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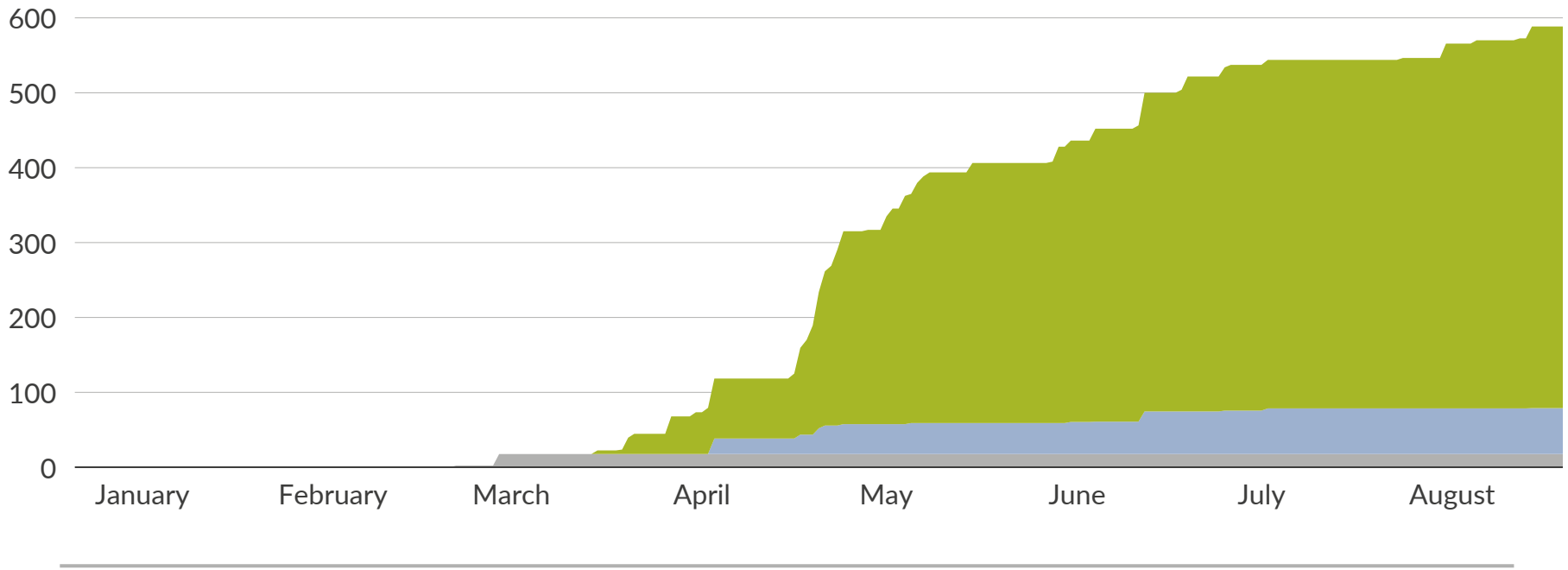
Making the Cut - renewable curtailment risks in the Polish power system

September 2024

Renewable curtailment has reached almost 600 GWh in Poland in 2024, with utility-scale solar being the most affected

Cumulative curtailment, H1 2024
GWh



Share of monthly generation curtailed
% of GWh generated

	January	February	March	April	May	June	July	August
Utility-scale solar[1]	0	4	15	16	6	2	4
Onshore	0	0	1	1	1	0	0

PV Wind Uncategorized[2]

1) Based on capacity and load-factor based share of total monthly solar generation. 2) PSE reporting does not allow for a split of curtailment reported on 3-10 March 2024. Part of this can be attributed to PV curtailment, albeit the exact split could not be determined.
Sources: Aurora Energy Research, PSE, ENTSO-E, Forum Energii

