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ENERGY RESEARCH

Locational Risks for Renewable Investments in Italy

Public Report

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Our team

Matteo Coriglioni
Head of Italy
Matteo.Coriglioni@auroraer.com

Maddalena Cerreto
Senior Associate
Maddalena.Cerreto@auroraer.com

Federica Marazza
Associate
Federica.Marazza@auroraer.com

For more information on the Italian power market, please contact:

Foteini Kakavia, Commercial Associate foteini.kakavia@auroraer.com

After several stagnating years, renewable buildout has accelerated in Italy, although distributed unevenly across the country

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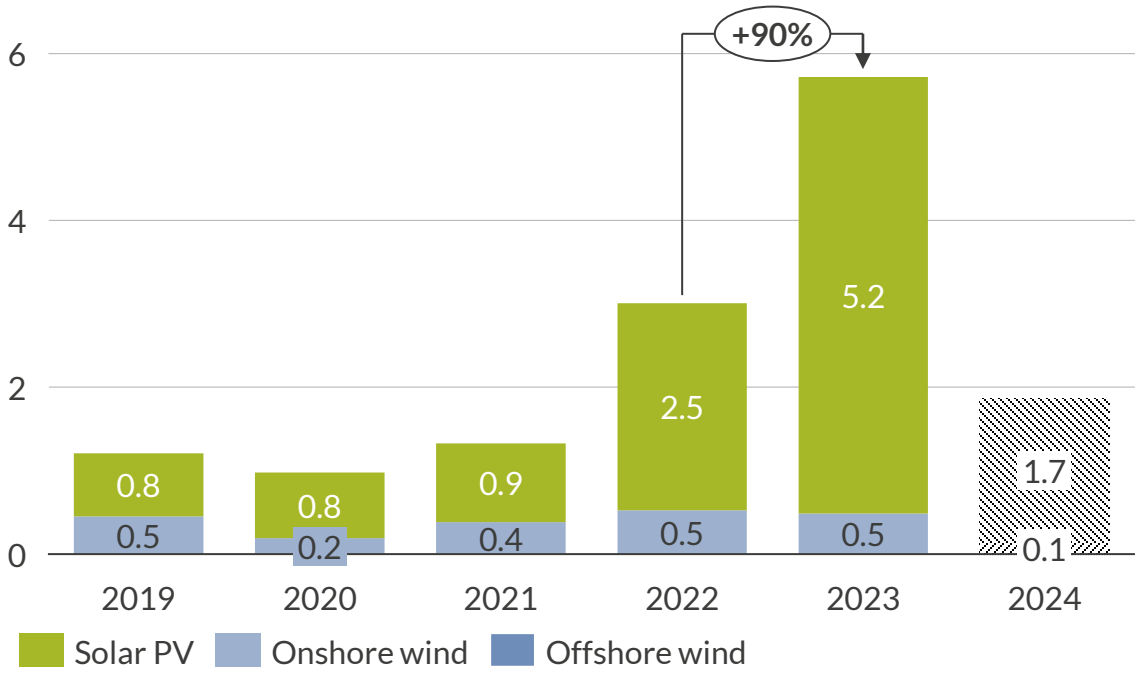
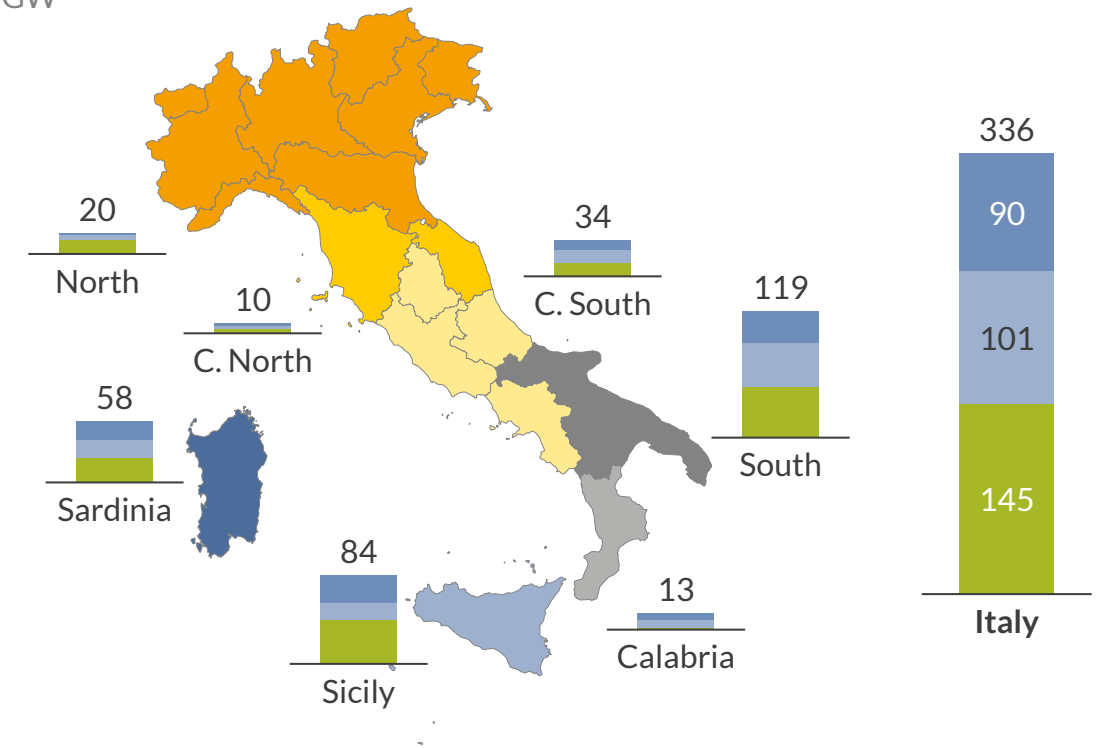
Renewables net buildout
GW/year



- Buildout of wind and solar sped up in 2023, with solar buildout amounting to 5.2GW, 90% higher than in 2022.
- The first months of 2024 confirmed the accelerating trend, as solar capacity buildout in the first three months is almost double the 2021 annual increase.

RES grid connection requests by zone[1]
GW



- 336GW of RES project have requested grid connection as of May 2024, 43% of which are for solar PV projects (145GW).
- Requests are highest in the price zones South (35%), Sicily (25%) and Sardinia (17%), with zone South representing the main development area for onshore wind.

1) Only includes requests for the high voltage transmission grid; data retrieved on 10/05/2024.

Sources: Aurora Energy Research, Terna

Geographical mismatch of demand and RES resources leads to location being a key factor to assess under all potential routes-to-market

- High power demand in the North and favourable conditions for renewables in the South put increasing pressure on the transmission grid, resulting in zonal price divergence and amplifying cannibalisation.
- Renewable assets in Italy have three main routes-to-market, which entail different types of exposure to locational risk.

