Powering the Energy Transition - Security of supply in Poland

March 2025

Public Webinar

Agenda

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While Poland's coal exit is approaching rapidly, insufficient dispatchable replacement capacities are entering the market

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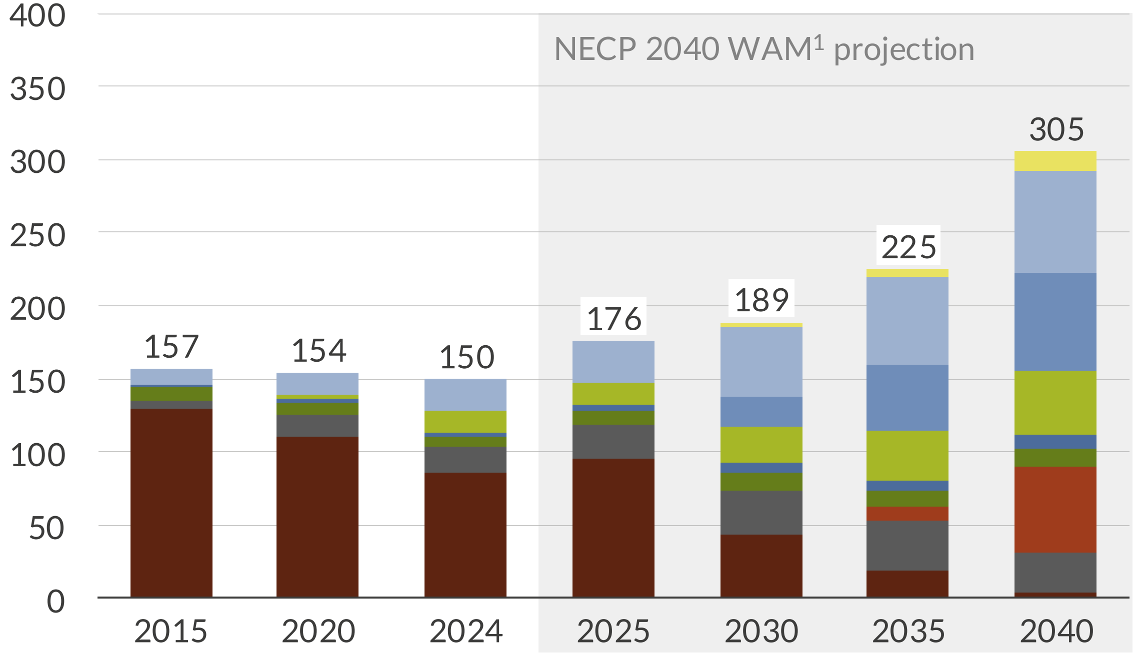
Generation

TWh



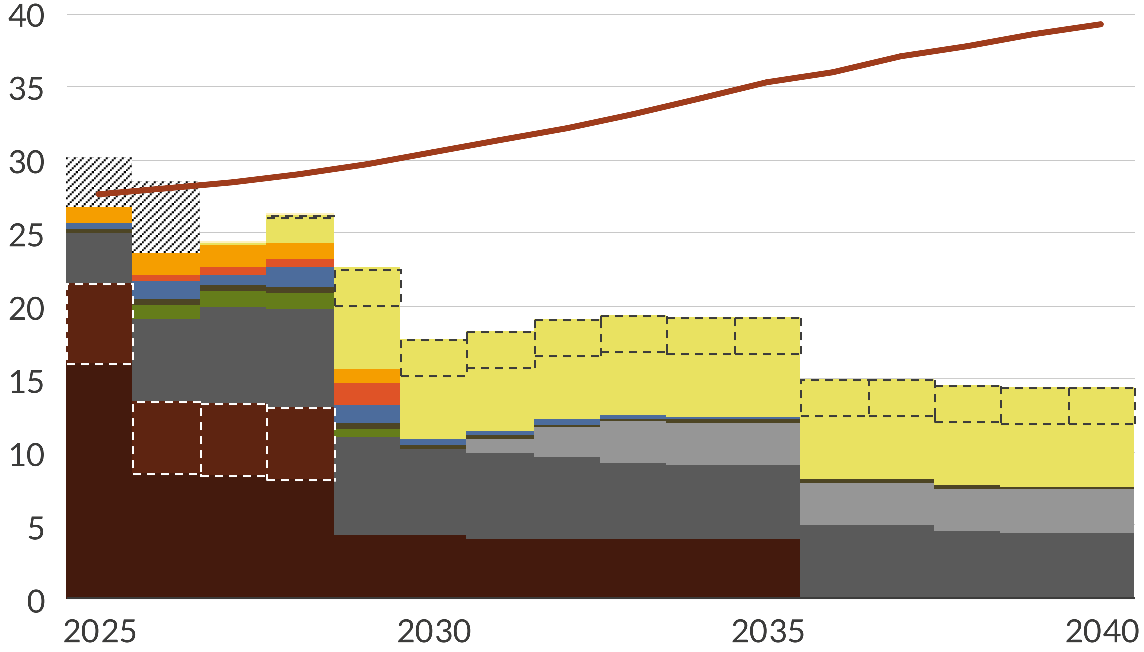
Low-carbon[2] share of demand

%

2015	2020	2024	2025	2030	2035	2040
22%	30%	52%	61%	80%	90%	98%

Currently contracted and expected dispatchable capacities and demand

GW



- Existing capacities are rapidly declining amidst the expected withdrawal of coal capacities. Capacity Market support for coal declines from 16GW in 2025 to just 4GW by 2029 and reach 0GW by 2036.
- At the same time, demand increases, with peak inflexible demand growing by 4GW between 2025 and 2030 and reaching 39GW by 2040.

Coal and lignite | Nuclear | Hydro | Offshore wind | Peak Inflexible Demand | Supplementary Auctions[3] | BESS | Foreign
Gas | Biomass/biogas | Solar | Onshore wind | Complementary auctions[4] | BESS (underated) | DSR | Assumed gas[5]

1) National Energy and Climate Plan, With Additional Measures scenario. 2) Peak inflexible demand is the component of demand that cannot be shifted by more than 12 hours. 3) Refers to announced volume of T-1 auctions for existing capacities, 4) Aukcje Uzupełniające - new system for capacities of last resort, including coal, announced for 2025, more information in Section II. 5) Announced gas projects without secured Capacity Market contracts.