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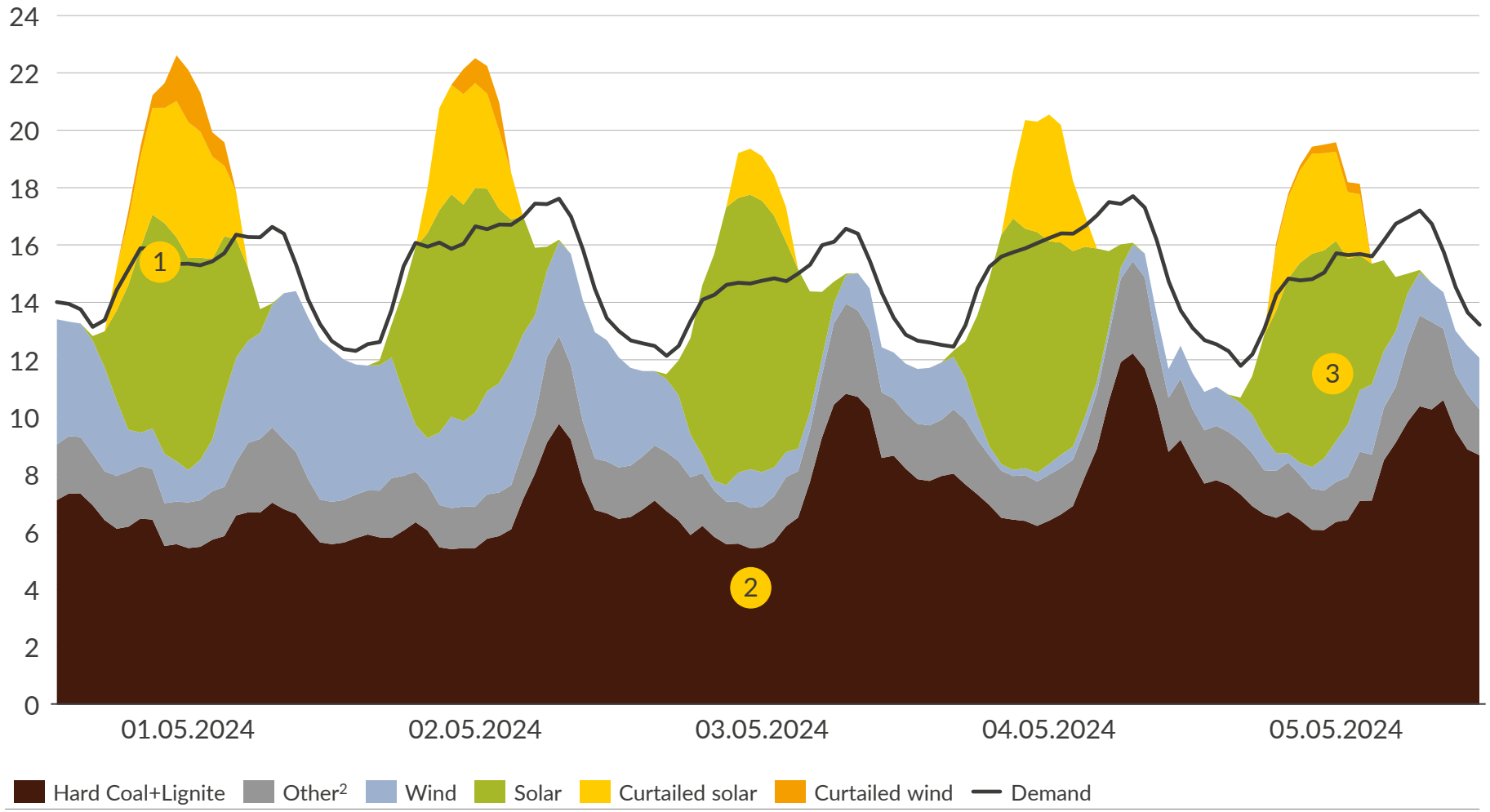
- Renewable curtailment in 2024 has reached unprecedent levels, with 87% of the curtailment coming from solar.
- Onshore wind has been less affected by curtailment than solar as its production pattern is less concentrated within the day and thereby less impacted by system oversupply.
- On the other hand, solar curtailment has disproportionately affected utility-scale plants as prosumer generation has not been curtailed.
- In May, the curtailment of utility-scale solar generation reached 16%, while onshore wind generation experienced 1% curtailment.

Renewable curtailment occurred in Poland because high renewable generation could not be absorbed by an inflexible power system

Hourly demand, generation, and curtailment, 1-5 May 2024
GWh



1) Transmission system operator (TSO). 2) Other includes gas, biomass, hydro, and pumped storage.

