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Renewables Summit

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GRID CONSTRAINTS IN EUROPE: RISKS & OPPORTUNITIES

Grid congestion is leading to delays in renewables deployment and higher costs for consumers

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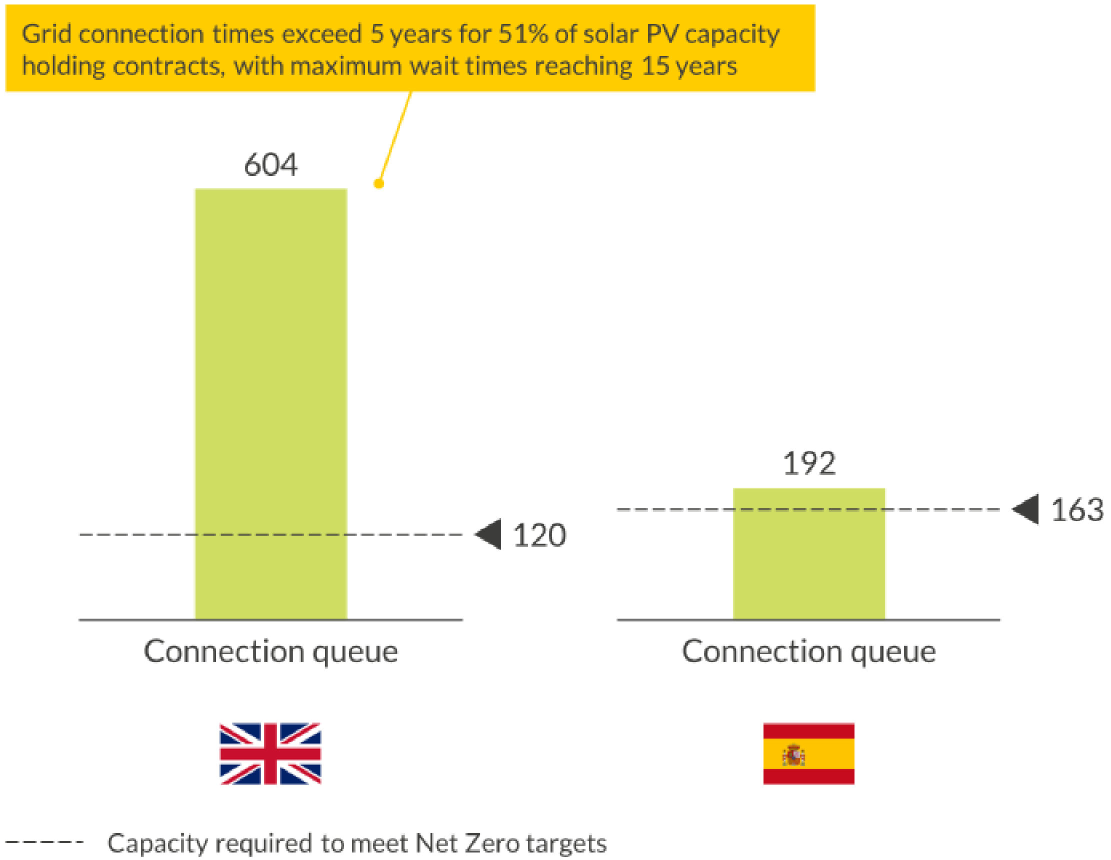
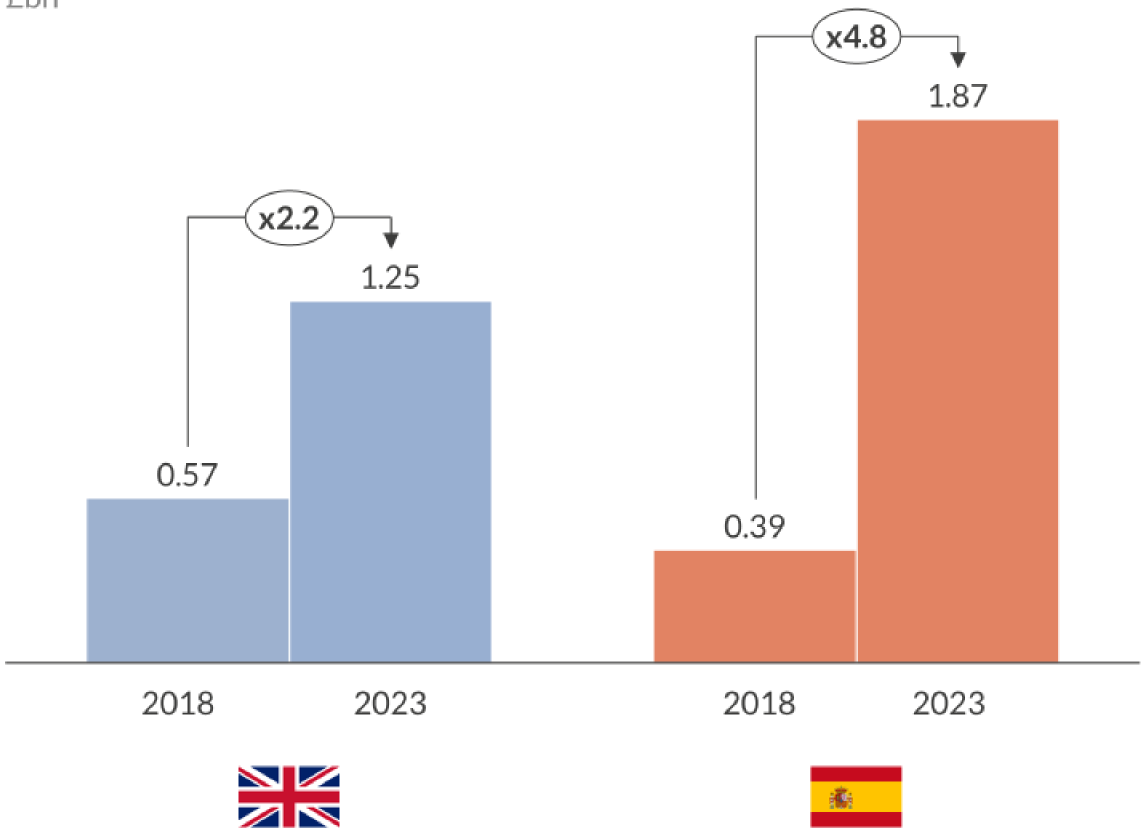
1 Grid connection queues of hundreds of gigawatts are seen across much of Europe, although not all of this capacity is required to meet net zero targets

Renewable capacity in 2035 required to reach Net Zero and grid connection size for renewables[1], GW



