Aurora Keynote:

The next frontier in green energy: Finding the perfect site for onshore renewables

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Renewables Summit

London 2023

Agenda

RES revenue optimisation

- Where is the most locational value on the system?
- What are the impacts of co-location?
- What are the potential benefits of a 7-zone model with greater locational granularity?

Net Zero Policy

Grid Development

Key Takeaways

Rising cost for RES is leading developers to find revenue optimising opportunities

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Challenges

Solar PV hardware costs increased by 90% over 2020–22, mostly due to increasing price of polysilicon used in the module component

Onshore wind hard costs grew 22% over 2020–22 due to increasing steel and copper prices

Interest rates have risen 4.35% since Jan 2022 and **grid connection costs** are steadily rising

Opportunities

A Optimised Siting

- Assets can be sited in locations with high load factors and gain additional revenue by solving energy imbalances due to grid congestion (Balancing Mechanism system actions)
- This siting can be future-proofed against network build uncertainty, Net Zero policy, and market reforms (i.e., locational marginal pricing under REMA[1])

B Co-location

- Co-locating with battery storage allows for sharing grid connection access and costs, as well as
- Optimisation of renewables output against non-firm grid connections and line constraints

Source(s): Aurora Energy Research

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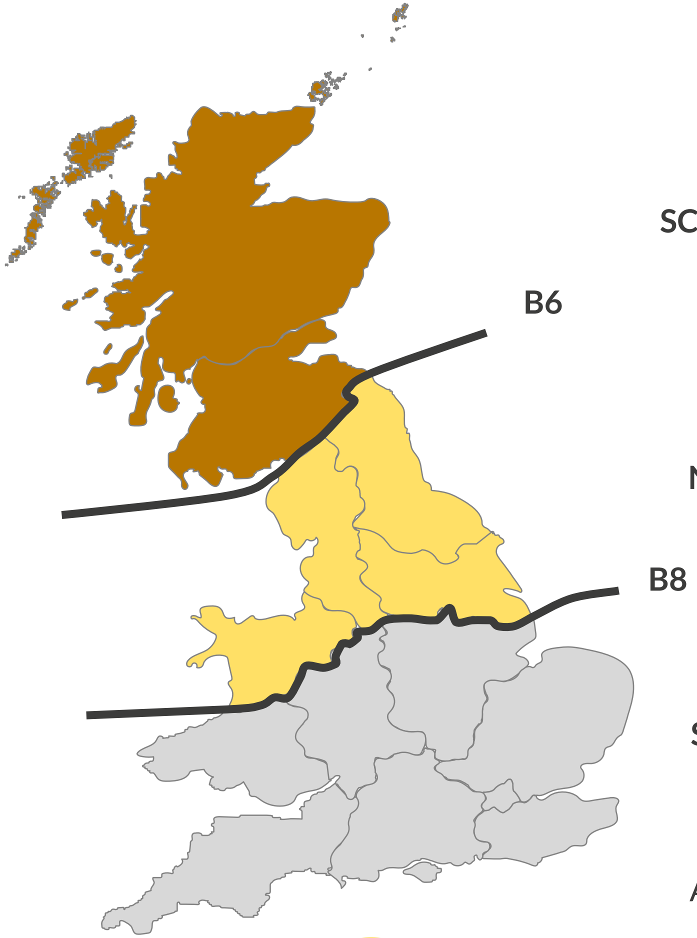
Developers can optimise for location and/or co-locate with storage to improve project returns

Technology-specific Locational Value Relative to National Average (Aurora Central)[1]

	Onshore wind	Onshore wind + battery	Solar	Solar + battery
SCOTLAND	1.11x	1.05x	0.92x	0.99x
NORTH	1.04x	1.02x	0.99x	1.0x
SOUTH	0.85x	0.93x	1.09x	1.01x
National Avg. IRR[2]	~10%	~14%	~7%	~9%



Increased Value (green) | Decreased Value (orange)