Sources: Aurora Energy Research, ARE, Ministry of Climate and Environment

Three groups of technologies may constitute the backbone of the Polish dispatchable capacity in the transition period

	Security of supply			Affordability		Sustainability
	Availability	Flexibility of dispatch	Feasibility by 2030	Dispatch costs[1]	Support eligibility	Low carbon g/kWh[4]
BESS	◔	●	◕	N/A	◕	System dependent
OCGT/ CCGT	◕	◕	◑	◑	◕	490
Coal	◕	◔	◔	◕	◔	820
Nuclear[2]	◕	◑	○	◑	◑	12

- - Focus

1) Based on short-run marginal costs (SMRC), SMRC for batteries largely depends on generation from other power sources, therefore not shown on this slide. 2) Nuclear power is unlikely to be available in the focus period (2029-2035), therefore, it is considered out of scope for this study. 3) As per the European Green Deal targets.4) Median lifecycle emissions.

Source: Aurora Energy Research, IPCC

Poland struggles to square energy trilemma during transition.

- **Security of supply** - Poland needs to cover energy demand domestically. The growing share of intermittent power requires high availability and high flexibility components.
- **Affordability** - Poland aims to ensure that the cost of the energy transition is minimised.
- **Sustainability** - Poland is committed to the EU-level 55%[3] emissions reduction by 2030 and 90% by 2040.

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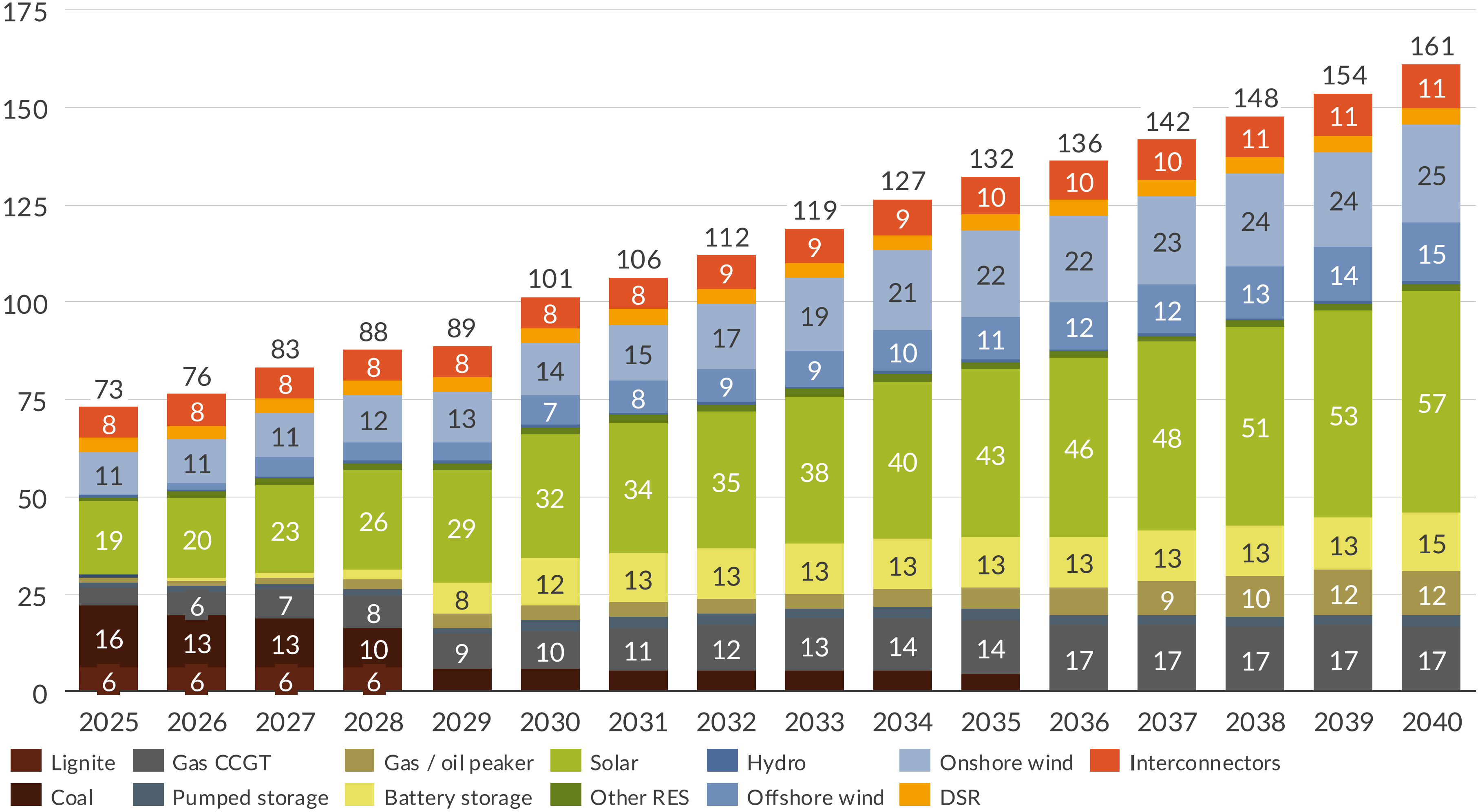
Considering the trajectory of the Polish system, we can expect 36% of dispatchable capacities to be BESS by 2030

Installed capacity in the Polish System[1]

GW



1) The capacity stack is a direct reflection of the above-mentioned capacity mechanisms, including Main Auctions, Additional Auctions, Supplementary Auctions and Extra Auctions. We also consider the new NFOSiGW scheme.

Source: Aurora Energy Research

Key drivers

1. Poland sees a sharp decline in coal capacities post-2028 as high emitters are banned from participation in CM auctions due to 550g CO_2 rule. Unsupported, coal units are unable to compete and have to shut down.
2. After accounting for all existing and planned types of Capacity Market, dispatchable capacities in Poland will total 34GW by 2030, 36% of which is BESS.
3. A steep increase in BESS arises from the previous auctions and projections of the upcoming 2030 CM results.
4. Gas projects face high risks and financing headwinds, but some capacities are procured as part of overtime auctions.

Poland is committed to withdrawal from coal, but aging plants and worsening economics are speeding up the transition

