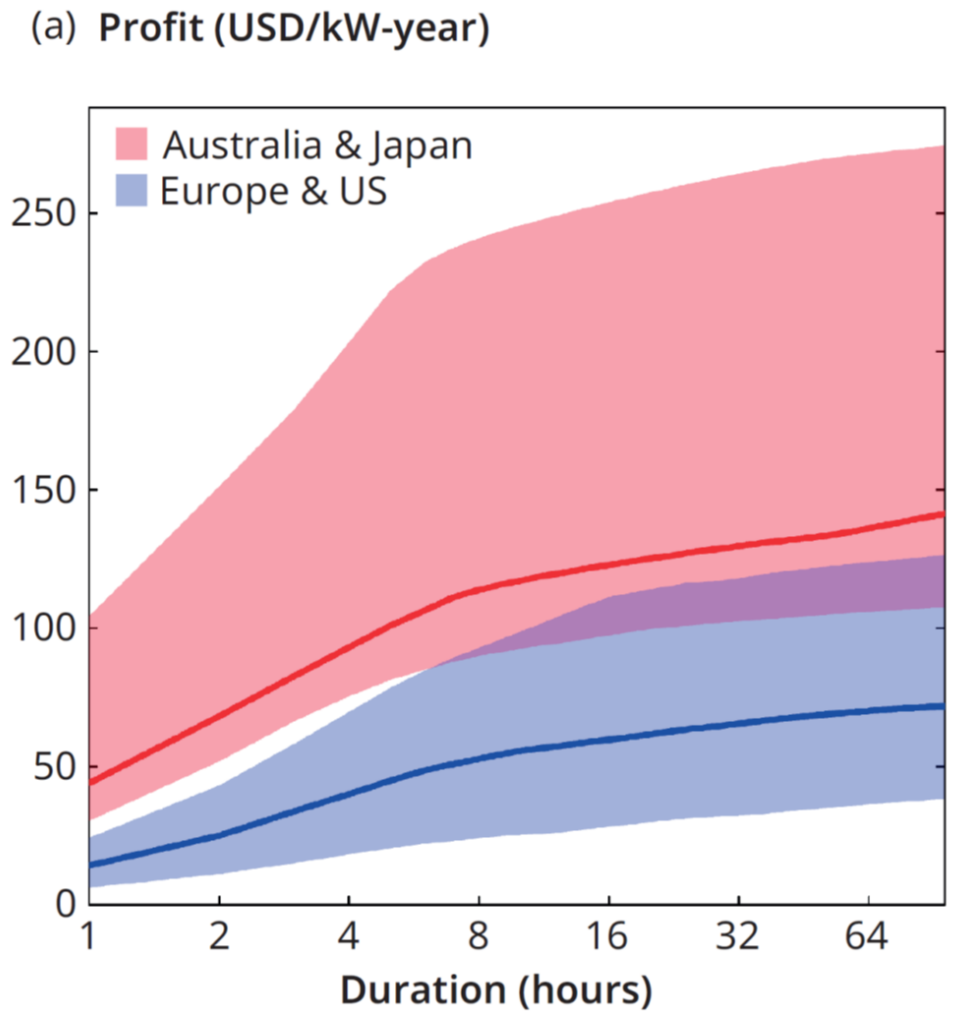
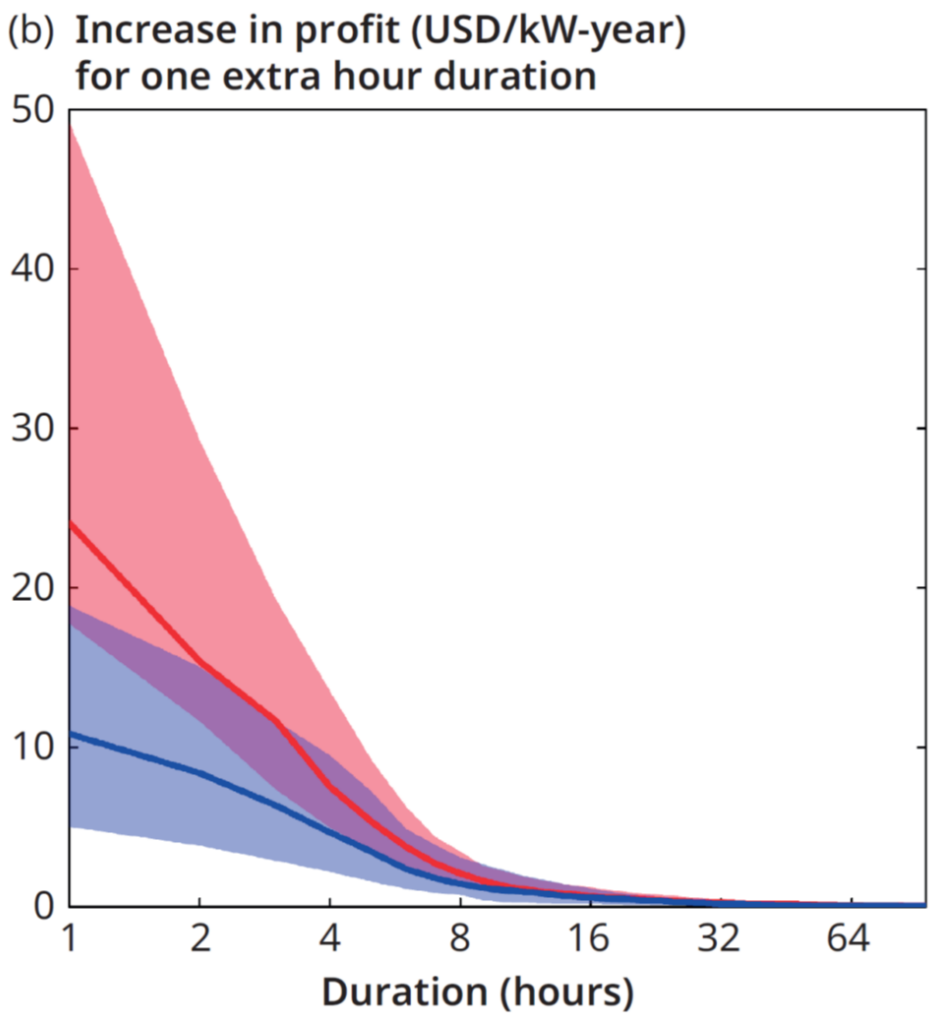