Sources: Aurora Energy Research, PSE, ENTSO-E

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1. Renewables' curtailment occurs due to system imbalances during periods of oversupply and low demand.
2. Inflexible coal generation is a main driver of curtailment, as coal plants are incentivized to run even during periods of high RES generation to keep ramping capacity available for evening demand peaks. The ramping flexibility of coal plants is limited by long start-up times.
3. Inflexible RES generation drives oversupply, as a significant share of the renewable capacity in Poland is remunerated through subsidy schemes and does not respond to market signals.

As starting up a coal plant, even from a hot state, takes much longer than ramping up when operational, many units need to stay on

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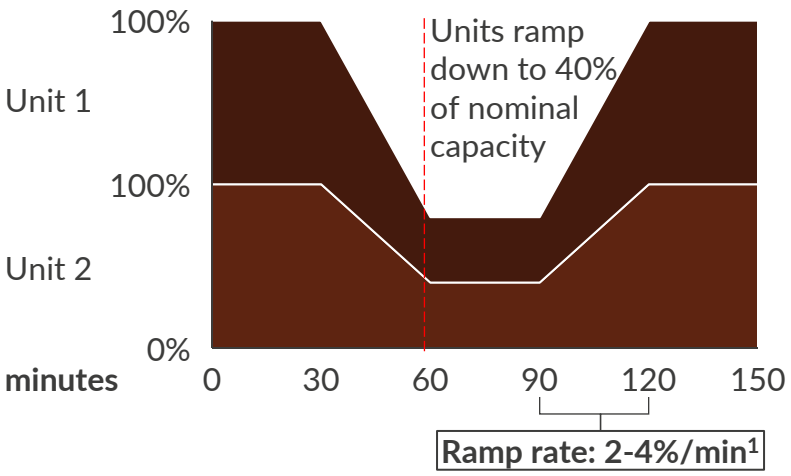
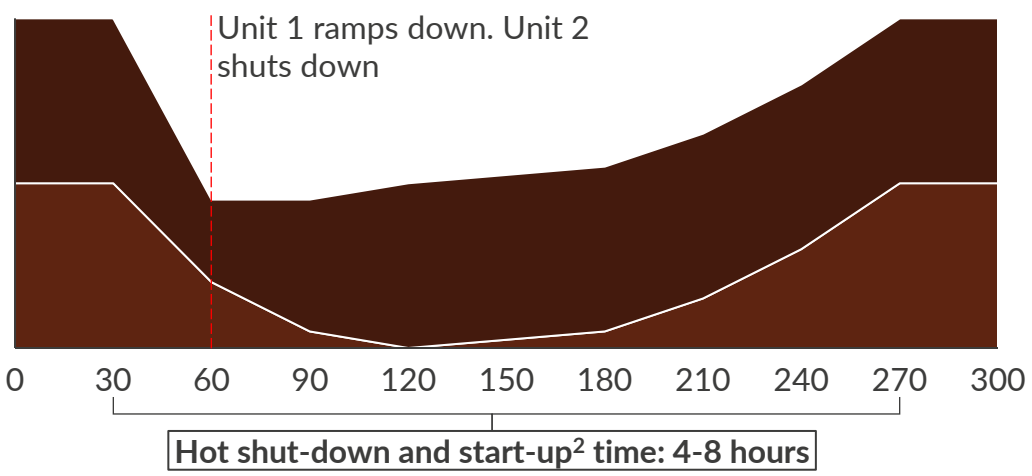
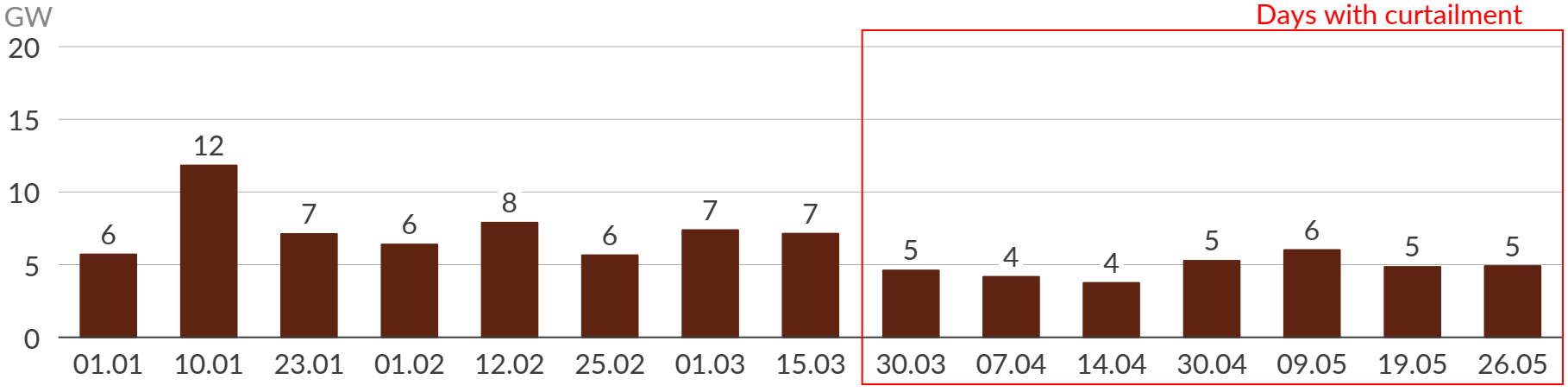
Exemplary hard coal generation, units ramping down
% of nominal unit capacity