2 Failing to manage the connection queues have led to a consistent increase in constraint management costs

Constraint management costs
£bn



1) Net Zero reached by 2040 in GB and 2050 in Spain

Sources: Aurora Energy Research, National Grid ESO, REE

Insufficient grid capacity leads to curtailment for renewables, which may or may not be compensated depending on the market and connection agreement

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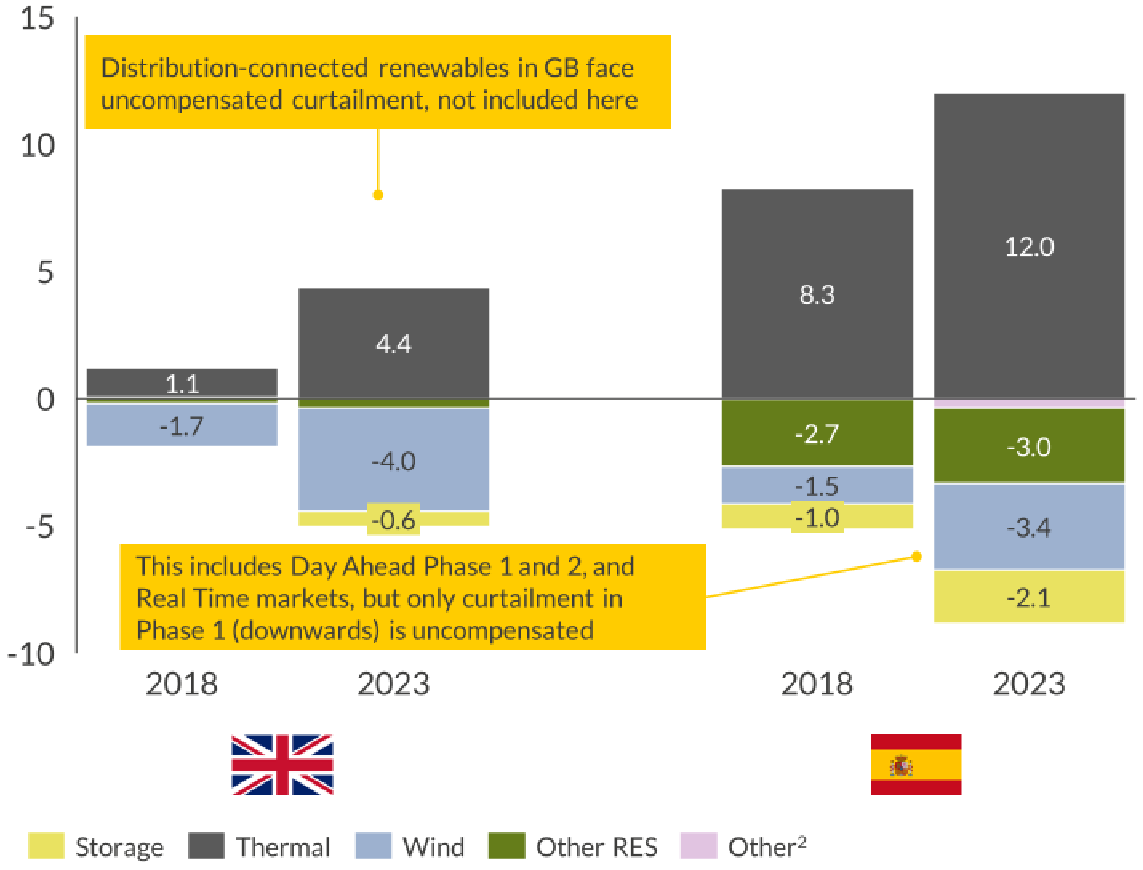
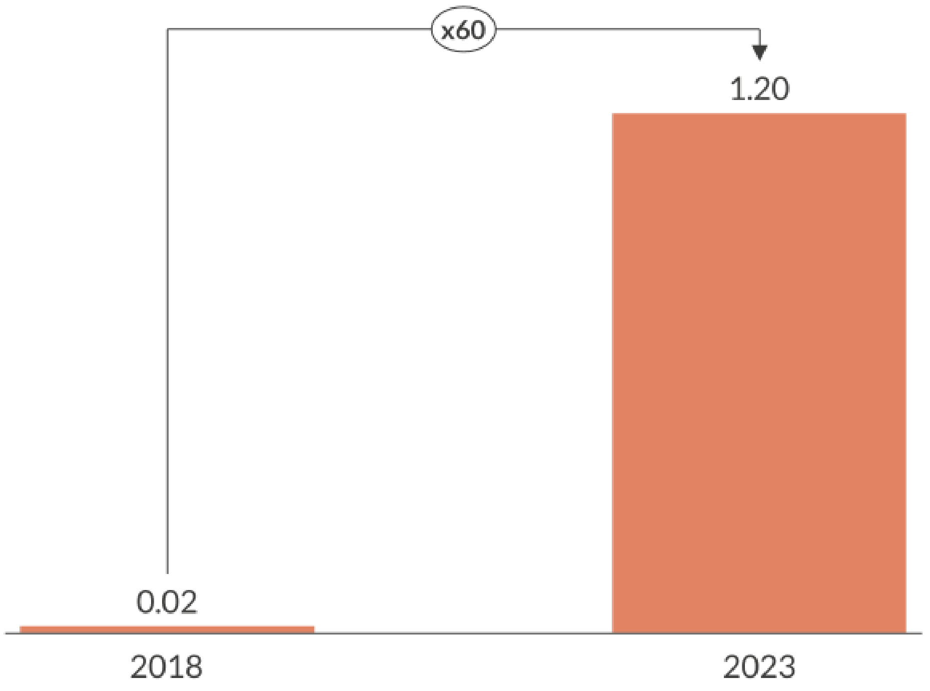
While transmission-connected renewables in GB are paid to reduce generation when thermal constraints occur, distribution-connected renewables are curtailed without compensation; in Spain, all curtailment in the Technical Restrictions Market (TRM) is uncompensated

Balancing volumes by technology[1]
TWh



Uncompensated curtailment for non-firm connection in Spain
TWh



1) For Spain, this refers to curtailment in the DA Phase 1, Phase 2 and Real time, wherein only Phase 1 Downwards (Technical Restrictions) curtailment is uncompensated; 2) Other include volumes of demand, interconnectors and nuclear assets.

Sources: Aurora Energy Research, Elexon, REE

Uncompensated curtailment in the Technical Restrictions Market poses a key risk to investment in renewables in Spain...