ORIGIN + CHRONOS

A Optimised Siting

- **Onshore wind** sited in Scotland gain the highest revenues due to higher load factors **and BM turn-down revenues**
- **Solar** predominately gains more revenue in the south from **higher load factors**

B Battery Co-location

- Battery co-location leads to **4 and 2 p.p. higher IRRs** for wind and solar on average
- **Co-location reduces the significance of location:** bringing onshore wind in the South and solar in the North up in revenue

1) Transmission connected, 2023–2060 average yearly gross margins; 2) Pre-tax, for market entry in 2030

Source(s): Aurora Energy Research

Aurora recently investigated more granular locational value of renewables in the Balancing Mechanism

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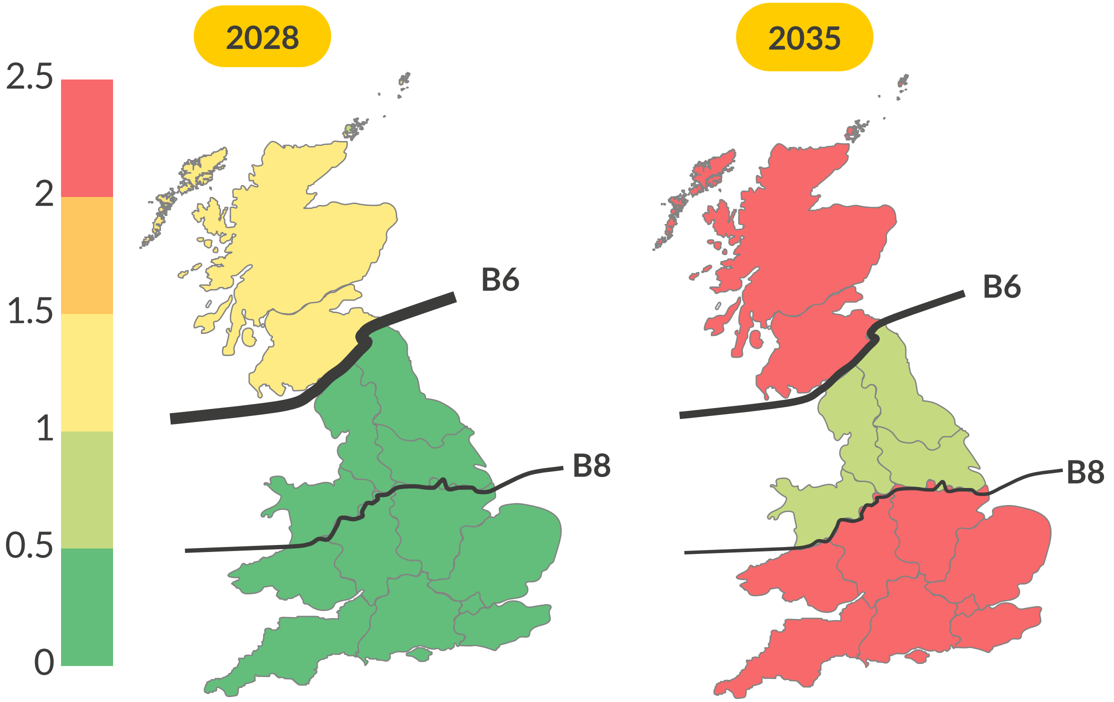
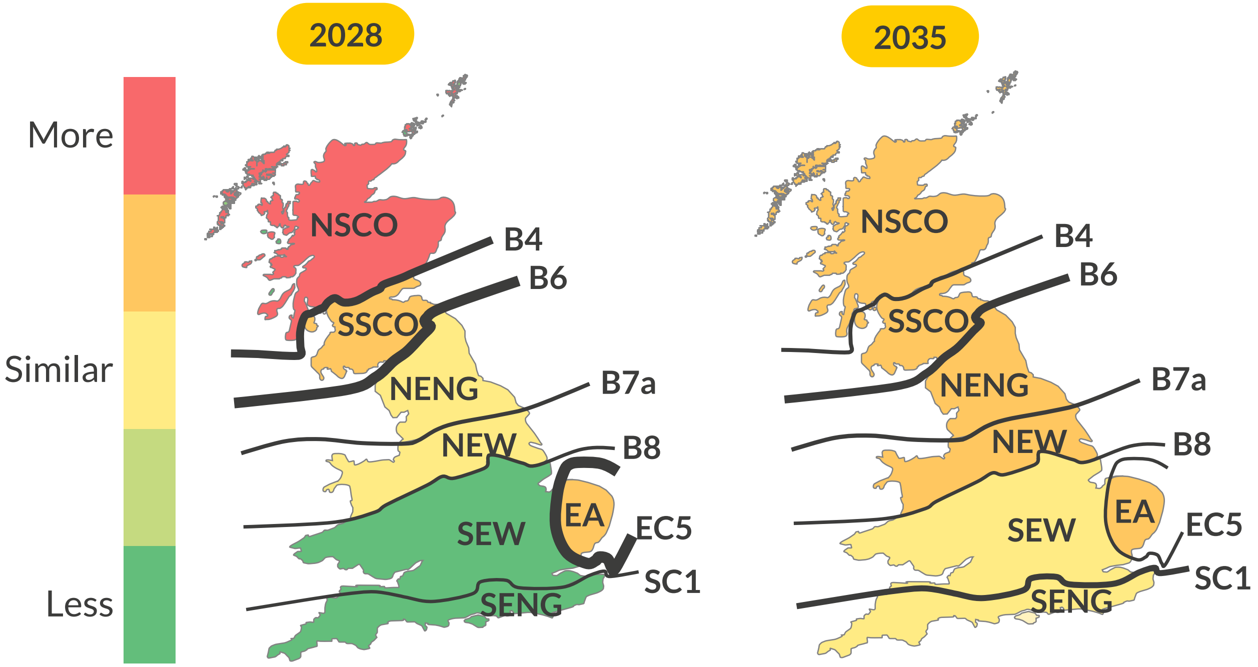
Wind Power Curtailment[1] and Boundary Congestion, 3-zone model
%