Renewables routes-to-market and locational risks exposure

A — RES subsidy schemes

- In the last decade RES support schemes have been the main route to market in Italy for solar and wind plants
- Newest RES support schemes, FERX, is based on symmetrical Contract-for-Differences (CfDs)
- **Differences in RES resources impact LCOEs across zones, and ultimately bid levels**

B — Power Purchase Agreement (PPA)

- PPAs provide a market-based alternative to subsidies for generators to secure their revenues
- Though the PPA market in Italy is still relatively small, it is growing quickly and provides bankability to merchant projects
- **Generation under a PPA is still exposed to zonal prices divergence through CCT fees**

C — Merchant revenues

- In Italy favorable economics could lead to high merchant build-out of RES plants, particularly solar
- Merchant returns particularly attractive in the short-term given the high-price environment
- **Zonal demand and supply balance will lead to divergence in RES capture prices**
- **Local penetration of RES and conditions of the grid can lead to increasing curtailment**

Source: Aurora Energy Research

The FERX subsidy scheme aims at providing locational price signals to solar and wind plants by adjusting submitted bids for the merit-order

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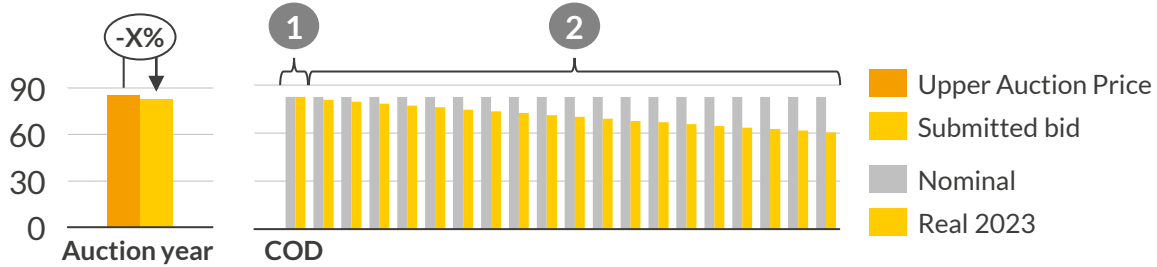
Auctions

- **57GW of subsidised RES capacity**, with a 5GW drop in solar PV since the previous draft, with **at least two auctions per year** between 2024-2028.
- **Full authorisation** required or positive VIA[1] outcome. Assets can opt to contract **only part of their capacity**, allowing for merchant or PPA exposure.
- Presented offers must include a **% reduction from the Upper Auction Price**, with no minimum discount requirement.
- **Zonal coefficients used to rank bids, providing locational price signals.**[2]

Remuneration

- **20-year CfD** with awarded **price adjusted for inflation:**
  1. 100% indexing between auction and contract start year
  2. Partial indexation over 20-year contract duration

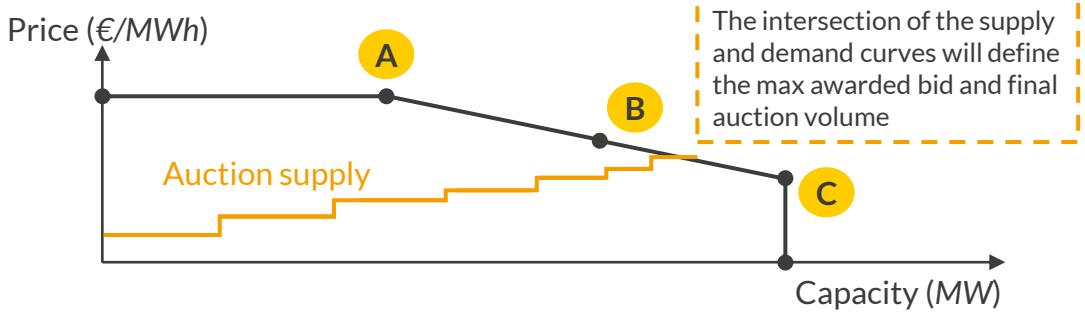


- **CfD payment based on potential energy production** in case of 1) grid curtailment, 2) accepted bid for downward regulation[3], 3) Day-ahead prices <= 0

Main auction parameters for solar PV and onshore wind

Technology	Total Capacity[4] GW	Reference Auction Price[5] €/MWh	Lower/Upper Auction Price[5] €/MWh	COD[6] months after auction results
Solar PV	40	85	75 / 90	21
Onshore wind	16.5	85	75 / 90	34

Auction demand curve



To promote competition within auctions, the demand curve will be dynamic and defined by:

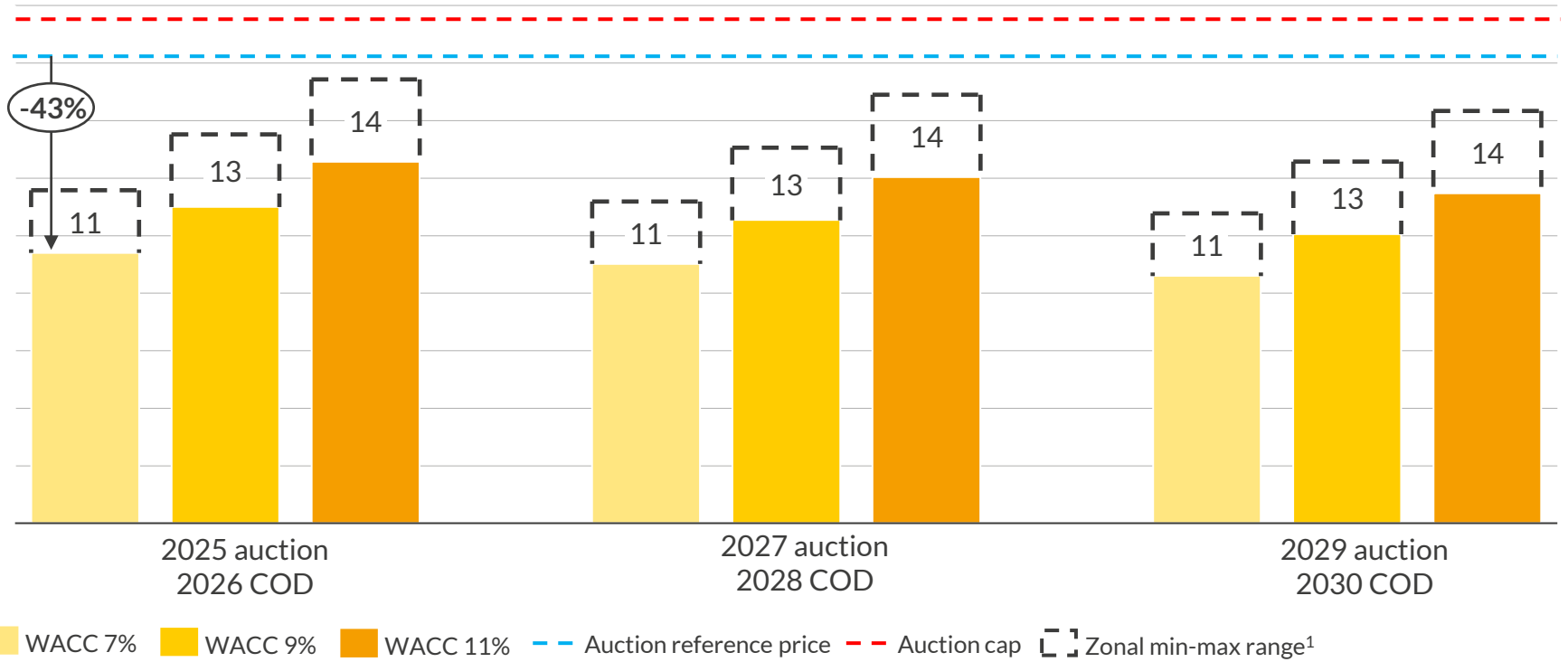
- Point A : **minimum** target volume. Bids up to **Upper Auction Price**
- Point B : **target** volume, paid up to to the **Auction Reference Price**
- Point C : **maximum** target volume. Bids up to **Lower Auction Price**