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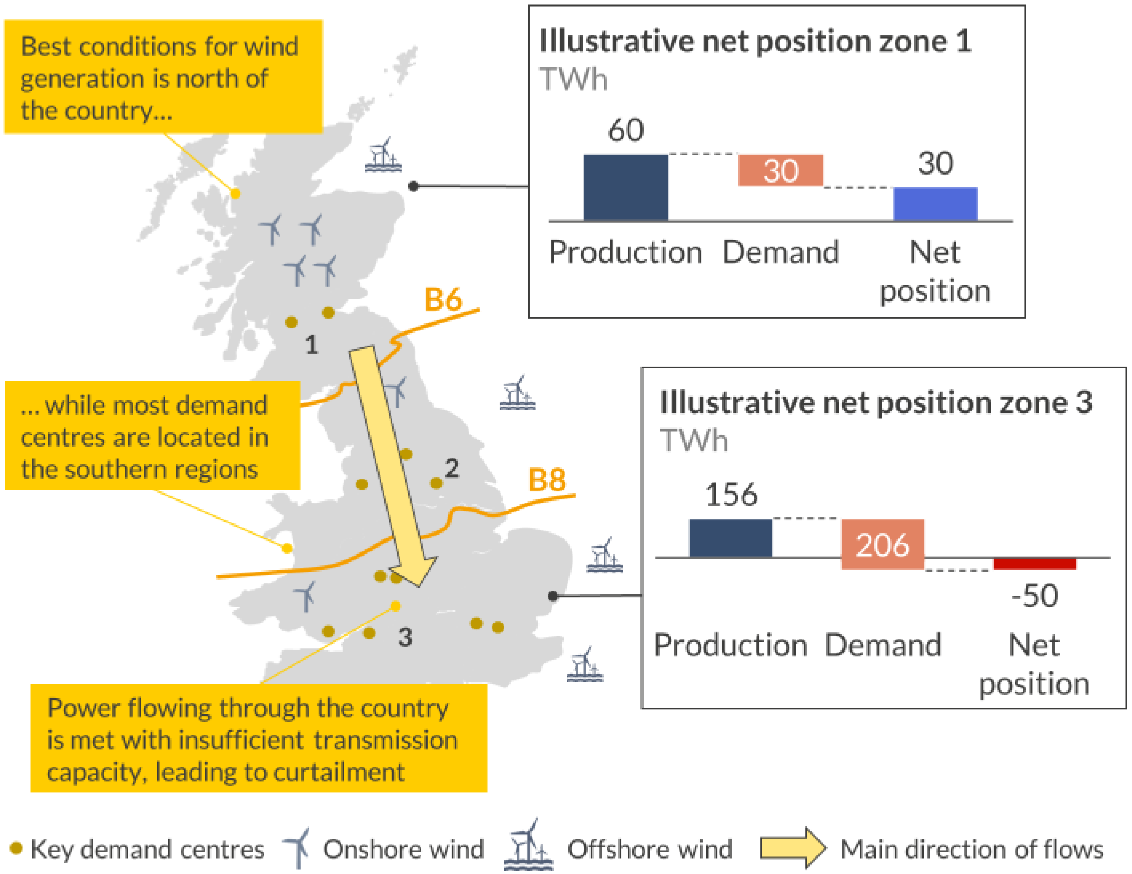
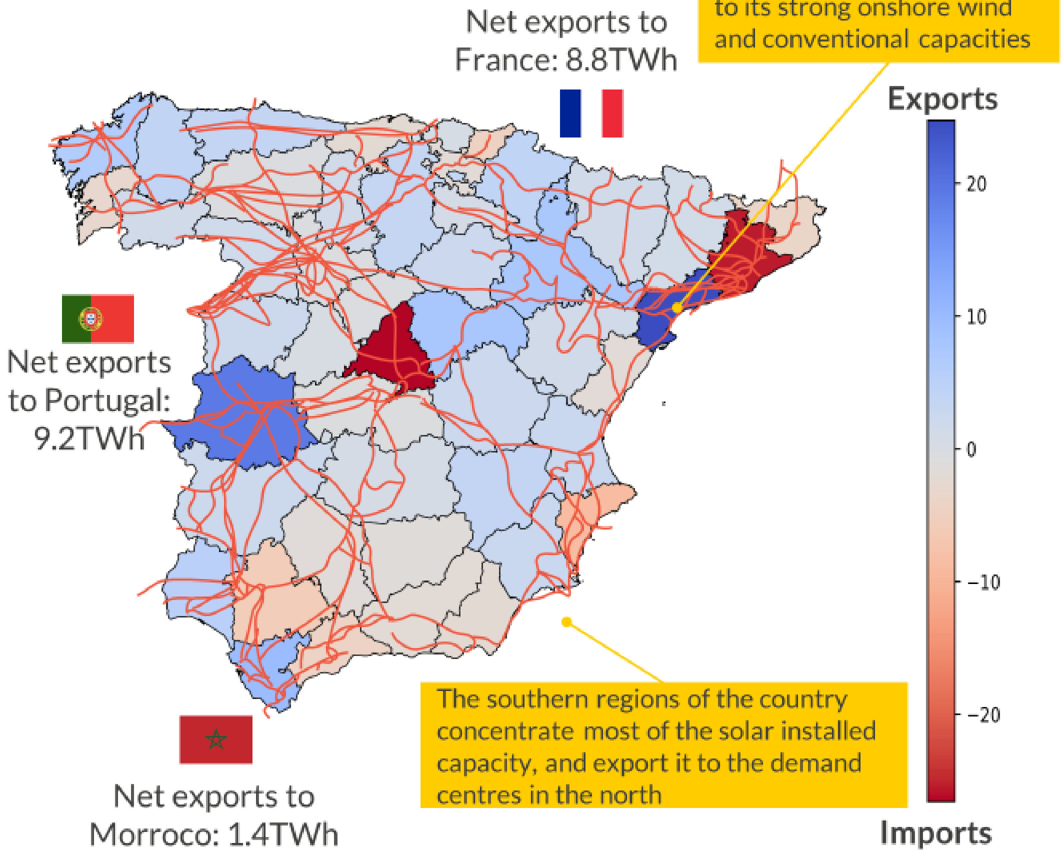
1 Curtailment occurs when grid capacity is insufficient to transport power from generation hubs to demand centres

GB example of grid congestion at the B6/B8 boundaries



2 In Spain, 26% of the demand is concentrated in Madrid and Barcelona, while renewables are located far from demand centres, putting strain on the grid