Chart from www.EnergyStorage.ninja

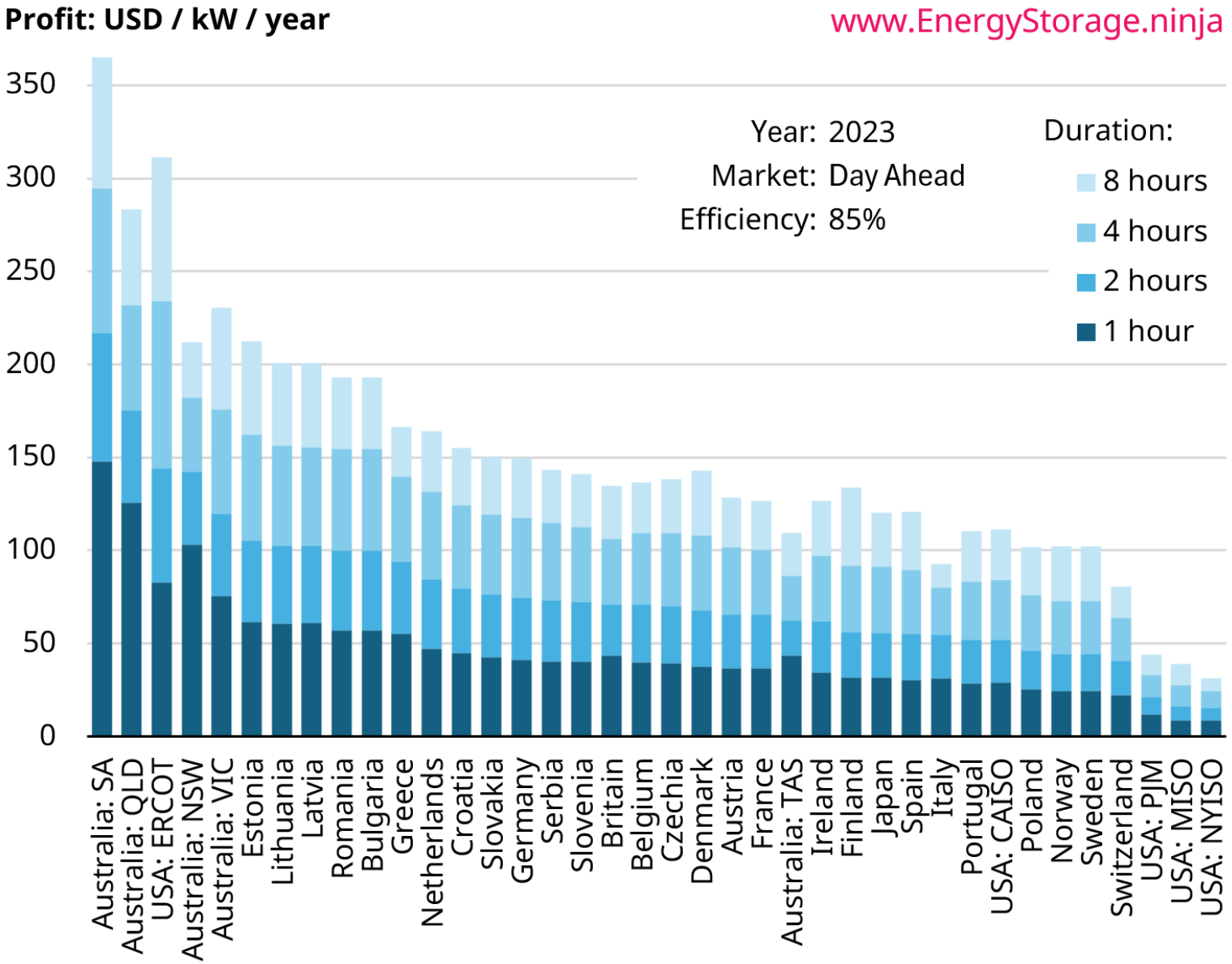
Increasing discharge duration beyond 8 hours adds no value