1) Environmental assessment; 2) Zonal coefficients to be published within 60 day of decree; 3) FERX assets > 1MW to have mandatory MSD participation; 4) Assets with capacity > 1MW; 5) Prices valid for 2024 auctions, to be adjusted for inflation in each subsequent auction year; 6) Commercial Operation Date. Penalties applied in case of delays: 0.2% reduction on awarded price per month for first 9 months, 0.5% for following 6 months. > 6-month delay incurs automatic expulsion from scheme.

Sources: Aurora Energy Research, MASE

FERX reference price is above the minimum required level for solar even in the North, which requires 11+EUR/MWh more than South

Auction minimum bids for solar tracking, by auction year and WACC
€/MWh (real 2023)



Assumptions

Auction reference price €/MWh (real 2023)	Construction period/ Lifetime Years	Subsidy duration Years	CAPEX[2] k€/MW	OPEX[3] k€/MW	Inflation coverage[3,4] %
82.5	1 / 30	20	802	18	11%

1) Max bids correspond to assets located in price zone North, while minimum bids to assets located in Sicily; 2) For COD 2026; 3) Average over the asset's lifetime; 4) During the 20 years of subsidy, the remuneration is *partially* adjusted for inflation. The portion of inflation that is taken on is calculated as the ratio of OPEX and the maximum remuneration that the participant can bid.
Sources: Aurora Energy Research

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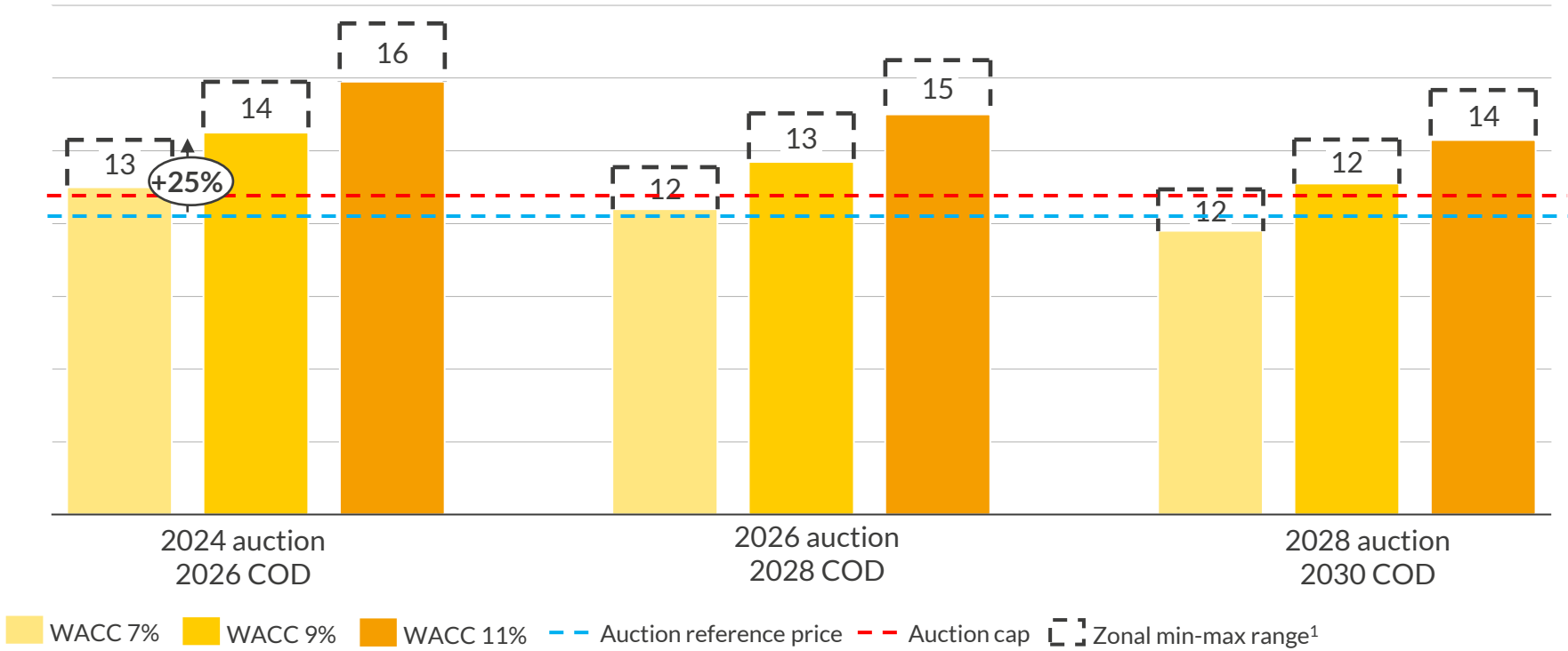
Zonal outlook for minimum bids

- Compared to solar asset in Southern zones, assets located in Norther zones with lower load factors would have to bid higher in order to achieve similar returns.
- Minimum bids vary across zones by 11 to 14 €/MWh, depending on the level of WACC assumed, with assets in zone North presenting the highest bids.
- However, even taking into account the zonal variation of bids, the reference price of 85 €/MWh nominal (i.e., 82.5 €/MWh real 2023) remains above minimum bids even assuming an 11% WACC.

Wind plants require bids higher than FERX reference prices with the possible exception of South, with zonal deltas up 12+EUR/MWh

Auction minimum bids for onshore wind, by auction year and WACC
€/MWh (real 2023)



Assumptions

Auction reference price €/MWh (real 2023)	Construction period/ Lifetime Years	Subsidy duration Years	CAPEX[2] k€/MW	OPEX[3] k€/MW	Inflation coverage[3,4] %
82.5	2 / 27	20	1,598	47	27%

1) Max bids correspond to assets located in price zone Sicily, while minimum bids to assets located in South; 2) For COD 2026; 3) Average over the asset's lifetime; 4) During the 20 years of subsidy, the remuneration is *partially* adjusted for inflation. The portion of inflation that is taken on is calculated as the ratio of OPEX and the maximum remuneration that the participant can bid.
Sources: Aurora Energy Research

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Zonal outlook for minimum bids

- Compared to wind assets in zone South, assets located in zones with lower load factors would have to bid higher in order to achieve similar returns.
- Minimum bids vary across zones by 13 to 16 €/MWh in initial auctions, depending on the level of WACC assumed
- Zonal deviations are significant in all auctions and the cap is set at overall too low of a level: in a 2028 FERX auction and with a 7% WACC, assets in zone South can barely bid below the reference price while everywhere else would still require a minimum bid above the auction cap.