Yearly provincial net positions[1] in 2022
TWh/year



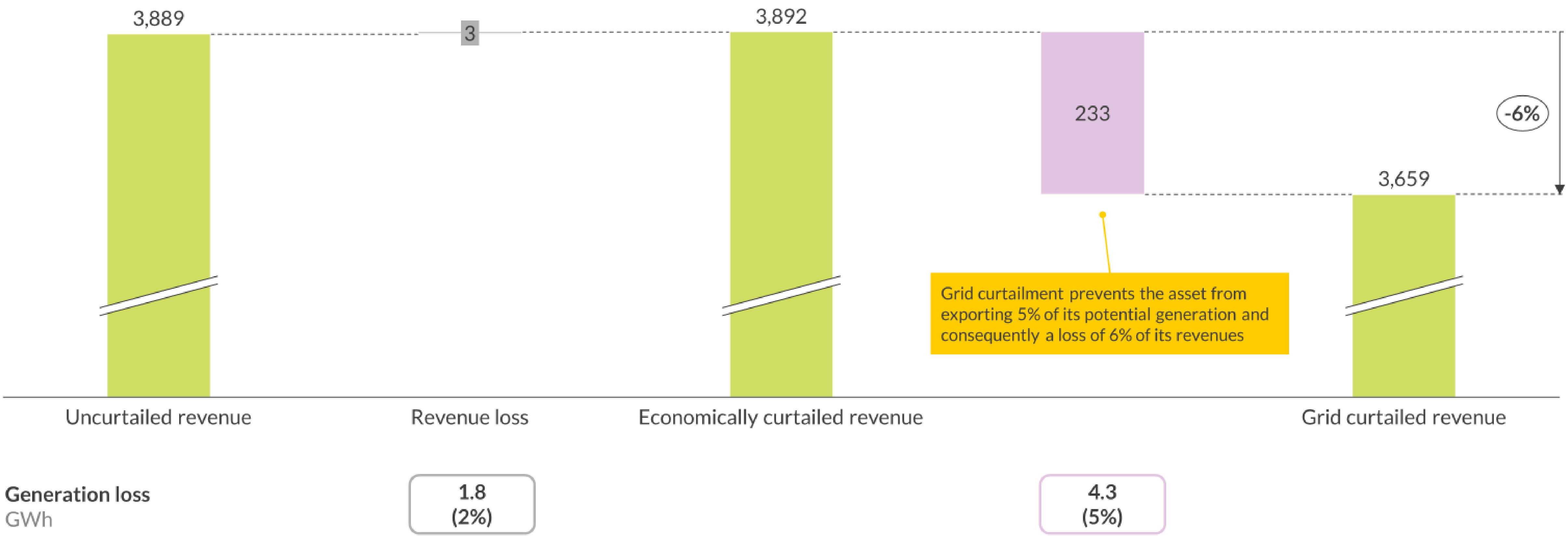
1) The net position of a province is the difference between the production and the demand in this province

Sources: Aurora Energy Research

… but the downside can be quantified to help reduce uncertainty and enable the delivery of renewables projects

A 50MW solar PV asset in Badajoz would see 4.3GWh of lost generation (or 5% of the total generation in 2026), amounting to a total loss of 233k € in revenues due to curtailment in the Technical Restrictions Market (TRM)

Revenues in 2026
k€ (real 2023)



Sources: Aurora Energy Research

Co-location and siting decisions help manage the risks of uncompensated curtailment, but the key mitigations are grid expansion and market reforms

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X Deep-dives

Developers

Siting (A)

- Grid constraints are highly location-specific
- Alternate sites can alleviate constraints but might have lower load factors

Co-location

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- Co-location enables renewables to shift their generation to less constrained times
- The battery may be able to participate in other ancillary markets

Government/Regulator/ESO

Market reforms (B)

- Governments are considering reforms to reduce the need for grid expansion
- Reforms like zonal pricing could incentivise co-location of demand and generation

Expansion of grid capacity (C)

- The primary solution to grid constraints is to expand the grid capacity
- Governments are in the process of accelerating the deployment of grid

Sources: Aurora Energy Research

Siting can greatly impact curtailment levels, resulting in significantly higher revenues for assets despite lower production levels

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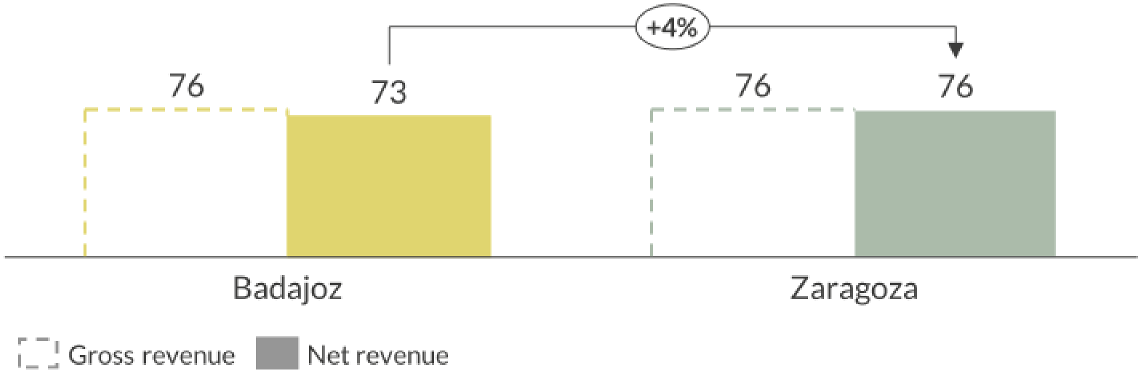
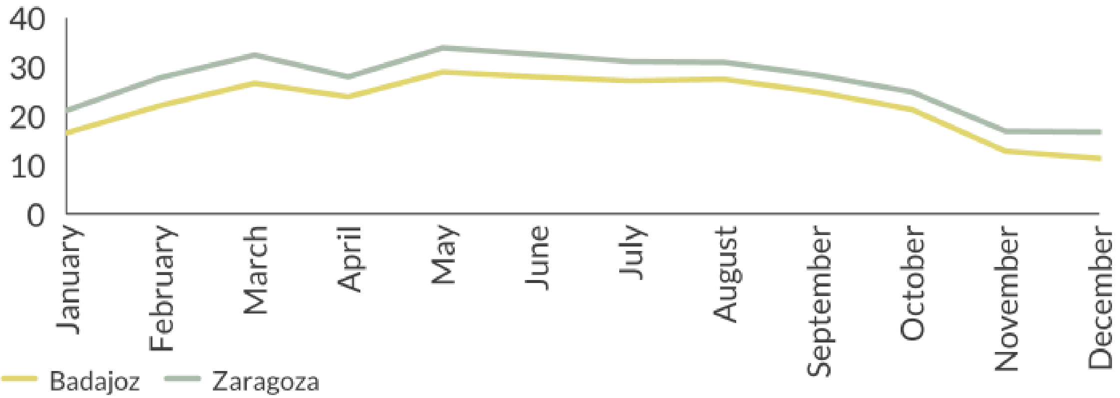
1 **If a solar PV project were to be located in Zaragoza instead of Badajoz, its revenues would be 4% higher**

