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AURORA KEYNOTE

CHARGING AHEAD: THE GRID CHALLENGE IN EUROPE'S PURSUIT OF NET ZERO

Europe[1] has set ambitious renewable targets by 2030, requiring almost a tripling of renewable installed capacity relative to 2023

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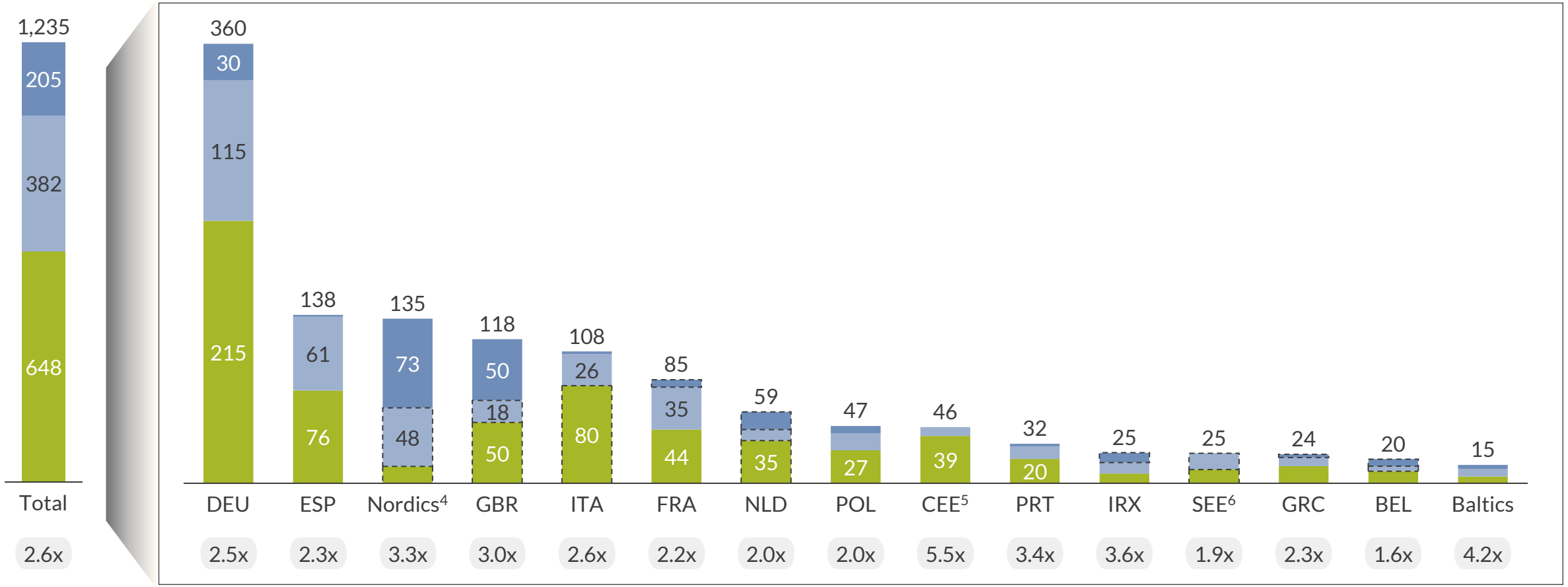
Target RES[2] installed capacity by 2030[3]

GW



1) Europe here includes the EU27, GB, CHE, NOR & SRB but excludes LUX, CZE, SVK, MLT & CYP. 2) Renewables. 3) National Energy and Climate Plans (2020) or 2023 drafts where available at the time of the analysis. 4) Capacity targets based on Nordic TSO forecast and announced offshore wind tenders. 5) Central Europe (AUT, CHE, HUN & SVN). 6) Southeastern Europe (BGR, HRV, ROU & SRB). 7) Estimated based on draft targets, announced targets in TWh and/or relevant Aurora assumptions where applicable.
Sources: Aurora Energy Research, European Commission, RTE, Nordic TSO, NECPs, National energy strategies

Aurora's forecasts assume that 2030 targets are not met; the path towards Net Zero requires a further acceleration of RES deployment

