Aurora Keynote:

Act Global, Think Local: global decarbonisation challenges and local solutions

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Agenda

I. What is the outlook for global decarbonisation?

II. Key decarbonisation challenges and how to overcome them

1. Challenge 1 – Renewables investment returns have compressed. Where to find attractive returns?
2. Challenge 2 – Roll-out of grids is not keeping pace with renewables build out. What are the solutions?
3. Challenge 3 – How to keep the lights on in a Net Zero System?

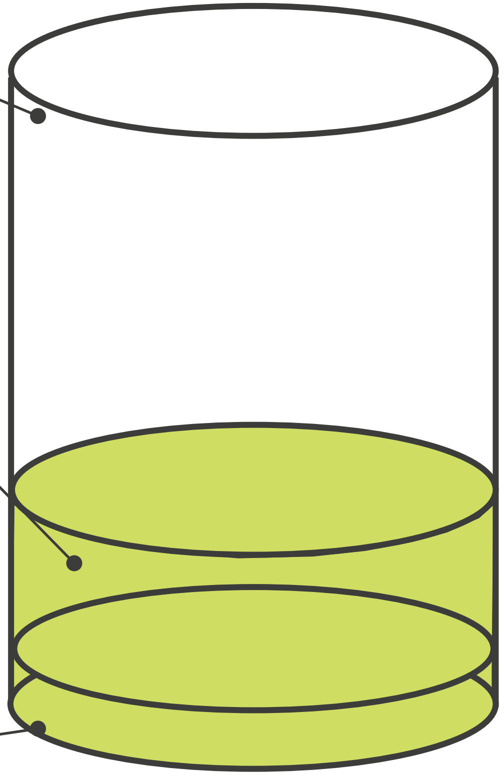
2,000 GW of renewables capacity has been built globally since 2000, with investment averaging at $280bn per year since 2010…

The evolution of global renewables capacity

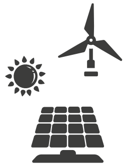
Global generation capacity stood at 7,782 GW in 2020

2020 global installed renewables capacity was about 2,800 GW: 739 GW solar, 737 GW wind[1] and 1,324 GW hydropower

In 2000 global wind and solar capacity was only 30 GW and hydropower was only 767 GW

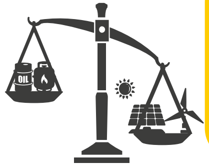


In the last 10 years…



Solar capacity has doubled every three years and wind every five years [2]

A total of $3.4 trillion was invested into renewables between 2009 and 2021



Renewables overtook upstream oil and gas investments in 2020

1) Also includes 16 GW geothermal capacity, Excludes biogas and biomass installations 2) Compared to their 2010 capacity levels

Sources: IEA WEO 2021, BP Stats Review 2021, IRENA, BNEF, IHS, IHA

… but fossil fuel production has also continued to grow, and the world was still 83% reliant on fossil fuels in 2020

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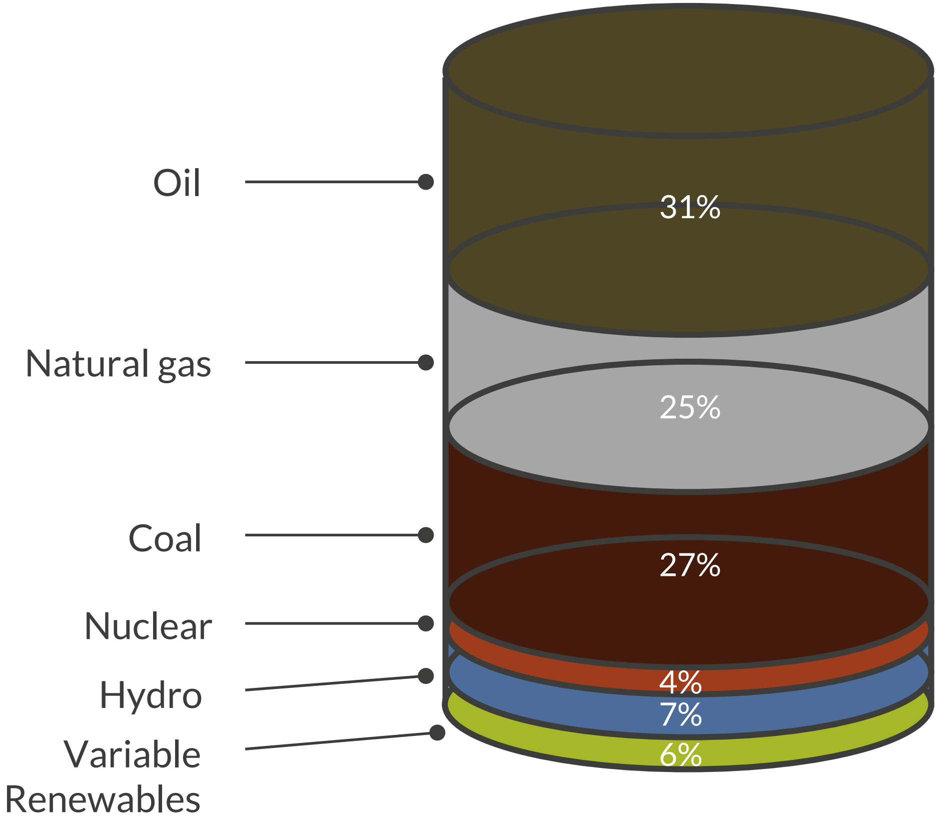
Fossil fuels still accounted for 83% of total primary energy consumption in 2020, with variable renewables amounting to 6%

Primary energy consumption by fuel type in 2020

%



Driven by rising energy demand, total fossil fuel production is growing despite efforts to increase share of renewables generation

Primary energy supply by fuel type in 1990-2020

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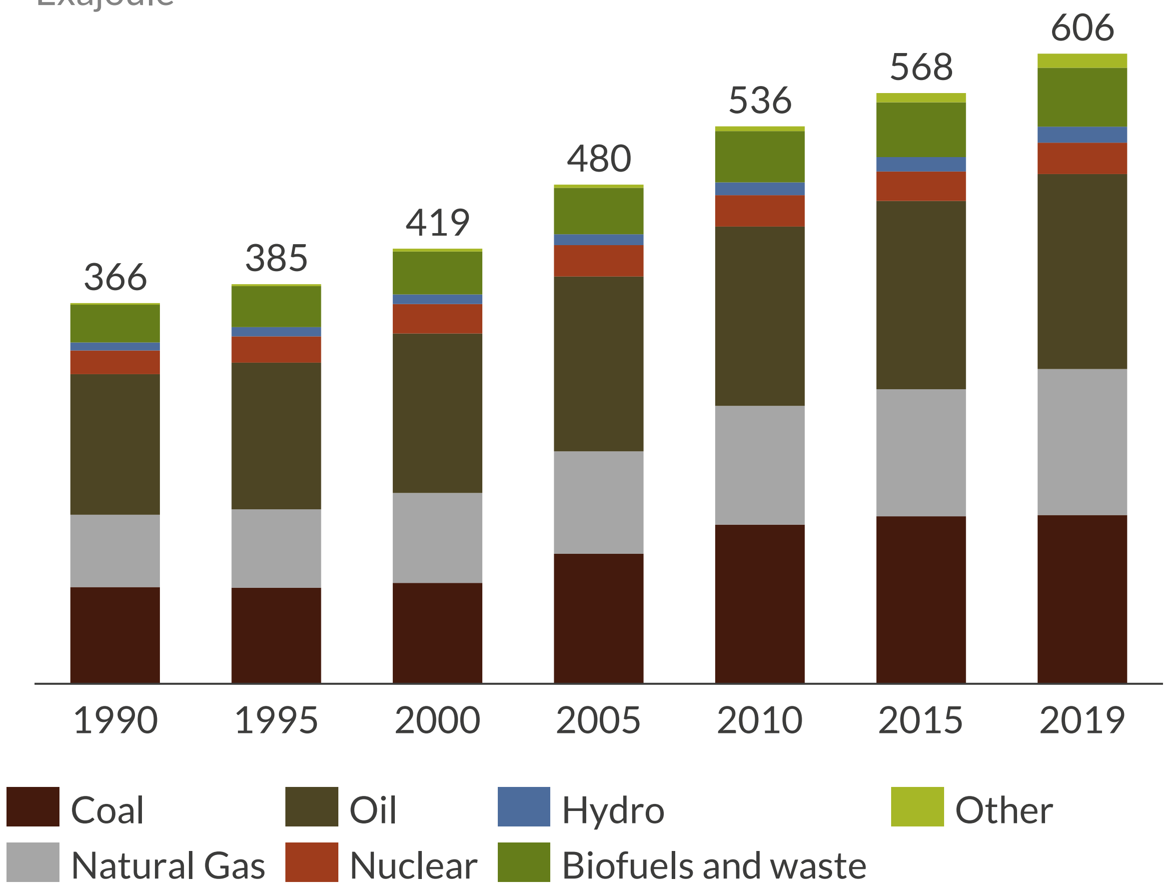