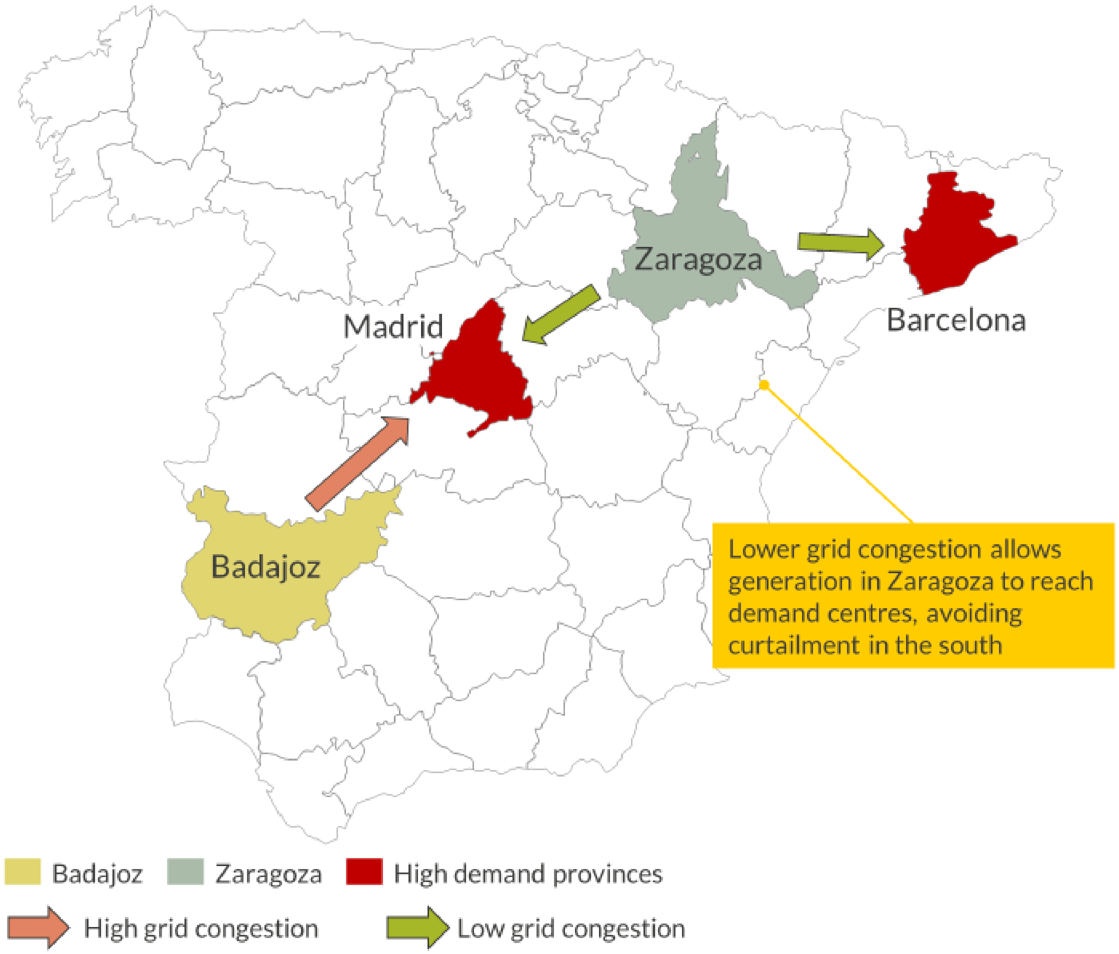
Net revenue of a solar PV asset between 2025-2030
€/kW/year (real 2023)



Intra-year generation profile for a solar PV asset
%



2 **Excess capacity in Badajoz faces insufficient grid capacity to supply Madrid and Barcelona, resulting in high curtailment levels**



Zonal pricing proposed in REMA introduces market risk, but the existing TNUoS regime is subject to significant regulatory uncertainty