Based on day-ahead wholesale prices from 2012-19 in various markets

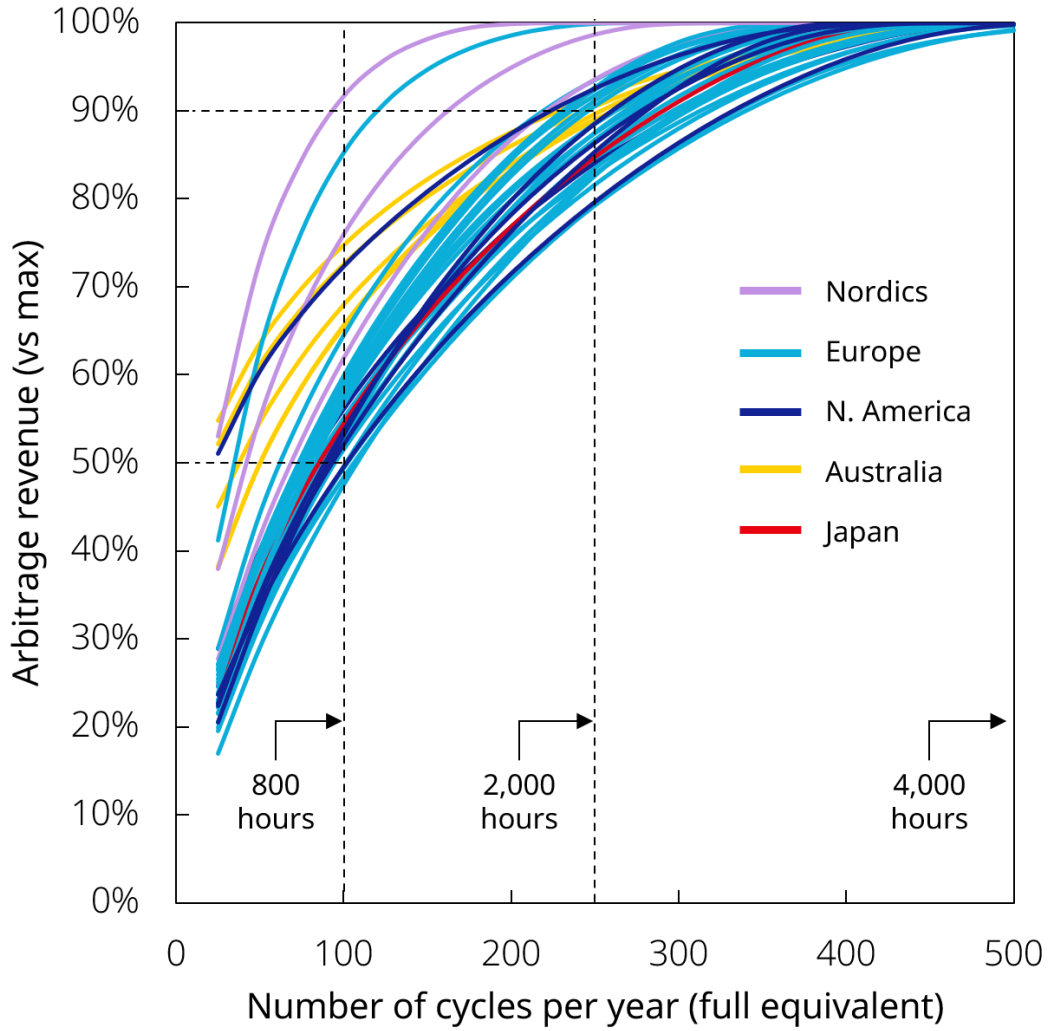
Highest profits are possible in Australia, but still insufficient