Wind Power Curtailment[1] and Boundary Congestion, 7-zone model
Difference to 3-zone model



- Aurora's 3-zone model captures constraint management actions across 2 key transmission boundaries
- These actions, **solicited through the Balancing Mechanism and economic curtailment**, are highly locational and can significantly impact renewables revenue through curtailment actions

Line thickness proportional to boundary congestion

- Looking at system actions over 7 zones allows Aurora to capture new localised congestion impacts
- A **7-zone view captures 5% curtailment in EA in 2035, unseen in 3-zone view**
  - Revenue opportunities for co-location with storage
  - Improved understanding of project risk for developers

1)Average curtailed fraction of all onshore wind

Source(s): Aurora Energy Research

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RES revenue optimisation

Net Zero Policy

- What effect does Net Zero policy have on locational value in a 7-zone model?
- How does this impact renewables developers?

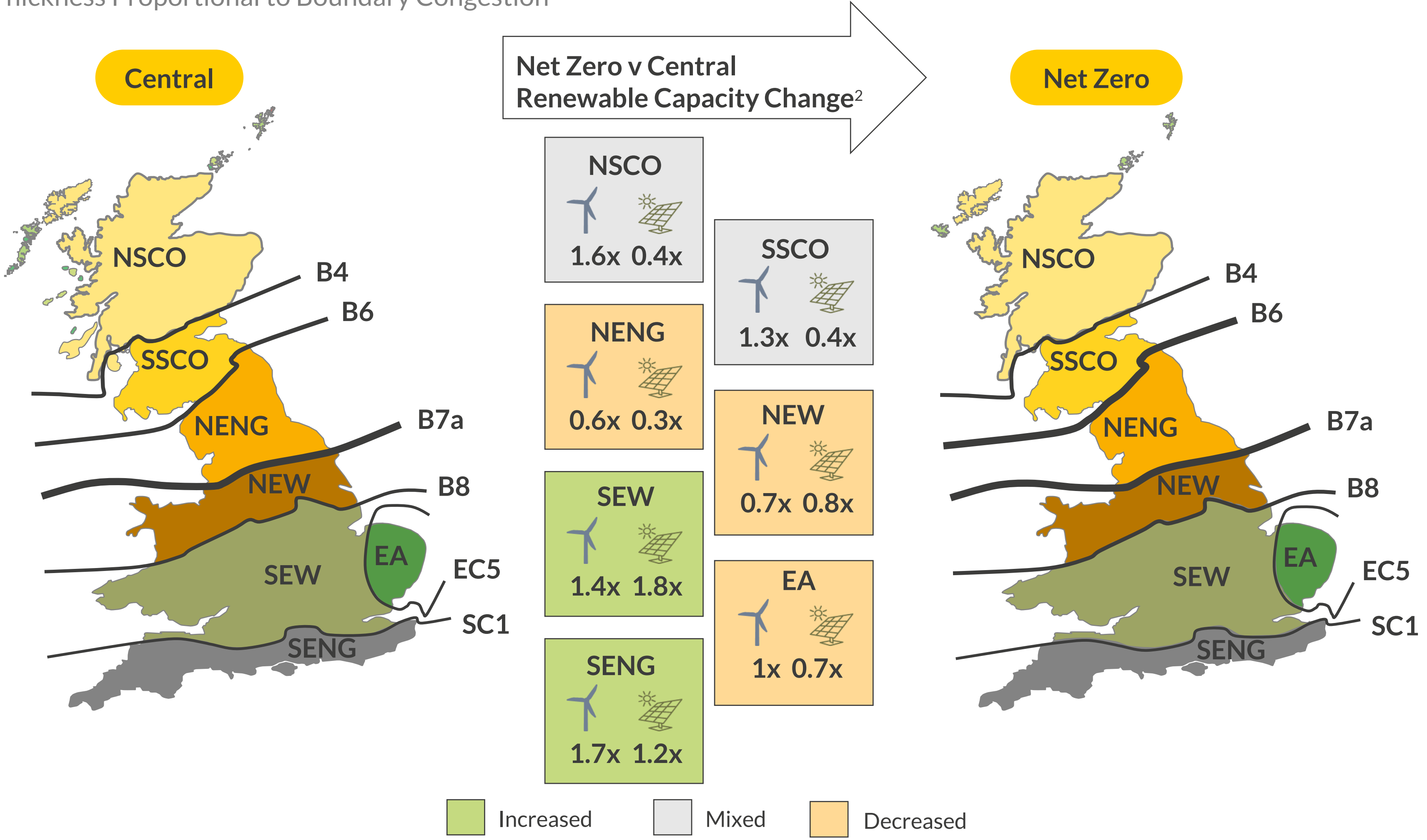
Grid Development

Key Takeaways

In a 7-zone model, Net Zero policy leads to a geospatial buildout of renewables that reflects locational value

2050 Transmission Boundary Congestion[1]

Line Thickness Proportional to Boundary Congestion



1) Estimation of interzonal BMS costs based on constrained periods beyond boundary capacity; 2) Ratio of Net Zero renewables capacity to Central renewables capacity

Source(s): Aurora Energy Research

Network constraints

- Even in 2050, under the same transfer capacity development, **B4 and B6 experience higher congestion** under net-zero policies

Capacity build

- Geospatial capacity buildout reflects both load factors and policy → Capacity build is pushed to advantageous locations
- Scottish onshore wind exposed to higher congestion costs under Net Zero

