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Battery Conference

London 2023

AURORA KEYNOTE

The sensitivity of battery profitability to the evolution of Great Britain's power market

Caroline Still
Senior Associate, Aurora

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Setting the scene

- What fundamental market assumptions are most likely to risk batteries' profitability?

The variability of battery IRRs

- How sensitive are battery IRRs to variations of these assumptions?

The impact of location and duration

- Can duration or location of storage play a role in maximising the profitability of batteries?

The evolution of the GB power system will impact the size and prices of the key markets batteries can operate in, risking profitability

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What makes a battery market weaker?

The market **prices falling**

The market **size shrinking**

What makes a battery market stronger?

The market **prices rising**

The market **size growing**

What are the key markets that batteries can operate in?

1. **Wholesale market** — Day-ahead market
2. **Wholesale market** — Intraday market
3. **Balancing mechanism** — Energy Actions
4. **Balancing mechanism** — System Actions
5. **Ancillary services**
6. **Capacity market**

Energy trading: Batteries can **hedge risk** and **maximise opportunity** by trading between these markets

Which GB system assumptions will impact the size and prices of the markets that batteries operate in?

▪ **Direct competition** assumptions	Changes in total BESS[1] capacity deployed in system
▪ **Indirect competition** assumptions	Changes in total LDES[2] capacity deployed on the system (such as PSH[3]) or changes in other flexible technologies (peakers, DSR[4], interconnectors, Electric Vehicles or electrolysers)
▪ **System composition** assumptions	Changes in baseload and intermittent renewable deployment which alters the system flexibility requirements
▪ **System infrastructure** assumptions	Changes to the network and grid buildout which impacts the locational value of BESS

1) Battery Energy Storage System. 2) Long Duration Electricity Storage. 3) Pumped hydro storage. 4) Demand Side Response.

Source: Aurora Energy Research

We have identified four key industry concerns which will impact the evolution of the GB power markets and thus battery profitability

	Direct competition	Indirect competition	System infrastructure	System composition
Key industry concern	What would be the impact of an **oversaturation of batteries?**	What would be the impact of **increased PSH capacity?**	What would be the impact of **a slower grid buildout**?	What would be the impact of **a smaller nuclear fleet**?
Why?	**Why?** Aurora's BESS capacity estimate assumes approximately 25% of the pipeline will materialise by 2035[1]	**Why?** The renewed emphasis on LDES policy could lead to improved PSH economics	**Why?** National Grid's planned transmission line buildout could face delays	**Why?** Long lead times and significant cost over-runs risk nuclear deployment

1) Aurora's Central scenario assumes 15 GW of BESS by 2035, whereas the BESS projects in the TEC register exceed 60 GW, from application submitted and including co-located assets.

Sources: Aurora Energy Research, National Grid

We are able to model these industry concerns as separate GB power market scenarios using Aurora's power market modelling tool Origin

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	Direct competition	Indirect competition	System infrastructure	System composition
Key industry concern	What would be the impact of an **oversaturation of batteries?**	What would be the impact of **increased PSH capacity?**	What would be the impact of **a slower grid buildout**?	What would be the impact of **a smaller nuclear fleet**?
Why?	**Why?** Aurora's BESS capacity estimate assumes approximately 25% of the pipeline will materialise by 2035[1]	**Why?** The renewed emphasis on LDES policy could lead to improved PSH economics	**Why?** National Grid's planned transmission line buildout could face delays	**Why?** Long lead times and significant cost over-runs risk nuclear deployment
Scenario name	**Battery overbuild**	**Pumped hydro[2] overbuild**	**Delayed grid buildout**	**Delayed nuclear deployment**
Difference to Aurora Central	8.3 GW more battery capacity by 2050 (**50% more**)	4.5 GW more long duration storage by 2050 (**120% more**)	7 GW less transmission capacity on B6 boundary by 2050 (27% less) 5 GW less transmission capacity on B8 boundary by 2050 (18% less)	5.1 GW less nuclear capacity by 2050 (33% less)[3]
Likelihood[4]				

1) Aurora's Central scenario assumes 15 GW of BESS by 2035, whereas the BESS projects in the TEC register exceed 60 GW, from application submitted and including co-located assets. 2) Pumped storage hydro is also referred to as PSH. 3) Aurora's Central scenario reaches 15.6 GW of Nuclear by 2050, whereas the Delayed Nuclear Deployment scenario reached 10.4 GW. 4) Indicative likelihood.

Sources: Aurora Energy Research, National Grid

The four scenarios change the evolution of the GB power market by altering capacity, price spreads and market depths

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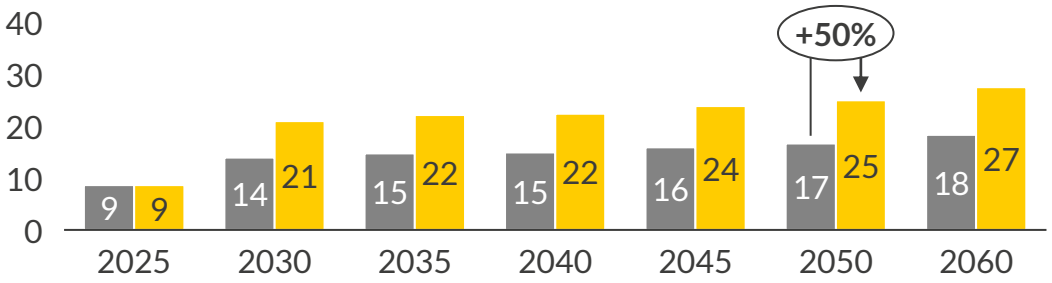
Central scenario
Alternative scenario