Exemplary hard coal generation, one of two units shutting down
% of nominal unit capacity



Daily minimum operational capacity in 2024



- Coal assets have significant deviations in the time it takes for the asset to reach its nominal capacity if they are starting from a minimum stable load compared to a shut off state.
- Standard operating hard coal units have ramping rates between 1.5-4% of nominal capacity/minute and minimum stable loads between 25-40%, meaning they can ramp up to full capacity within 1 hour.
- However, standard hard coal units have a shut down and start up time from a hot start (off for less than 8 hours) between 3-8 hours.
- Furthermore, shut down and start up are costly procedures for coal plants both the efficiency of the asset falls and the degradation increases.

1) A 2-4% ramp rate means an asset can ramp from 40% of nominal capacity to the nominal capacity within 30 minutes. 2) A hot start-up occurs if the unit has been off for less than 8 hours. 3) Lignite units are less flexible, with average ramp rates at 1-2% of nominal capacity/minute and hot start-up times of 4-6 hours.
Sources: Aurora Energy Research, Agora Energiewende, PSE

Revenue risks for renewables are dependent on the type of asset and on their right to receive compensation for non-market redispatch

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When do you get curtailed?

Renewables get curtailed as a "**last resort**" by the TSO in order to balance the power system, considering the necessary regulatory levels of ramping and operational reserve capacities.

What determines RES plant curtailment?

The TSO curtails generating units connected to the coordinated 110 kV network and the transmission network in **proportion to their installed capacity**. Behind-the-meter assets are excluded until all larger assets are curtailed.