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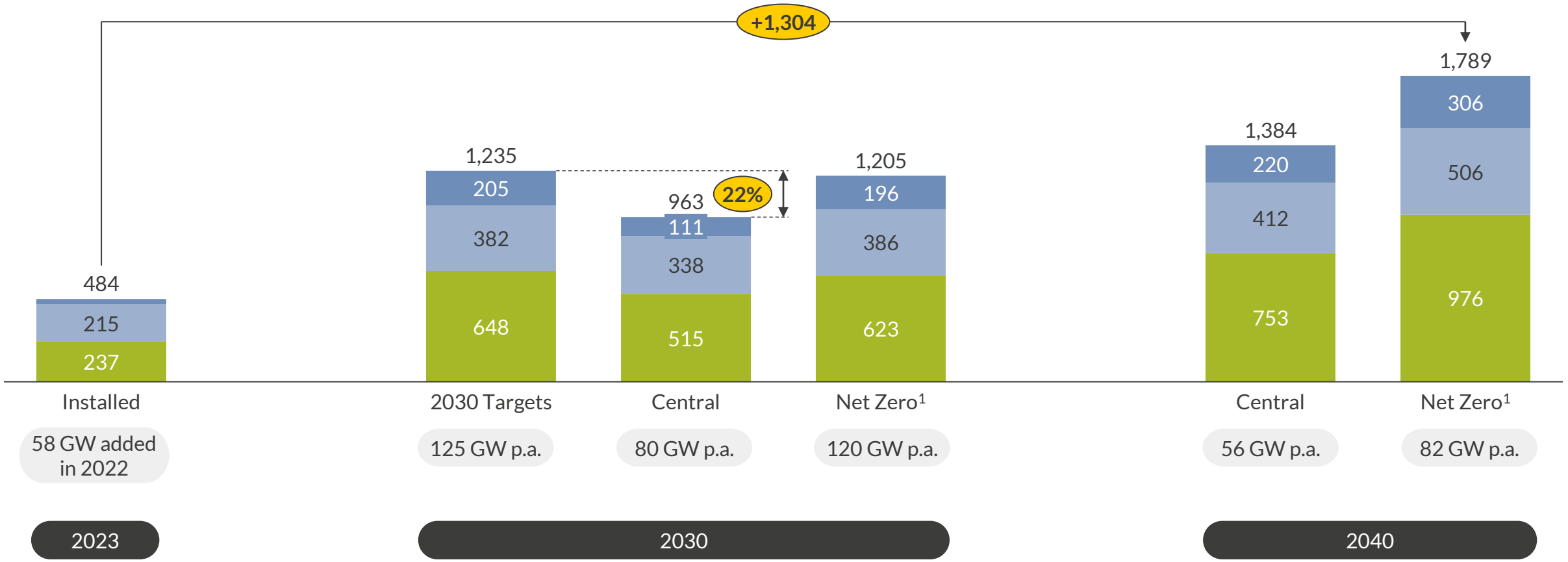
Installed RES capacity across Europe by Aurora scenario
GW



1) For markets where Aurora does not model a separate Net Zero scenario: Nordics and Baltics are assumed to meet 2030 goals, CHE and AUT use Central which approaches Net Zero.

Source: Aurora Energy Research

There are several challenges in achieving Net Zero ambitions, but grids are becoming the key bottleneck

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Capital cost and availability

Supply chain capacity and availability

Security of supply concerns

Regulation and market design

RES cannibalisation

Demand inflexibility

Permitting and site availability

Deep-dive

Grid operability

Grid connections

The cost of needed grid investments vary significantly by TSO; but estimates suggest that 1.54 trillion Euros are required to upgrade grids

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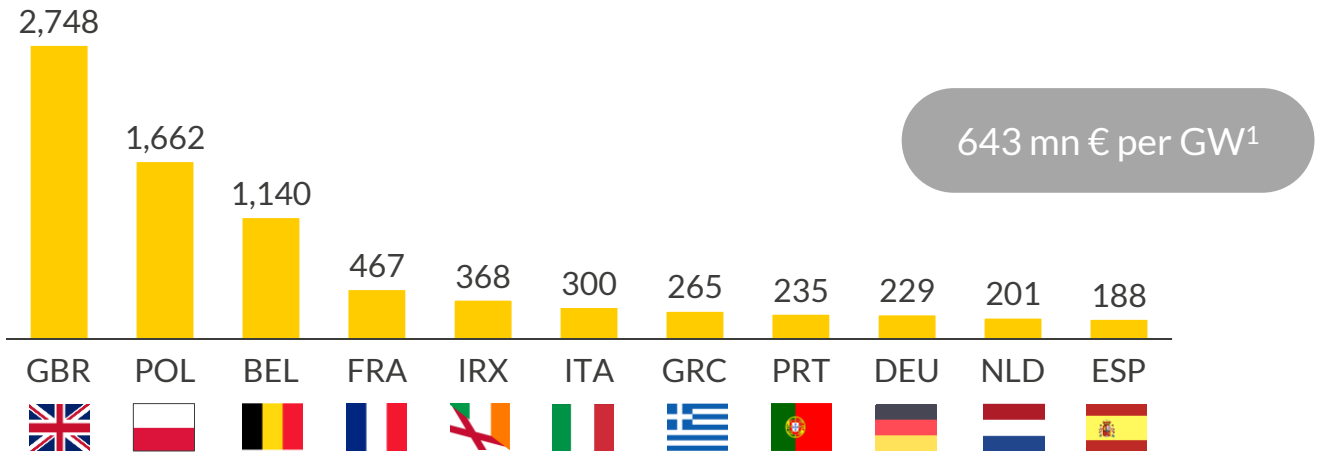
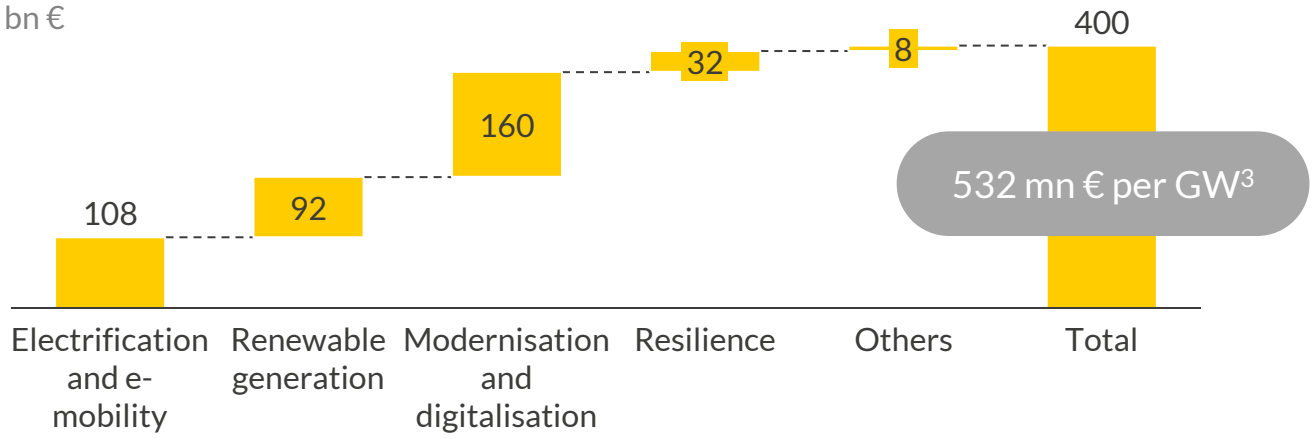
Planned transmission network investments
mn €/GW of planned renewables



