

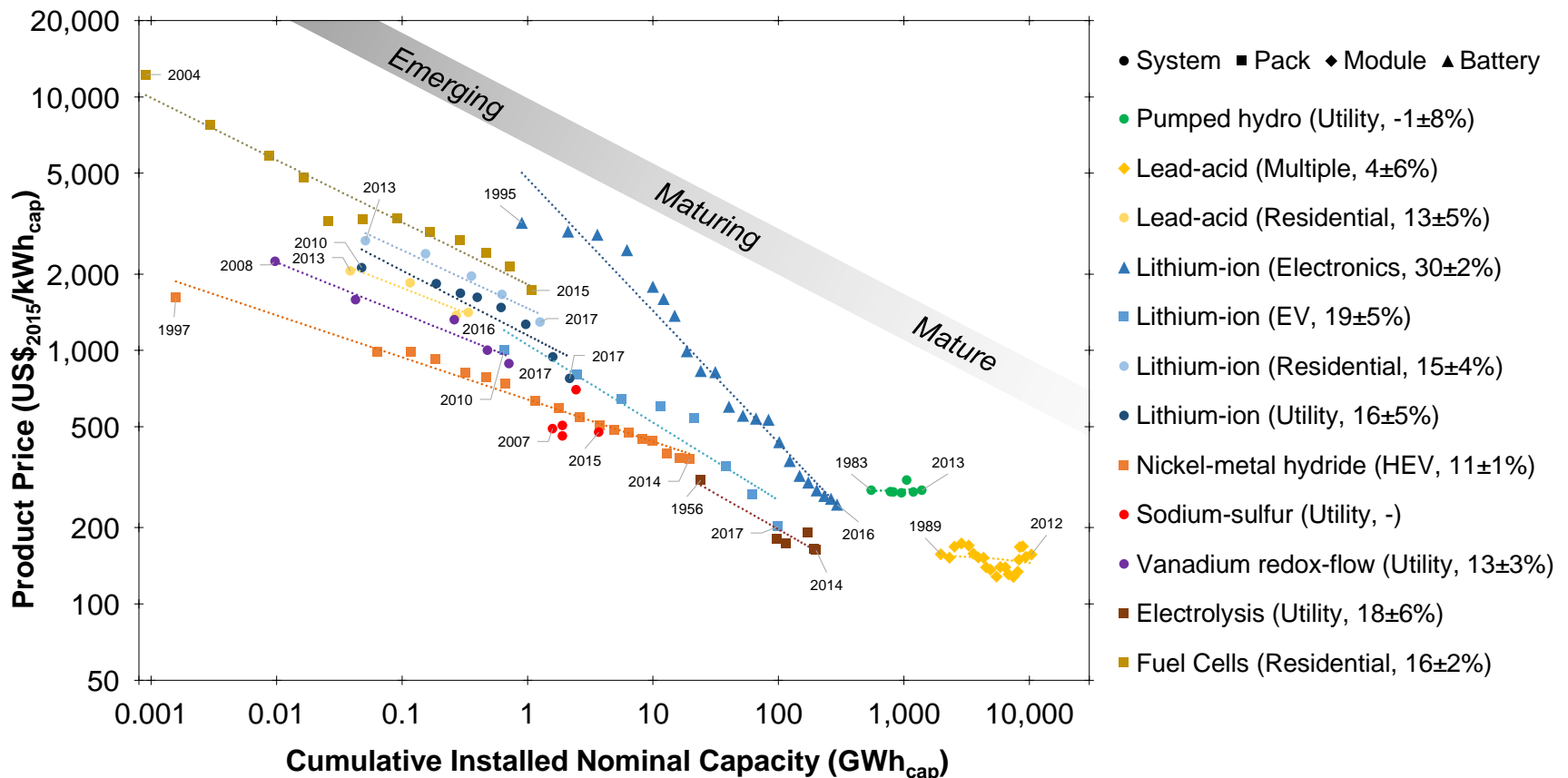
Projecting levelised cost of storage – a basis to determine future value?