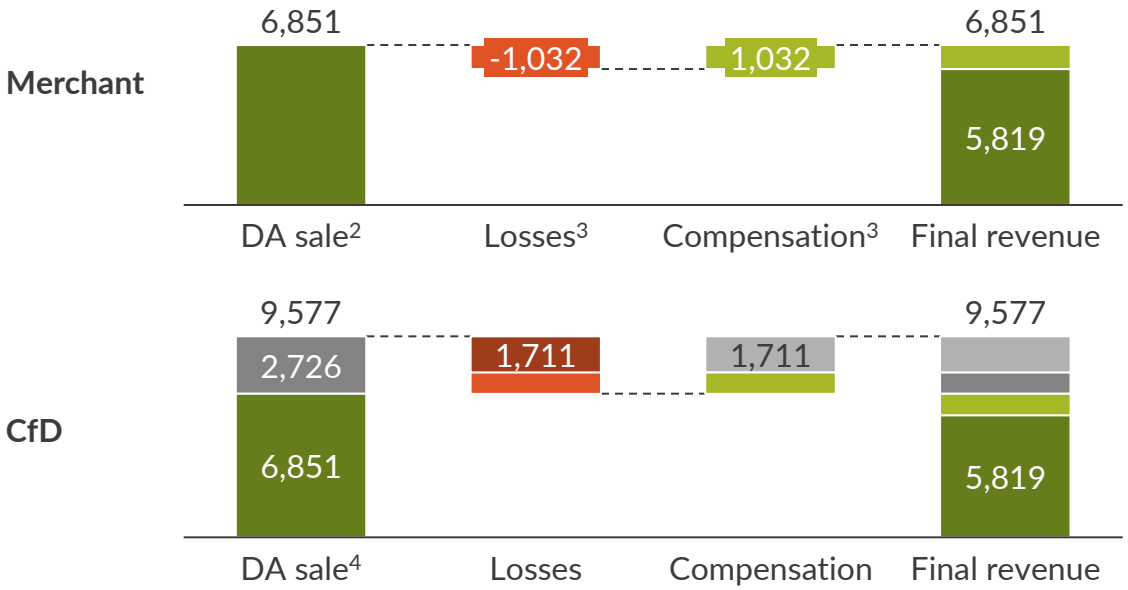
Compensation

If non-market curtailment is applied, **financial compensation** must be provided by the TSO. The compensation is based on both imbalance costs faced by assets due to the curtailment and lost CfD revenues. The only exceptions to compensation are assets with an **exclusion clause** in their **grid connection agreement.**

What will change?

From 2026, the balancing market settlement will automatically correct for imbalance created by non-market redispatch, thereby allowing assets to **avoid imbalance costs from non-market redispatch**.

Exemplary utility-scale solar revenue during curtailment hours in May 2024
zł/MW(nominal)



- Because curtailment occurs after the closure of the DA market but before the BM settlement, assets are exposed to imbalance prices for the curtailed capacity. To offset this, compensation is awarded based on the imbalance price and, from 2026, redispatch will be accounted for in BM settlement.
- However, CfD assets also lose possible CfD revenues as they have less volume to sell. Only assets that receive compensation will be protected.

Merchant revenue | Imbalance cost from curtailment | Merchant compensation
CfD revenue | Missed CfD revenue | CfD compensation

1) Includes curtailed volume as part of the generation. 2) day ahead revenues based on the fixing 1 price in curtailment hours and the estimated solar asset uncurtailed generation. 3) Losses and compensation based on curtailment periods with positive imbalance prices. 4) CfD revenues calculated for 100% of CfD volume at a strike price of 326 zł/MWh.

Sources: Aurora Energy Research, Art. 9c. - Obligations of system operators - Energy Law, Polish Photovoltaics Association curtailment report, PSE, ENTSO-E

The requirement for coal to provide ramping capability will remain high until sufficient gas capacities enter the system

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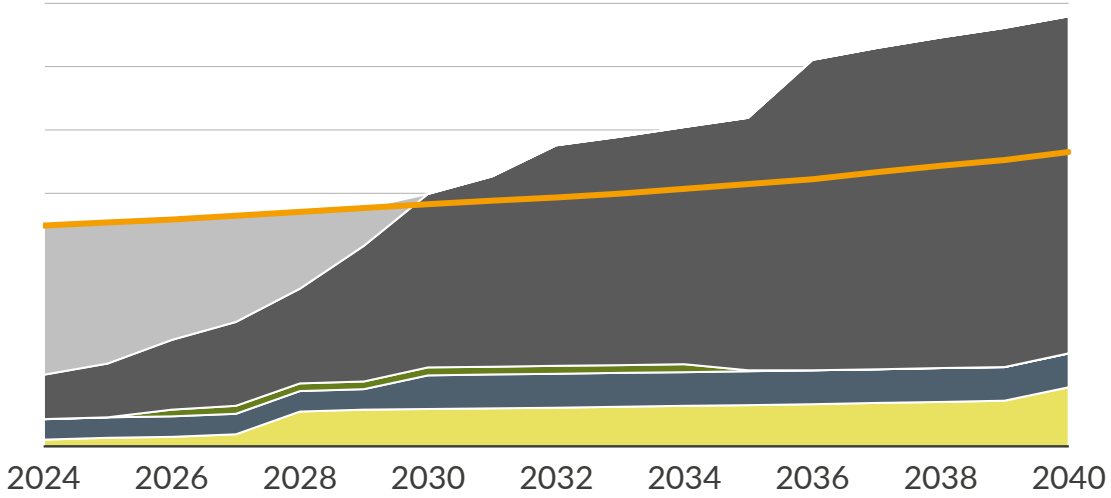
A large share of the residual demand in the Polish system…