Global emissions continue to increase, and while announced pledges hold below 2 degrees, stated policies remain off track

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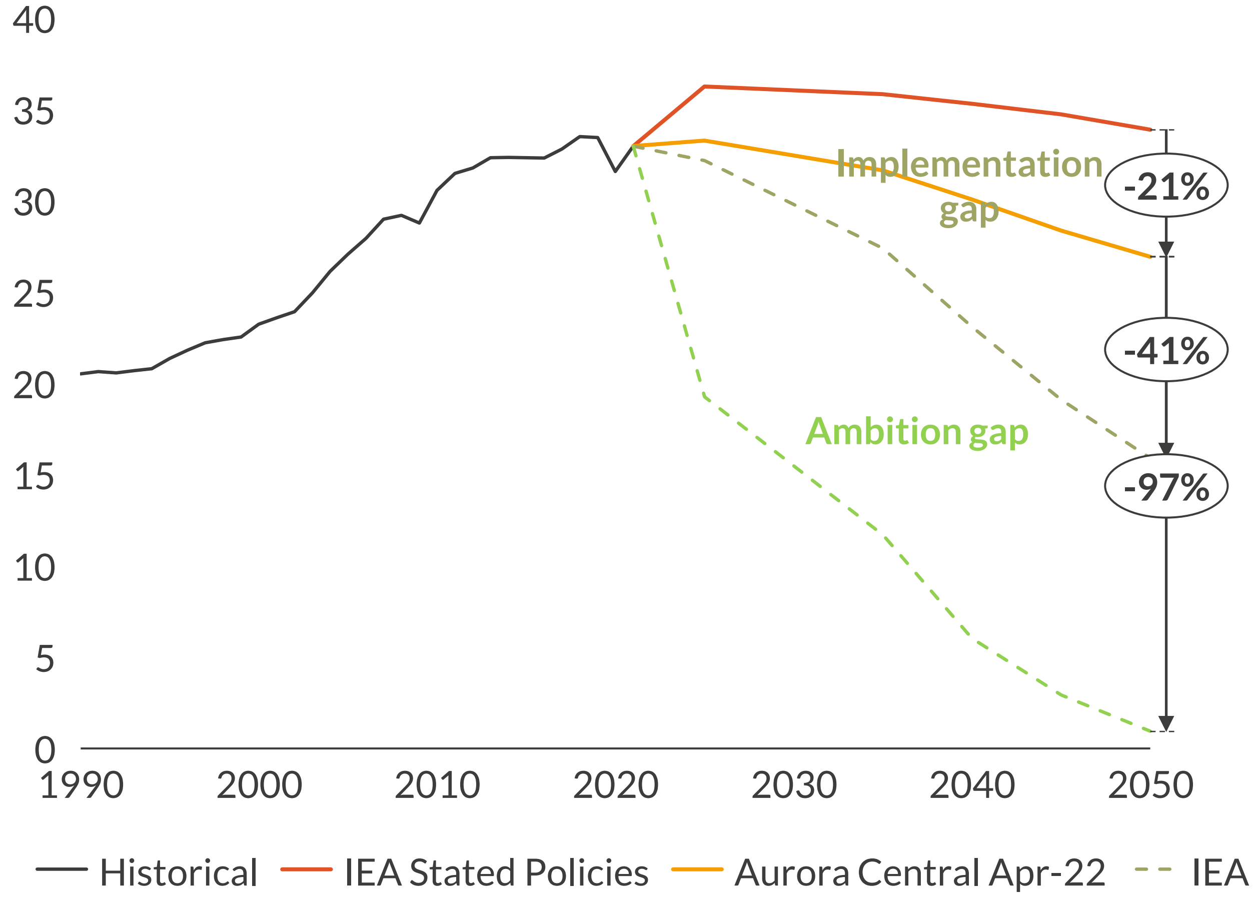
Annual global energy sector CO_2 emissions by scenario
$GtCO_2$



Scenario	Average global temperature rise by 2100 (˚C)	Delta emissions from Aurora Central 2021 in 2050 (Gt/y)
IEA Stated Policies	2.6	-0.7
Aurora Central 2022	2.4	-4.4
IEA – Announced Pledges (COP26)	1.8	-18.7
IEA – Net Zero Emissions by 2050	<1.5	-34

1) IEA Announced Pledge Scenario (APS) as announced during COP26 and published in November 2021. 2) IEA Net Zero scenario as from IEA WEO 2021. Here we only consider emissions from combustion. In order to reach Net Zero global carbon emissions, the residual emissions from combustions in 2050 need to be offset

Sources: Aurora Energy Research, IEA WEO 2021

Getting to Net Zero represents a HUGE investment opportunity: 37,000GWs green energy investment worth $53 trn globally to 2050

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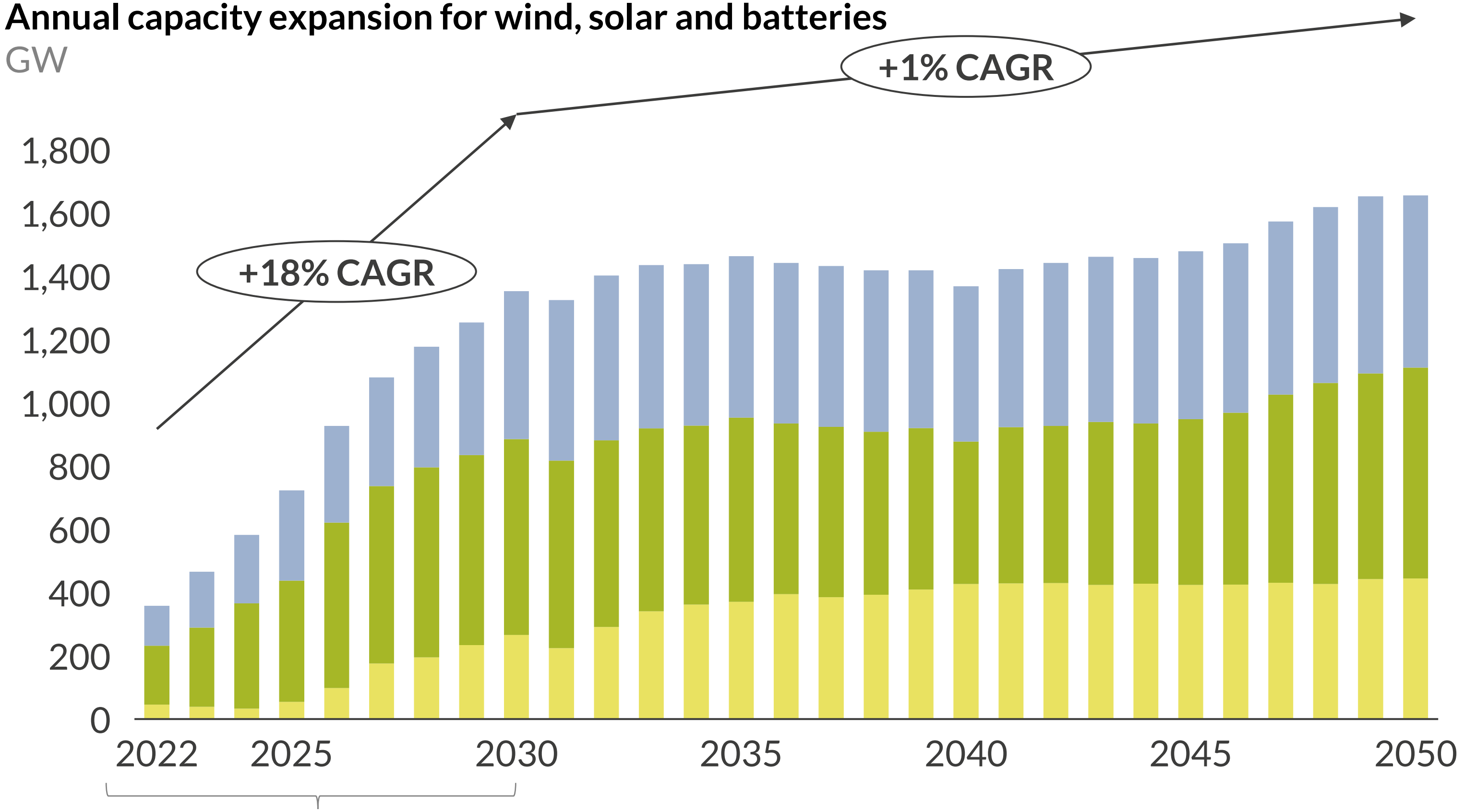
Annual capacity expansion for wind, solar and batteries
GW