The localisation of the asset has an important impact on PPA's contract since the asset owner becomes exposed to a fee for the usage of cross-zonal capacity

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- The Italian power market zonal design exposes demand and supply to different price levels.
- Producers and consumers do not face the same price in the wholesale market:
  - **Consumers pay the "*Prezzo Unico Nazionale*" (PUN)**, calculated as the demand weighted average of prevailing prices of the different zones
  - **Producers receive the "Zonal Prices"** as they result from the hourly auction
- In order to uphold the principle of asymmetric pricing even in bilateral contracts outside of the wholesale market, **operators signing a PPAs pay** (receive if negative) to the market operator GME for each hour a **transmission capacity fee («*Corrispettivo per la Capacità di Trasporto*» - CCT)** on the contracted generation, equal to the difference between the average national price (PUN) and the zonal price.

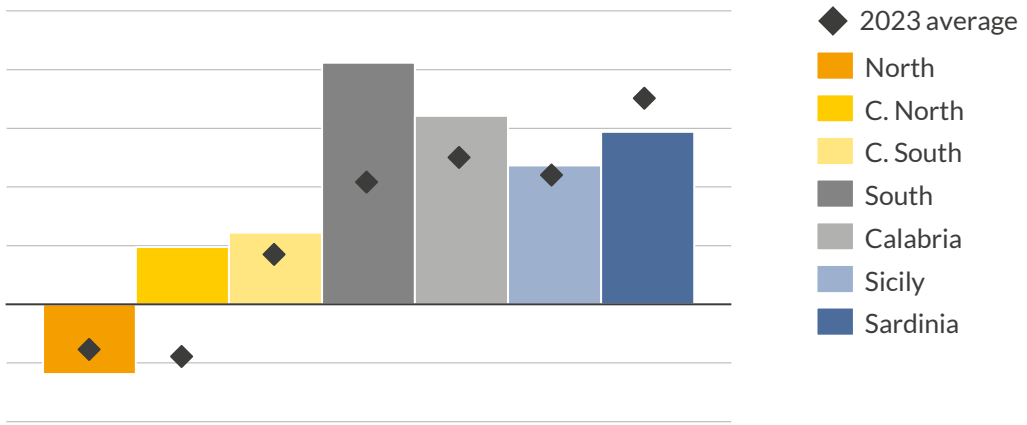
- Using historical data, we have calculated the 2023 yearly average CCT fee for MWh for solar PV[1]
- Using Aurora Central forecasts[2], we computed the expected yearly average CCT fees for solar PV between 2025 and 2035, finding that larger availability of RES and higher electricity outflows cause CCT fees to increase in absolute terms above the average 2023 levels in most zones

For more information on how to evaluate locational risk in Italy for renewables, reach out to **Foteini Kakavia, Commercial Associate**

foteini.kakavia@auroraer.com

Average CCT fees for Solar PV per MWh produced

EUR/MWh, real 2023

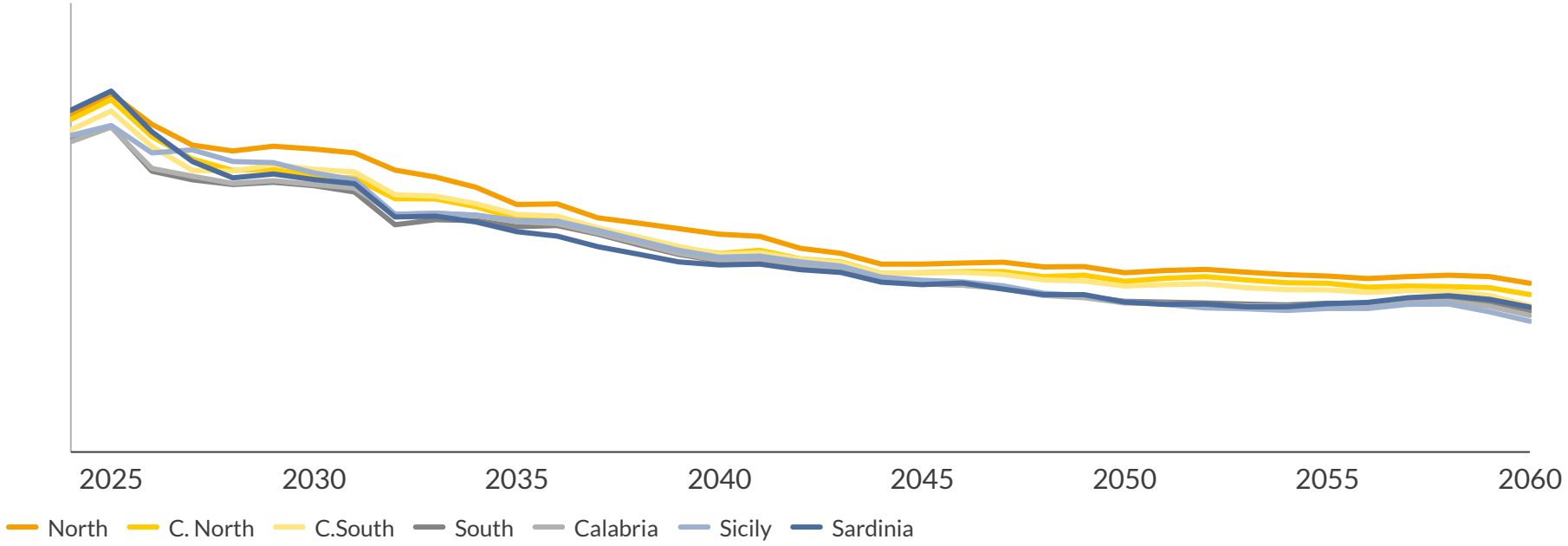


1)) CCT yearly average values are obtained using data from January to December 2023 and assuming the generation profile of new built solar PV tracker (average load factor of 21% across the seven Italian zones); 2) CCT yearly average values are obtained using Aurora Central scenario forecasts (April 2024) and assuming the generation profile of the previous note.

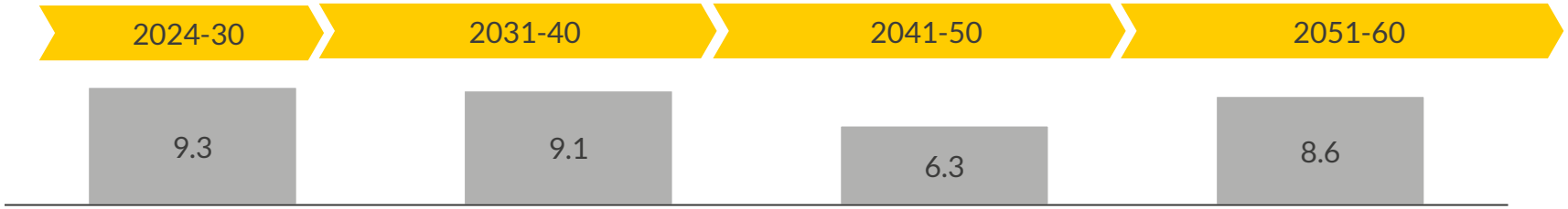
Source: Aurora Energy Research, GME

Divergence of solar capture prices across zones remains stable at ~9 €/MWh, with an inflection in the 2040s as buildout decelerates

Solar PV capture prices[1]
€/MWh (real 2023)



Average zonal spread of solar PV capture prices[2]
€/MWh (real 2023)



1) Solar PV capture prices are uncurtailed generation-weighted averages of tracking and fixed solar PV; 2) Average, over the decades, of the difference between the highest zonal capture price and the lowest zonal capture prices.