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London, UK**

Experience curve dataset for storage technologies can predict investment cost

Experience Curve Dataset



But, comparison of technologies must be based on levelised cost of storage (LCOS)

LCOS Formula

- Investment cost
- Construction time
- Replacement cost / interval

- Charging cost
- O&M cost

$$LCOS \left[\frac{\$}{MWh} \right] = \frac{\text{Investment cost} + \text{Operating cost} + \text{Disposal cost}}{\text{Electricity discharged}}$$

- Round-trip efficiency
- Depth-of-discharge
- Annual cycles
- Cycle life
- Calendar life
- Degradation

- End-of-life cost or residual value

▶ The discounted cost of a “MWh” discharged from the storage device

We model LCOS of 9 storage technologies in 12 power system applications up to 2050

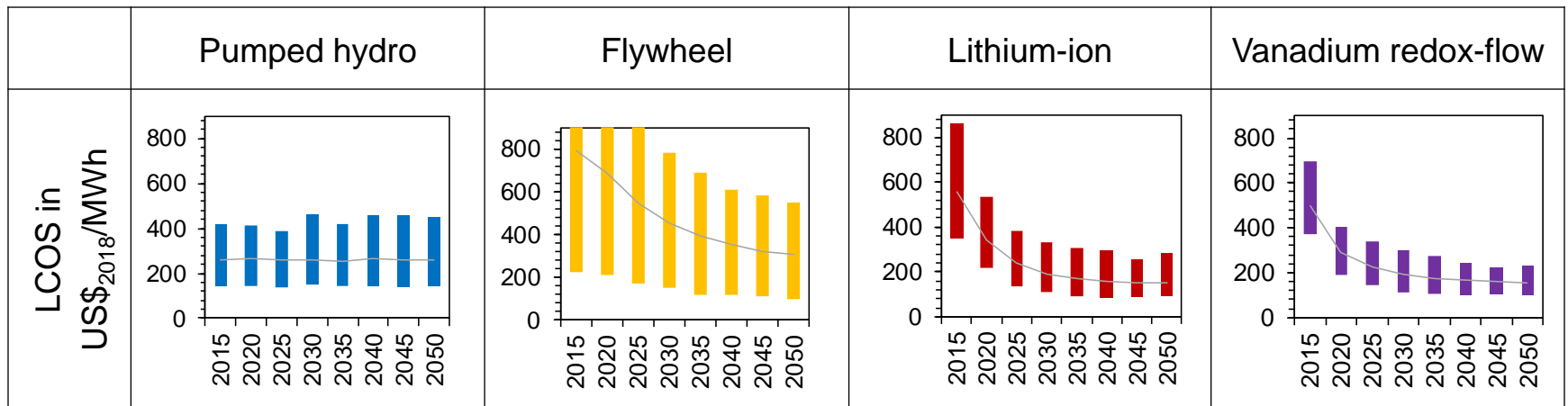
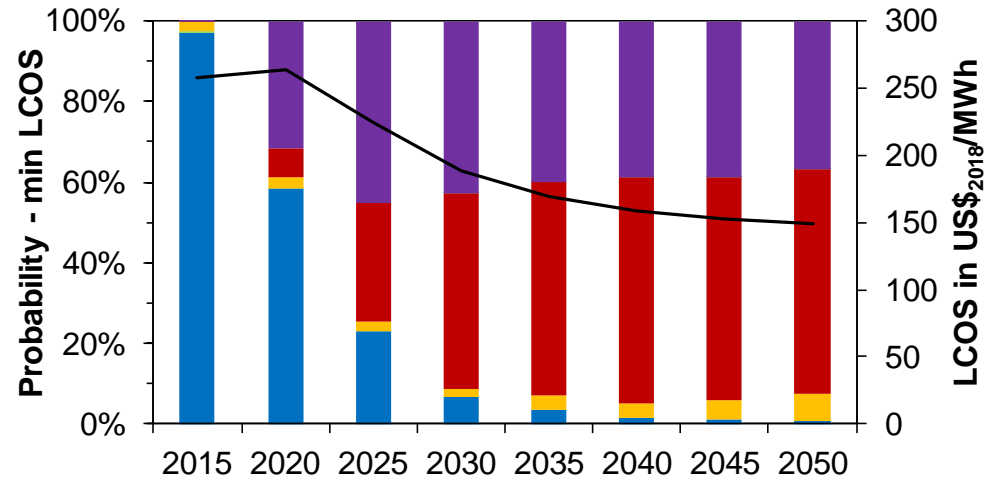
Applications vs Technologies