Volume growth drives CAPEX spending in the 2020s. Later cost reduction results in a slow-down of annual CAPEX spending, especially for solar

Wind Solar Batteries

Total CAPEX investment 2022-2050
$trn, real 2021

Wind & solar	$ 29trn
Batteries	$ 7trn
Grid expansion[1]	$ 17trn
Total	$ 53trn

1. Incremental grid expansion associated with high uptake of renewables could require further annual additional investment of $465bn - $714bn pa from 2020 to 2050. Source: IRENA, "Global Energy Transformation: A Roadmap to 2050" (2018 edition). We show the mid-point of this range.
Sources: Aurora Energy Research, BNEF, IRENA

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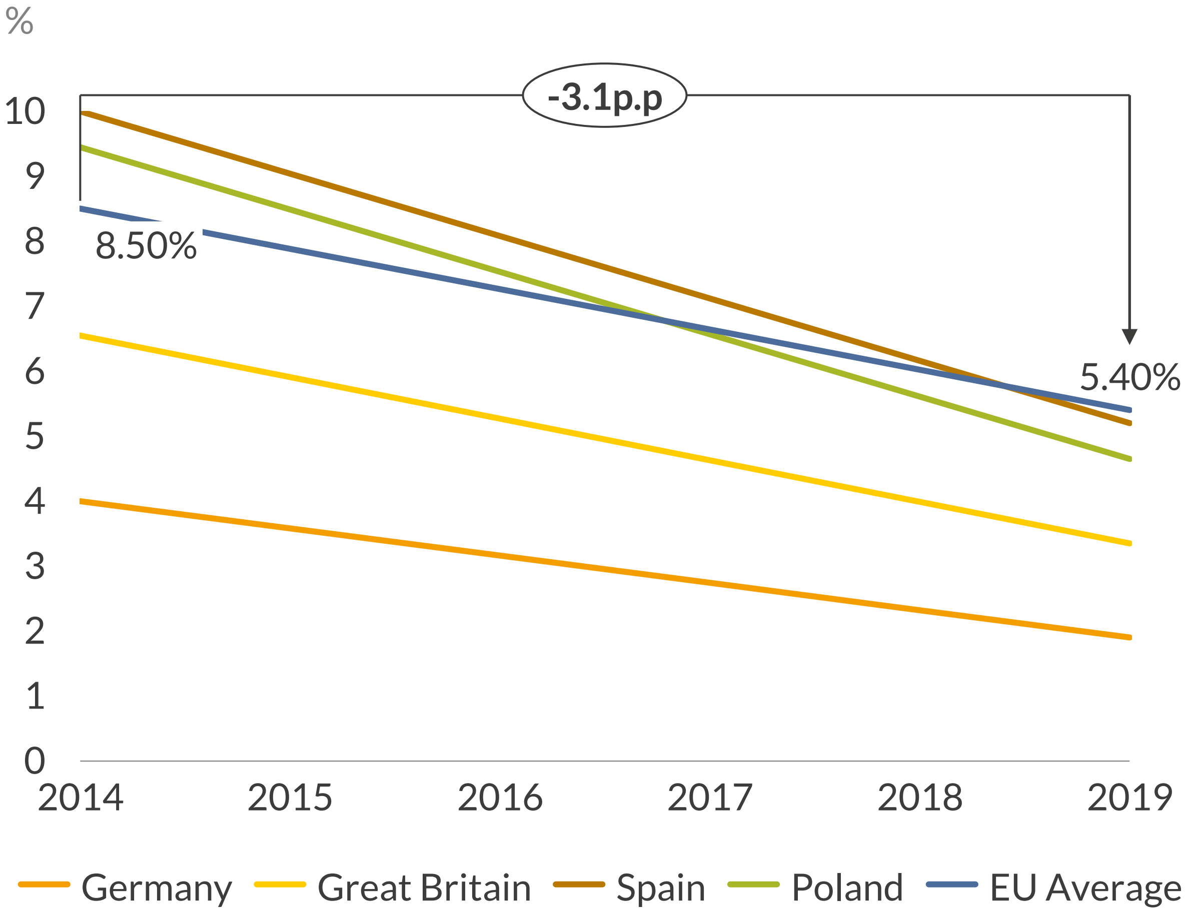
Renewables yields have fallen significantly in recent years as the sector has matured, but fall in risk free rate has reversed

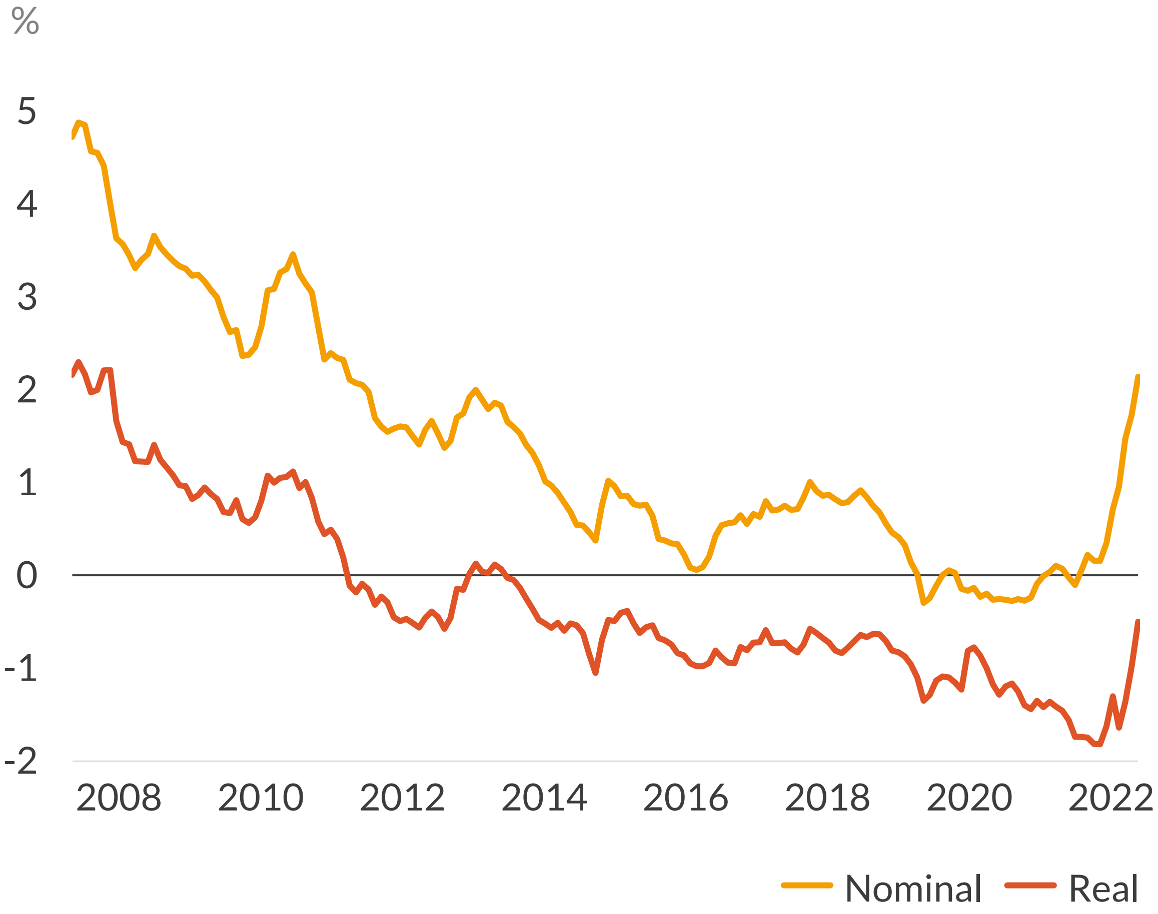
Fall in risk free rate and increased maturity of renewables sector led to WACCs to fall by 3.1 percentage points in recent years