Net Zero increases locational value for Scottish wind but decreases for solar PV

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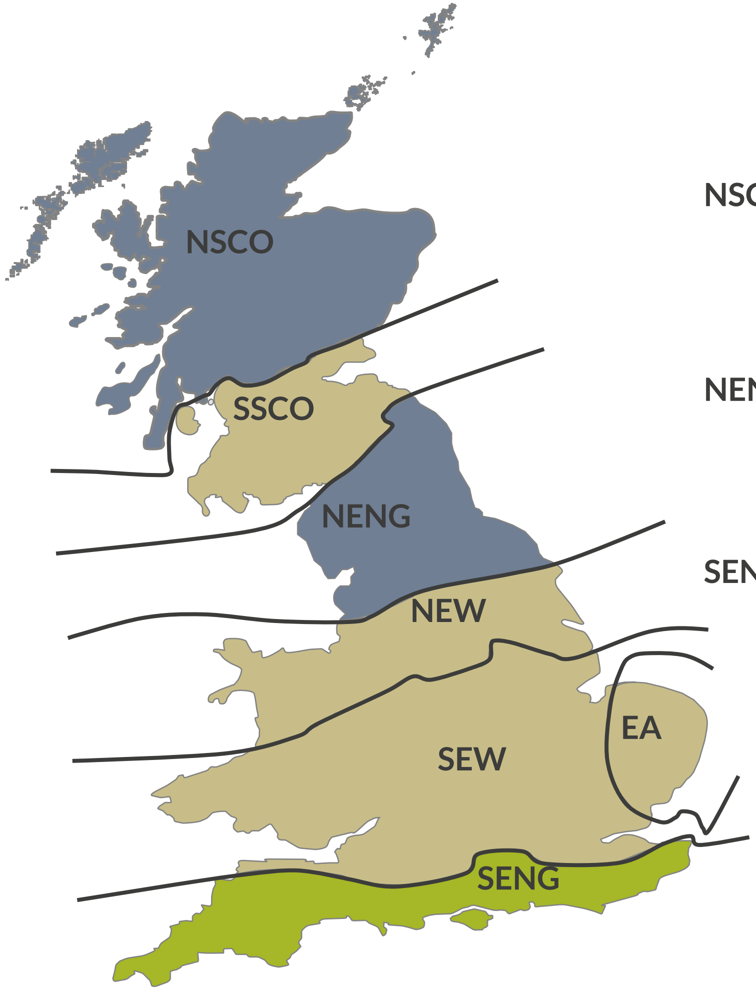
Technology-specific Balancing Mechanism System Locational Value Relative to National Average

Standalone

	Central	Net Zero
NSCO (wind)	1.23x	1.28x
NENG (wind)	1.13x	1.10x
SENG (solar)	0.86x	0.84x

- Higher wind build out in Scotland leads to more instances of system tightness with renewables exporting across boundaries to high demand zones, increasing
- This leads **to increased chances of curtailment** in oversupplied zones and **fewer chances in undersupplied zones**

Increased Value | No change | Decreased Value



Co-located

	Central	Net Zero
NSCO (wind + 2hr)	1.17x	1.21x
NENG (wind + 2hr)	1.10x	1.08x
SENG (solar + 2hr)	0.92x	0.90x

- Co-locating with storage leads to lower relative locational value losses as they capitalise on differences in dispatch in the BMS to resolve system constraints
- **NZ build increases constraint costs and reduces volumes, which co-location counters with ability to absorb cheap power**
- SENG solar assets see less BMS revenue than the national average, but co-location improves their ability to capture it

Source(s): Aurora Energy Research

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Asset Co-location Capabilities

Net Zero Policy

Grid Development

- What effect does a constrained network build have on locational value in a 7-zone model?
- How does this impact renewables developers?