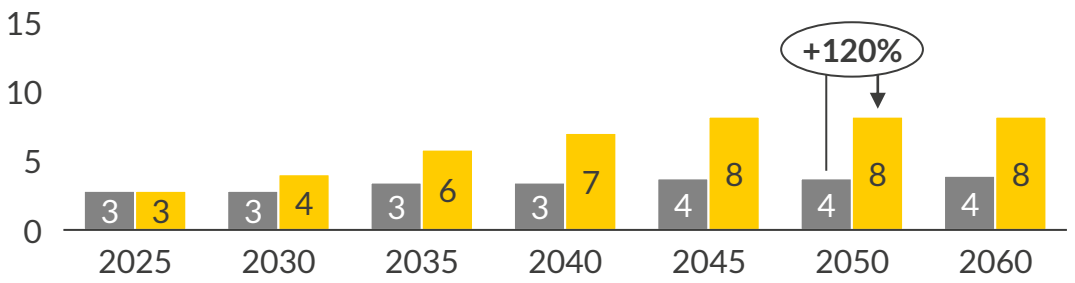
Battery overbuild

Battery capacity
GW



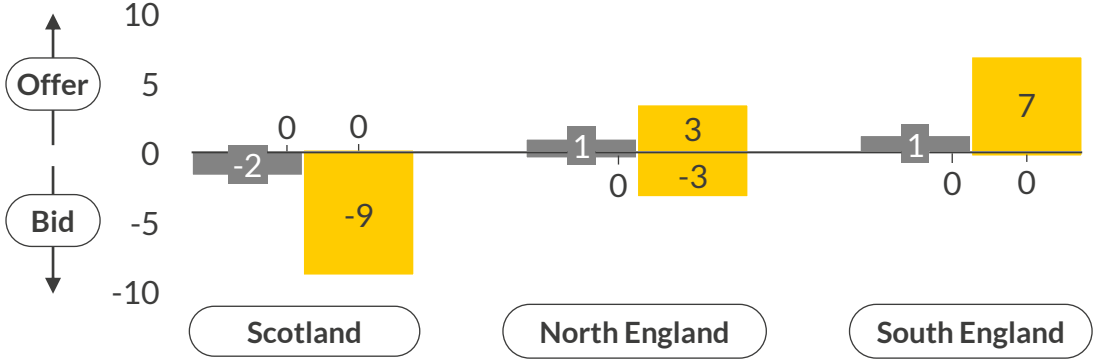
Pumped hydro overbuild

Pumped hydro (PSH) capacity
GW



Delayed grid buildout

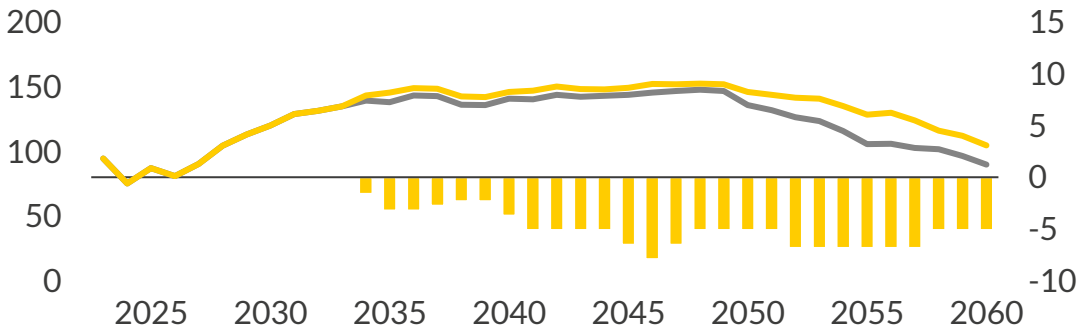
Average annual system action taken[1]
TWh



Delayed nuclear deployment

Wholesale price spread[2]
£/MWh

Nuclear capacity delta to Central
GW



1) By all technologies participating in the BM and averaged between 2023-2060. 2) Between 95th and 5th percentile of the wholesale market prices.

Source: Aurora Energy Research

Using Aurora's dispatch model, Chronos, we tested six battery archetypes in all scenarios, using Aurora Central as a benchmark

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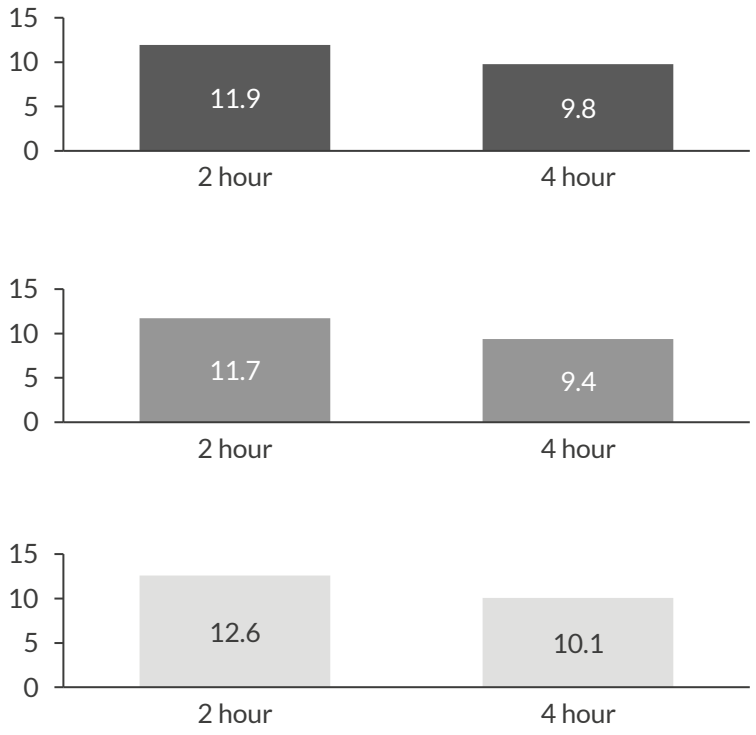
1 The BESS archetypes covered 2 durations in 3 locations

Duration	2 hour	4 hour
Cycle rate	2 cycles/day	1 cycle/day
Location	All three Aurora zones[1]	
Connection	Distribution connected	
Repowering	63%	
Lifetime	2027-2060	
Business model	Hybrid[2]	
Capacity market	Rolling T-4 1-year contracts	
CAPEX$_{2026}$	£540/kW	£817/kW

2 The Central scenario[3] was used to benchmark performance

IRR
% (real 2022, pre-tax)



1) Scotland, North England and North Wales, South England and South Wales. 2) Hybrid business model includes energy trading, dynamic containment and ancillary services. 3) Central Scenario GB Power Market Forecast, Q3, October 2023.