Sources: Aurora Energy Research

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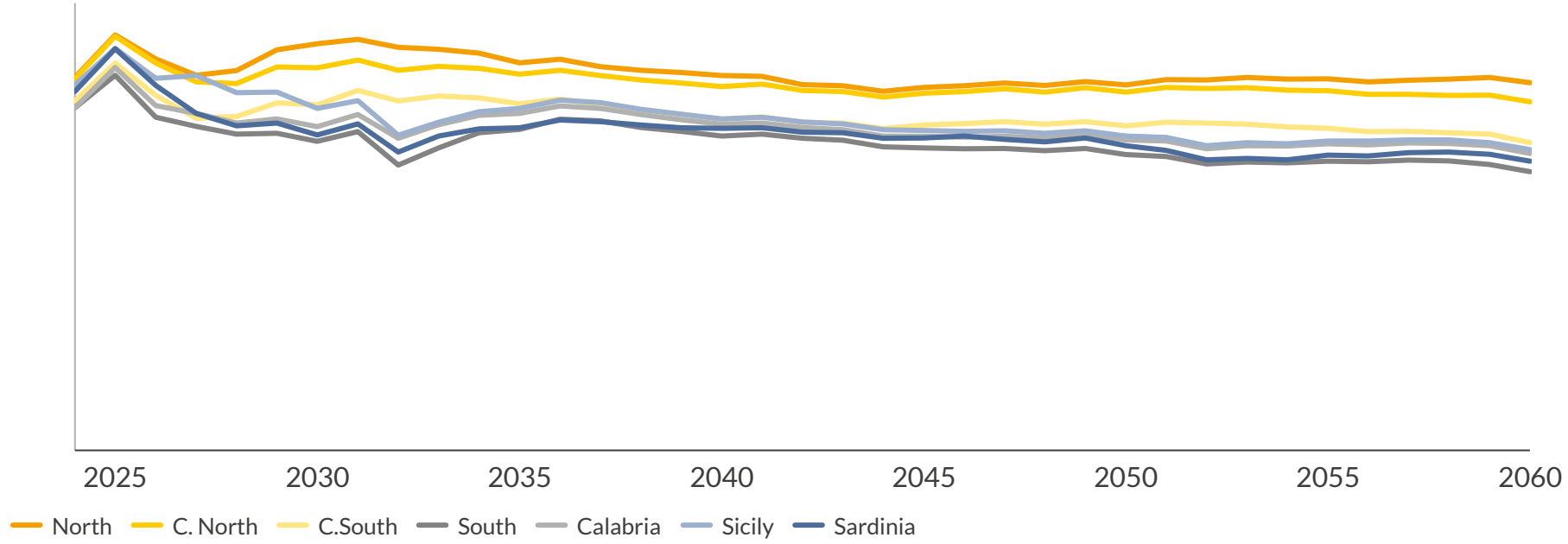
Outlook for solar PV capture prices

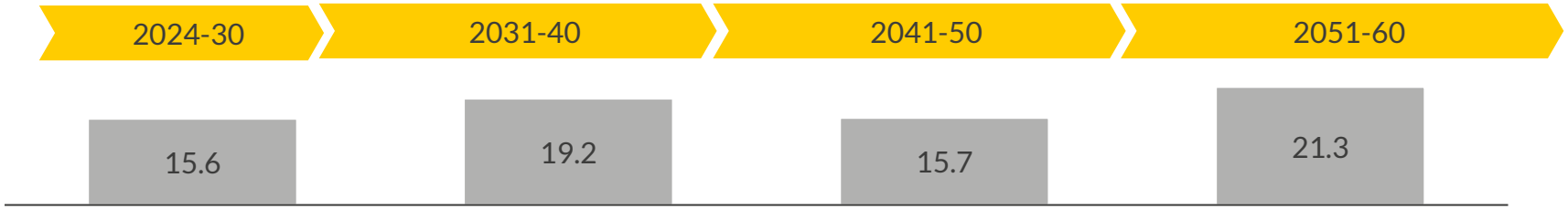
- Solar PV capture prices decrease across zones throughout the forecast, as more capacity enters the system.
- Zonal differences are evident: while Southern zones experience higher capture price cannibalisation, in the North prices are less cannibalized due to higher power demand and lower load factors.
- However, zonal divergence of PV capture prices remains mostly stable at ~9€/MWh, as solar build-out in Southern zones is offset by the increased battery penetration and the reinforcement of the grid capacity from South to North.
- Zonal capture price convergence is strongest in the 2040s, when solar build-out slows down in Southern zones.

In the 2030s, zonal capture price spreads for onshore wind reach 19 €/MWh, due to offshore wind plants coming online in Southern Italy

Onshore wind capture prices[1]
€/MWh (real 2023)



Average zonal spread of onshore wind capture prices[1]
€/MWh (real 2023)



1) Average, over the decades, of the difference between the highest zonal capture price and the lowest zonal capture prices.

Sources: Aurora Energy Research

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Outlook for onshore wind capture prices

- Capture prices are the lowest in South and Sardinia throughout the forecast, as access to higher wind speeds leads to increased levels of buildout.
- Capture prices in the North and C. North are the highest, as the restricted availability of land for onshore wind development limits cannibalisation.
- In the 2030s, the divergence of zonal capture prices increases to 19€/MWh, as prices in South and in the islands experience higher cannibalisation due to floating offshore wind capacity coming online in these zones.
- As the onshore wind subsidised fleet retires in the 2040s and is only partially replaced by new assets, zonal price spreads decrease, before rising again in the 2050s.