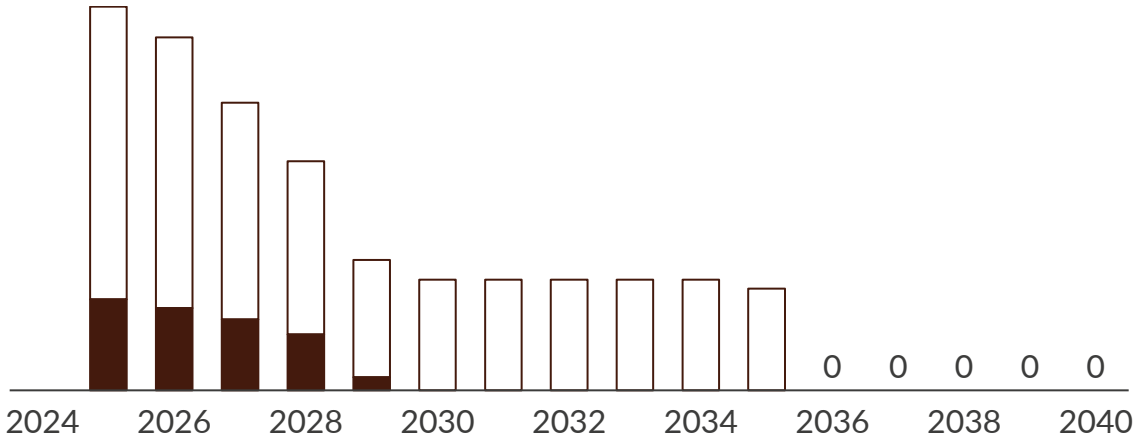
Maximum annual daily residual demand and flexible dispatchable capacities
GW



- The **residual demand** here refers to the amount of demand in the system that cannot be met by renewables and must-run CHPs. Therefore, dispatchable capacities are required run to cover the remaining demand.
- In Poland, the flexible dispatchable capacities grow as new gas and battery capacities enter the system, replacing coal and fully covering the residual demand by 2030.

… will need to be covered by decreasing coal capacities in the next years.

Available and minimum operational capacity
GW



- Currently, coal capacities must satisfy the ramping requirements of the system, leading to a significant portion of the fleet remaining operational, even in periods of oversupply.
- However, as more gas capacities become operational, the required coal ramping capacity decreases.
- By 2030, the ramping capacity in the system can be met by faster dispatchable units, meaning coal capacities will face competition.

Flexible gas capacity | Biomass | Pumped storage | Battery storage | Residual demand | Minimum running requirement | Available coal & lignite[1]

1) Excluding CHP units.

Sources: Aurora Energy Research

Economic curtailment will decrease as improvements in system flexibility mitigate further RES growth