Role	Application	Pumped hydro	CAES	Fly-wheel	Li-ion	Sodium-sulfur	Lead-acid	VRFB	Hydrogen	Super-cap.
System operation	1. Energy arbitrage	✓	✓		✓	✓	✓	✓	✓	
	2. Primary response			✓	✓	✓	✓	✓	✓	✓
	3. Secondary response	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4. Tertiary response	✓	✓		✓	✓	✓	✓	✓	
	5. Peaker replacement	✓	✓		✓	✓	✓	✓	✓	
	6. Black start	✓	✓	✓	✓	✓	✓	✓	✓	✓
	7. Seasonal storage	✓	✓					✓	✓	
Network operation	8. T&D upgrade deferral	✓	✓		✓	✓	✓	✓	✓	
	9. Congestion mgmt	✓	✓		✓	✓	✓	✓	✓	
Consumption	10. Bill management				✓	✓	✓	✓	✓	
	11. Power quality			✓	✓	✓	✓	✓	✓	✓
	12. Power reliability				✓	✓	✓	✓	✓	

Lithium-ion and vanadium redox-flow will compete for secondary response

③ Secondary Response

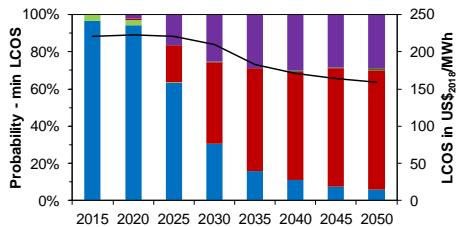
Power capacity	100 MW
Discharge duration	1 hour
Annual cycles	1,000
Response time	>10 seconds
Electricity price	50 \$/MWh



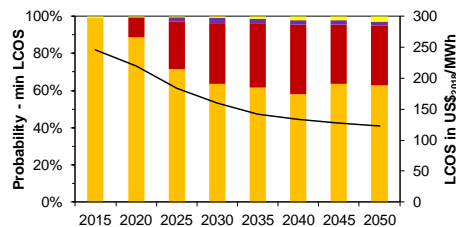
Lithium-ion becomes dominant technology in most applications by 2030