Weighted average cost of capital onshore wind, post-tax nominal



But the risk-free rate is increasing after an almost 15-year continuous decline, squeezing margins

Eurozone 10-year nominal and real interest rates



Sources: European Commission, Macrobond, ICAP, Aurora Energy Research

Technology and business model innovation can help to improve economics and returns from renewable investments

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Deep-dive on next slide

Optimal siting of projects – finding the optimal location can drive higher capture price, load factors and revenues

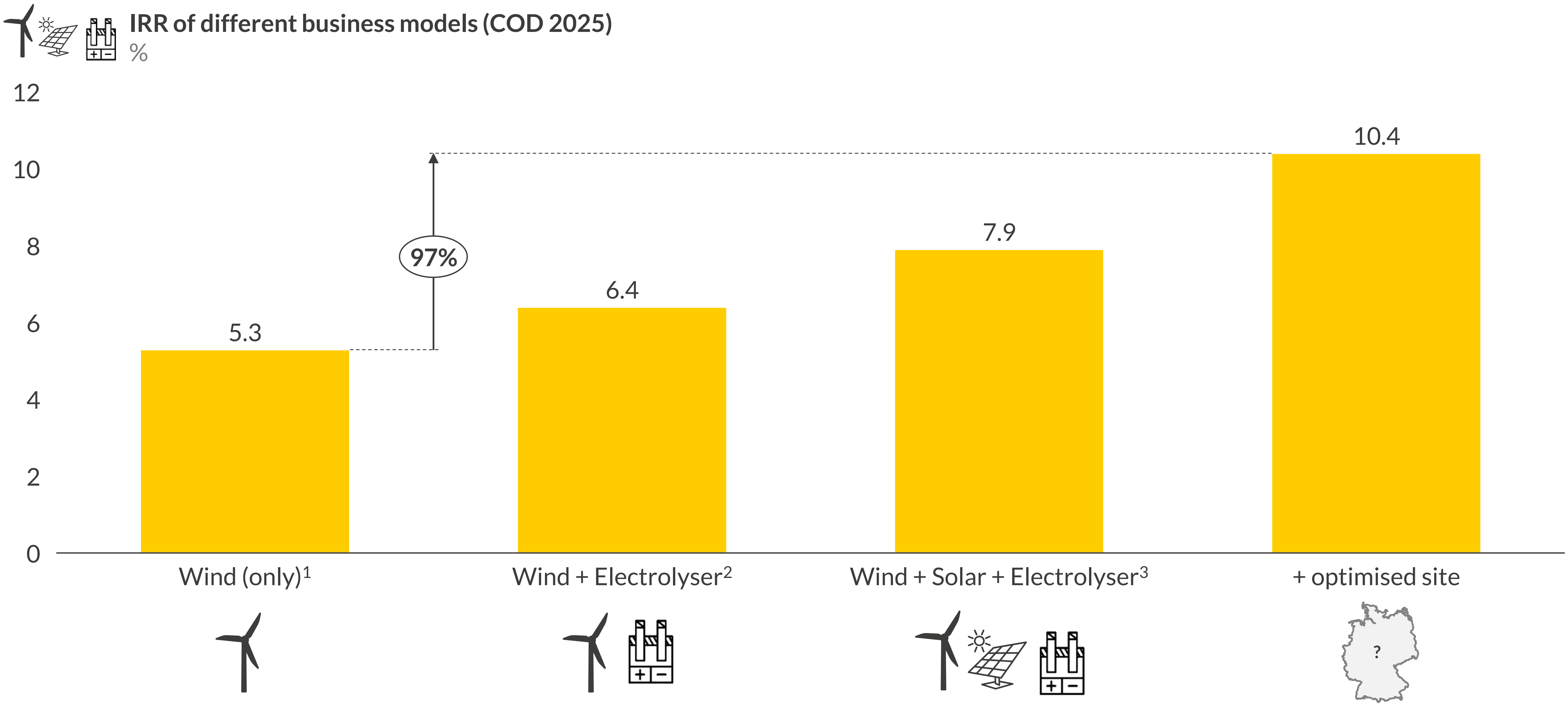
Wind + Solar colocation – complementary generation and oversizing helps to optimise grid connection

Wind / Solar + electrolyser co-location – green hydrogen production in hours of low wholesale prices helps to diversify revenues

Wind / Solar + battery co-location – sharing grid connection costs and ability to capture curtailed generation improve overall returns

Solar trackers and bifacials – increase efficiency to achieve higher load factors and capture prices

Co-location of wind and solar with an electrolyser almost doubles IRR at an optimal site in Northern Germany



1) 100 MW onshore wind asset 2) 100 MW onshore wind asset + 30 MW electrolyser 3) 50 MW solar, 50 MW onshore wind, 20 MW electrolyser 4) Same as 3, but at favourable location in North-west Germany, all electrolyser business models assume offtaker price of 5 EUR/kg

Sources: Aurora Energy Research,

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Grid investment is not keeping pace with renewable energy investment, increasing congestion and grid management costs

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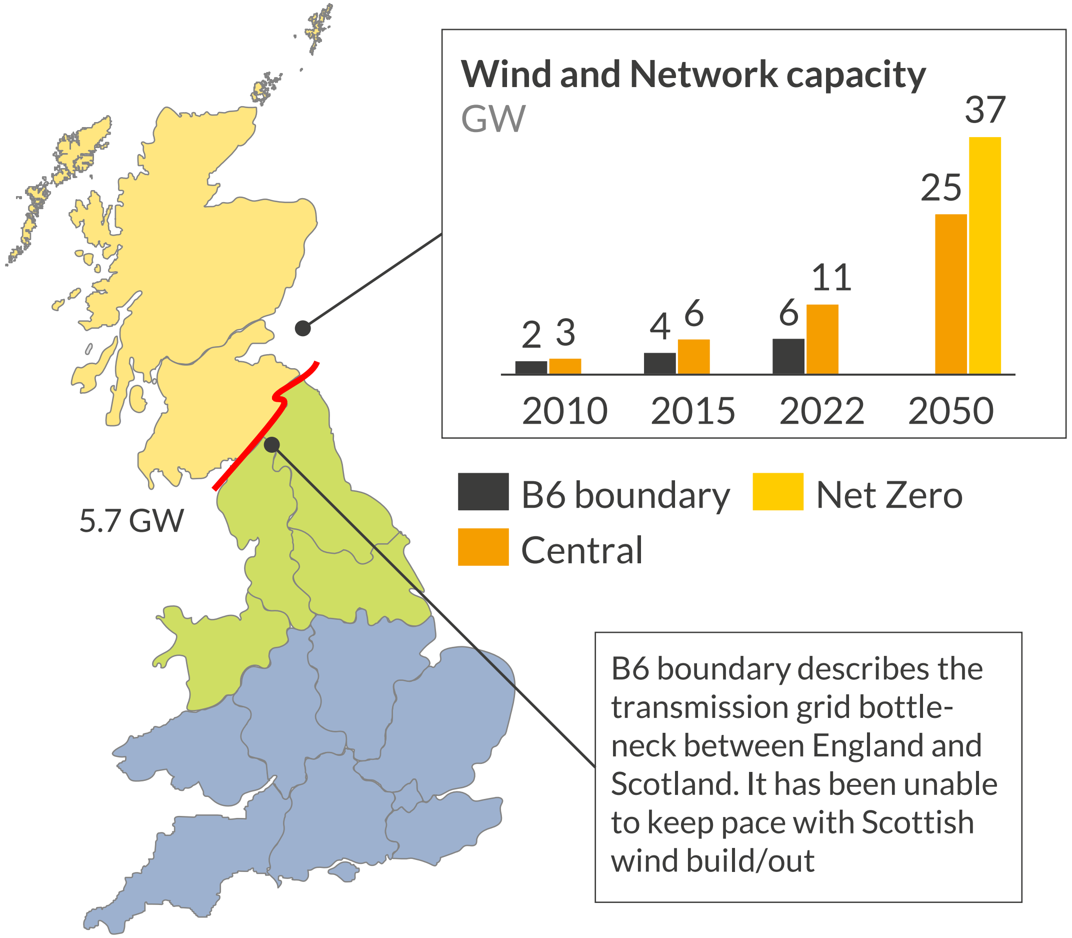
Total installed wind capacity in Scotland