Source: Aurora Energy Research

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Battery profitability varies broadly across the scenarios and archetypes – we will explore the key trends and drivers next

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Region	2h 2 cycles per day	4h 1 cycle per day
Scotland	IRRs % -25% +10% 8.9 10.3 11.9 12.5 13.1	IRRs % -25% +12% 7.3 8.2 9.8 10.8 10.9
North England and North Wales	IRRs % -27% +10% 8.6 10.4 11.7 12.3 12.9	IRRs % -27% +12% 6.9 8.1 9.4 9.8 10.5
South England and South Wales	IRRs % -24% +9% 9.5 11.3 12.6 13.5 13.7	IRRs % -25% +10% 7.6 8.9 10.1 10.8 11.1
Likelihood	Central	Central

Source: Aurora Energy Research

Batteries are most profitable in the scenario where nuclear capacity is reduced, with the slower grid buildout scenario also providing upside

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Region	2h 2 cycles per day	4h 1 cycle per day
Scotland	IRRs % -25% +10% 8.9 10.3 11.9 12.5 13.1	IRRs % -25% +12% 7.3 8.2 9.8 10.8 10.9
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Likelihood	Central	Central

Source: Aurora Energy Research

How big is the upside for batteries in a scenario where…

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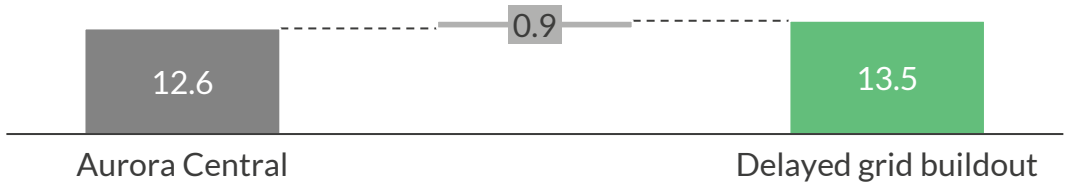
Illustrative battery for this analysis - 2h 2 cycles, South England and South Wales

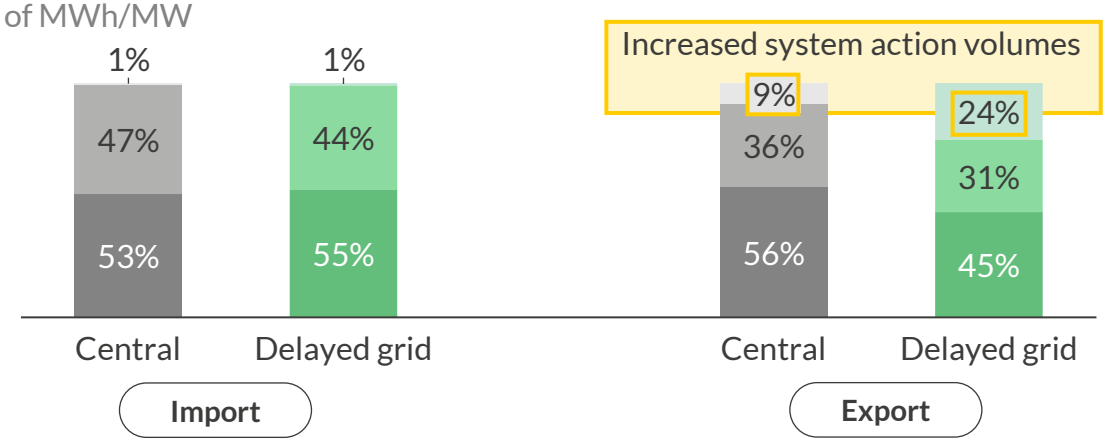
1 …transmission infrastructure falls short of National Grid's targets?

IRRs
%



What is the **main driver?**

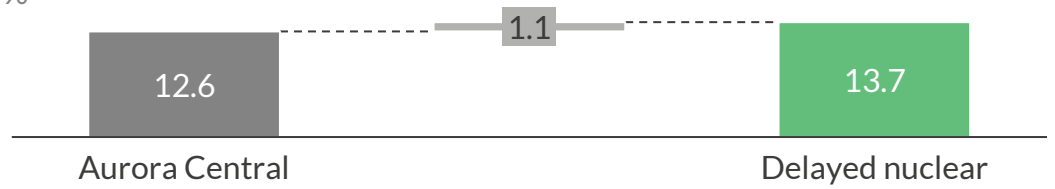
Average annual distribution of export/import hours[1,2]
% of MWh/MW



Illustrative battery for this analysis - 2h 2 cycles, South England and South Wales

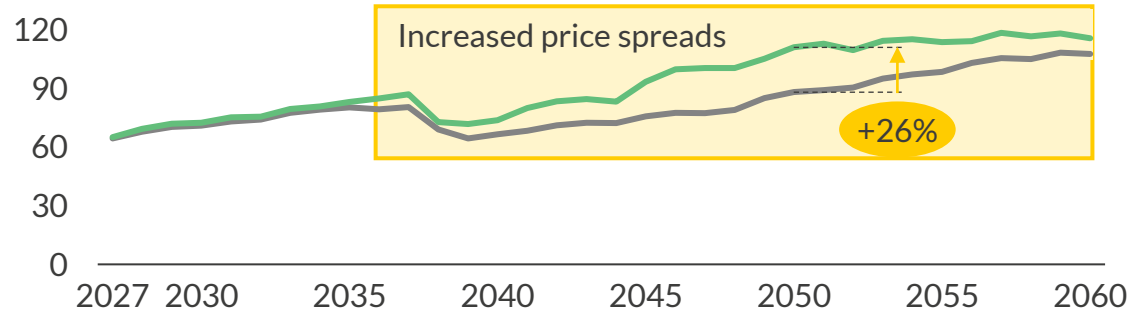
2 …nuclear capacity rollout is slower than expected?

IRRs
%



What is the **main driver?**

Average capture spreads[3]
£/MWh



Wholesale Market | BM (Energy Actions) | BM (System Actions)

Aurora Central | Delayed nuclear deployment

1) 34 years, 2027-2060. 2) BESS dispatch is based on an average cycling target of 2.0 cycles/day for the illustrative battery in South England and South Wales. Import hours exceed export hours due to round-trip efficiency losses.3) Per MWh of export energy trading (including Churn) for 2h 2 cycles in South England and South Wales.