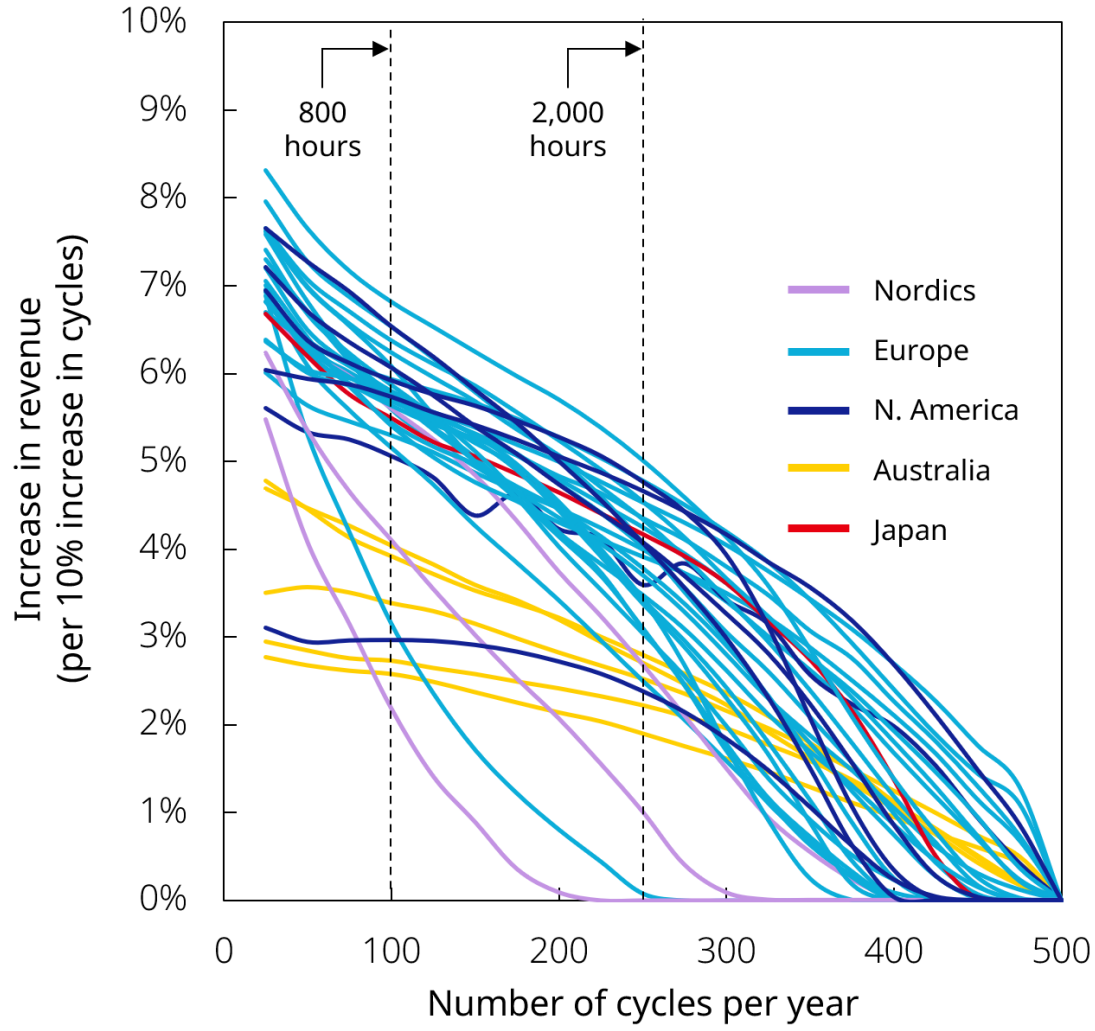
- Four states of mainland Australia (SA, QLD, NSW, VIC) offered highest profits via wholesale power trading in 2023
- But, full revenue potential is difficult to capture, due to
  - realtime spot market vs day-ahead markets (e.g., Europe)
  - volatility being extreme, but short-lived