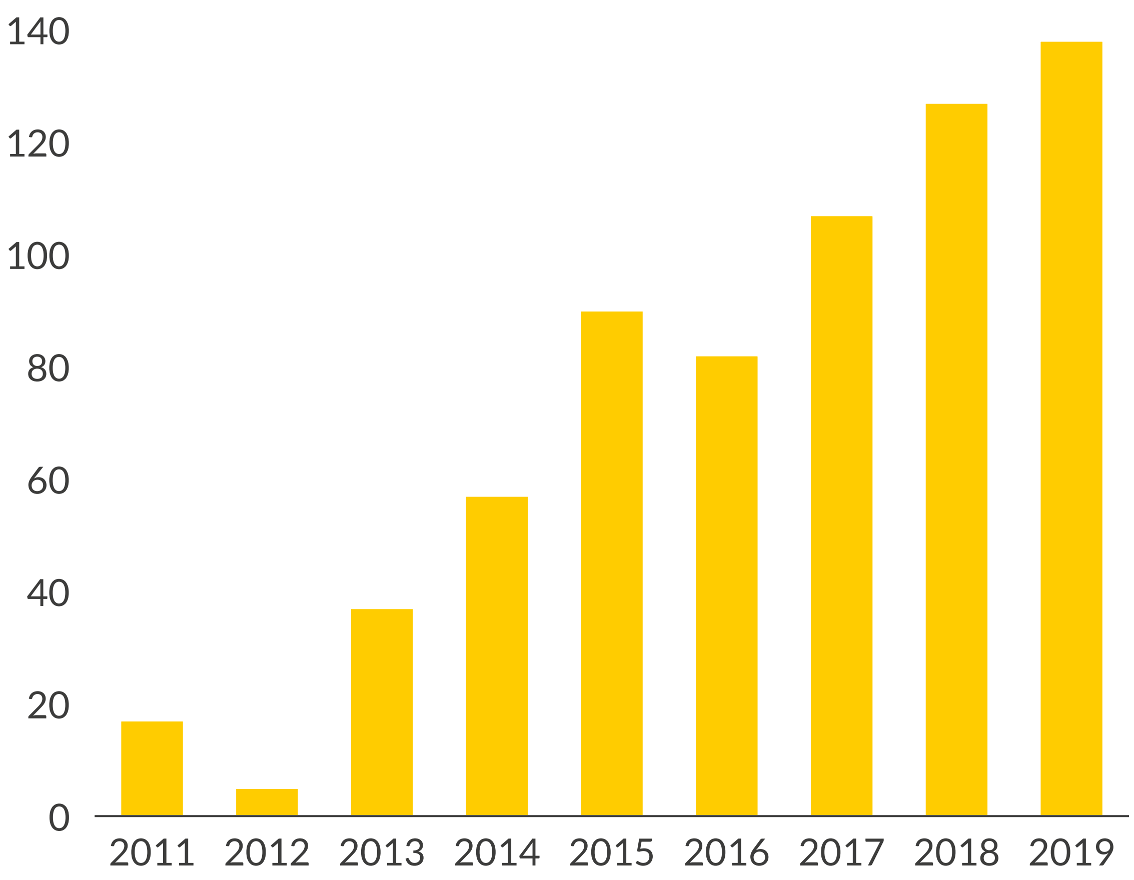
GW



B6 boundary describes the transmission grid bottle-neck between England and Scotland. It has been unable to keep pace with Scottish wind build/out

Annual constraint payments to wind farms via the Balancing Mechanism in GB

GBP mil.



Source: Aurora Energy Research, National Archive, ensg, Renewable Energy Foundation

Potential solutions are grid expansion, rising flexibility and zonal pricing, depending

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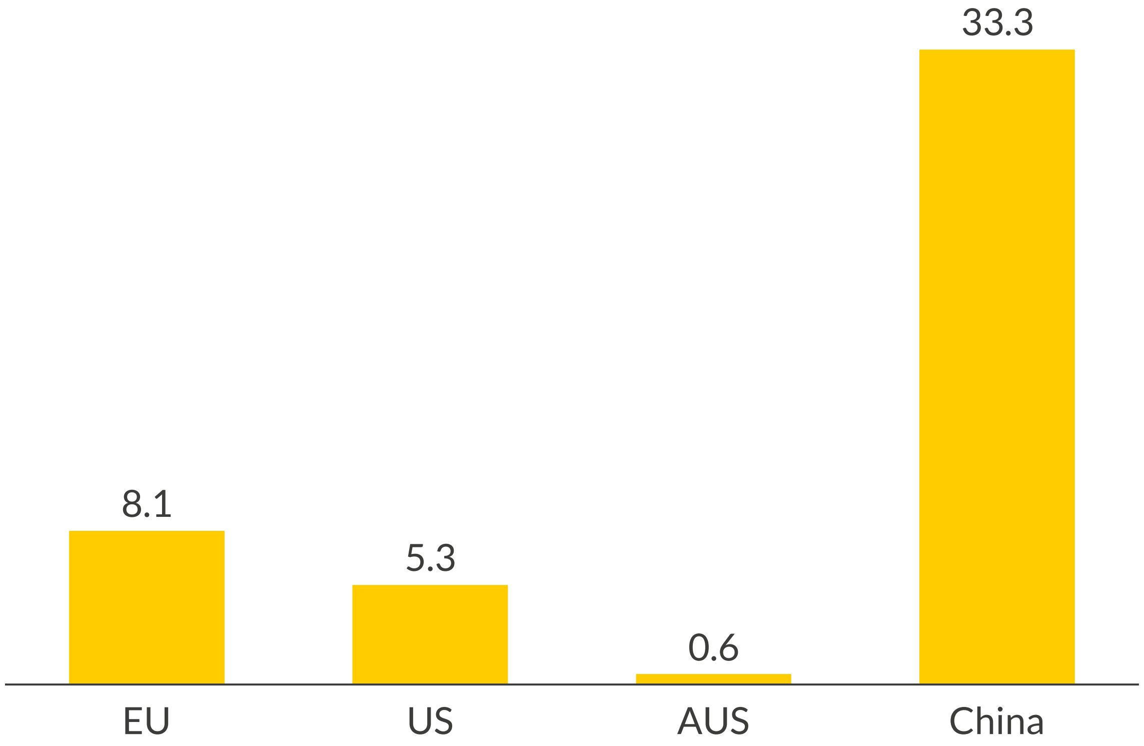
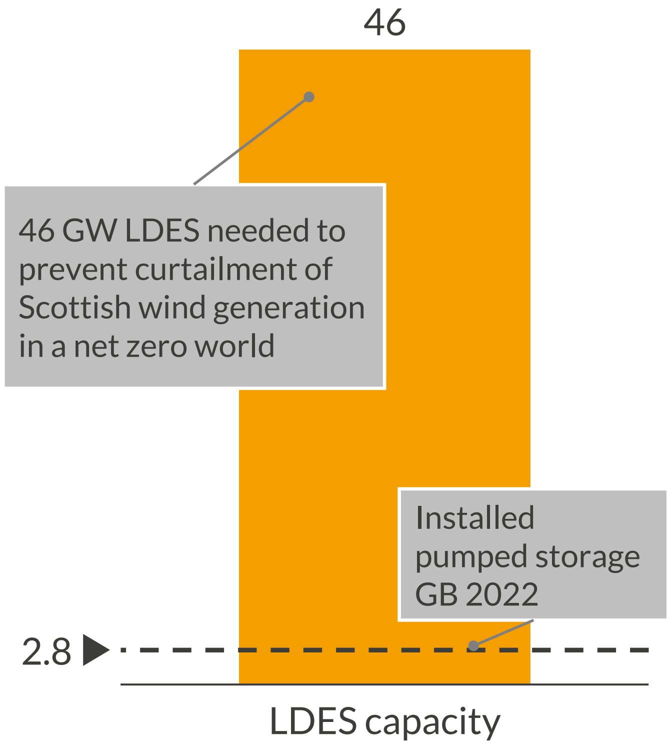
Expanding the grid is a solution but can take years, depending on the market…