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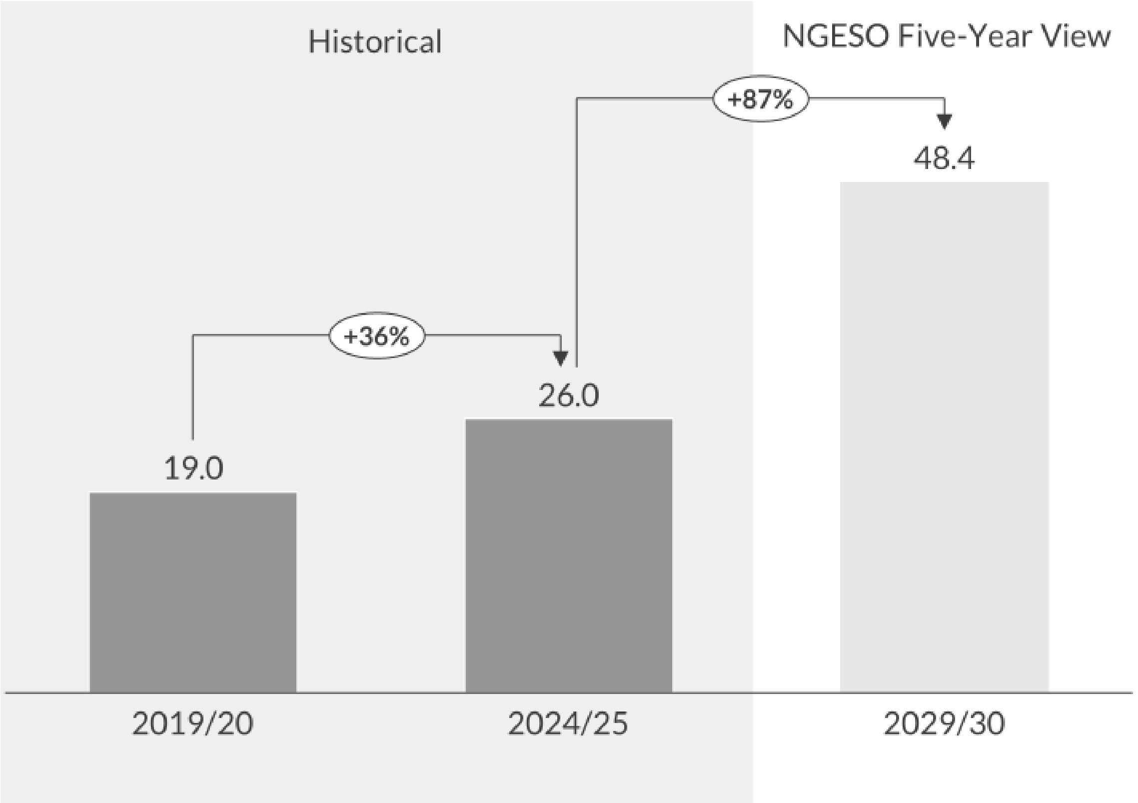
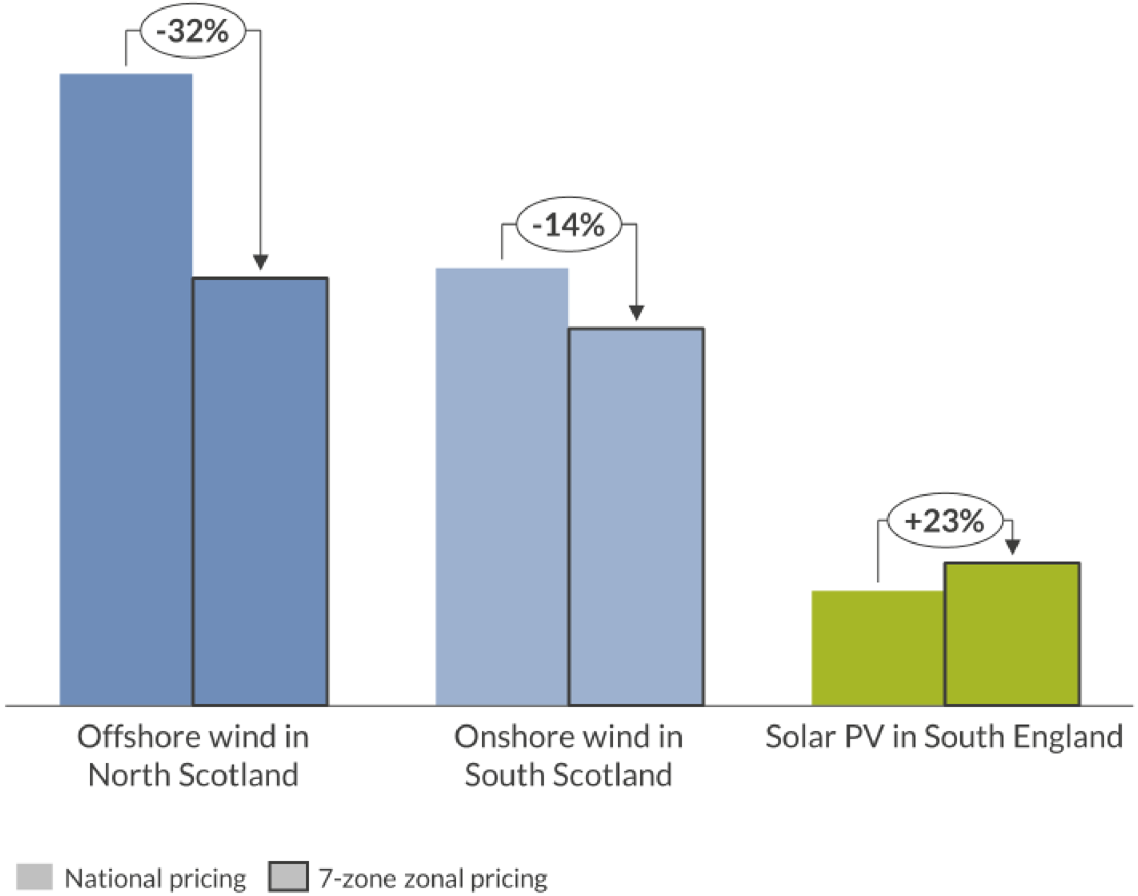
1 TNUoS charges have increased by 36% between 2019-24 in Zone 1, and are forecasted to increase a further 87% by 2029/30

TNUoS wider tariff for an intermittent asset in North Scotland[1]
£/kW



2 Zonal pricing exposes generators to market risk, which can be better understood through scenario analysis than regulatory risk

Average gross margins (2030-40)
£/kW



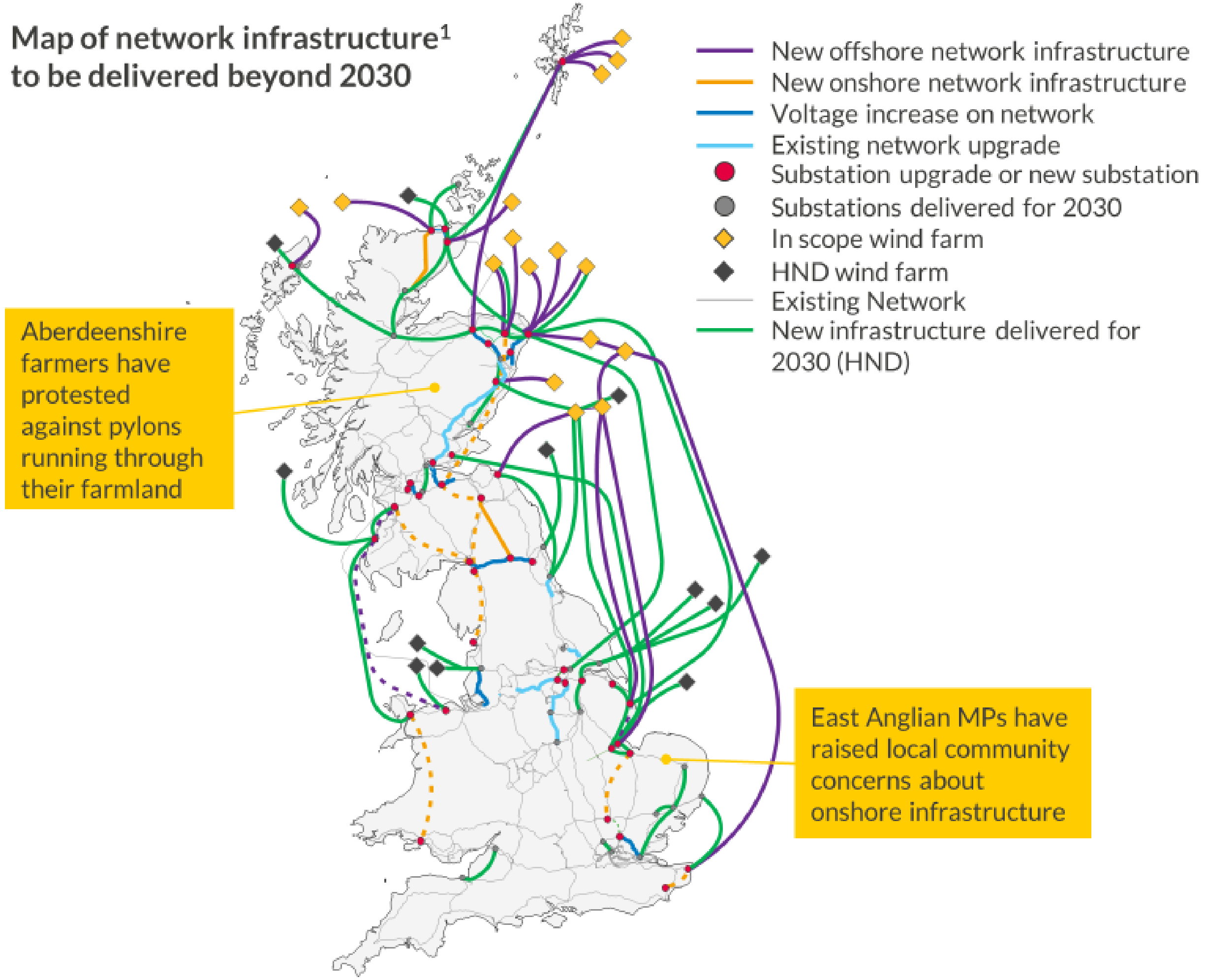
1) Asset with an average load factor of 45%