Application overview

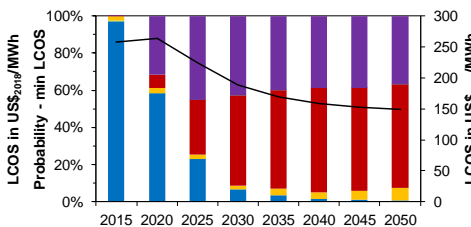
① Energy Arbitrage



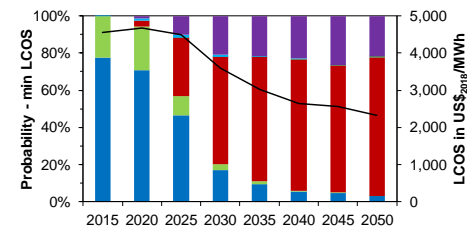
② Primary Response



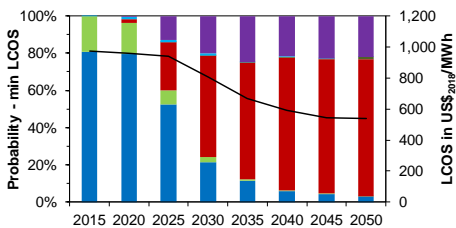
③ Secondary Response



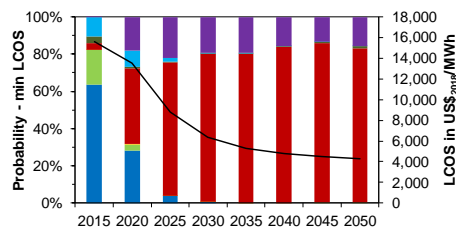
④ Tertiary Response



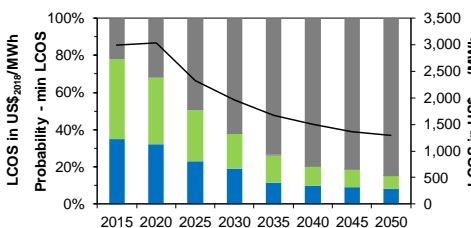
⑤ Peaker Replacement



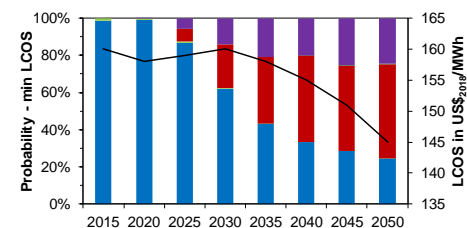
⑥ Black Start



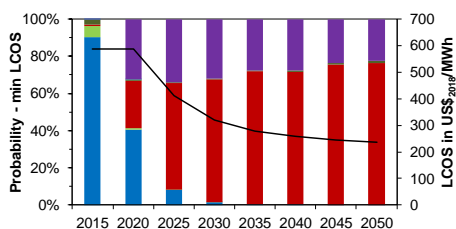
⑦ Seasonal Storage



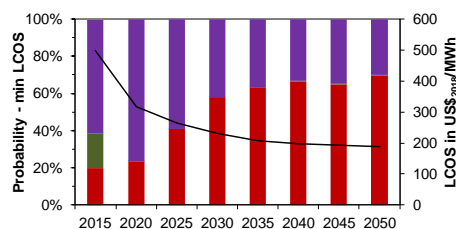
⑧ T&D Inv. Deferral



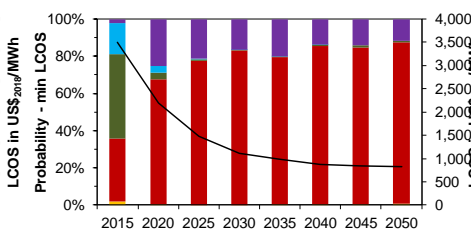
⑨ Congestion mgmt



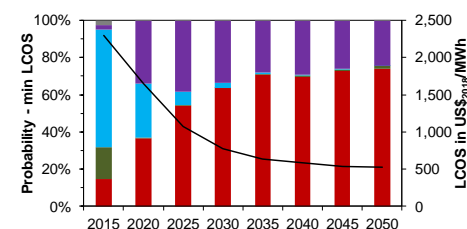