90% of the value can be captured trading 25% of the year

a) Revenue (vs max)

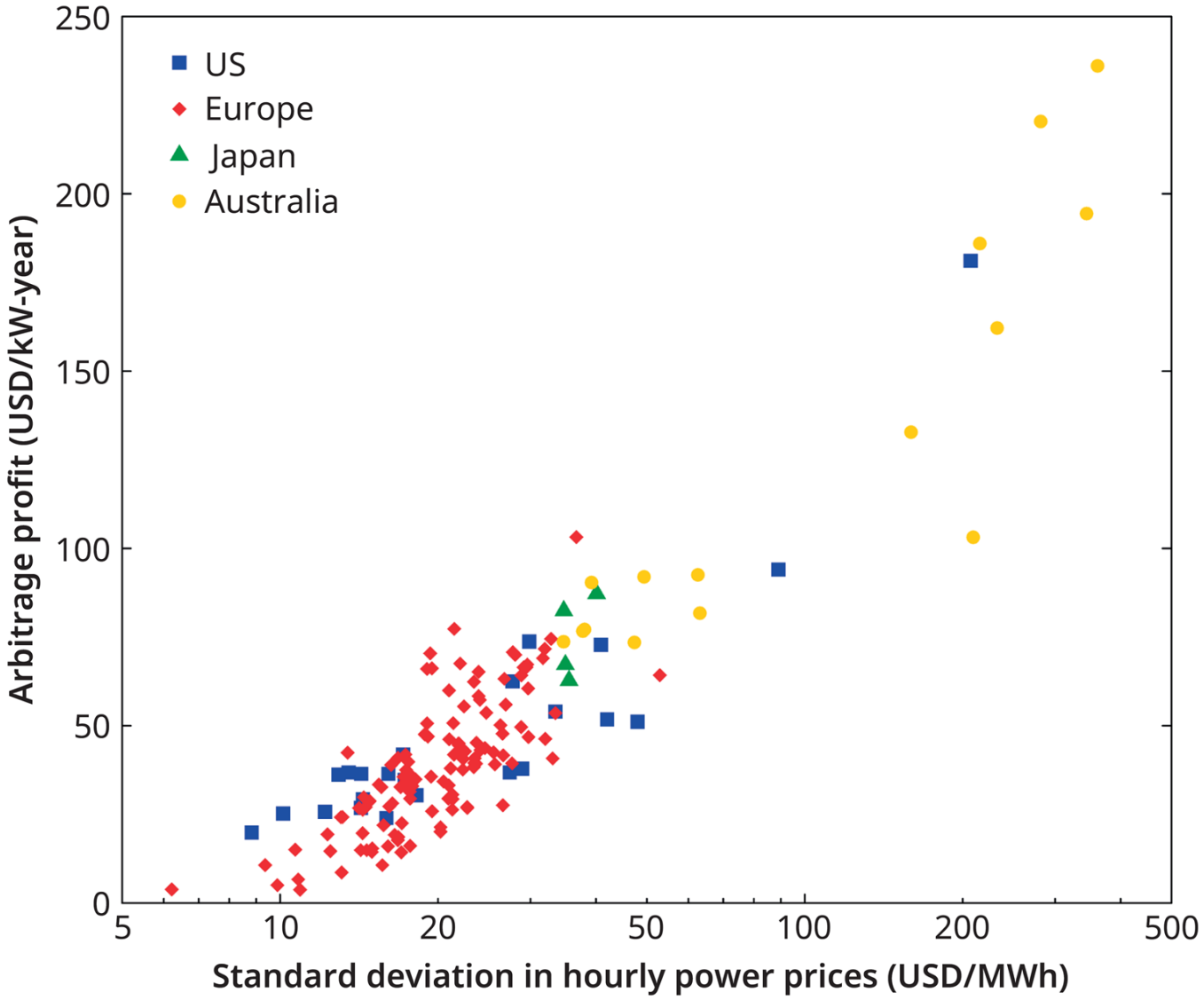