Sources: Aurora Energy Research, NGESO

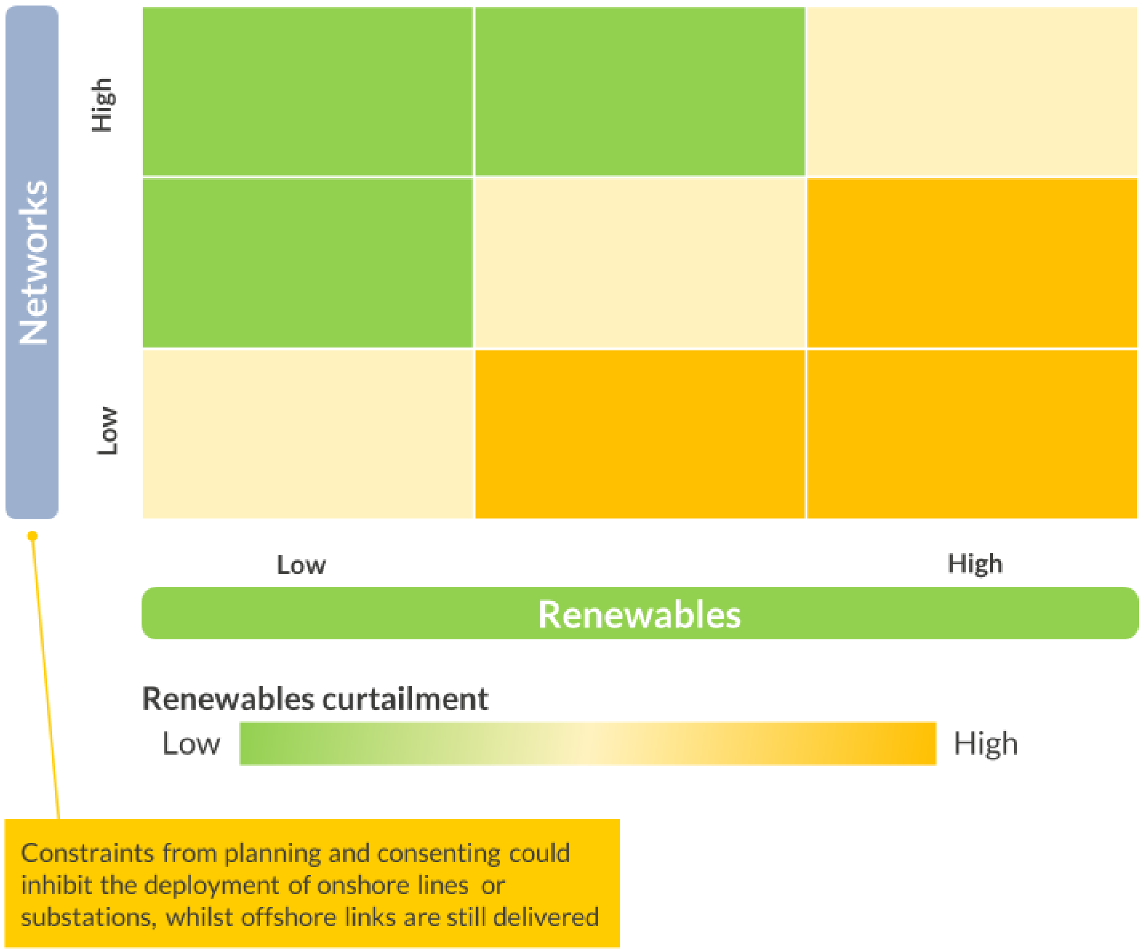
The ESO has plans for a significant expansion of the grid capacity, but the system faces a significant coordination risk in addition to risks from planning

1 NG ESO assessed 200 network options to recommend this high-level network design required to connect an additional 21GW of offshore wind beyond 2030

Map of network infrastructure[1] to be delivered beyond 2030



2 Coordination risks between the development of renewables and grids, as well as onshore and offshore networks can create uncertainty for investors



1) Dashed lines represent low maturity options. **Note:** all routes and options shown on this map are for illustrative purposes only

Sources: Aurora Energy Research

Aurora has modelled the impact of insufficient grid capacity on the system, as well as on asset economics for distribution-connected renewables