⑩ Bill management



⑪ Power quality

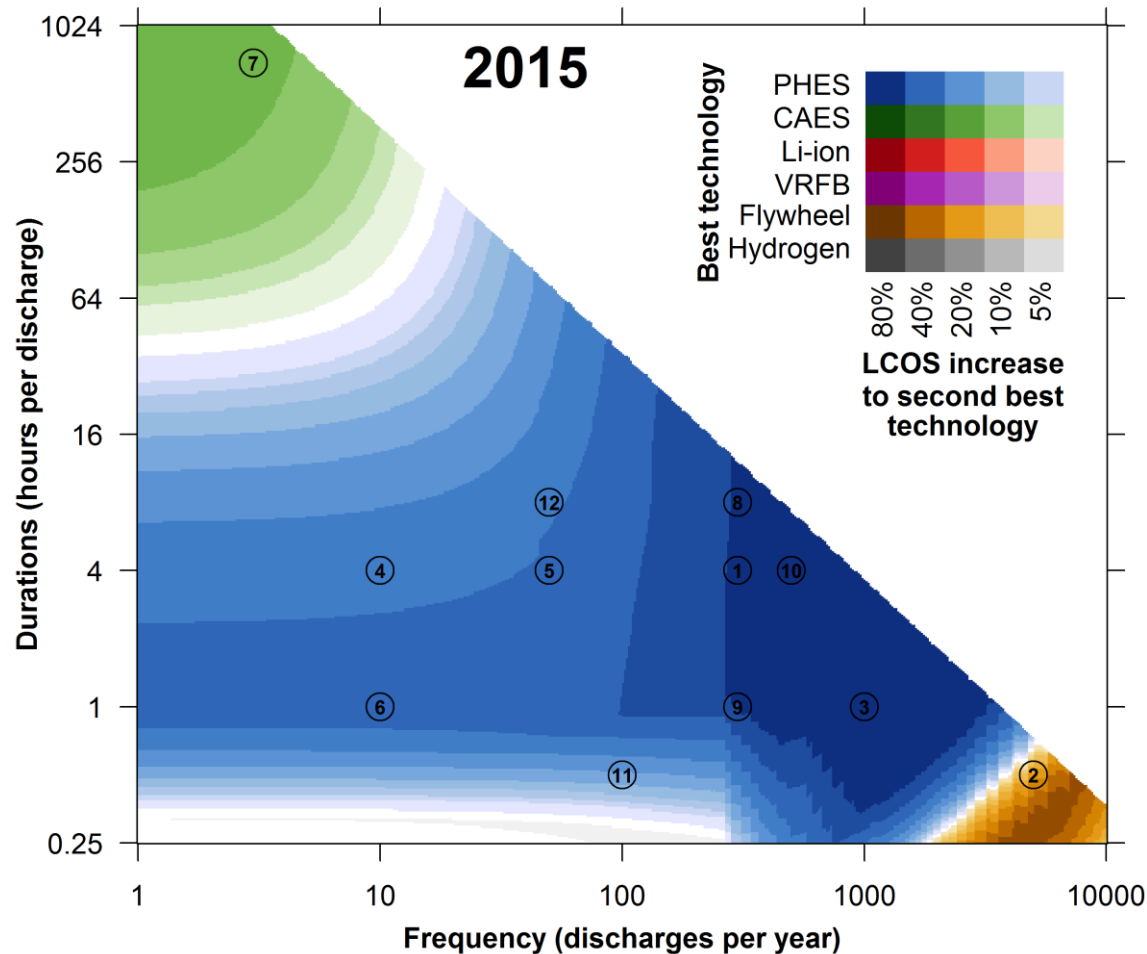


⑫ Power reliability



Overall, pumped hydro and compressed air give way to lithium-ion and hydrogen

General overview



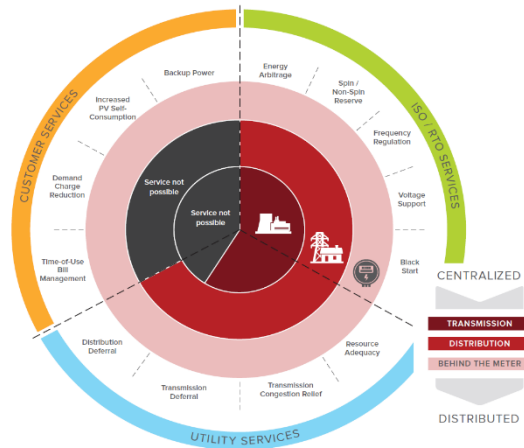
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There are different perspectives to look at the value of storage

Value of storage - perspectives

Market Value

Profitability in market-specific use case (near-term)

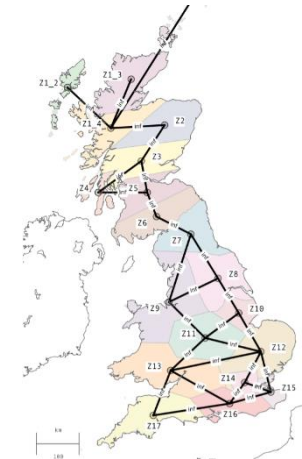


Sub-level analyses

- Optimal / strategic operation
- Market cannibalisation
- Benefit-stacking
- Policy impact
- ...