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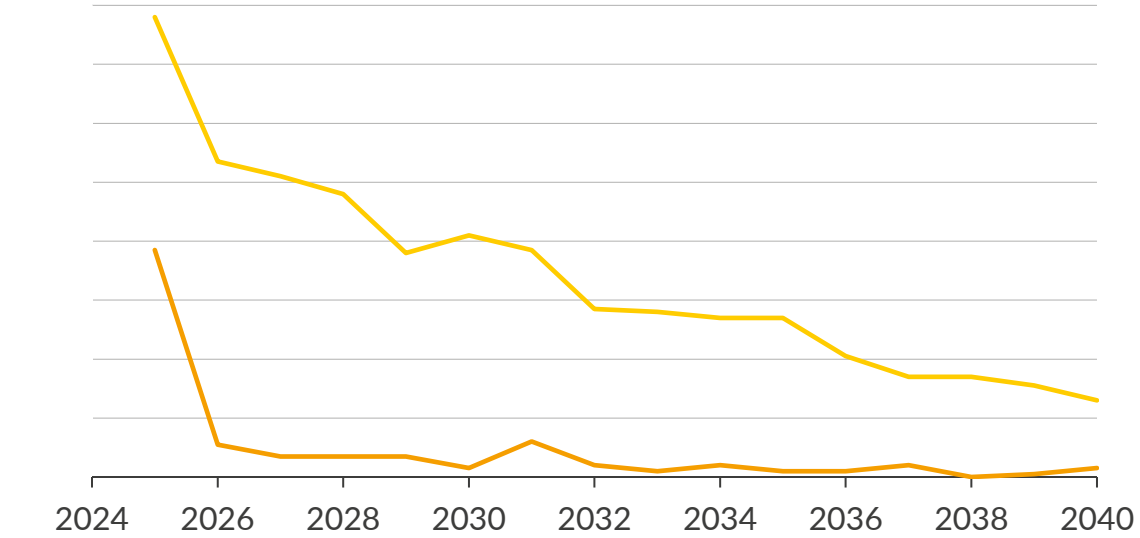
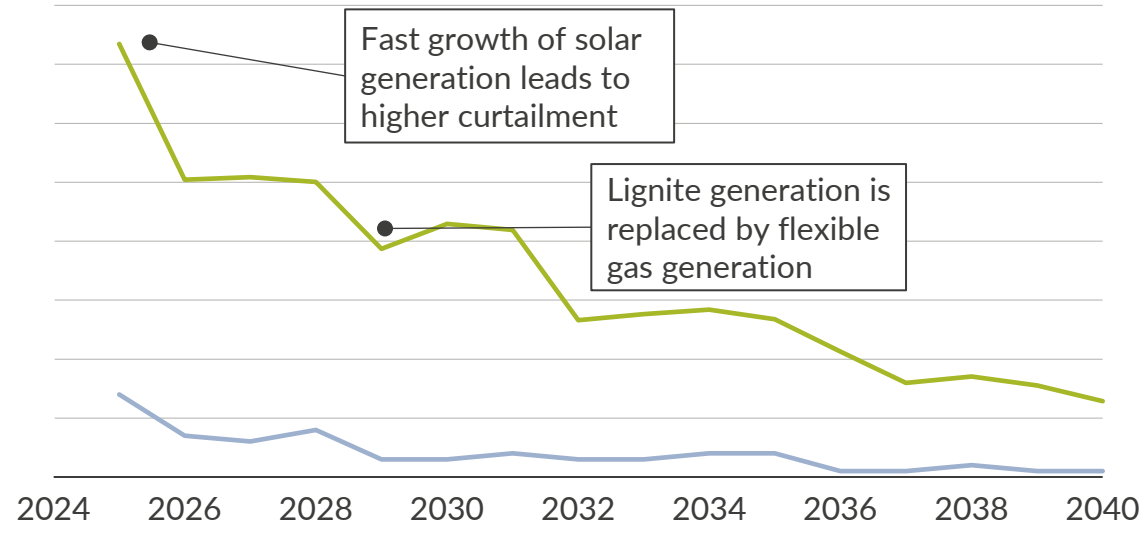
Total number of negative price hours
Hours per annum



- Our modelled number of negative price hours is highest in 2024.
- Higher RES and inflexible coal generation drives the high number of negative price hours in 2024, while new flexible capacities in the later 2020s reduce the number of negative price hours.
- Periods of 6+ consecutive negative price hours plummet in 2026 because they are dependent on imbalances in non-peak solar production periods.

Volume impact[1] for solar PV & onshore wind
%



- Negative wholesale prices lead to the economic curtailment of RES generation. Economic curtailment mainly affects solar PV, with a hig -volume impact in 2025 for a merchant asset.
- Solar generation has a higher volume impact than onshore wind, as solar generation is highly correlated. Onshore wind is less affected due to broader production profiles and more distributed generation than solar.

1) The volume impact assesses the share of generated electricity affected by the respective negative price rule for an asset (i.e., electricity generated in these negative price periods divided by total generation of the asset). 2) Historical values include data until July 2024. 3) Based on historical generation and curtailment volumes until Sept 2024 and then extrapolated for the remainder of the year.
Sources: Aurora Energy Research, PSE, ENTSO-E

Details and disclaimer

Publication
Making the Cut - renewable curtailment risks in the Polish power system

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17 September 2024

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