Massive renewable penetration in small market zones raises concerns over their market and grid integration, leading to two types of curtailment risk

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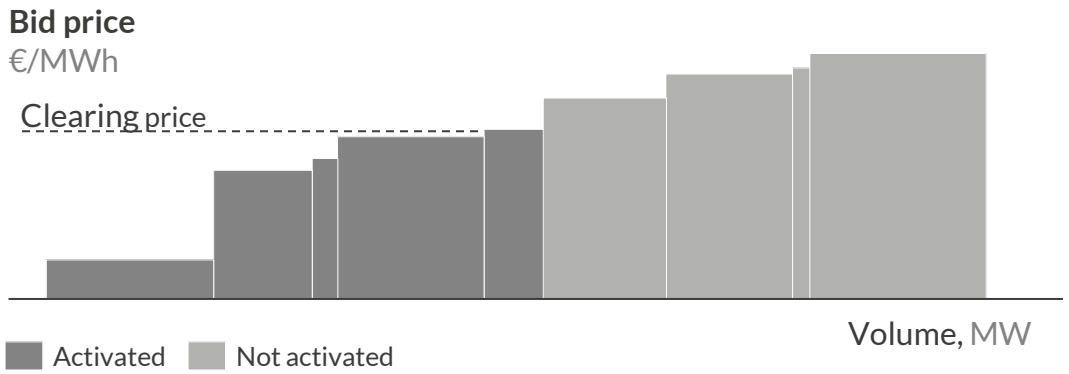
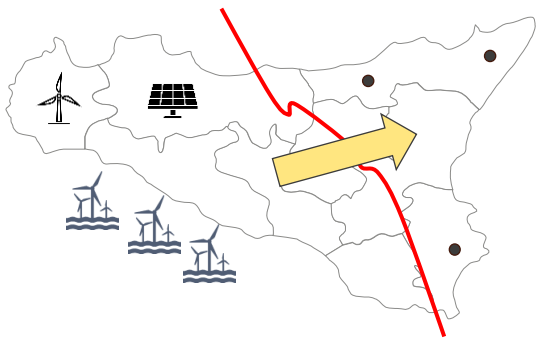
Economic Curtailment

- Economic curtailment occurs when the cost of generating electricity exceeds the market price.
- The price at which a generator will curtail depends on its variable costs and the structure of its revenues:
  - Generators with higher variable costs will curtail first;
  - Generators subsidised through a fixed Feed-in-Tariff scheme will choose to generate even when prices are below their variable costs.

Grid Curtailment

- To ensure the safe operation of the power system, the TSO can curtail renewable production.
- Grid curtailment occurs when:
  - Grid capacity is insufficient to transport power from generation to demand centres;
  - Conventional plants are required to run for the regulation of the system;
  - Intra-province bottlenecks or lack of DSO/TSO infrastructure.
- Grid curtailment is most prevalent in times of high renewable production and low demand.

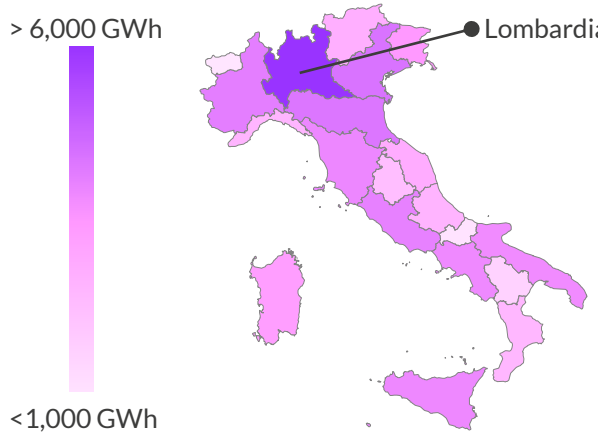




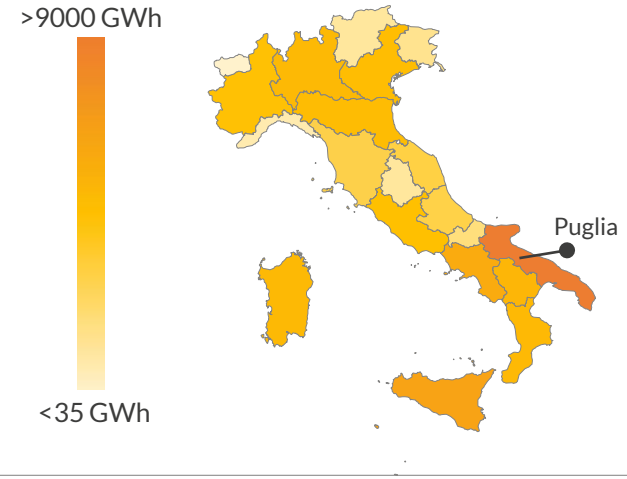
Source: Aurora Energy Research

Fundamental driver of grid curtailment risk is the local distribution of demand and inflexible generation

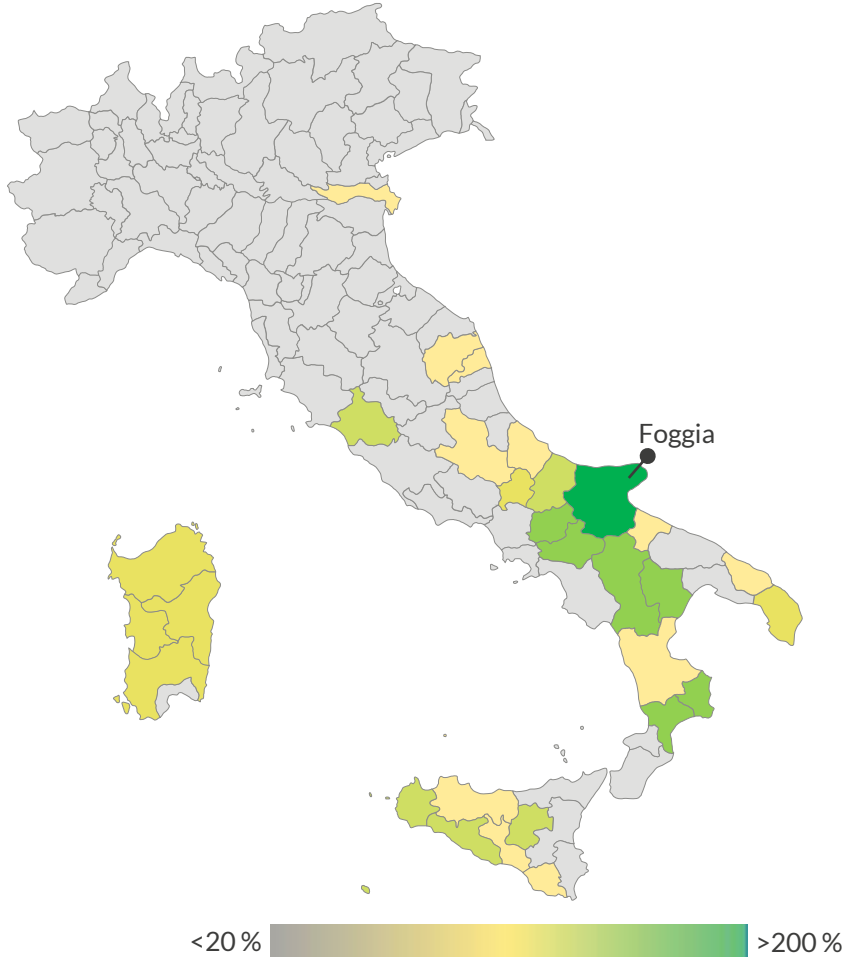
Consumption (2022)



Solar and Wind Generation (2022)



Solar and Wind generation / Consumption (2022)



Source: Aurora Energy Research, Terna

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Key facts:

- Due to favourable conditions, onshore and solar generation in South represent 42% of 2022 Italian generation, with Puglia alone contributing 20%.
- The biggest exporters of solar and wind energy (South, Sicily and Sardinia) are located far from major national demand centers, putting additional strain on the grid.
- The province of Foggia is the primary green electricity exporter in Italy, with a production that is more than 2.5 times its consumption.
- In 2022, zone North accounted for 56% of the national consumption; thanks to the high demand and the low renewable penetration Northern regions are generally expected to be less exposed to curtailment risk.