System Value

Net savings for system-specific scenario (long-term)



Sub-level analyses

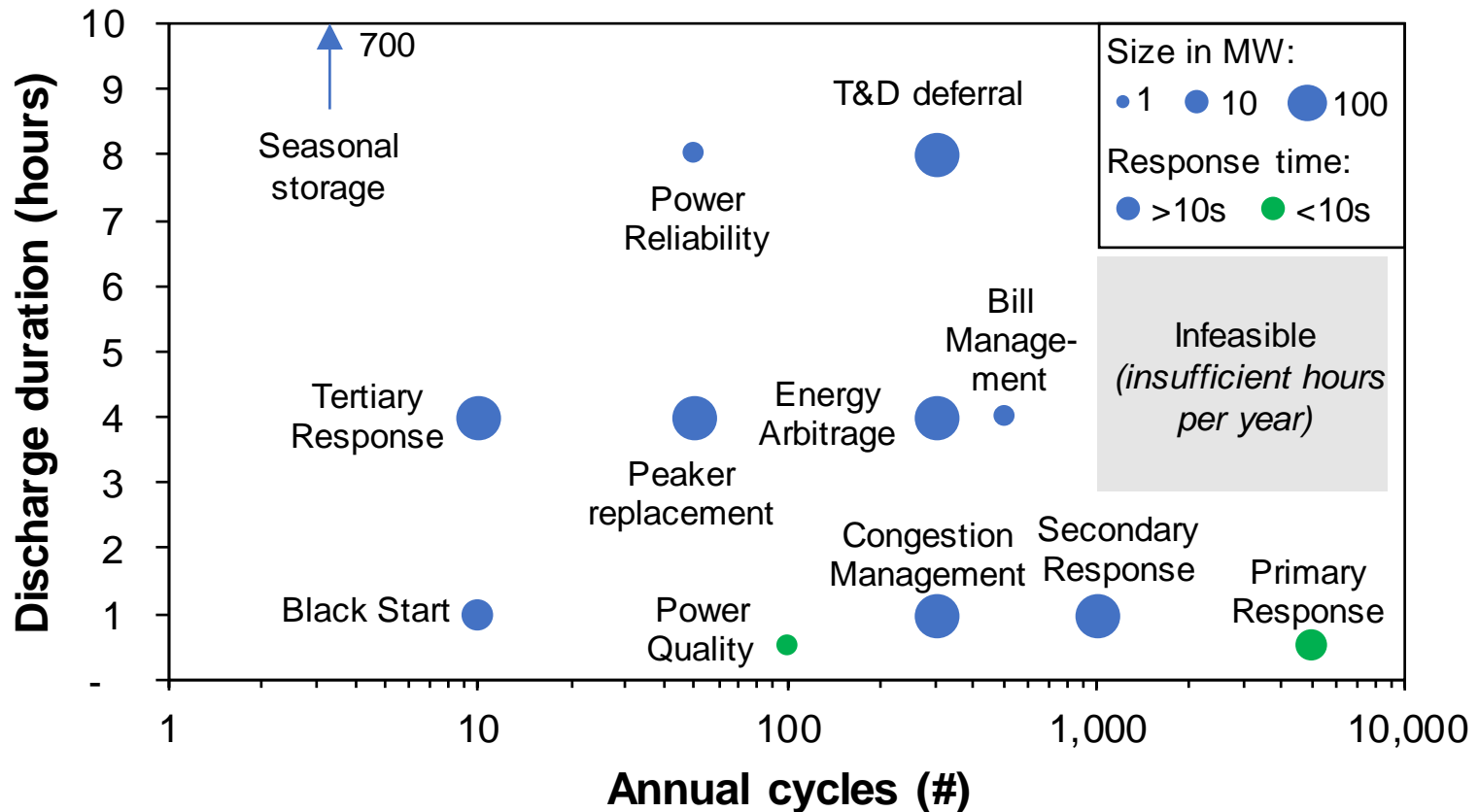
- Renewables integration / curtailment
- CO₂ emission reduction
- Optimal location in network
- Energy access
- Energy sector integration, ...