b) Increase in revenue



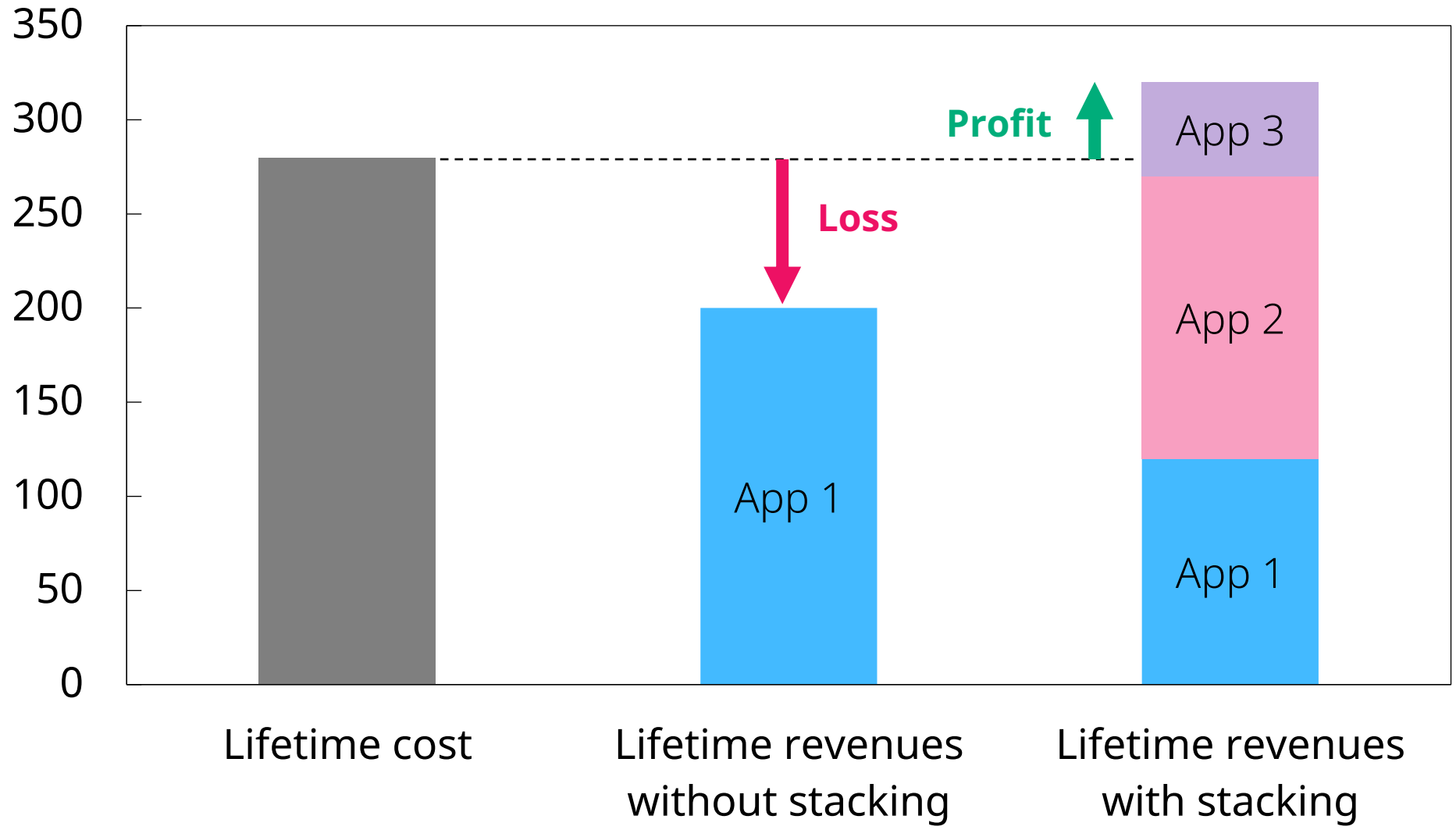
Note: Based on day-ahead wholesale prices from 2012-19 in various markets