Source: Aurora Energy Research

Batteries are least profitable in the scenario with 50% battery overbuild, with increased PSH buildout also eroding profitability

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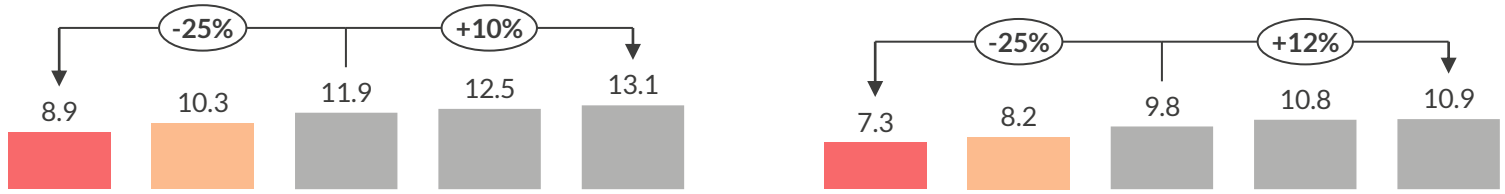
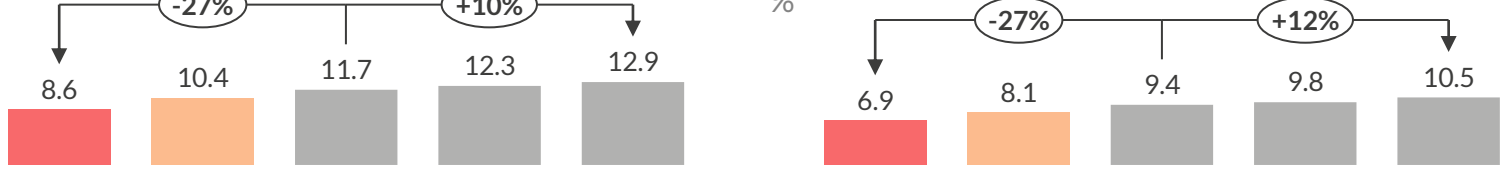
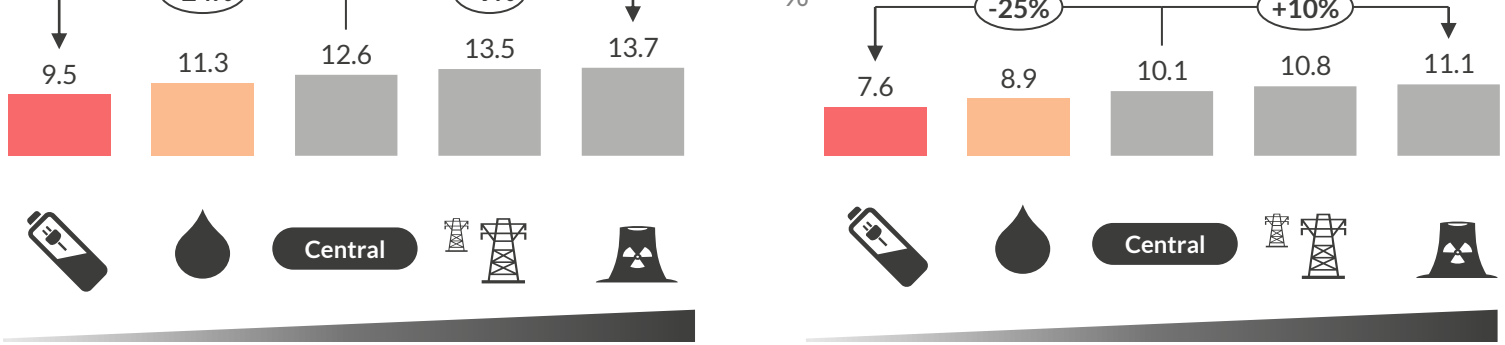
Region	2h 2 cycles per day	4h 1 cycle per day
Scotland			
North England and North Wales			
South England and South Wales			
Likelihood			

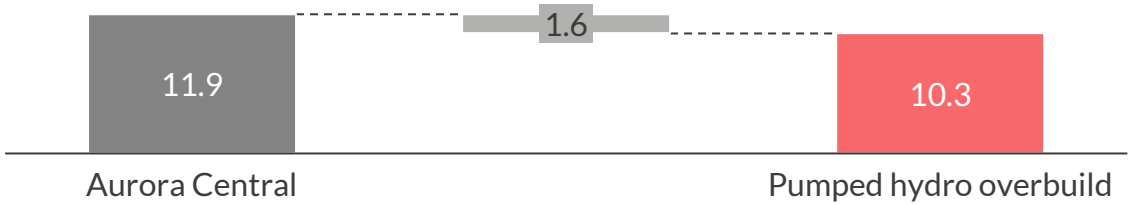
Source: Aurora Energy Research

How big is the downside for batteries in a scenario where…

Illustrative battery for this analysis - 2h 2 cycles, Scotland

1 … pumped hydro storage is higher by 120% (4.5 GW) by 2050?

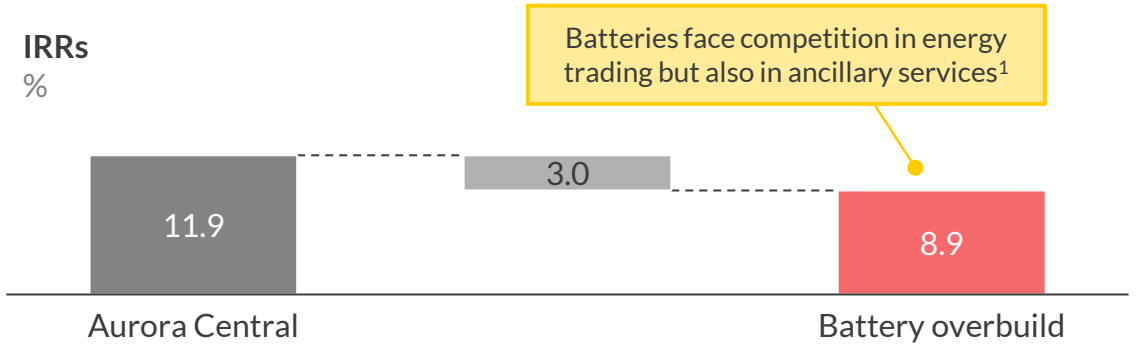
IRRs
%



Illustrative battery for this analysis - 2h 2 cycles, Scotland

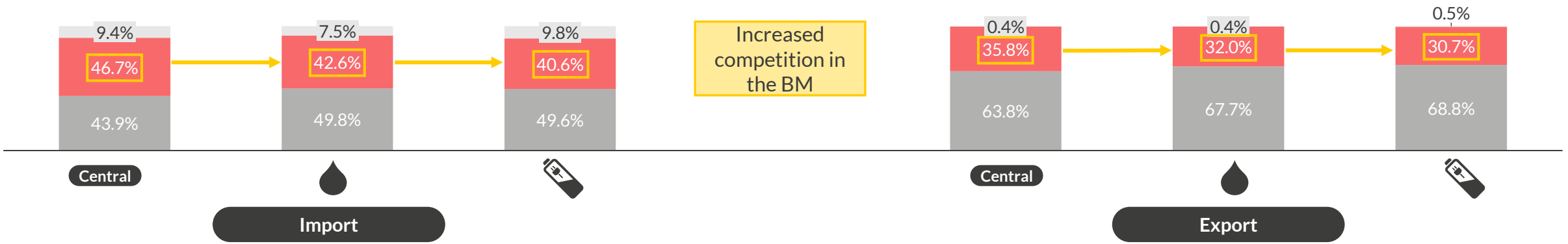
2 … there is a 50% (8.3 GW) overbuild of battery capacity?