Questions & Discussion

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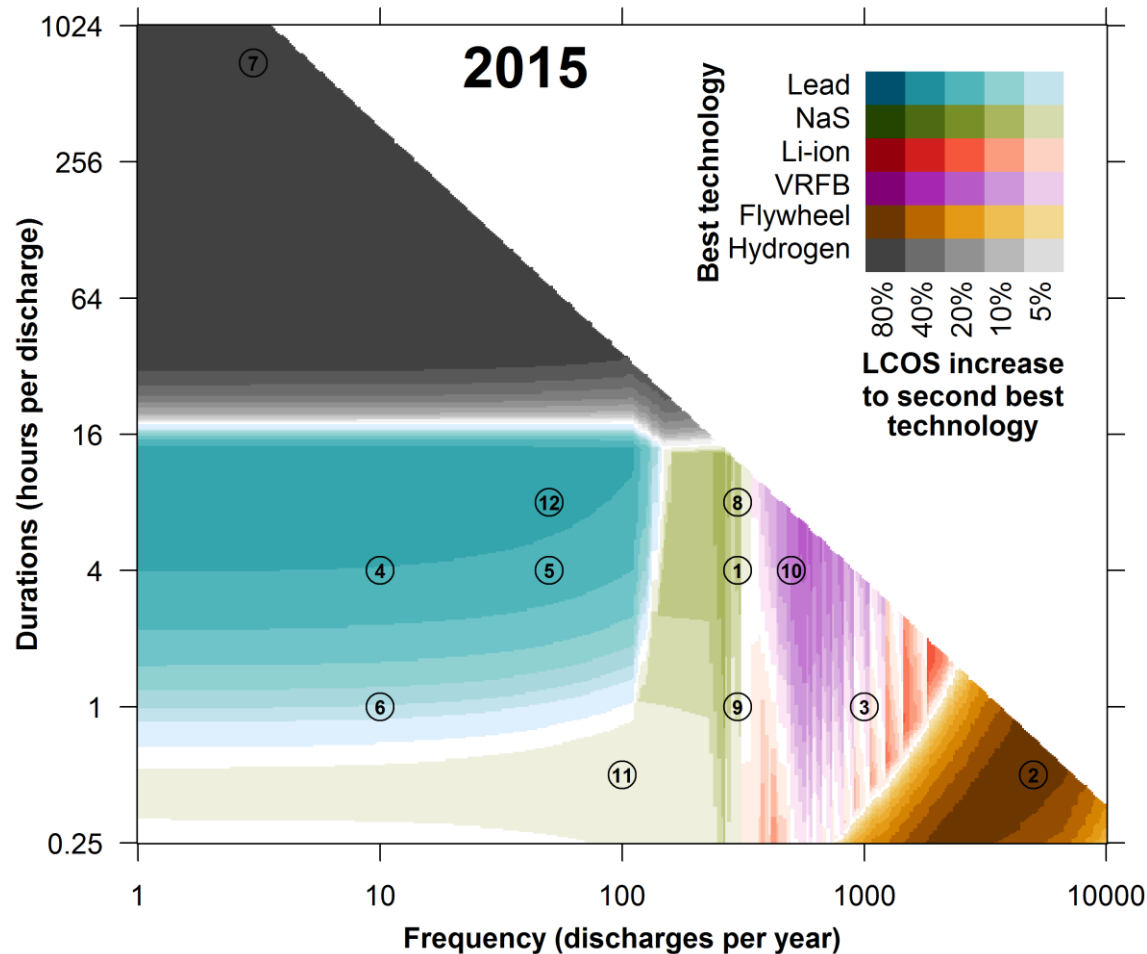
Modelled applications cover entire spectrum of performance requirements

Applications – Detail



Lithium-ion more competitive than all other battery technologies by 2030

General overview – excl. PHS, CAES



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