This highlights the need for storage to optimize volatility



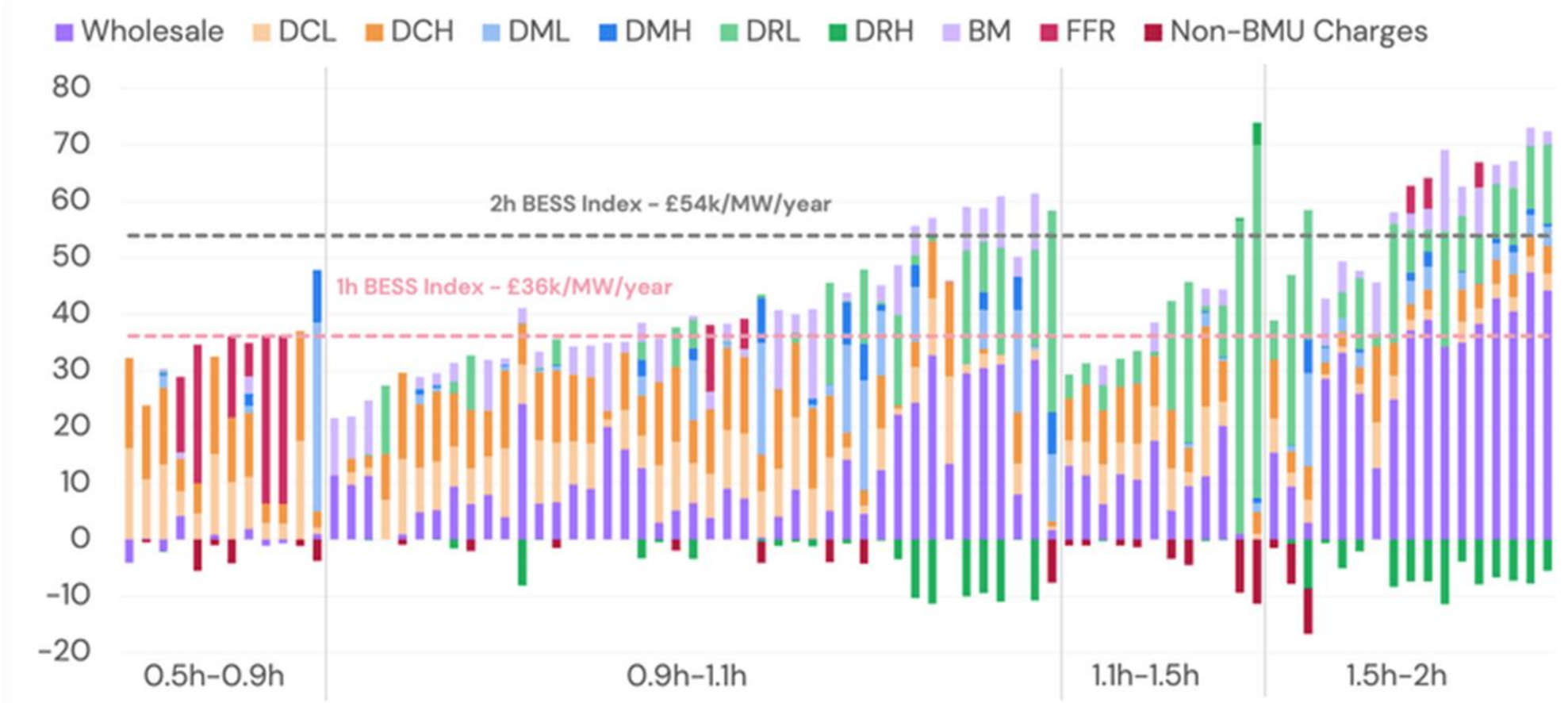
Revenues are **driven by volatility,** so instead of acting only in one market, revenues are maximized by **'skimming volatility cream' of multiple markets.**