Key Takeaways

In a future where grid development slows, congestion cost increases due to demand outpacing grid development

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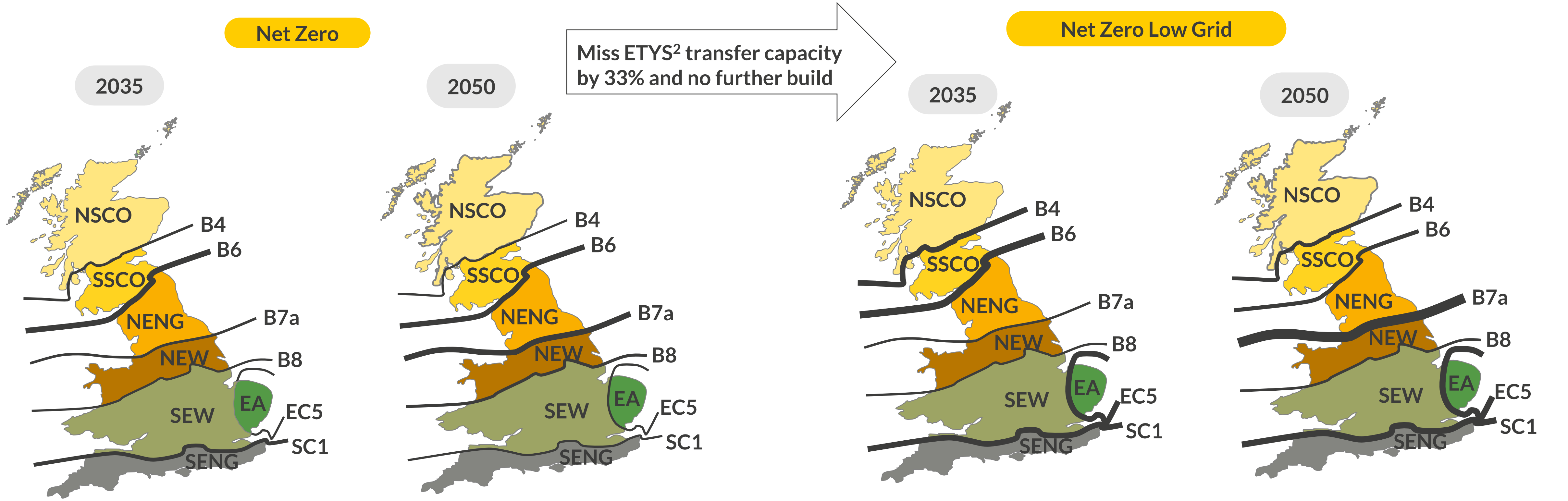
Transmission Boundary Congestion[1]

Line Thickness Proportional to Boundary Congestion



- When ETYS goals are met and grid development continues through 2050, physical grid constraints are fewer, as are congestion costs
- Pace of wind build-out necessary to meet Net Zero keeps pressure on the B6 boundary, even when grid expansion goals are met
- If the grid remains constrained, congestion revenues increase in the long-term, signalling long-term value in constraint management actions
- Co-location becomes critical if the grid is constrained to take advantage of cheap charging actions in BM system actions

1) Estimation of interzonal BMS costs based on constrained periods beyond boundary capacity; 2) Electricity Ten Year Study 2032 goals.

Source(s): National Grid ESO, Aurora Energy Research

Delayed grid development in a Net Zero UK pushes up gross margins further in the Balancing Mechanism for wind, but downward for solar