IRRs
%



What is the **main driver?**

Average annual distribution of export/import hours[2,3]
% of MWh/MW



1) Dynamic frequency response services (DC, DR and DM). 2) Average over 34 years, 2027-2060. 3) BESS dispatch is based on an average cycling target of 2.0 cycles/day for the illustrative battery in Scotland. Import hours exceed export hours due to round-trip efficiency losses.

Source: Aurora Energy Research

How big is the downside for batteries in a scenario where…

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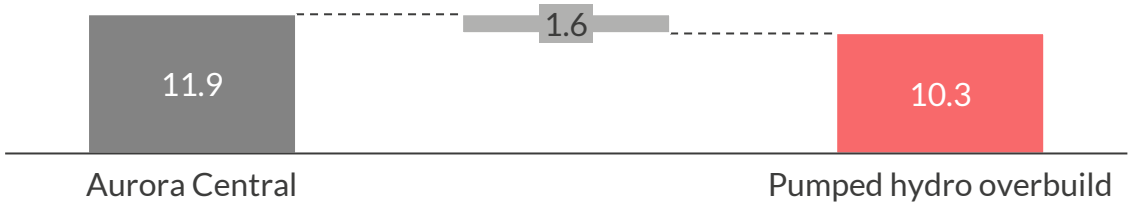
Illustrative battery for this analysis - 2h 2 cycles, Scotland

1 … pumped hydro storage is higher by 120% by 2050?

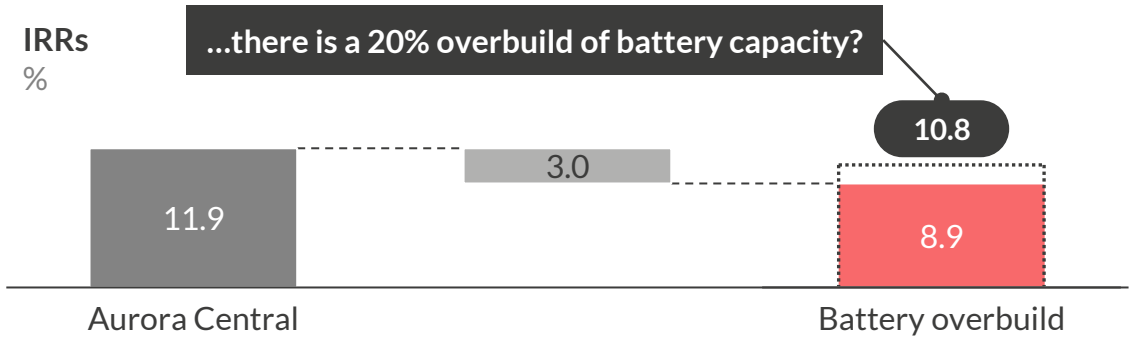
IRRs
%



Illustrative battery for this analysis - 2h 2 cycles, Scotland

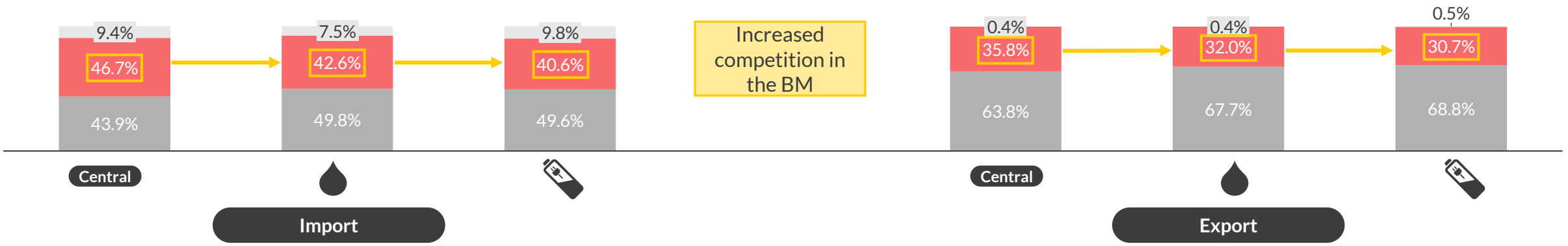
2 … there is a 50% overbuild of battery capacity?

IRRs
%



What is the **main driver?**

Average annual distribution of export/import hours[1,2]
% of MWh/MW



1) Average over 34 years, 2027-2060. 2) BESS dispatch is based on an average cycling target of 2.0 cycles/day for the illustrative battery in Scotland. Import hours exceed export hours due to round-trip efficiency losses.

Source: Aurora Energy Research

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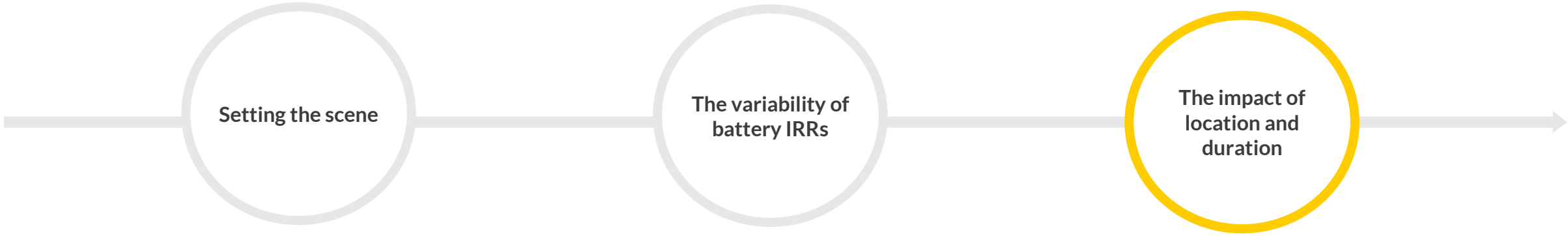

- What fundamental market assumptions are most likely to risk batteries' profitability?
- How sensitive are battery IRRs to variations of these assumptions?
- Can duration or location of storage play a role in maximising the profitability of batteries?