Required distribution network investments[2]
bn €



2030	2040
1.18 bn € per GW	1.18 bn € per GW
✖	✖
720 GW *by 2030[4]*	1,304 GW *by 2040[4]*
=	=
850 billion € *by 2030*	1.54 trillion € *by 2040*

1) Average weighed by renewable capacity needs for 2030 Net Zero scenario. 2) Eurelectric and EDSO "Connecting the Dots". Investment estimates through 2030. 3) Average of range of estimates provided, divided by GW of new renewable capacity expected under 2030 targets. 4) Based on Aurora's Net Zero Scenario.

Sources: Aurora Energy Research, Eurelectric , EDSO, Elia, EirGrid, ITA, National Grid ESO, REE, Reuters, RTE, Terna, TenneT

The scale of the required investment poses a challenge, both in terms of historical deployment rates and typical investment timelines

1 Deployment rates

850 billion €
Required by 2030

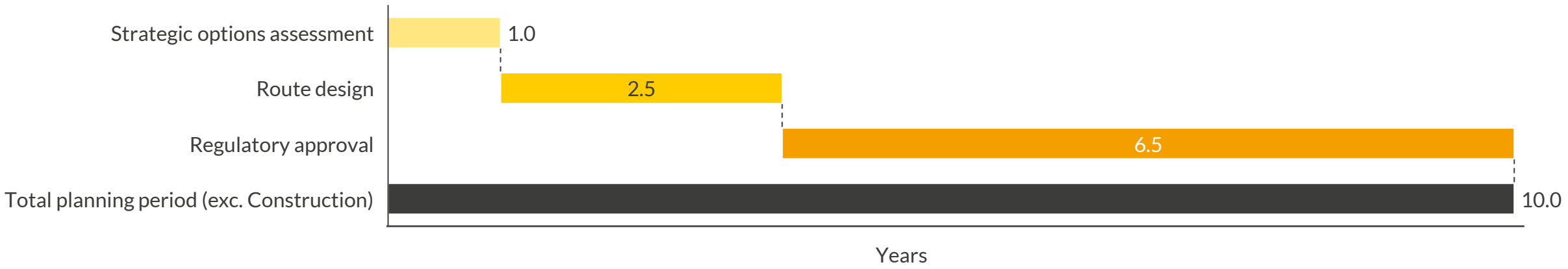
142 billion €
per year through 2030

vs.