Total HVDC power lines built
‘’000km of lines

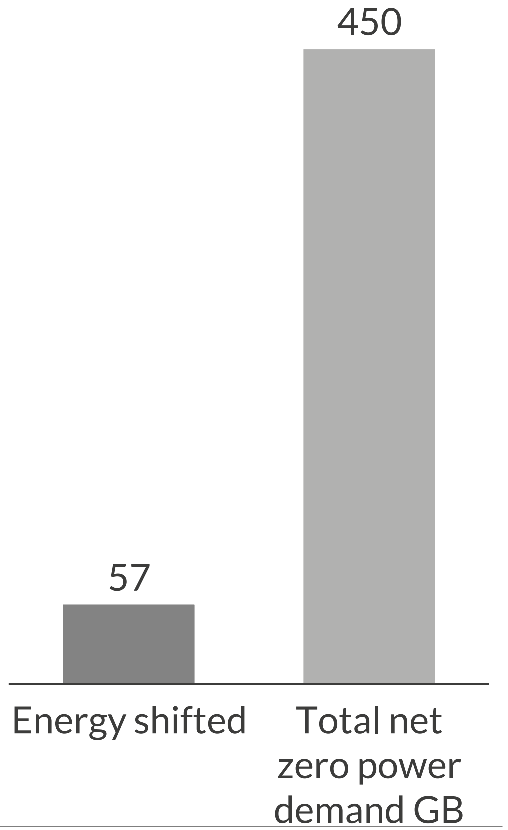


…and relying on long duration would require very high buildout of long duration energy storage capacity

LDES power requirement, 2035 GB
GW



Energy available to be shifted vs. power demand 2035 GB
TWh



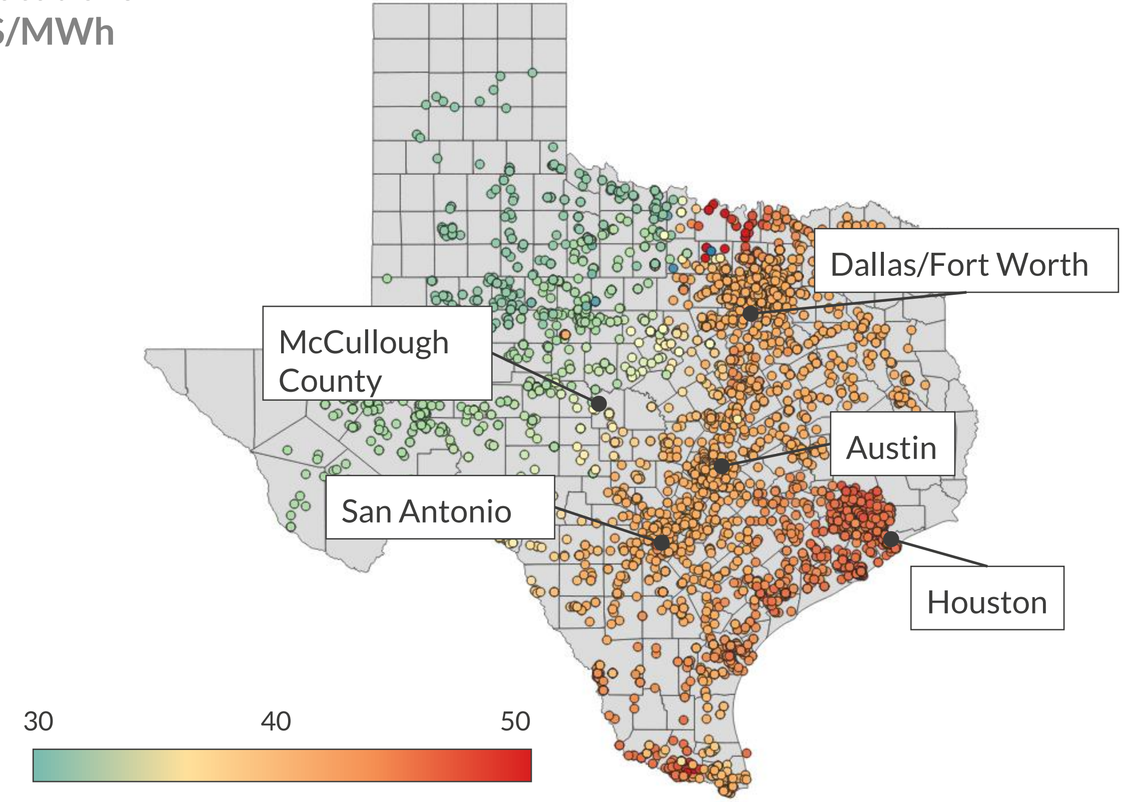
1) Electricity only, no supplier admin costs

Sources: Aurora Energy Research, US EIA, Europa Cable, TenneT

Network constraints can be priced through changes to market design, but this creates risks for developers and investors to manage

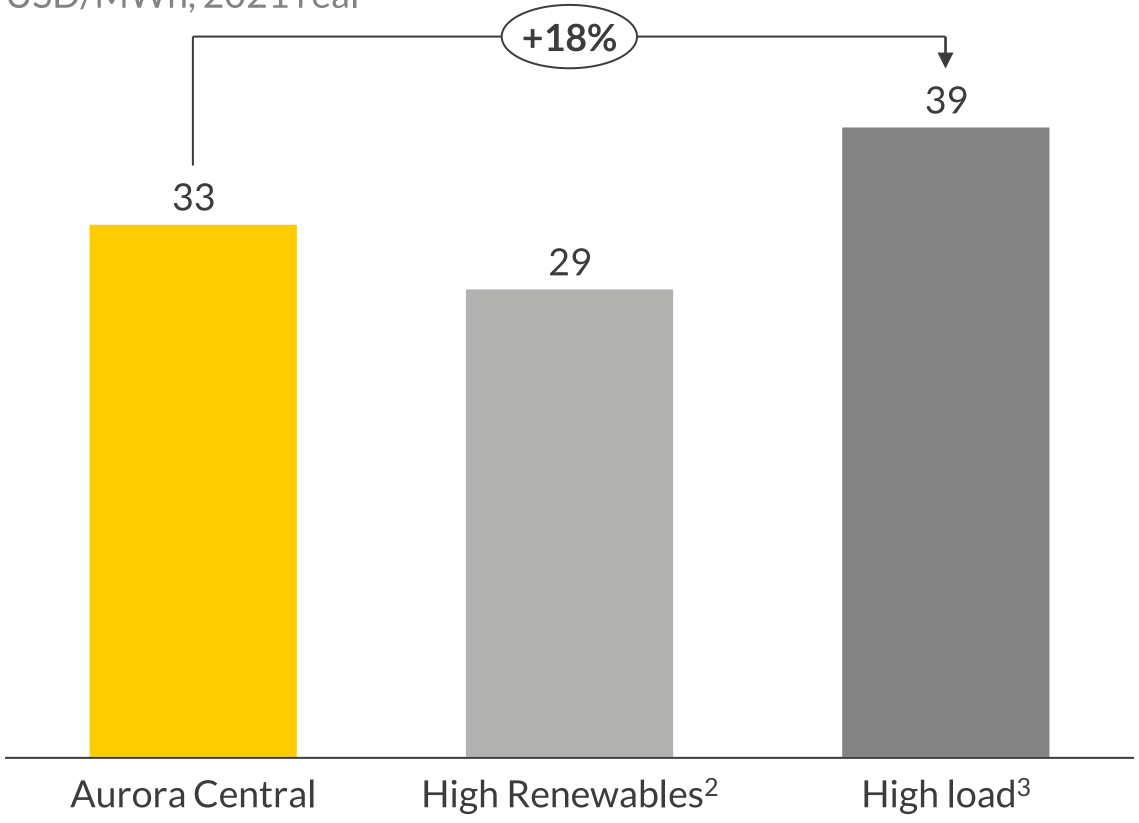
Nodal pricing incentivises capacity to locate closer to demand centres reducing their impact on the network…