Longer duration batteries can help in mitigating the variability of profitability as they are able to maximise import/export at high spreads

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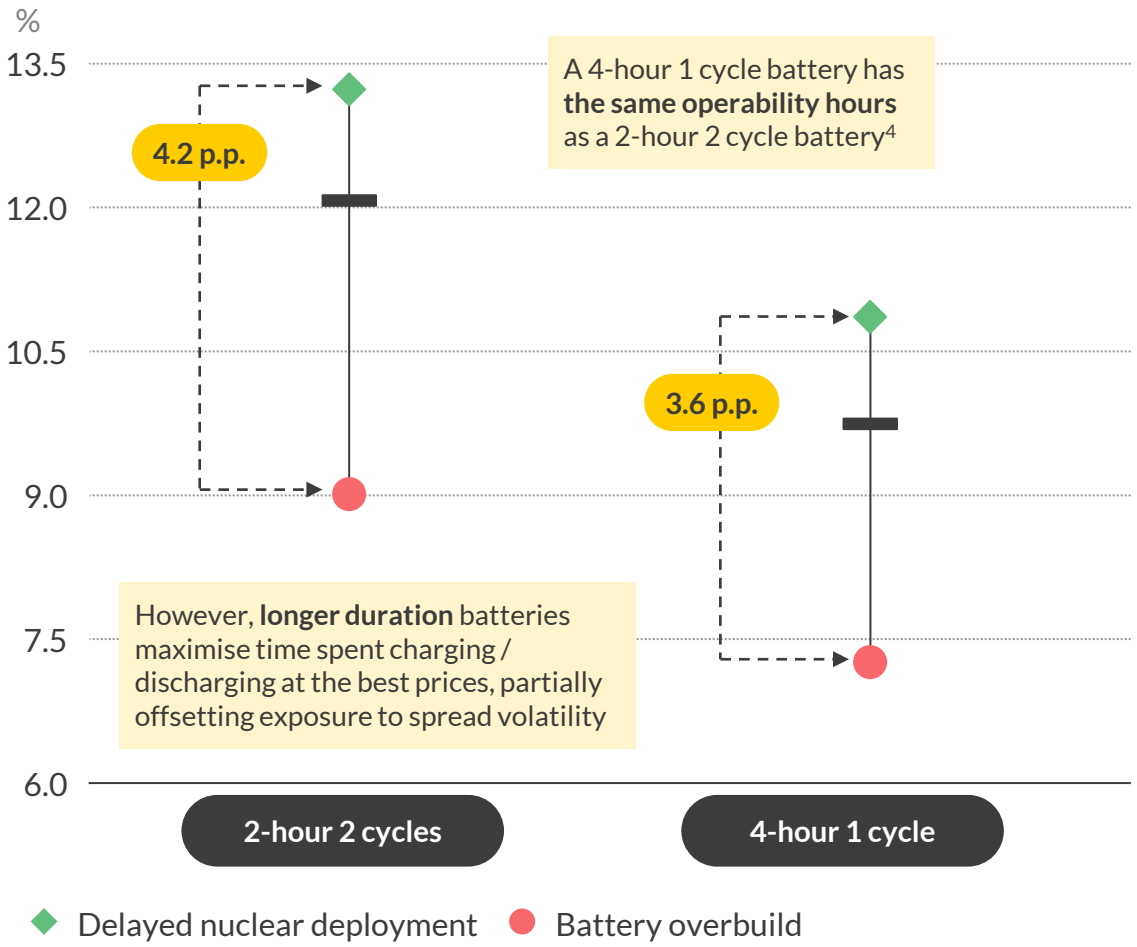
1 Batteries with longer duration have less IRR variability

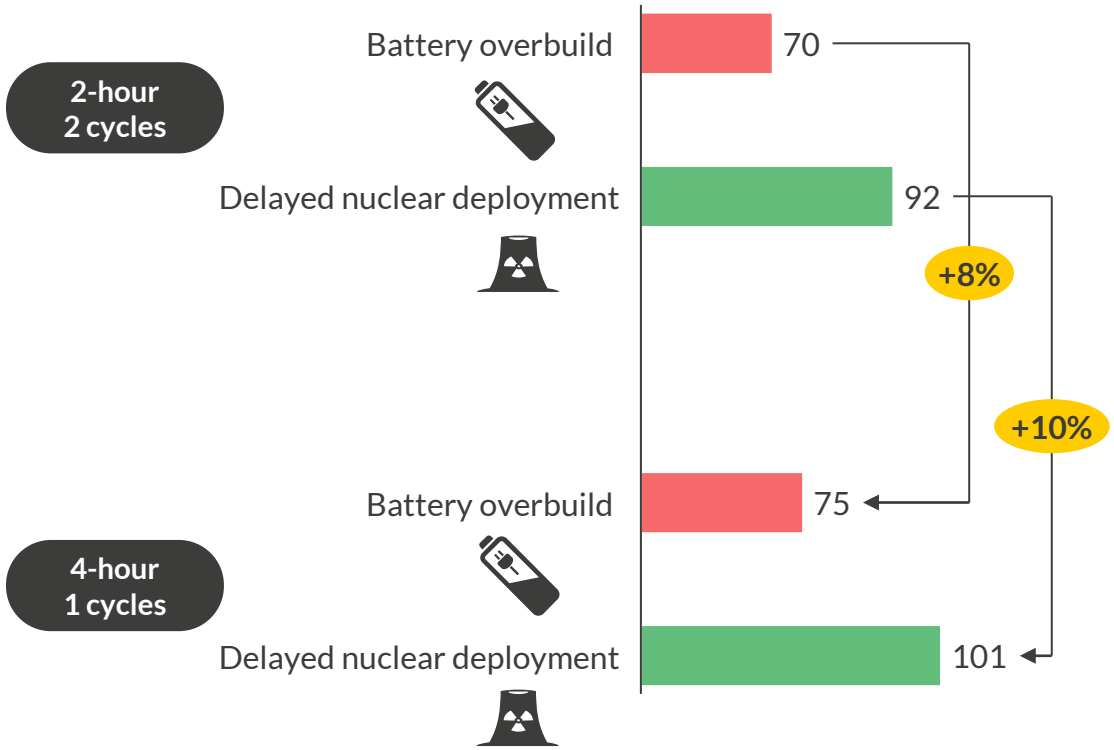
Maximum variation of IRRs[1]



2 As they are able to maximise favourable spreads

Average capture spreads[2,3]

£/MWh of export



Despite a 4-hour battery capturing bigger spreads than a 2-hour battery, a **53% increase in its CAPEX results in a lower IRR**

1) Averaged across locations for each duration. 2) 34 years, 2027-2060 and across locations. 3) Captured spreads from Energy trading (including Churn) in per MWh of export. 4) Before accounting for the effects of degradation.