Therefore, multiple revenue streams must be combined



In GB, complex revenue stacking is the reality

Annualized revenues of battery assets in Q4/2023 by market and duration



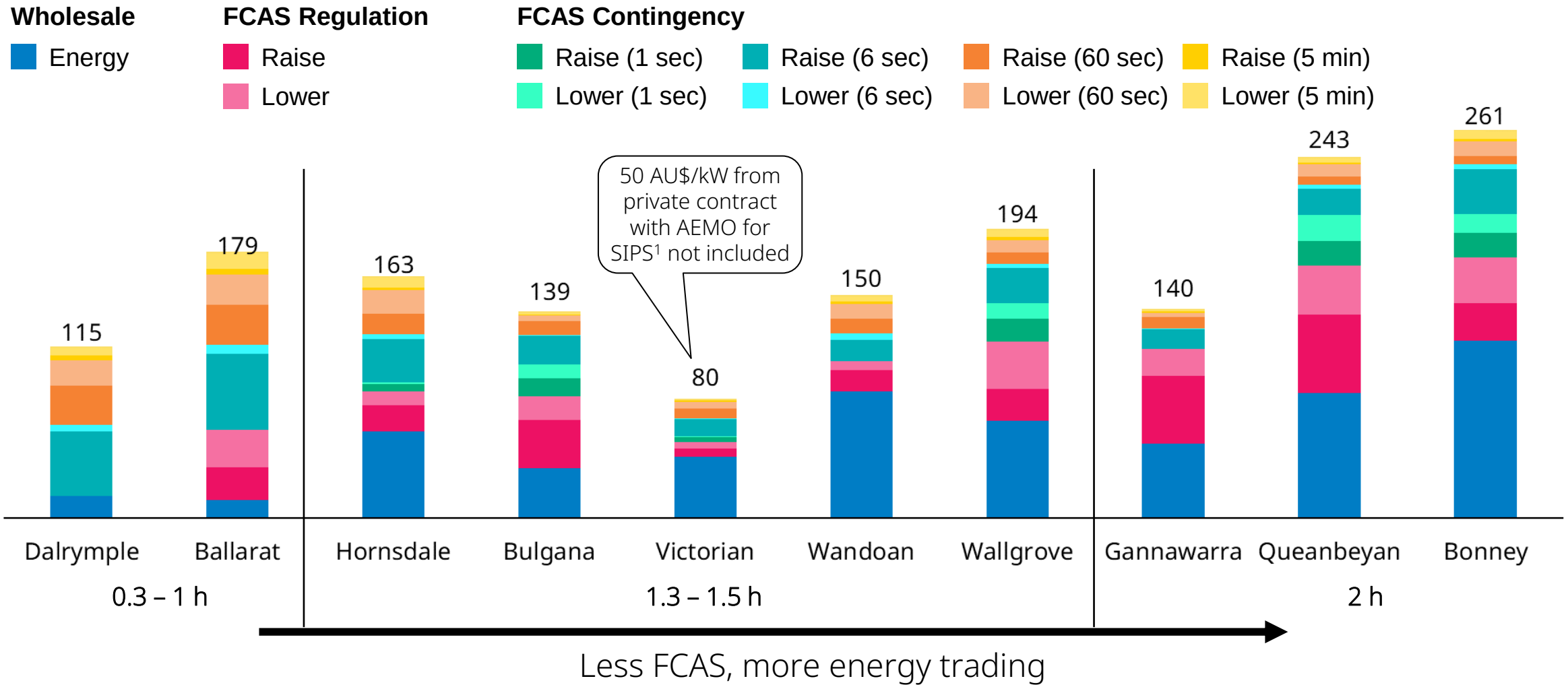
Each bar represents one specific battery asset

Longer duration battery = More arbitrage services (Wholesale, BM)

Source: Matt Middleton (Modo Energy, 2024)

In Australia as well, resembling the same trend

Annualized revenues of battery assets in 2023[1] (AU$/kW)



Source: https://nembess.com/batteries; 1) Revenues from non-market services like System Integrity Protection Scheme (SIPS), System Restart Ancillary Services (SRAS), Voltage Control Ancillary Services (VCAS), Synthetic Inertia, System Strength that are negotiated in private agreements with AEMO are not included

All the insights and tools shown here are available in this book and website

"Essential for me as an investor to navigate this complex, fast-paced energy storage industry."

Gerard Reid, Alexa Capital

"The go-to resource… exemplary in terms of academic rigour set in a real world context."

Jim Skea, Chair of the IPCC

User-friendly tools for custom analyses: www.EnergyStorage.ninja