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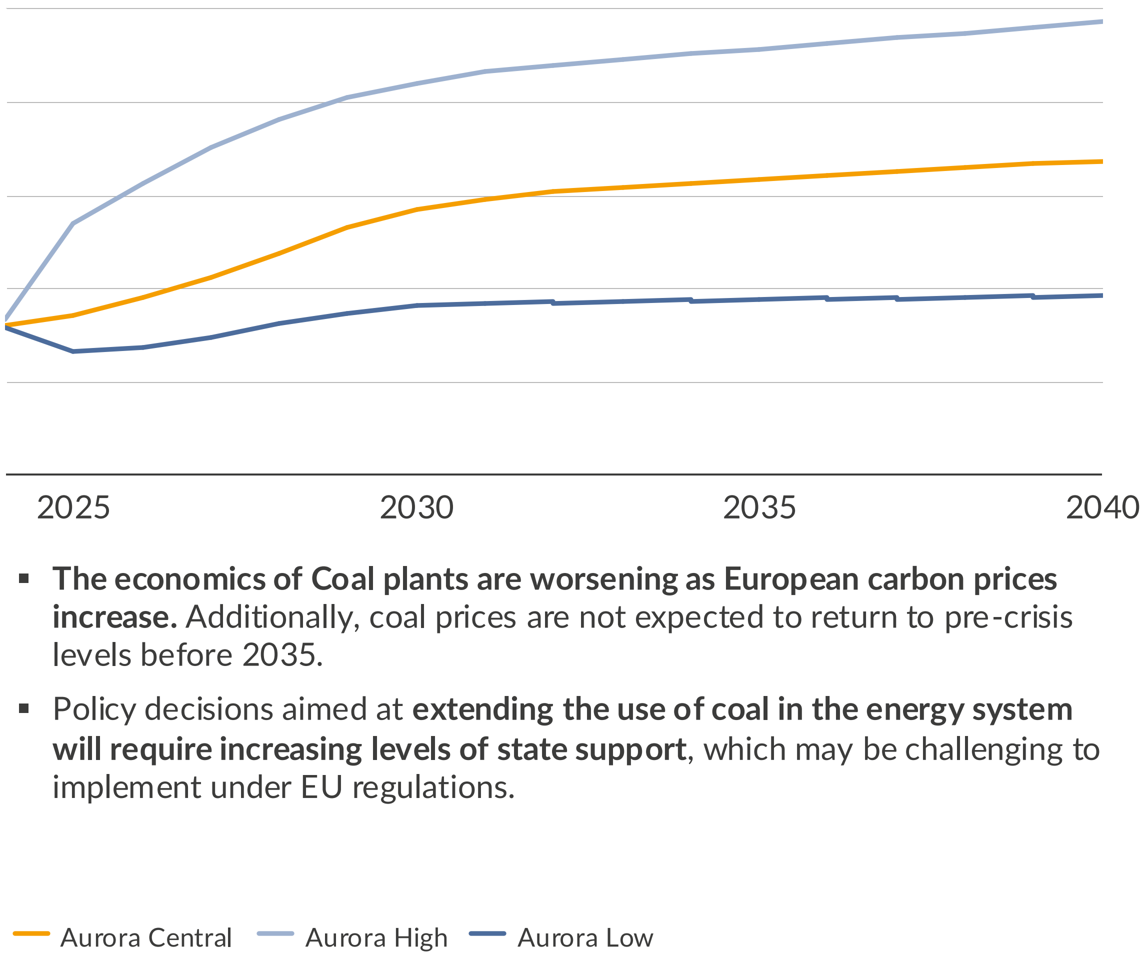
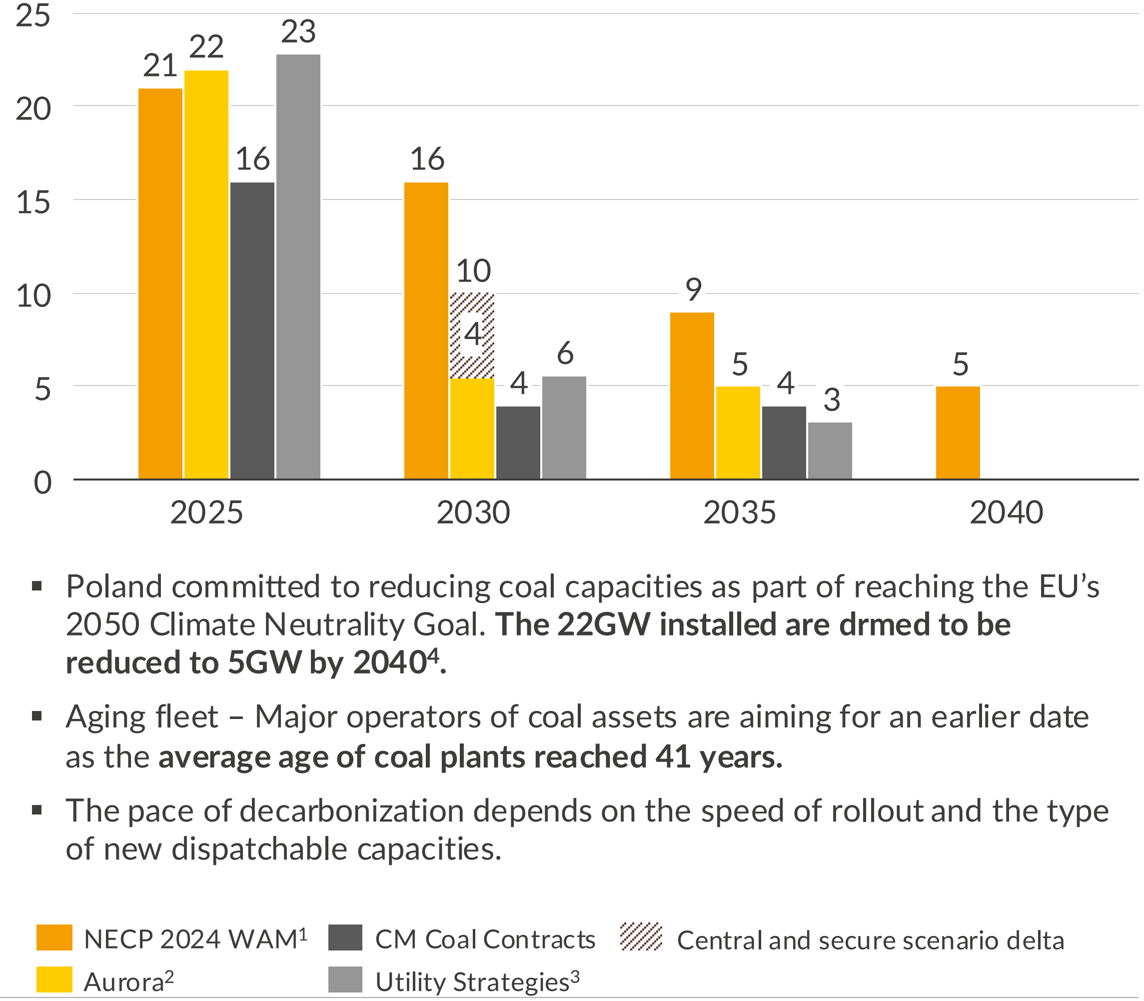
Carbon prices
€/tCO_2 (real 2023)



- **The economics of Coal plants are worsening as European carbon prices increase.** Additionally, coal prices are not expected to return to pre-crisis levels before 2035.
- Policy decisions aimed at **extending the use of coal in the energy system will require increasing levels of state support**, which may be challenging to implement under EU regulations.

Installed capacities in coal
GW



- Poland committed to reducing coal capacities as part of reaching the EU's 2050 Climate Neutrality Goal. **The 22GW installed are drmed to be reduced to 5GW by 2040[4].**
- Aging fleet – Major operators of coal assets are aiming for an earlier date as the **average age of coal plants reached 41 years.**
- The pace of decarbonization depends on the speed of rollout and the type of new dispatchable capacities.