Average baseload price at different nodes, Central 2025, with asset locations
$/MWh



…but present a risk for investors as prices can vary significantly under different scenarios

Average GWA[1] price Wind Asset in ERCOT (West McCullough County) 2022-2030
USD/MWh, 2021 real



1) Generation weighted average (comparable to capture price) 2) -15% CAPEX costs for RES 3) +10% total load ERCOT wide by 2030

Source: Aurora Energy Research

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As thermal baseload retires and renewables are deployed, the need and opportunity for flexibility increases significantly

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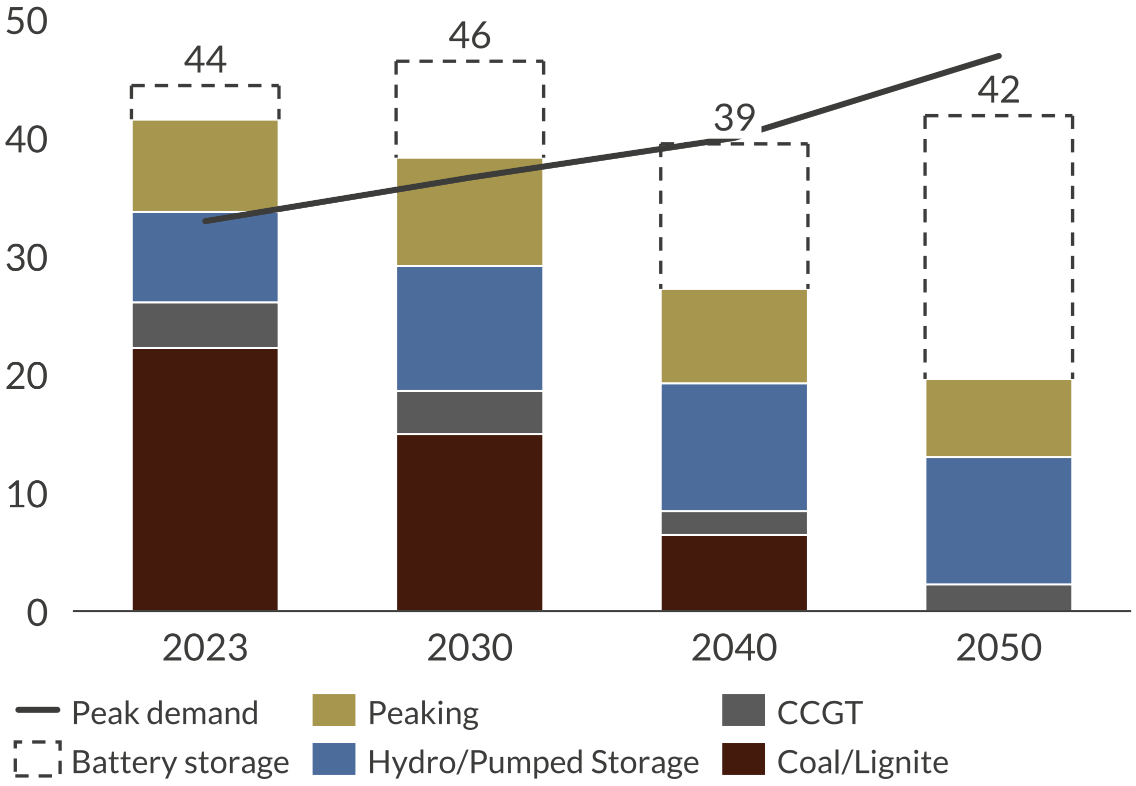
As thermal capacity declines in Australia, without new flexible assets, the power system will face security of supply risks

Australian National Electricity Market-wide capacity

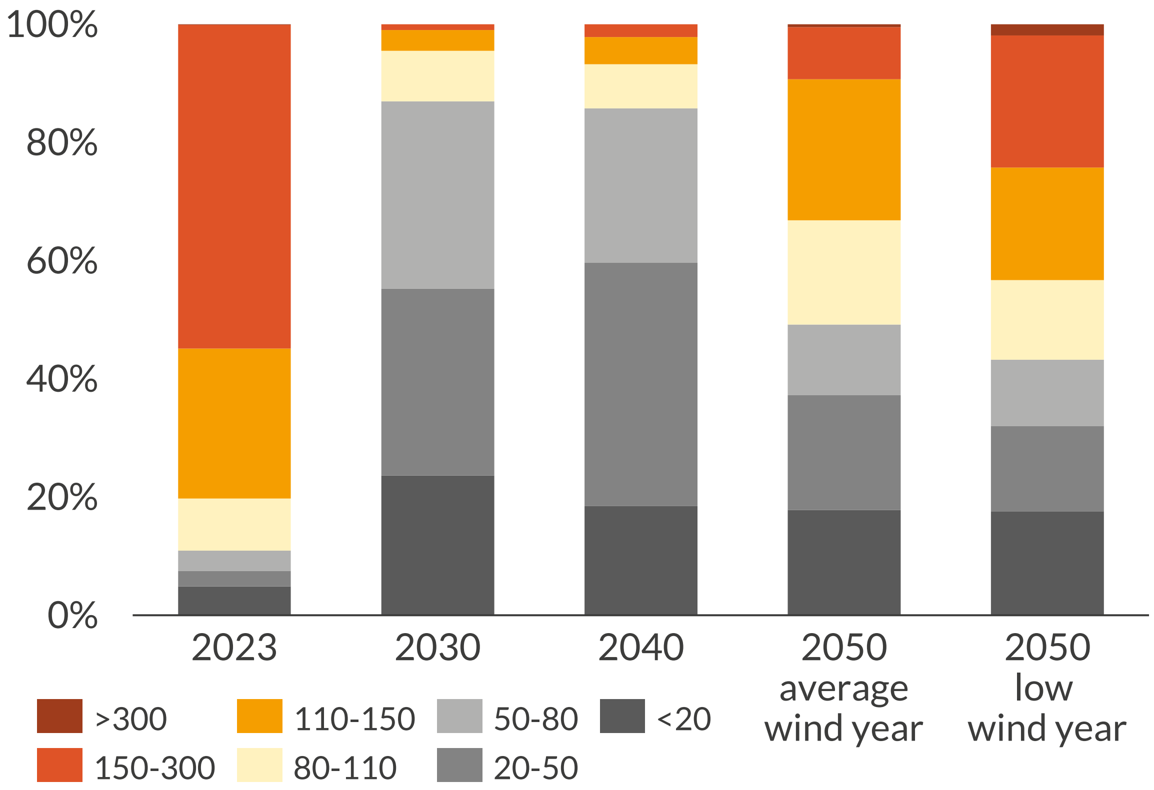
Nameplate GW



As Australia approaches Net Zero , variable renewables cause increasing price volatility and create opportunities for batteries

Electricity price frequency distribution April '22 Net Zero Scenario (EUR 2021 real) – Queensland, Australia

%



1) Includes behind-the-meter storage

Source: Aurora Energy Research

Well-designed ancillary markets are needed to cope with loss of thermal capacity, opening up new opportunities for flexible capacities