Source: Aurora Energy Research

Batteries located near demand centres and RES deployment zones are more resilient to changes to the GB power market

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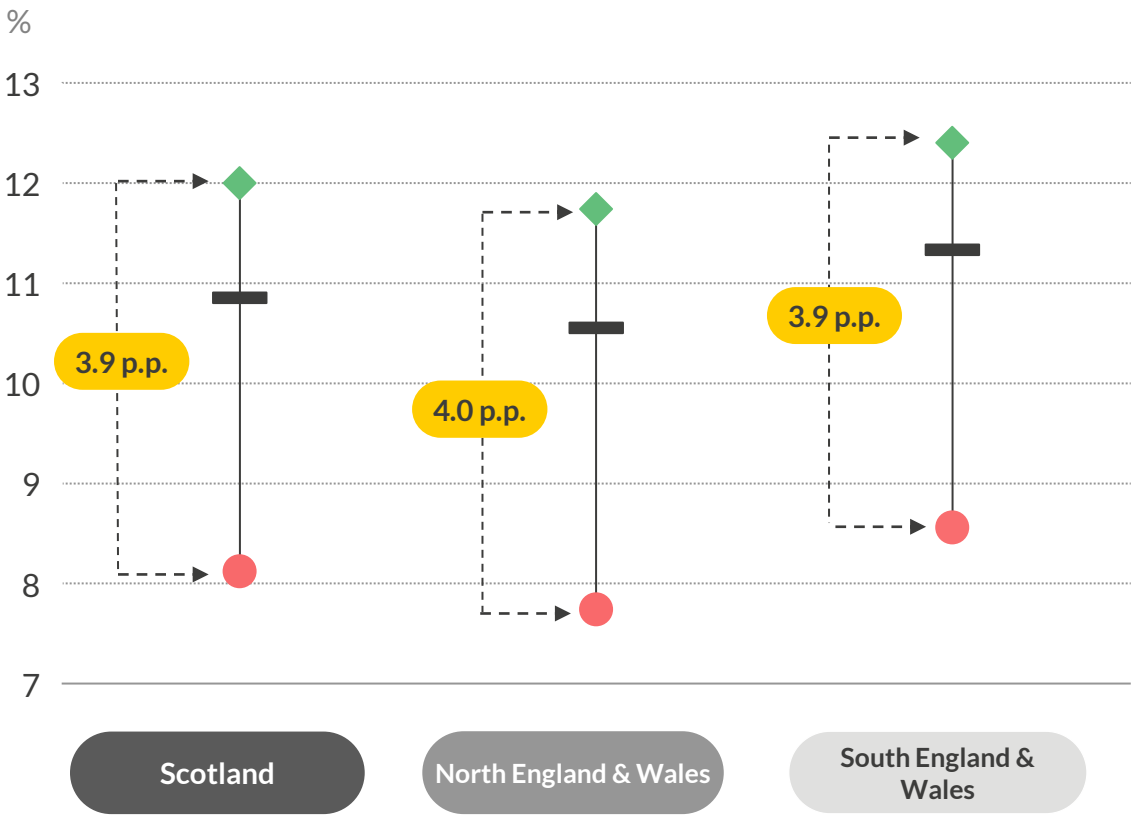
1 How much does a battery benefit from location…

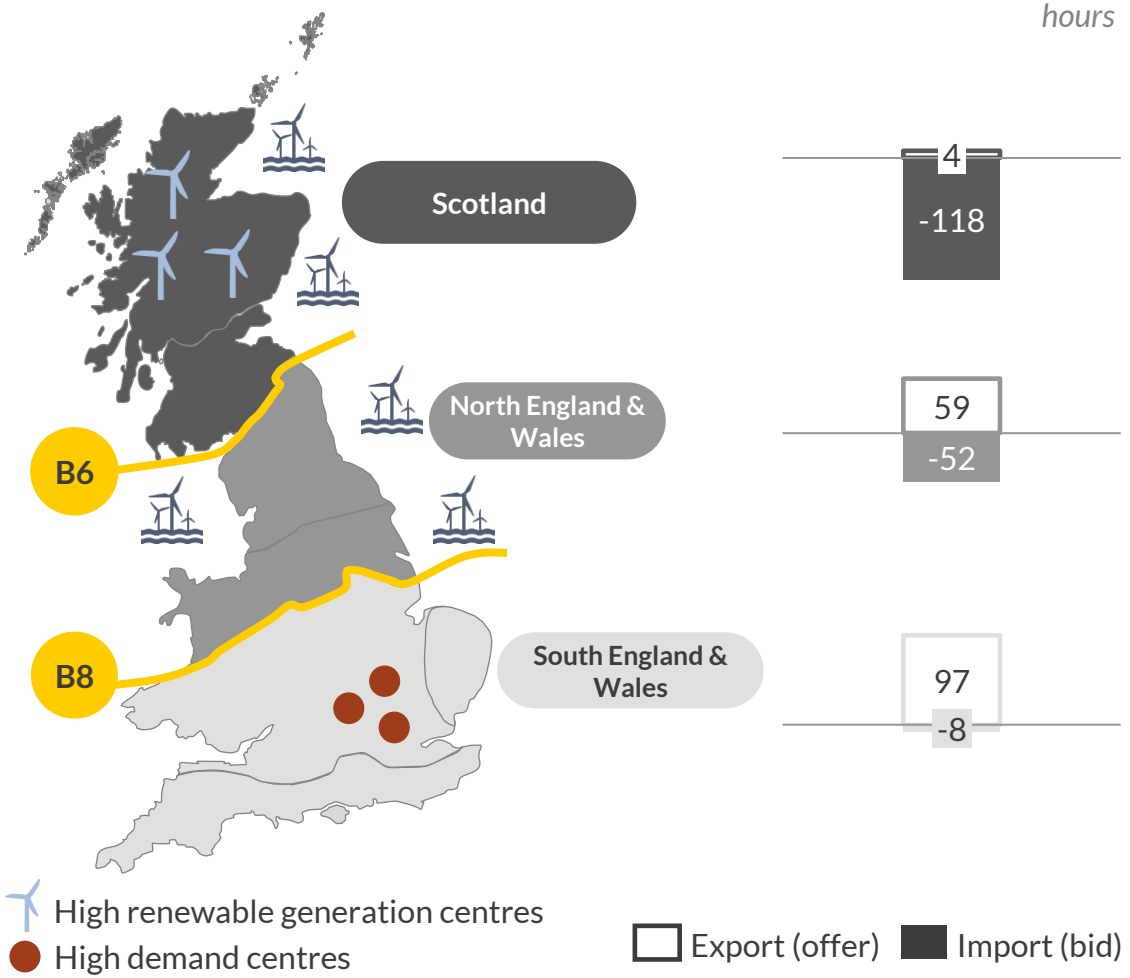
Maximum variation of IRRs[1]



2 …if the battery is closer to demand centres or renewable buildout zones?