1)National Energy and Climate Plan for Poland, scenario With Additional Measures released October 2024. 2) Range for coal withdrawal in Aurora scenario depends on approach to the security of supply. See chapter 4 for further details . 3) Based on Orlen, Enea, Tauron, PGE. 4) According to NECP 2024 WAM scenario.
Sources: Aurora Energy Research, ENTSO-E, Polish Gov, PSE

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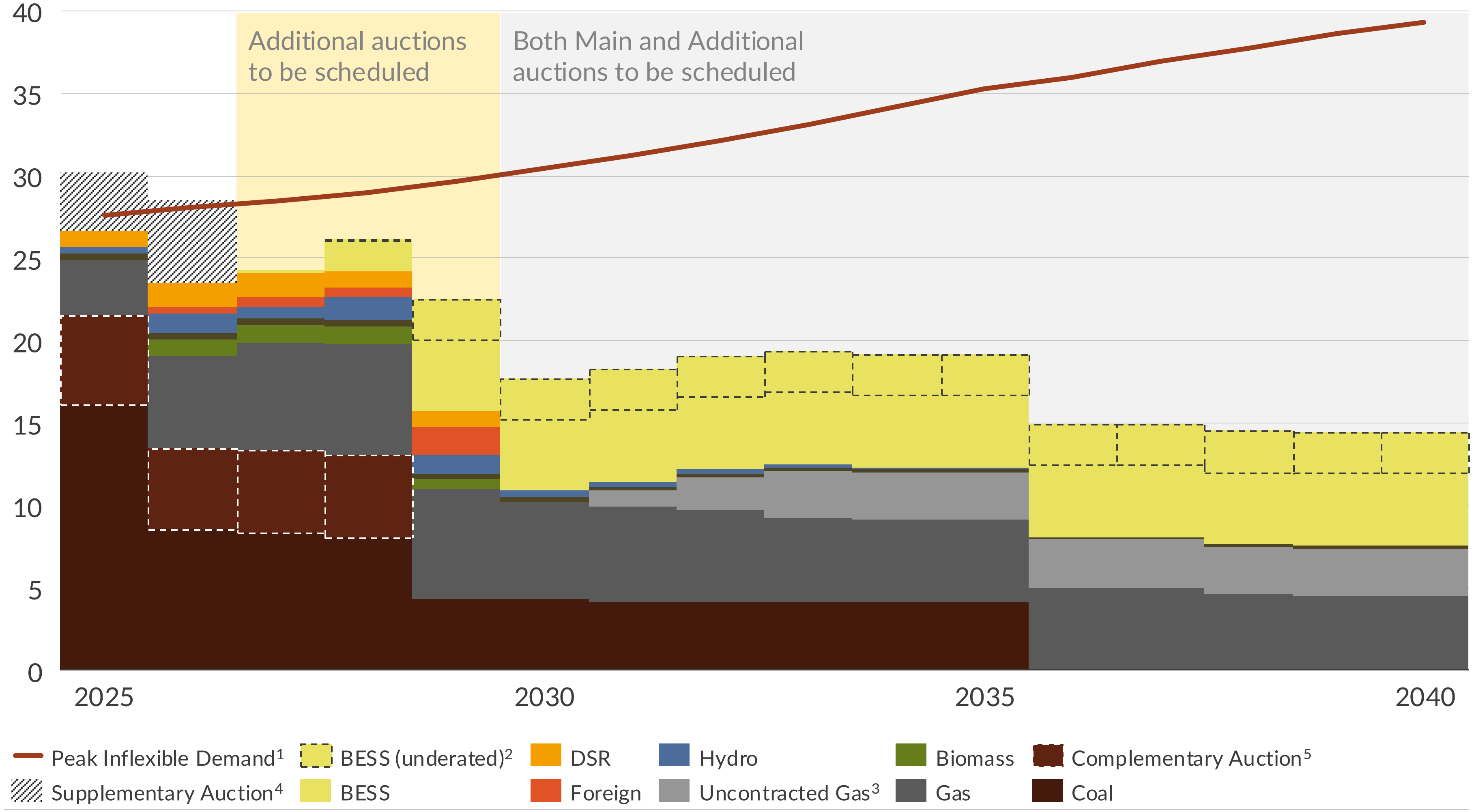
New types of CM auctions are being set up as an emergency measure, but are insufficient to meet long-term needs

Contracted/confirmed capacity and peak inflexible demand [1]
GW



1) Peak inflexible demand is the component of demand that cannot be shifted by more than 12 hours. 2) Underated BESS is calculated using the CM derating factors for CM auctions. 3) Announced gas projects without secured Capacity Market contracts. 4) announced T-1 volume. 5)Aukcje Uzupełniające - new system for capacities of last resort, including coal, announced for 2025, assumed later.
Sources: Aurora Energy Research, PSE, Forum Energii

Poland lacks firm capacity under the main CM mechanism.

- Poland has two standard types of capacity auctions:
  - **Main Auctions**: Yearly T-5 auctions, contracting newbuild capacities.
  - **Supplementary Auctions**: T-1 quarterly auctions keeping existing uncontracted capacities in the system.
- **The above have proven insufficient** as the capacity gap appeared in the short-term and is being addressed by emergency measures.
  - **We expect up to 3GW of gas projects** may be created as part of overtime auctions.
  - **We assume approx. 5GW of coal capacities** may be retained as part of Complementary auctions.

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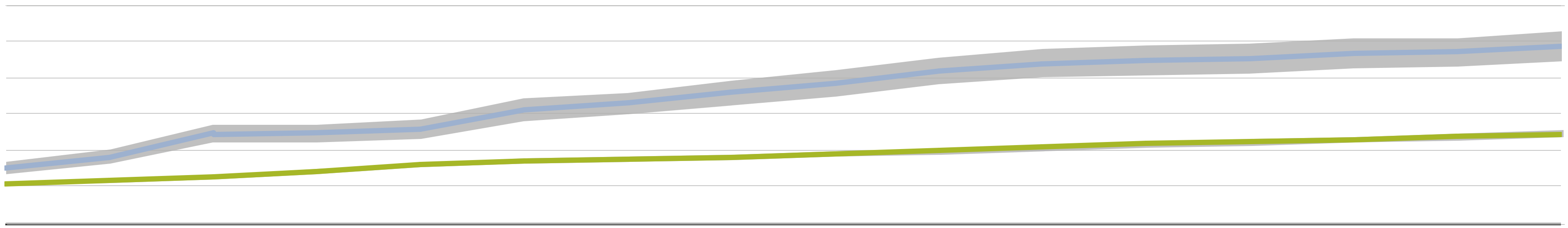
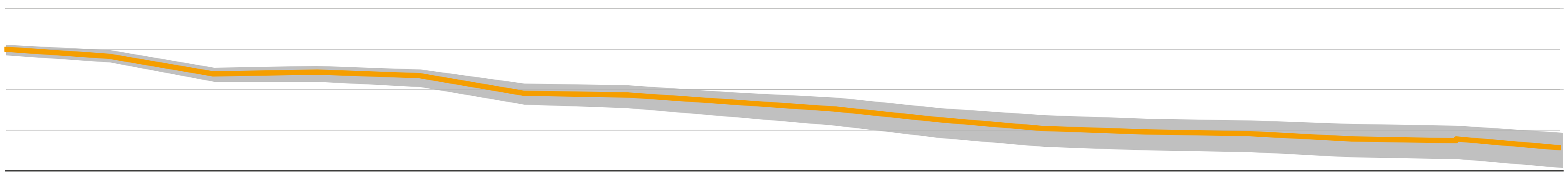
Reoccurrence of historical weather conditions may lead to 10% higher baseload price as RES supply and heating demand change