66 billion €
in 2022

2 Investment timelines

Sample grid planning timeline – the GB Case (prior to proposed reforms)



Sources: Aurora Energy Research, DESNZ, Energy Systems Catapult

Insufficient or delayed investment in grid infrastructure can hamper Net Zero targets in several ways:

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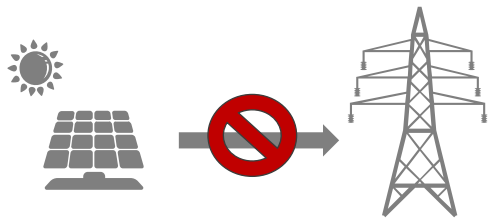
Deep-dive

Suboptimal flows across Europe

- By 2040, there is room for an extra 90 GW[1] of cross-border capacity across the EU
- Gas-based generation would decline by 75 TWh
- 9 bn € per year saved in generation costs

Grid operability: loss of generation from grid curtailment

- Operability issues with transmission and distribution networks are leading to growing grid curtailment
- In 2023 alone, Europe lost around 30 TWh of generation to **grid curtailment**
- Lack of data transparency prevents investors from making informed investment decisions



Grid connections: slower buildout of renewables

- Grid access queues across Europe are a major bottleneck to the development of new renewable capacity
- Grid access can delay renewable project development by 10+ years
- Lack of visibility on the status of required grid improvements limits investment

1) According to ENTSO-E Ten-Year Network Development Plan 2022 System Needs study, May 2023.

Sources: Aurora Energy Research, ENTSO-E

Nearly 30 TWh of generation was lost to grid congestion in 2023 across 6 countries in Europe, at a cost of close to 9 billion Euros

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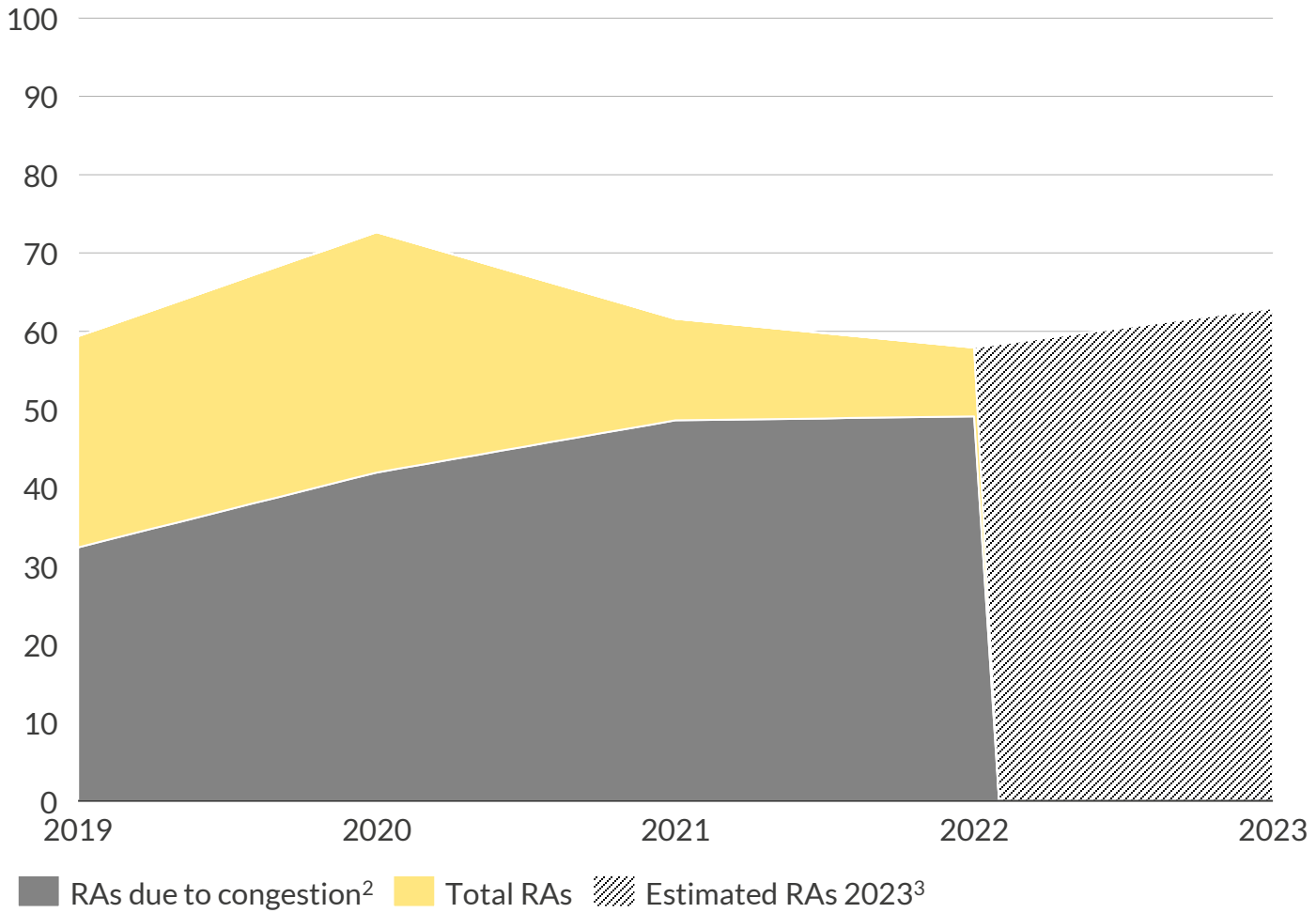
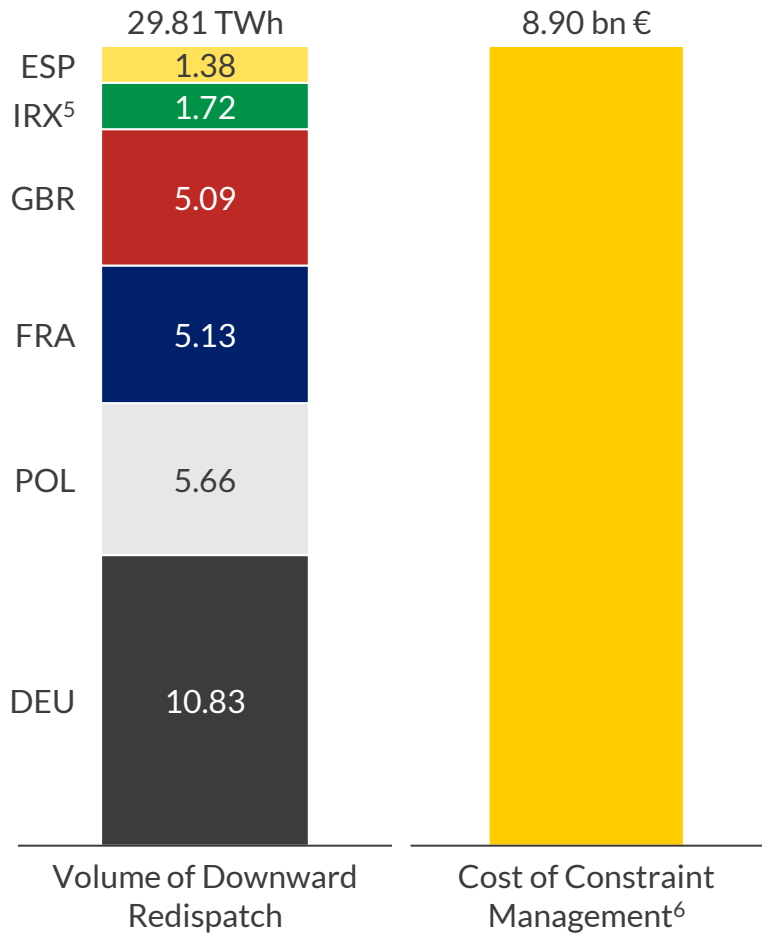
Growth in Remedial Actions (RAs) taken to ease grid congestion across Europe[1] since 2019