Our approach for estimating grid curtailment is based on the calculation of hourly net positions for each province within a zone

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A Net positions

Calculation of net position for each individual province

- The hourly net position is defined as the **difference between generation and demand**.
- We **exclude the thermal flexible generation** from the net position to consider the potential downward regulation in case of overgeneration.
- **We apply province-level splitting coefficients to the zonal generation for each technology and zonal power demand** from Aurora Central.
- The **splitting coefficients** are defined with different approaches for the various elements of generation and demand, blending historical data as well as forward-looking expectations.

B Export transfer capacity

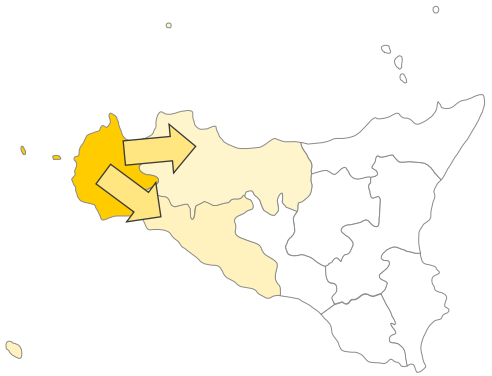
Definition of export capacity for each individual province

- For each province, the transfer capacity with interconnected provinces is **defined according to Terna's latest grid development plan**[1].
- Transfer capacity for each province is then weighted by its **likelihood of being available in export**, as neighbouring provinces compete for the use of the same capacity.

C Grid curtailment

Estimation of potential grid curtailment by province

- Grid curtailment is estimated **by comparing hourly net positions with available export capacity** at province level.



1) Only on the TSO's 400-220 kV grid.

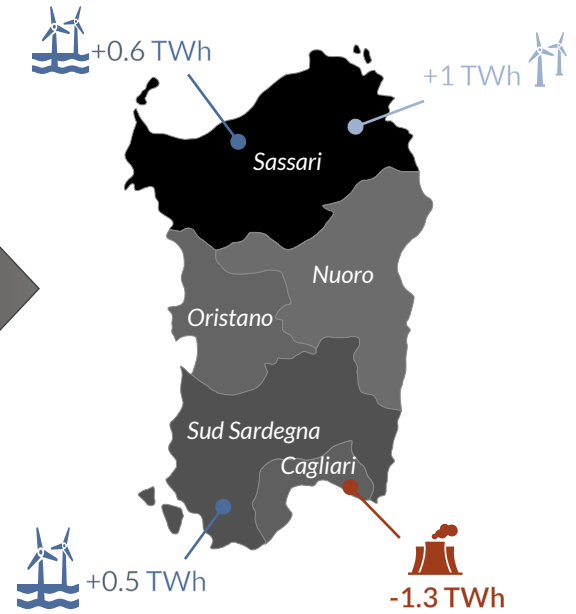
Sources: Aurora Energy Research

Renewable capacity concentration in some provinces, especially wind, is the main driver behind the evolution of net positions

The hourly net position, defined as *total generation*[1] *– demand*, is computed for each province separately, identifying each province as a net exporter or net importer.

Yearly provincial net positions in 2022 (historic data)
TWh/year

Yearly provincial net positions in 2030
TWh/year



1) The total generation includes only the CHP generation of the total thermal one, to account for the potential downward regulation of non-must run thermal plants.

Sources: Aurora Energy Research, Terna.

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Provincial net position evolution

- By 2030, all provinces in Sardinia become net exporters, thanks to the contribution of renewable generation.
- The yearly net positions in Sassari and Sud Sardegna increase by 2.3TWh and 1.6TWh, respectively, thanks to wind generation, especially offshore.
- Cagliari sees the net position decrease as the generation from the CHP plant "*Sarlux*" drops from 4.5TWh in 2022 to 3.2TWh in 2030, partially balanced by the increase in renewable generation.

Understanding grid topology is essential to determine the potential export capacity of each province

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Existing 380kV & 220kV lines – Italy

The low meshed HV grid in South results in voltage regulation and stability issues

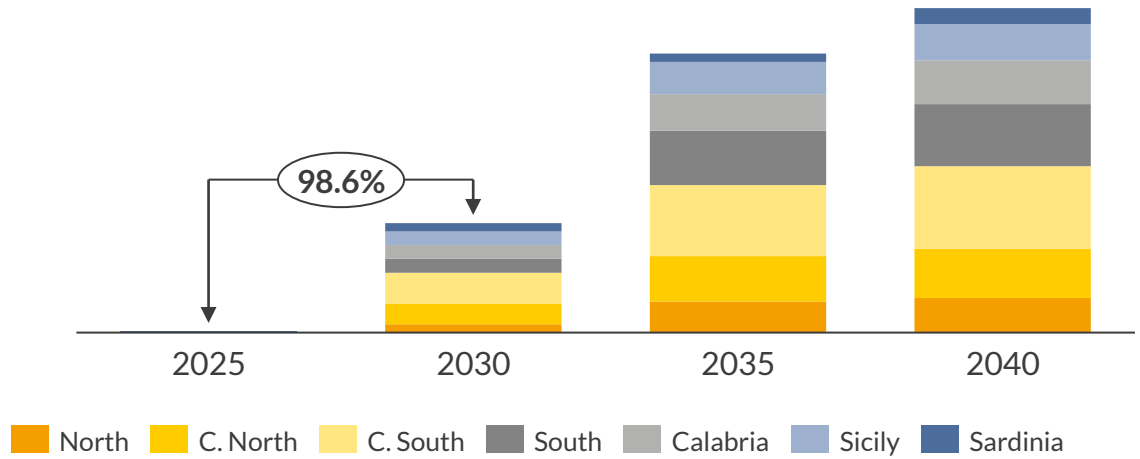
The only 380kV line[2] in Sicily connects the east side of the island, while most of the remaining provinces are interconnected through 220kV lines

380kV line
220kV line
380kV substation
220kV substation
Thermal Plant

Terna's grid developments

- In the 2023 development plan, Terna introduced the new "Hypergrid" project to reinforce internal transfer capacity and increase NTCs from Southern to Northern Italy.
- The Tyrrhenian Link connecting the two islands to the mainland is expected by 2028.