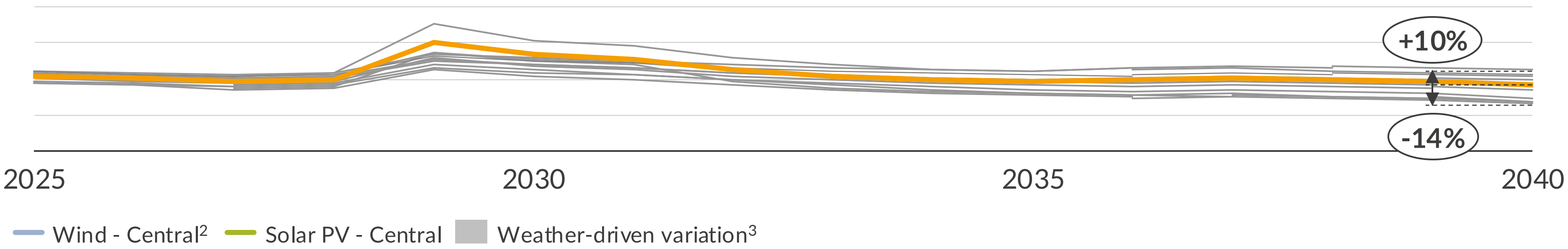
Renewables share of demand
%



Total residual demand[1]
TWh



Baseload electricity price
zł/MWh (real 2023)

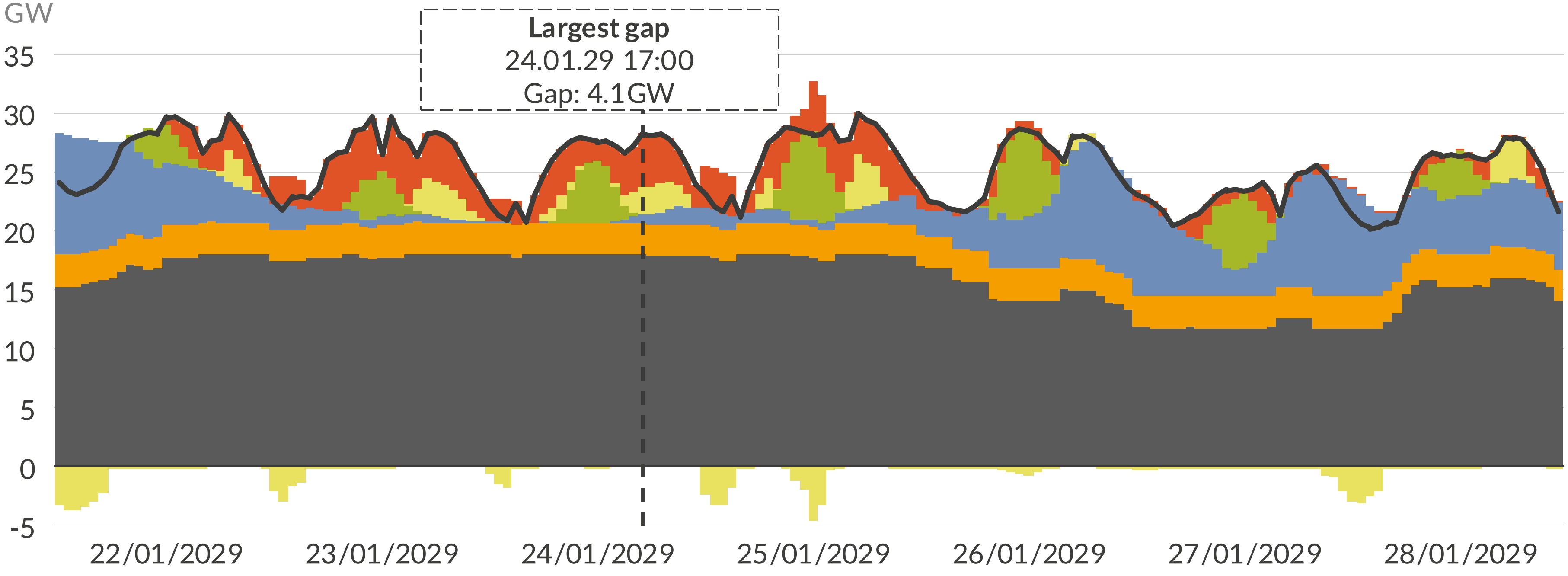


- The assumed relaxation of the 10H rule and the delivery of offshore wind projects drive a rapid **expansion in wind capacities that account for 31% and 48% of total demand by 2030 and 2040**, respectively.
- As energy generation becomes more reliant on intermittent capacities, **the system is more at risk from extreme weather events.**
- While solar load patterns are similar across years, **wind generation shows significant variation.**
- Residual demand variation is driven by the rising share of renewables and electrification in heating. **The standard deviation of residual demand increases from 2% in 2025 to 13% in 2040.**

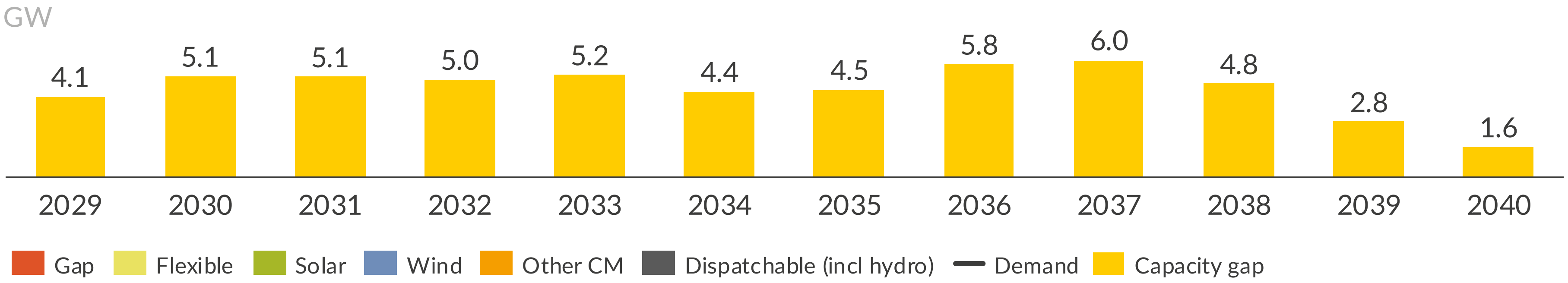
1) Residual demand describes the total power demand not covered by solar PV, onshore, and offshore wind. 2) Includes onshore and offshore wind. 3) Weather patterns as observed in 2006-2016.
Sources: Aurora Energy Research