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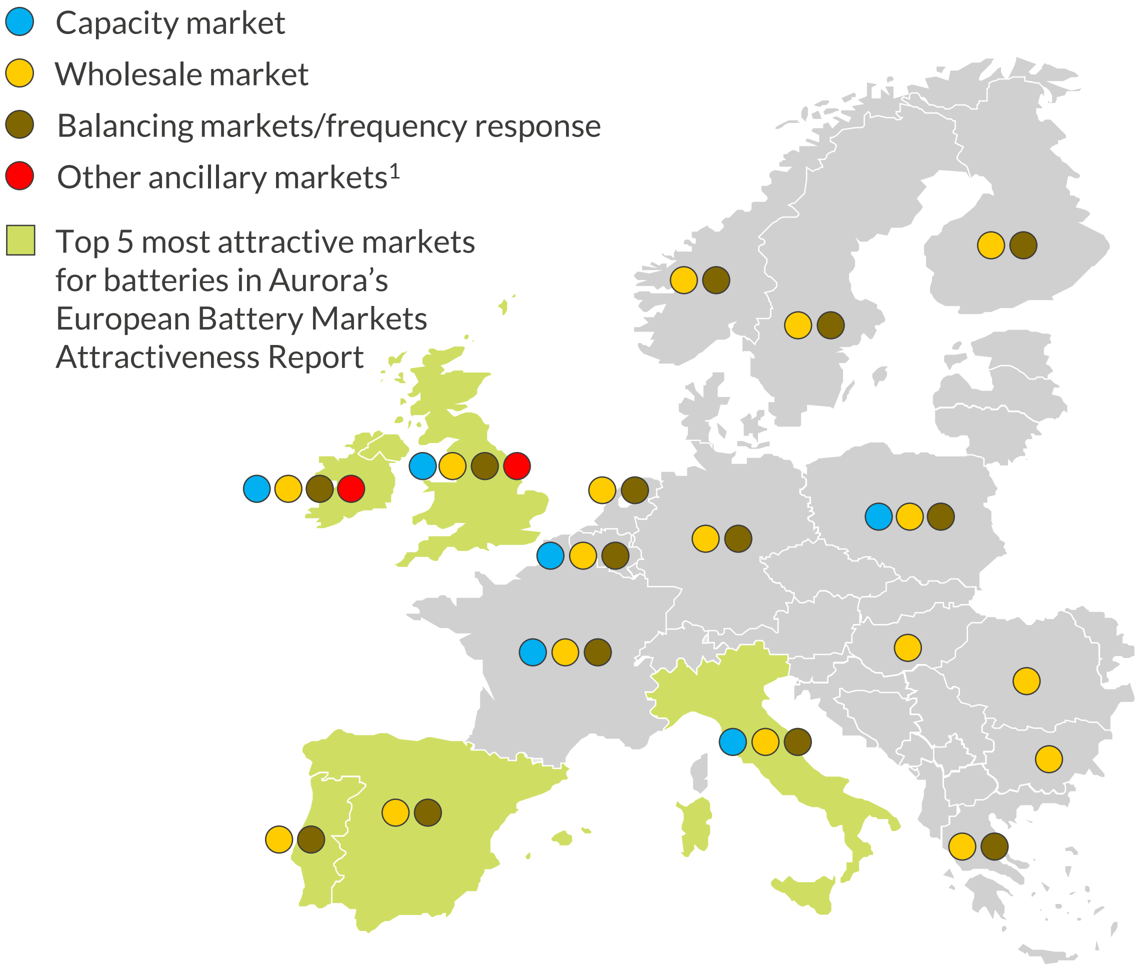
Availability of capacity, balancing and ancillary markets in Europe



Lessons learned on optimal market design

- Transparency
- Provide clarity on future system requirements
- Separate markets to address each flexibility 'service' to the grid
- Technology neutrality, harnessing the demand side
- Address carbon constraint (inside or outside CM)
- Stackability of revenue streams
- Mesh local, national, international requirements/markets

1) Includes inertia, black start, etc.

Source: Aurora Energy Research

The ability to stack revenue streams is crucial for grid-scale battery business models

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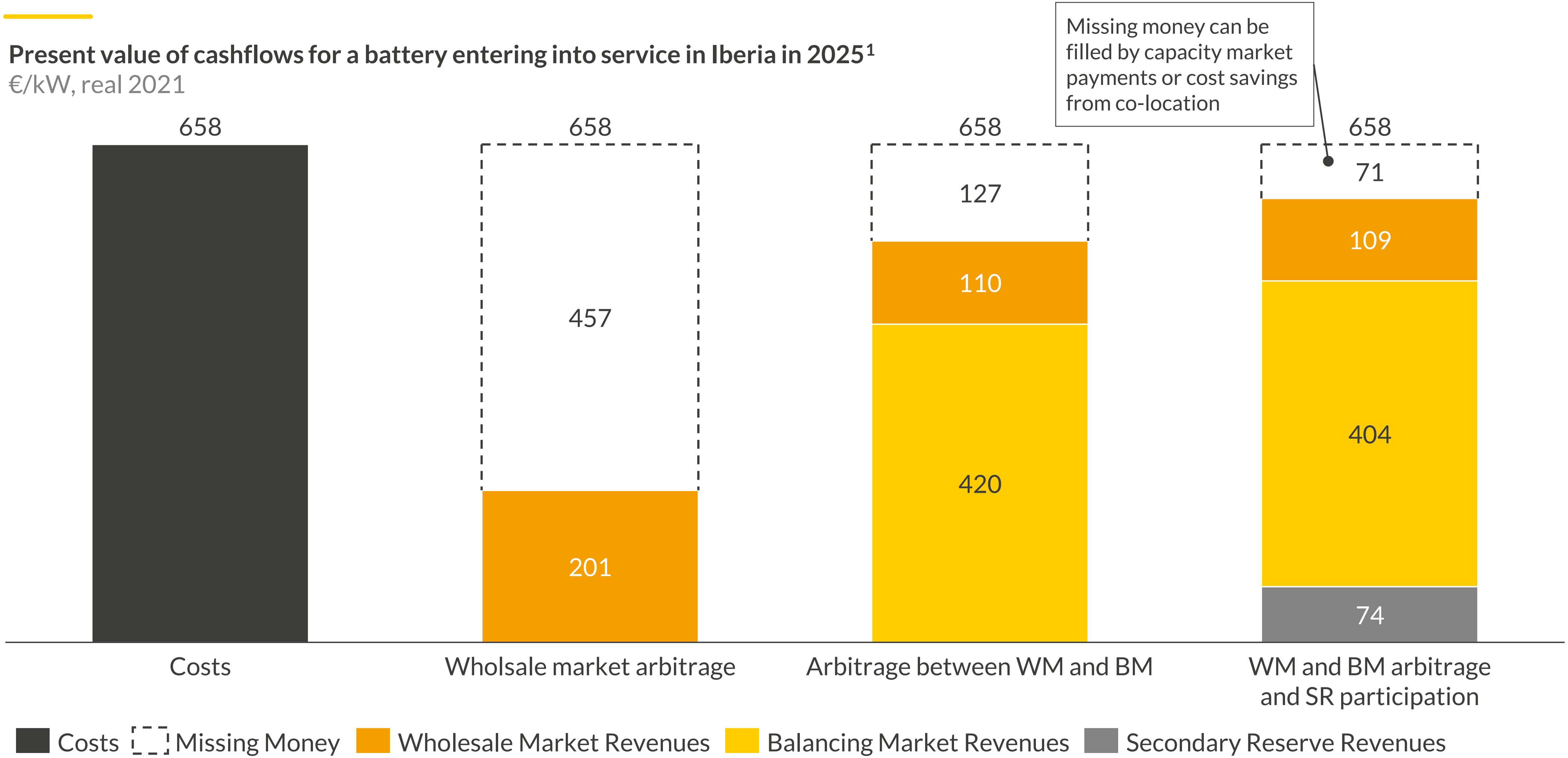
Present value of cashflows for a battery entering into service in Iberia in 2025[1]
€/kW, real 2021



1) Cashflows discounted at 9%. Average achievable cycling per day. 2-h duration battery with 90% round-trip efficiency entering in 2025, 2 cycles per day with a 0.0037% degradation per cycle. CAPEX of 549 €/kW and FOM of 11.5 €/kW/year. No repowering assumed.

Source: Aurora Energy Research

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