TWh



Constraint Management measures in 2023[4]

TWh and bn €



1) Europe in this case includes the EU27, GBR, NOR but excludes MLT and CYP. Data for most countries comes from ACER/CEER MMRs, or where unavailable from national TSOs. ITA excluded as data deemed unrepresentative by ACER and no data provided by Terna. 2) RAs due to congestion calculated from total volumes using ACER figures for congestion. 3) Estimates for 2023 RAs based on data from TSOs in 10 countries with highest congestion in previous years. 4) Based on downward dispatch actions reported by individual TSOs in most congested grids . 5) Only includes RES curtailment. 6) For 6 displayed countries; FRA cost estimated by comparing against DEU and GBR costs per volume.

Sources: Aurora, ACER, BNetzA, EirGrid, ENTSO-E, National Grid ESO, REE, RTE, PSE

As the pace of renewable development accelerates in resource-rich areas, congestion problems are expected to grow

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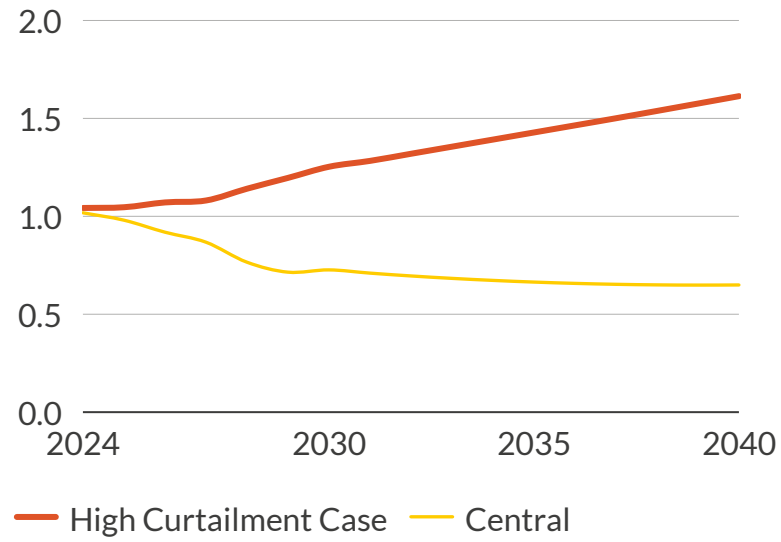
- Localised development of wind and solar is creating increasing congestion challenges across several areas in Spain
- The retirement of nuclear and increasing local demand (e.g., hydrogen) can help mitigate curtailment growth, but uncertainty remains