A low-wind week of the worst weather year in Jan 2029 requires 4.1GW of additional firm capacity to fill 296GWh energy gap

Firm capacity gap in the tightest period[1]



Missing capacity[2] across years



1) Dispatchable generation: gas, coal, hydro, biomass. Other CM: contracted DSR, foreign capacities. 2) Missing capacity is a result of identifying the largest capacity gap during loss of load.

Sources: Aurora Energy Research

- At its current trajectory, the energy system lacks security in extreme weather conditions due to several factors:
  - Prolonged periods of low renewable generation.
  - Declining coal capacities, especially post-2028, as they become economically unviable.
  - Batteries struggle to provide reliable capacity in longer peak stress periods.
- Despite a large battery capacity, mostly capable of covering demand in a standard weather year, extreme events can significantly strain the system.
- In the worst-case scenario, the system faces a gap of 4.1GW, amounting to 296GWh of unaccounted-for power.

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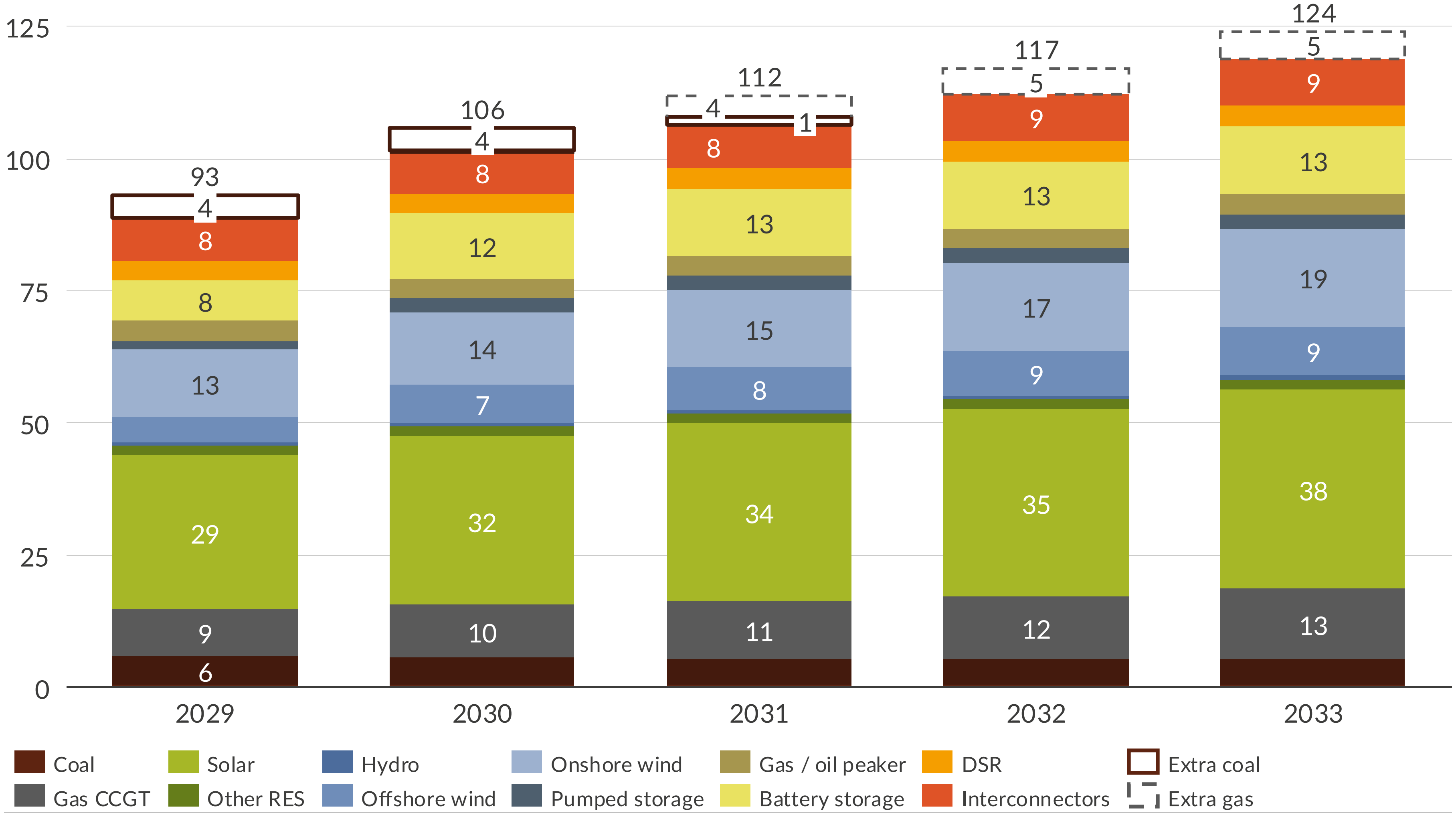
Additional firm capacities are required for system security, warding against the risk of extreme weather

Capacity stack of the secure system
GW



1. Additional coal capacities are required to remain in the system in 2028-2030, with residual capacities remaining in 2031. Coal extension is required due to the low volume of currently visible CCGT/OCGT projects. **This is a non-market behaviour that will need to be compensated.**
2. **We see a need for additional gas capacities in the early 2030s to stabilize the system.** CCGTs provide higher economic upside but are investment-heavy and struggle secure financing. OCGTs acting in peaking capacity may present a more feasible alternative.
3. Additional BESS capacity does not solve security issues as **each marginal BESS unit comes with decreasing availability.**