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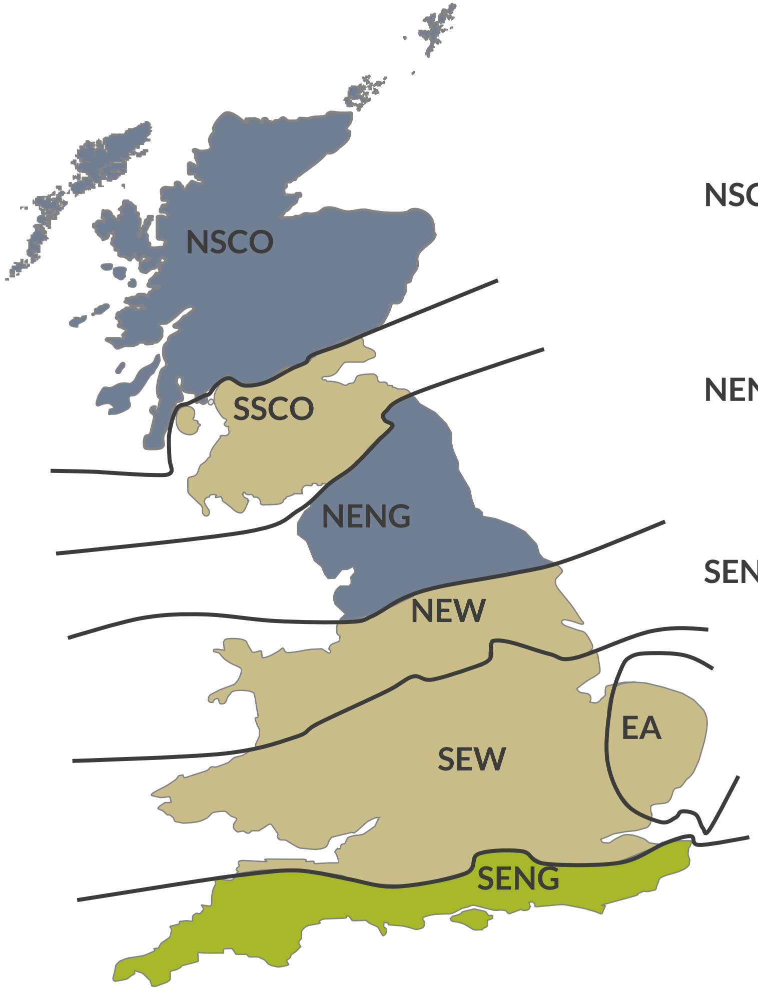
Technology-specific Balancing Mechanism System Locational Value Captured Compared to National Average

Standalone

	Net Zero	Low Grid
NSCO	1.28x	1.62x
NENG	1.10x	1x
SENG	0.84x	0.78x

- Sustained congestion on the B4 and B6 requires the **curtailment** of wind assets north of these boundaries, **increasing their value** in the BMS
- SENG is a high demand zone with scarcity in generation, resulting in **smaller BMS long volumes** and **lower BMS revenues** for RES assets



Co-located

		Net Zero	Low Grid
NSCO	+ 2hr	1.21x	1.46x
NENG	+ 2hr	1.08x	1.02x
SENG	+ 2hr	0.90x	0.90x

- Curtailment revenue for RES assets outpaces BMS revenues for batteries behind congested boundaries, thus a collocated asset sees more modest overall gains
- **Co-location mitigates RES BMS drops through temporal arbitrage, accessing both low-cost charging and high-revenue discharging periods**

Increased Value | No change | Decreased Value

Source(s): Aurora Energy Research

Agenda

Asset Co-location Capabilities

A More Granular Approach to Locational Value

Net Zero Policy

Grid Development

Key Takeaways

Key Takeaways

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Net Zero policy and grid development pathways will influence developer decision-making, with siting becoming a key consideration in future with high costs, renewables capacity, and congestion

1. Aurora's asset dispatch modelling capabilities already capture locational balancing benefits, but in an uncertain future, **more granularity can unlock further value and reduce down-side risk**

2. **A Net Zero UK sees a greater concentration of wind power above the B6 boundary and higher constraint costs;** by co-locating with battery storage, wind assets can capture more value through the BMS

3. If grid development stagnates in a Net Zero UK, **the value of locationality in the BMS increases for northern onshore wind, but a smaller benefit is seen by southern solar assets,** as they see fewer opportunities to trade in BMS

4. **The B6 and B8 boundary remain the most important constraints to consider for developers seeking locational value through co-location**, though a more granular view can reveal further benefits, particularly in a Net Zero world with slower grid build out