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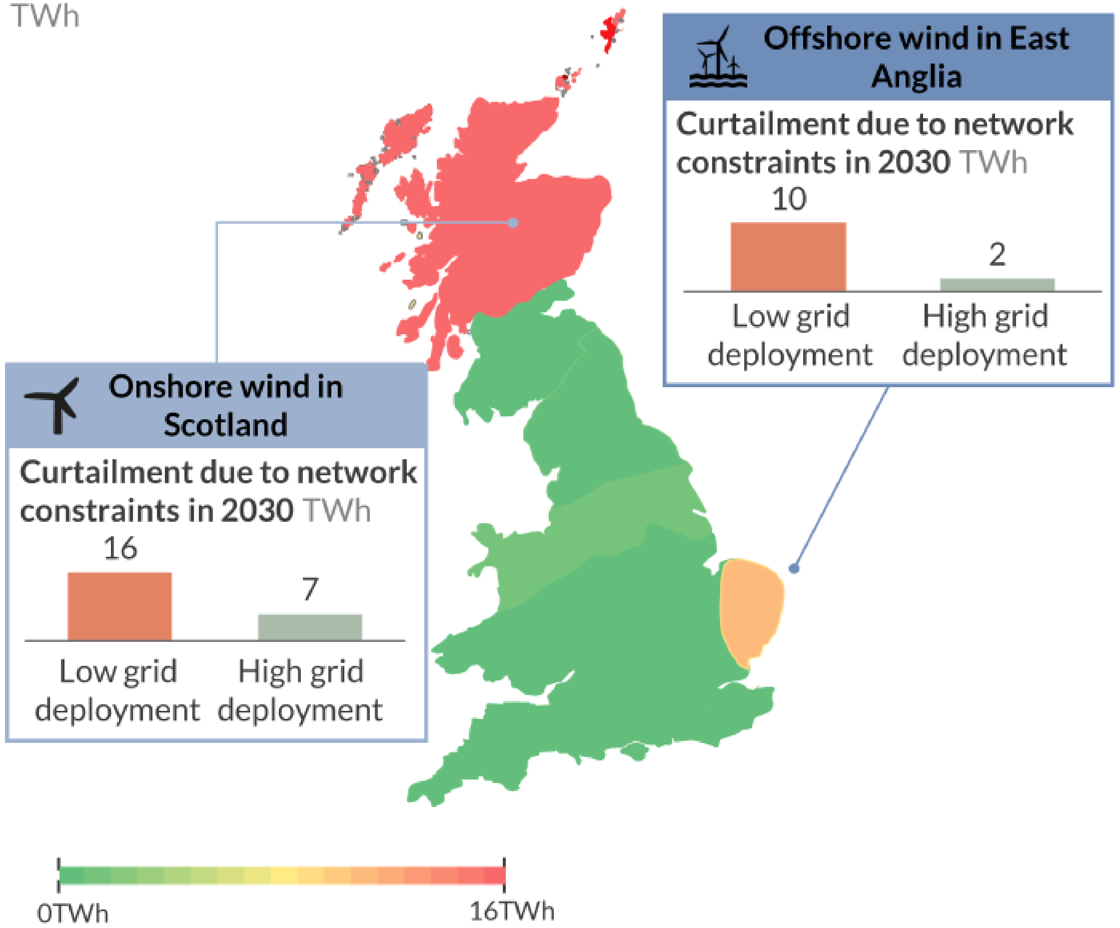
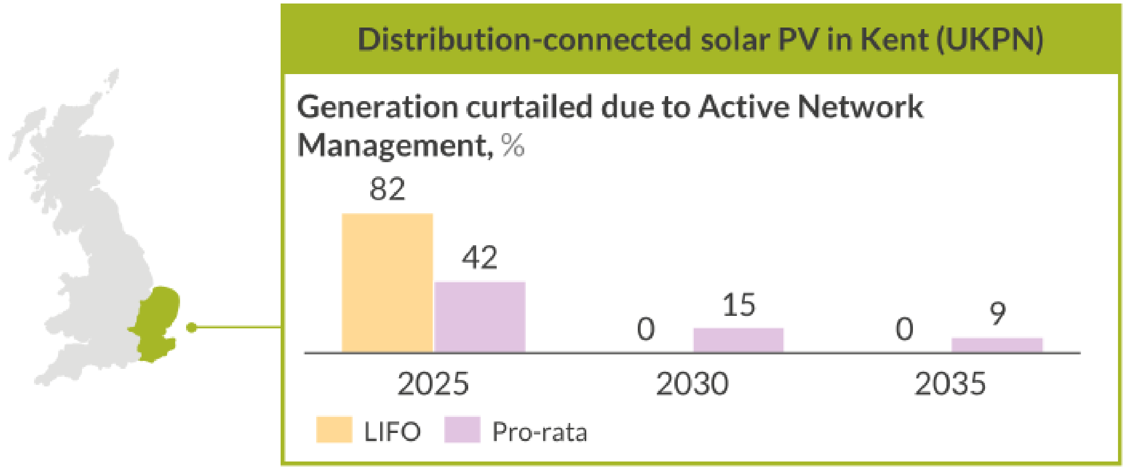
1 If 40GW of offshore wind is installed by 2030, failing to build critical infrastructure would curtail 13% of offshore wind generation

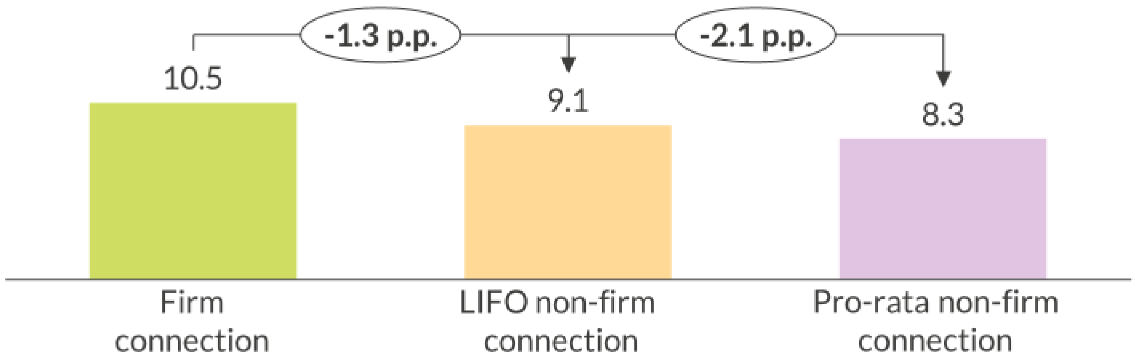
Curtailments due to grid constraints in 2030
TWh



2 Distribution-connected renewables can face uncompensated curtailment, with a solar PV project in Kent losing up to 2.1 p.p. of its IRR



IRR by entry year for a new build solar-PV asset in UKPN in 2025[2]
%, real pre-tax (real 2022)



1) Considers 40GW of installed capacity of offshore wind by 2030, falling short by 34% of critical infrastructure projects included in the Accelerated Strategic Transmission Investment (ASTI) framework; 2) A 50% discount on grid connection costs is considered for non-firm connection cases

Sources: Aurora Energy Research

Key Takeaways

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1 Insufficient grid capacity has become a bottleneck for the deployment of renewables across Europe, which has been a detriment for the decarbonisation efforts as well as costs for consumers

2 Grid congestion also leads to curtailment, which may or may not be compensated – all curtailment under the Technical Restrictions Market in Spain, or for distribution-connected renewables with non-firm connections is uncompensated

3 While siting and co-location can be tools for developers to mitigate the impact of insufficient grid capacity, the key solution is still rapid buildout of transmission networks, which faces challenges from planning and consenting

4 As developers face a high degree of uncertainty from grid availability, quantification of the downside through a range of network scenarios, which consider both grid deployment and market reforms, can help manage risk and deliver projects

Sources: Aurora Energy Research

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