Sources: Aurora Energy Research

1 A coal reserve of up to 4.4GW is necessary for system stability; long-term coal is not economically feasible

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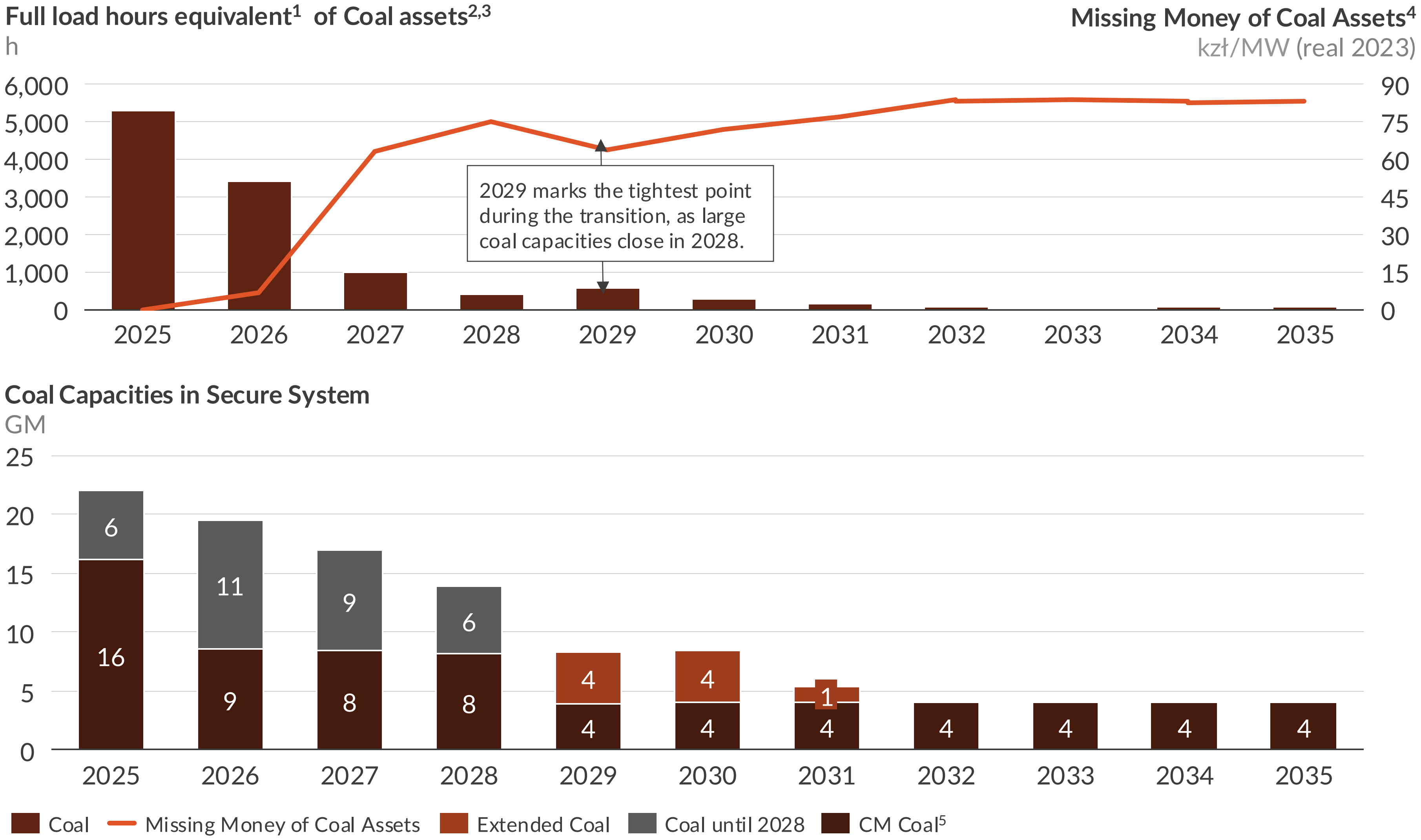


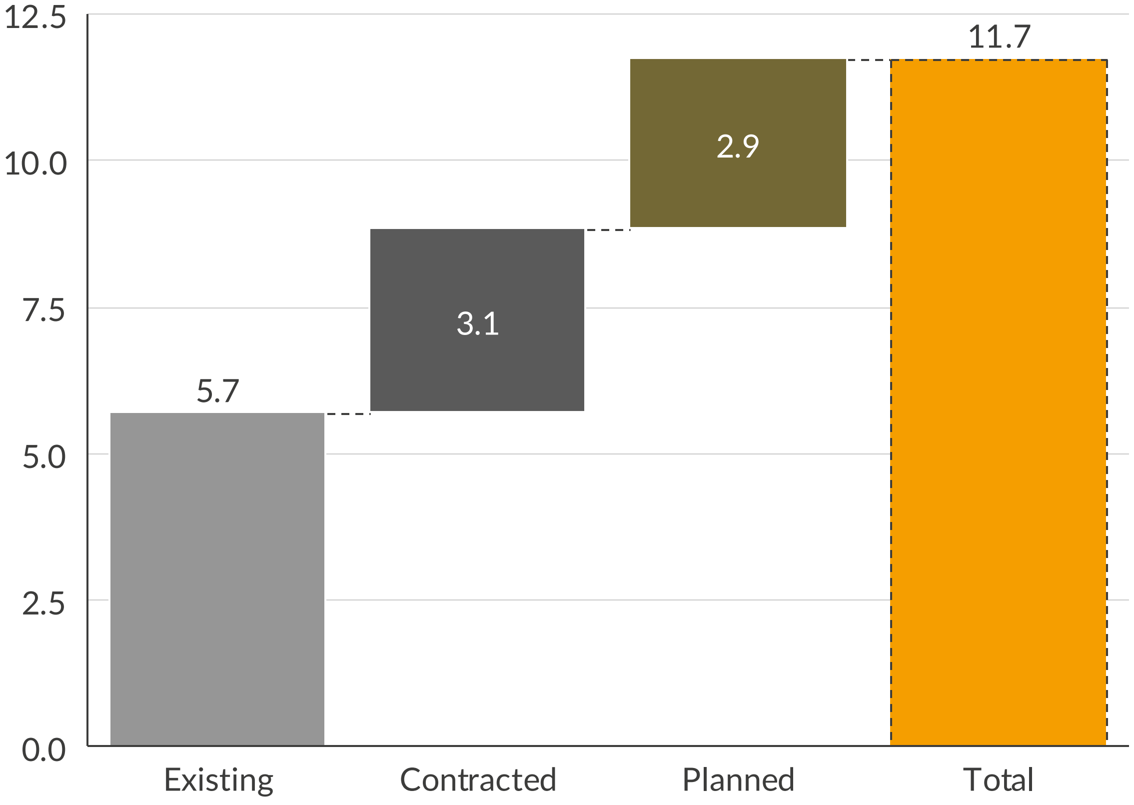
- To keep coal operational, an increasing non-market revenue stream is required, equal to the missing money gap. However, these capacities are ineligible for support post-2028 due to high emissivity.
- The missing money gap increases over time, in line with carbon prices, making the aging assets less competitive.
- Coal plants restrict operations to peak hours. However, while this helps mitigate losses, it is insufficient to cover fixed costs.
- Additionally, technical limitations make coal poorly suited to operate in this 'peaking' capacity. This is mainly due to their slow and costly start up times and ramping efficiency losses.