Average annual BM (System actions) of a battery[2,3]

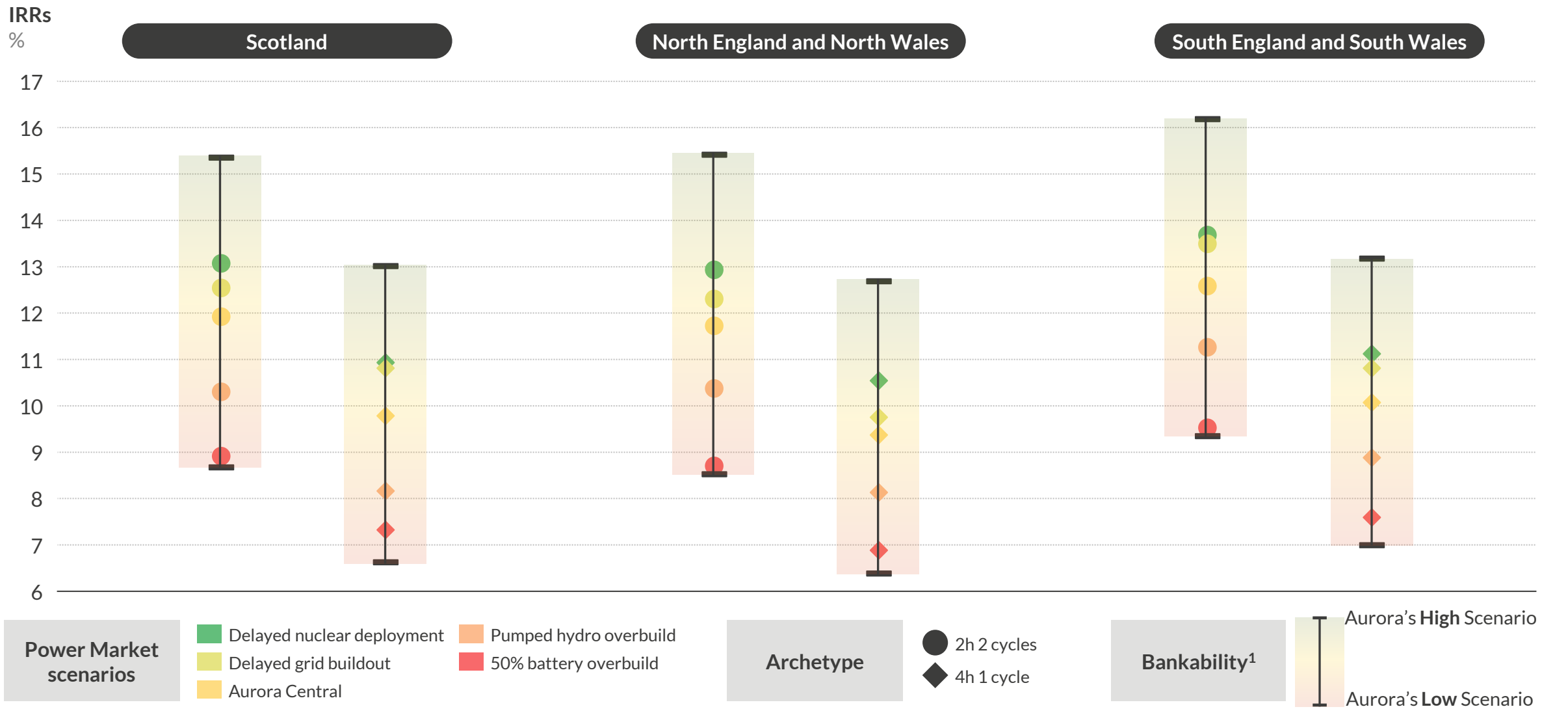
hours



1) Averaged across the 2-hour 2 cycles and the 4-hour 1 cycle batteries. 2) Averaged over 34 years, 2027-2060. 3) Illustrative battery for this analysis - 2h 2 cycles, Central scenario. BESS dispatch is based on an average cycling target of 2.0 cycles/day under Aurora Central scenario. Import hours exceed export hours due to round-trip efficiency losses

Source: Aurora Energy Research

Overall, the IRRs in all tested scenarios fall within the bounds of Aurora's High and Low scenarios, with more potential upside available



1) Aurora High scenario is a high commodity price (Gas and Carbon) and high demand environment of our Central scenario capacity assumptions. Aurora Low scenario is a low commodity price (Gas and Carbon) and low demand environment of our Central scenario capacity assumptions. These scenarios are used in conjunction with our Central scenario as part of debt and equity transactions.

Source: Aurora Energy Research

Key Takeaways

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1. Power markets that evolve with **increased competition** (direct and indirect) represent a **downside risk** for battery investments, whereas **delays to grid infrastructure** buildout and **delays to low carbon baseload** capacity deployment will be an **upside opportunity**.

2. The **downside scenarios tested impact IRRs** more than the upside, but the **likelihood** of a 50%/120% increase in battery/PSH capacity is low, whereas the likelihood of delays to the infrastructure requirements for nuclear and grid build-out is high.

3. In general, **battery profitability is relatively robust to the evolution of the GB power market** due to the **natural hedging** of the energy trading done within the wholesale markets and balancing mechanism.

4. The higher CAPEX of **longer duration batteries** will limit profitability in the near term, but their ability to **maximise favourable spreads** will mitigate the variability of their IRRs, providing more reliable returns.

5. Batteries located in the **South and in Scotland** are most likely to **benefit from locational constraint volumes**, providing an uplift in profitability under all market scenarios.

6. **All tested scenarios fall within Aurora's High and Low scenarios**, highlighting that the floor and ceiling provided by these scenarios are inclusive of significant deviations from Aurora Central (even extreme deviations like a 50% battery overbuild).

Details and disclaimer

Keynote, Aurora Battery Conference 2023

Date:
8 November 2023

Project lead:
Martina Fava

Analysis:
Christopher Chen

Approved by:
Caroline Still

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