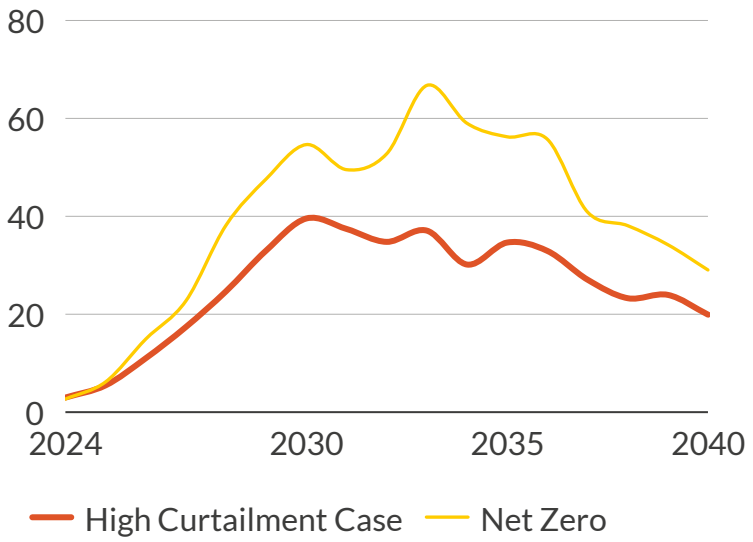
- Net Zero forecast anticipates 40 GW of the government's 50 GW offshore wind ambition by 2030, causing a rise in grid curtailment
- A new interconnector in 2030, and the ASTI[1] framework helps bring down curtailment over time

- High load factors in Southern Italy and Sicily attract large solar and wind buildout
- For this new capacity to reach demand centres, significant investment in cross-zonal capacity is required, but geography causes difficulties

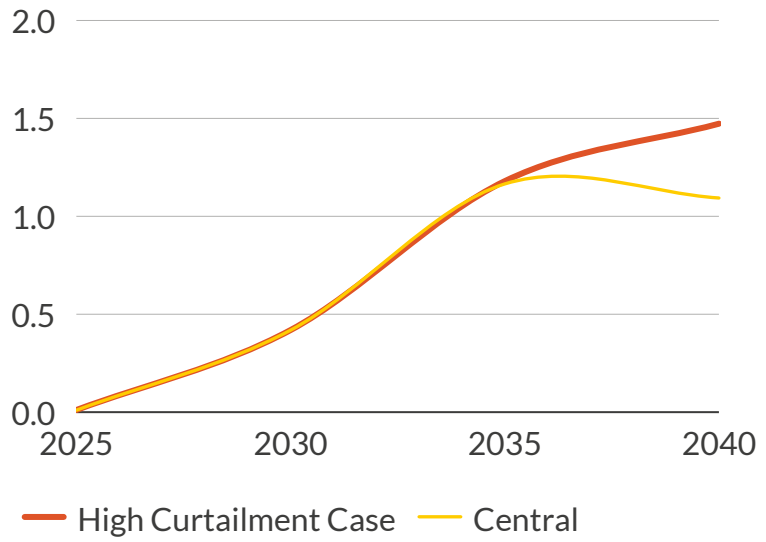
Curtailment forecast in key provinces[2]



Curtailment forecast[3]



Curtailment forecast in key congestion areas[4]



1) Ofgem's Accelerating Strategic Transmission Investment (ASTI) initiative. High Curtailment Case assumes that grid falls short of ASTI upgrades by 34%.2) Key provinces with high buildout of variable RES and transmission constraints, includes A Coruna, Badajoz, Caceres, Ciudad Real, Huesca, La Rioja, Navarra, Soria & Zaragoza. 3) Curtailment here covers only transmission connected assets and includes all energy sources. 4) Key congestion areas include Agrigento & Trapani.

Source: Aurora Energy Research

Information is patchy, but around 900 GW of capacity is still awaiting grid connection across Europe