Increase in cross-zonal transfer capacity relative to 2023 levels[1]
GW



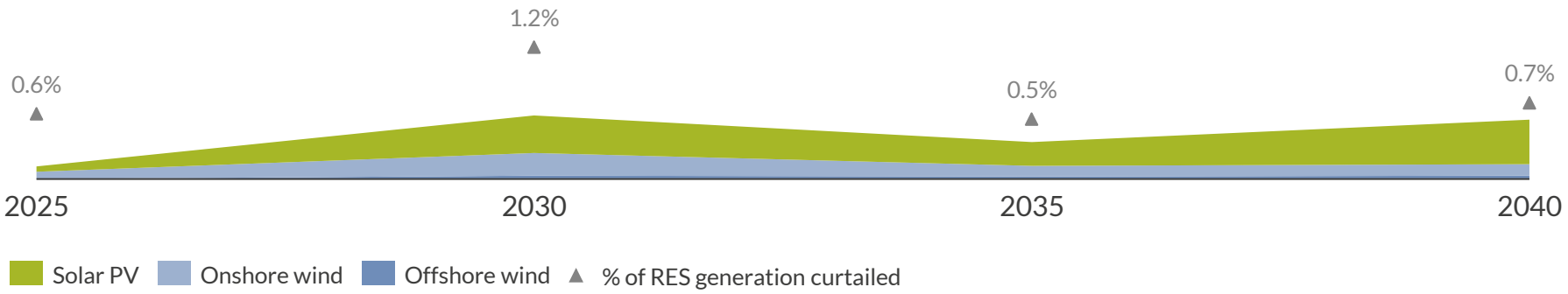
1) 2023 Terna's development plan.

Source: Aurora Energy Research, Terna

In Aurora Central, economic curtailment grows with RES penetration but tends to flatten out with battery build-out in the medium term

Total economic curtailment by technology (Aurora Central)[1]

TWh

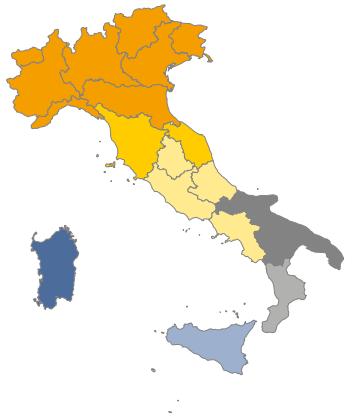


Top three zones for economic curtailment (Aurora Central)

Center South

South

Sicily



Outlook for economic curtailment

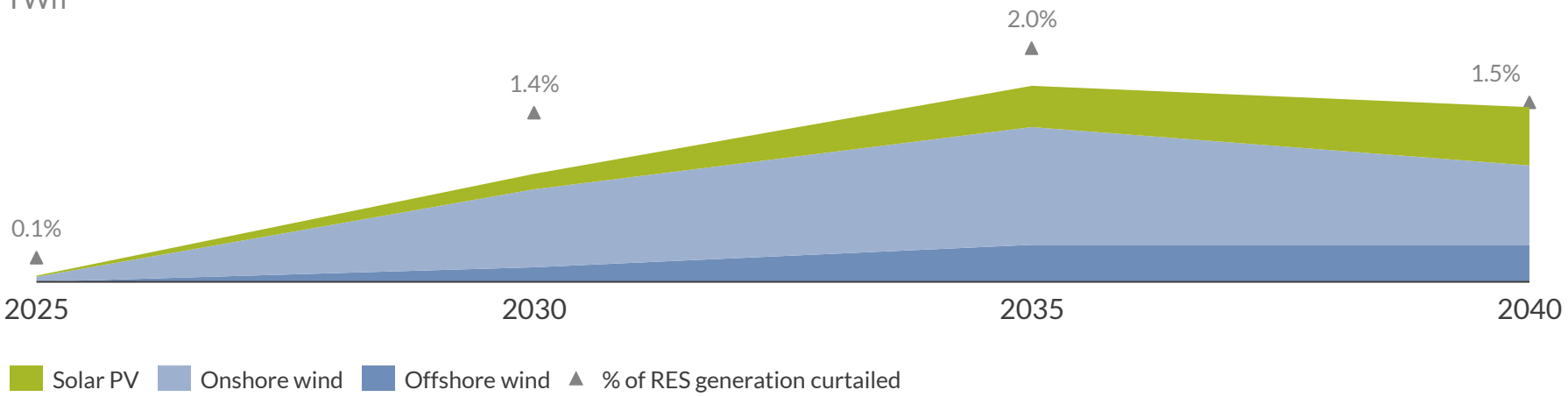
- Economic curtailment is a result of Aurora's fundamental modelling, occurring when market prices drop to zero or below zero.
- After a spike around 2030 due to offshore wind capacity coming online, economic curtailment flattens thanks to increased battery build-out and grid enhancements during the 2030s.
- Solar PV sees the largest share of curtailed volumes, as it becomes the predominant renewable technology in Italy.
- **Hosting most of the new wind capacity installed, in addition to solar, zone South shows high economic curtailment volumes, together with Sicily and C.South.**

1) Excluding hydro plants.

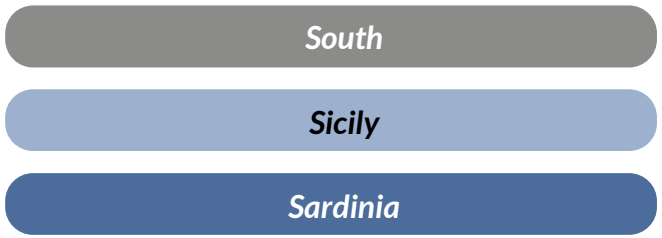
Sources: Aurora Energy Research

Grid curtailment volumes grow until 2035, driven by wind generation, and stabilize thereafter thanks to grid reinforcements

Total grid curtailment by technology (Aurora Central)[1]



Top three zones for grid curtailment (Aurora Central)



1) The analysis excludes zone North and provinces not connected to the high voltage grid.

Sources: Aurora Energy Research

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Outlook for grid curtailment

- Grid curtailment is estimated at the province level and occurs when the hourly net position exceeds the available export capacity of the province.
- Grid curtailment is estimated to steadily grow until 2035, driven mainly by the increase in wind generation. Afterwards, thanks to the grid improvements planned by the TSO and to the slowdown of onshore wind build-out, grid curtailment volumes slightly decrease.
- **In our analysis, zone South, Sardinia and Sicily are the most affected by overgeneration issues.**
- **Province breakdown shows strong heterogeneity of grid curtailment even within a price zone.**

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- **Utilisation rates** of key thermal technologies along different efficiencies
- **Capacity market clearing price** forecast and entries delivered by the mechanism by technology
- **EU-ETS carbon price forecasts**
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Three Group Meeting roundtable events with key market participants such as developers, investors, financiers, utilities, grid operators, government

Analyst Support

Biannual workshops and support from our bank of analysts, including native speakers and on-the-ground experts

Italian Renewables Grid Curtailment Add-on Service

Find out all the drivers and granular forecast for grid curtailment in Italy

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Italian Renewables Grid Curtailment Add-on Service

Report

- Overview of the market framework and policy developments
- Historical assessment of grid curtailment in Italy
- Aurora's grid curtailment forecast outlook for the Italian power market by province

Data

- The following deliverables will be given for the Central scenario up to 2060:
  - Demand per province
  - Capacity stack by province
  - Economic and grid curtailment in Italy
  - Grid curtailment by province
  - Post-curtailment renewables capture prices by province

For more information on the Italian power market, please contact:

Foteini Kakavia, Commercial Associate

foteini.kakavia@auroraer.com


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