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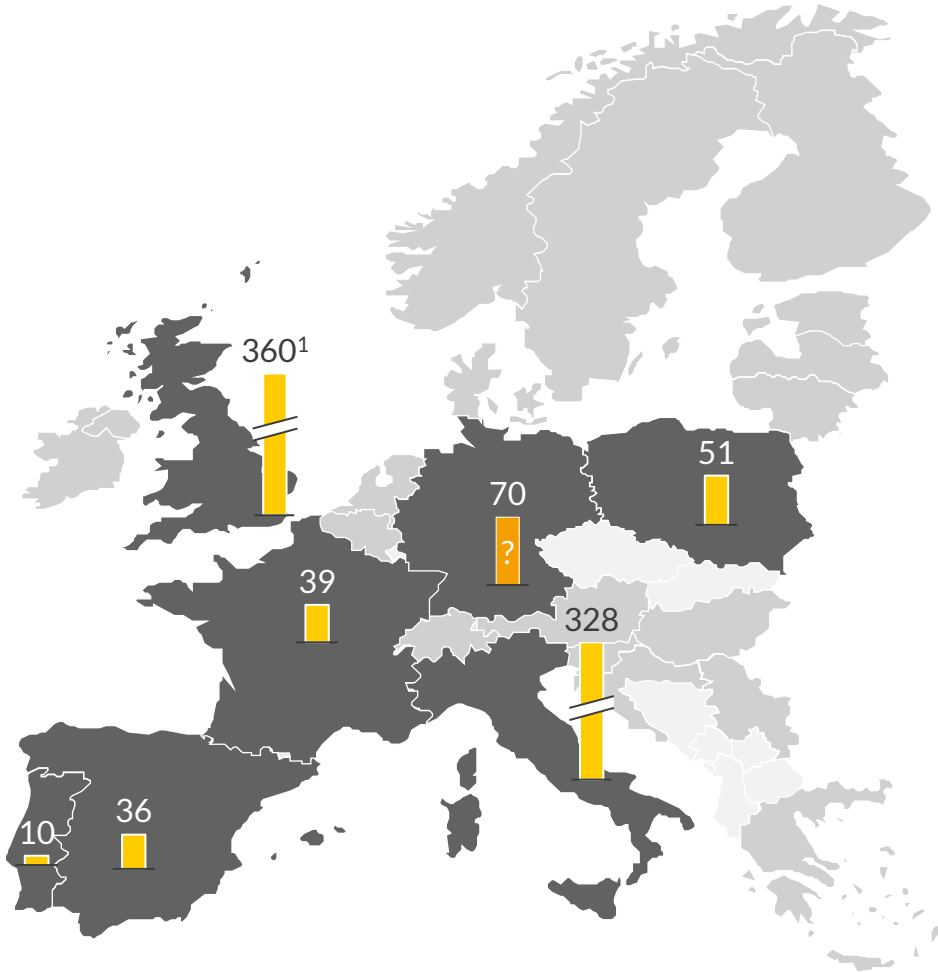
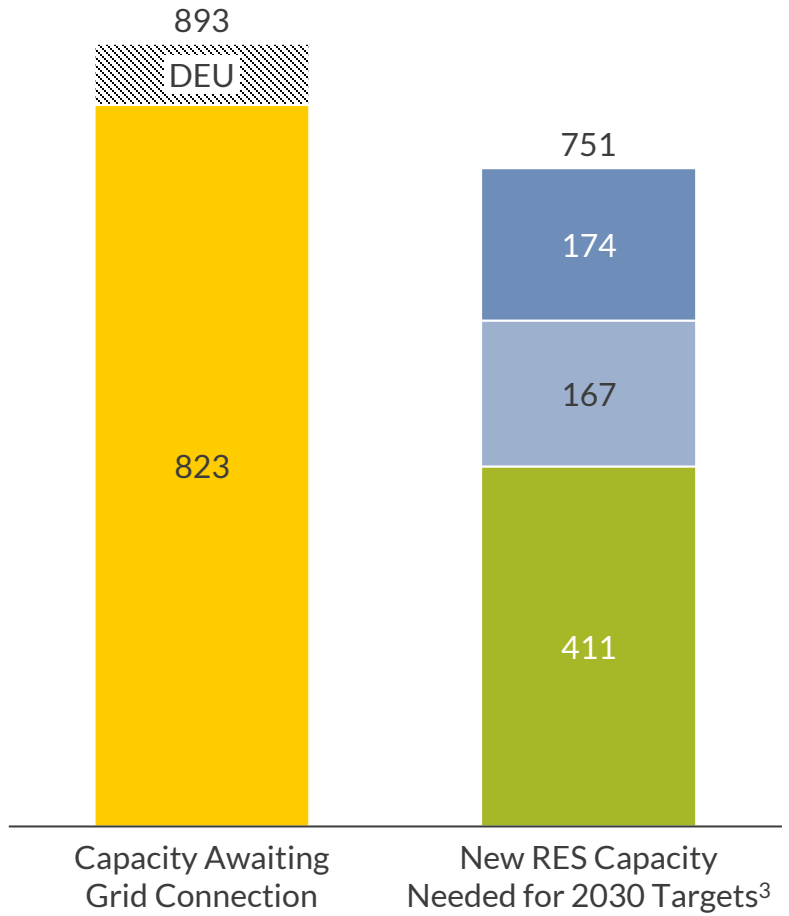
Capacity awaiting a grid connection

GW





Offshore wind | Onshore wind | Solar | / | DEU estimate[2] | Queue

1) Including 80 GW awaiting to connect to the distribution network. 2) Estimate for DEU based on onshore and solar buildout plan until 2026 minus pre-registered capacity. 3) RES capacity for 2030 for all Europe, capacity queue for displayed countries.

Sources: Aurora, Ember, Expresso, ODRE, REE, Terna

Grid access problems vary across Europe; different issues will require different solutions across markets

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Rising offshore wind capacity in remote areas requires significant grid reinforcement; **about 8GW of offshore HVDC lines** are currently in various stages of planning and construction.

Between 2022 and 2023, applications for grid connections have **risen by 80%** with **360 GW holding connection agreements in the queue.**[1]

More than 120 GW of projects have a connection date only **after 2030.**

Most grid connections in the future will only be available through auctions. Planned auction has already been delayed by 18 months.

Although **the pipeline of projects with both grid access and EIA[2] exceeds 70 GW**, there are an additional 36 GW awaiting grid connection.

The grid has been heavily congested for years, with **almost no new connections being granted**. Rejections for grid applications have increased from 64 projects in 2018 to 7023 in 2022. Applications for **51 GW of capacity were rejected in 2022**.

However, in August 2023 the Polish parliament adopted amendments to the Polish Energy Law, **introducing Cable Pooling**, i.e. connecting two or more renewable energy source installations to the same interconnection point.

Low grid bonds; first come, first served principles; and no expiry dates for grid access have created speculation and long queues for new projects.

More than 328 GW of projects are currently awaiting grid connection.

1) Considering both the transmission and distribution queue. 2) Environmental impact assessment.

Sources: Aurora Energy Research, Ofgem, Guardian

The EU has made several recommendations to tackle these issues, highlighting both regulatory incentives and process improvements[1]

1. National Regulatory Authorities (NRAs) should ensure that system operators **holistically assess the needs of the energy system,** including the need for flexibility and the potential of **energy storage.**

2. Regularly revisiting regulatory frameworks to ensure they recognise the importance of **anticipatory investments**, and account for both CAPEX and OPEX in network tariffs.

3. **Non-firm connection frameworks** should be designed so that they are:
   - Deployed where grid development may not be a long-term economic solution.
   - Do not disincentivise or delay grid buildout where it is the long-term economic solution.

4. NRAs[2] should disincentivise the **application for connection** requests where they are not substantiated by **solid projects**.

5. The vast financial resources required to upgrade the grid system in Europe will require a new effort to identify **tailor-made financing products** and instruments to support grid investments.

6. **Alignment of product designs, and grid connection requirements for new demand and generation** across the EU would enable suppliers to focus on delivering quantity rather than utilising time and resources in delivering tailored designs and manufacturing.

1) The paper "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions" includes a 14-point action plan. This provides a summary of some of the key points.
2) National regulatory Authorities.

Availability of data related to grids is also a key limiting factor for informed decision making for governments, regulators and investors

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Data Transparency Assessment[1]

Country or organisation	Grid curtailment information (volumes and costs)				Grid queue information (TSO level)			
	Data availability		Ease of access		Data availability		Ease of access	
Germany	No RES curtailment		Costs and vols from different sources		No clear reporting			
France	No RES curtailment		UI doesn't aggregate annual data		Information includes both transmission and distribution			
United Kingdom (excl. NI)	No RES curtailment				Central database includes just transmission			
Italy	Data "unrepresentative"		Terna do not supply to ACER		Information includes both transmission and distribution			
Spain	Some RES reporting		Difficult to access Excels		Information includes both transmission and distribution			
Ireland and Northern Ireland	Annual RES curtailment report						Available but no clear summary	
Poland	No RES curtailment				Indicative data available, but harder to access granular detail			
ENTSO-E	No systemic reporting of RES curtailment, lacking redispatch data for most countries		Difficult to access data on scale required		No Pan-EU reporting			

Legend: Complete, accessible and explorable; Largely available, but not easily accessible or explorable; Missing or incomplete

1) Based on research undertaken in the development of this keynote presentation.

Key takeaways

1. The trajectory towards Net Zero will require the development of 1,304 GW of new solar and wind capacity across Europe by 2040

2. To integrate new renewables and upgrade Europe's ageing grids, an investment of over 1.54 trillion € will be required by 2040

3. Lack of investment in grids will not only limit the renewable energy that can get to customers, but jeopardise the development of new renewable capacity needed to meet Net Zero targets

4. Grid operability issues in 2023 resulted in the curtailment of close to 30 TWh at a cost of close to 9 billion € for 6 countries across Europe; total EU numbers, if readily available, would be significantly higher

5. There are currently over 893 GW of capacity awaiting grid connection across the largest markets in Europe[1]; this is equivalent to 118% of the capacity that needs to be built by 2030

6. Solving the complex and varied set of issues facing grids across Europe requires a holistic review of regulatory frameworks and processes related with grid investments, connection requests, and the management of grid congestion

7. Data transparency is a key barrier to the understanding of challenges and potential solutions to connection queues and grid congestions issues

1) 823 GW out of 893 GW are in confirmed queues with a further 70 GW of estimated capacity for Germany.

Sources: Aurora Energy Research


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Details and disclaimer

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