1) Hours a plant needs to run at full capacity to generate the same amount of electricity. 2) Lignite example plant with 30% HHV thermal efficiency. In the model, thermal plants are required to run with a minimum efficiency, a measure not implemented in this example 3) Based on average weather pattern 4) Missing Money = Wholesale Gross Margin – Fixed Costs.5) Hard coal and lignite.
Sources: Aurora Energy Research

2 The known potential capacity of gas projects stands at 12GW by 2030, as greenfield projects are not feasible in the short timeframe

1 **The total capacity of planned, contracted and existing projects totals 11.7GW in 2030.**

Feasible gas capacities until in 2030[1]
GW



2 **Larger newbuild capacities are unlikely due to long project lead times.**

Existing

- **Mostly modern gas facilities with the majority coming online post-2017.**
- The single largest gas project is Dolna Odra CCGT, with a net capacity of 1.4GW, coming online in 2024.

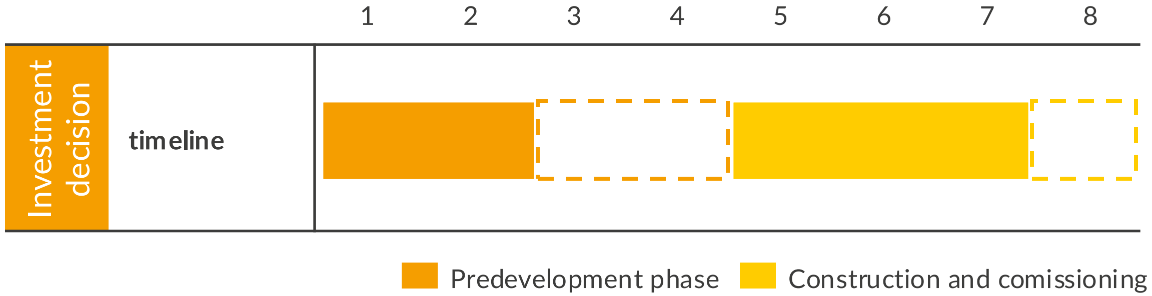
Contracted - Capacities procured under the CM yet to begin operations.

- Mostly large CCGTs contracted during 2025-2027 auctions. Small peaking capacities totalling around 100MW have been procured in 2028 and 2029 CM auctions, amidst low auction results.

Planned - Large CCGT projects that failed to secure contracts during the 2028 and 2029 auctions.

- Includes Gdańsk, Kozienice, Łagisza and Siekierki, projects that are publicly known and in various stages of preparedness.

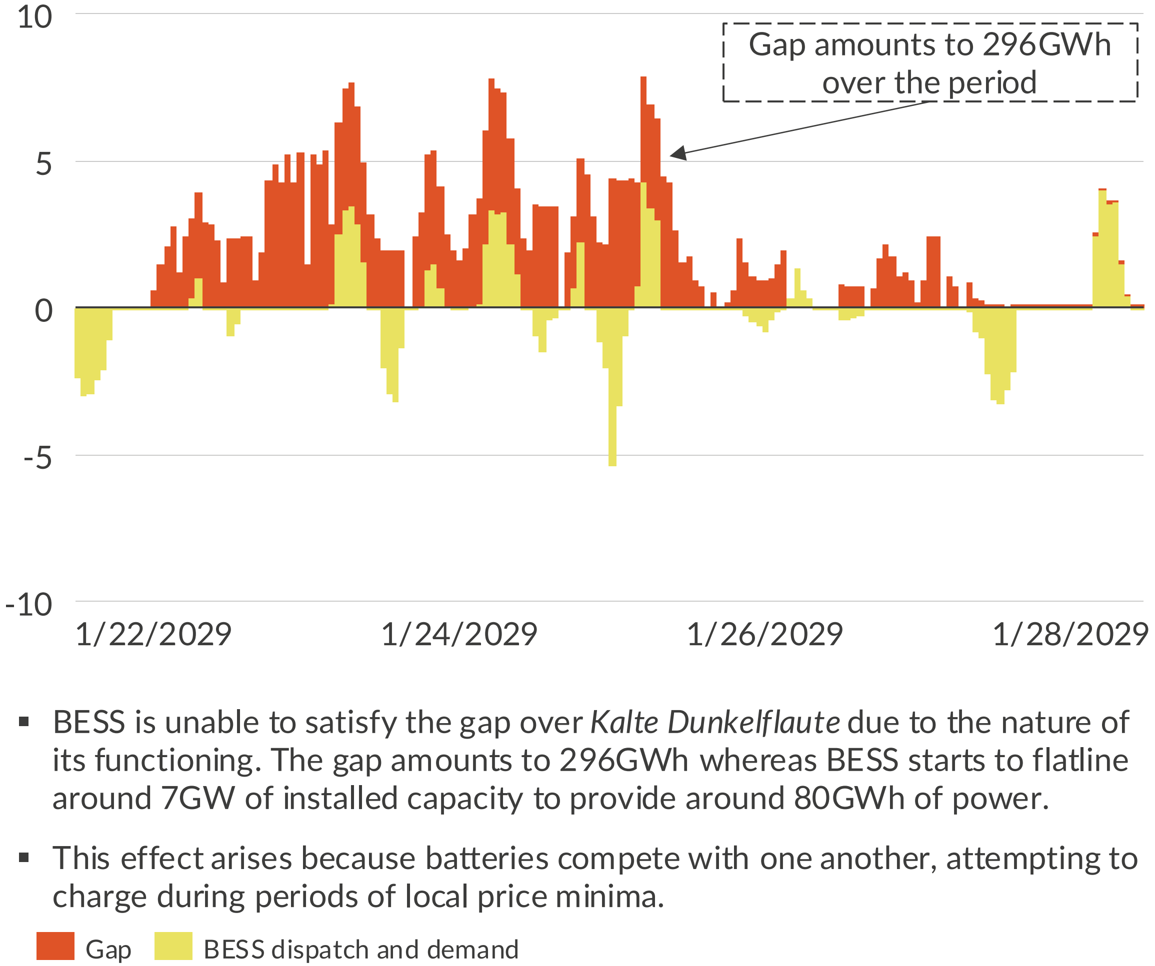
Recently opened gas projects needed a lengthy lead time, with a typical project duration spanning 5-8 years



1) Excluding expected gas replacements of existing coal district heating plants, which total 3GW by 2030. 2) Existing capacities constitute of small CHP, and several larger projects; existing plants above 100MW include Nowa Sarzyna, Wrotków, Rzeszów, Zielona Góra, P łock, Włocławek, Toruń, Stalowa Wola, żerań, Dolna Odra.
Sources: Aurora Energy Research

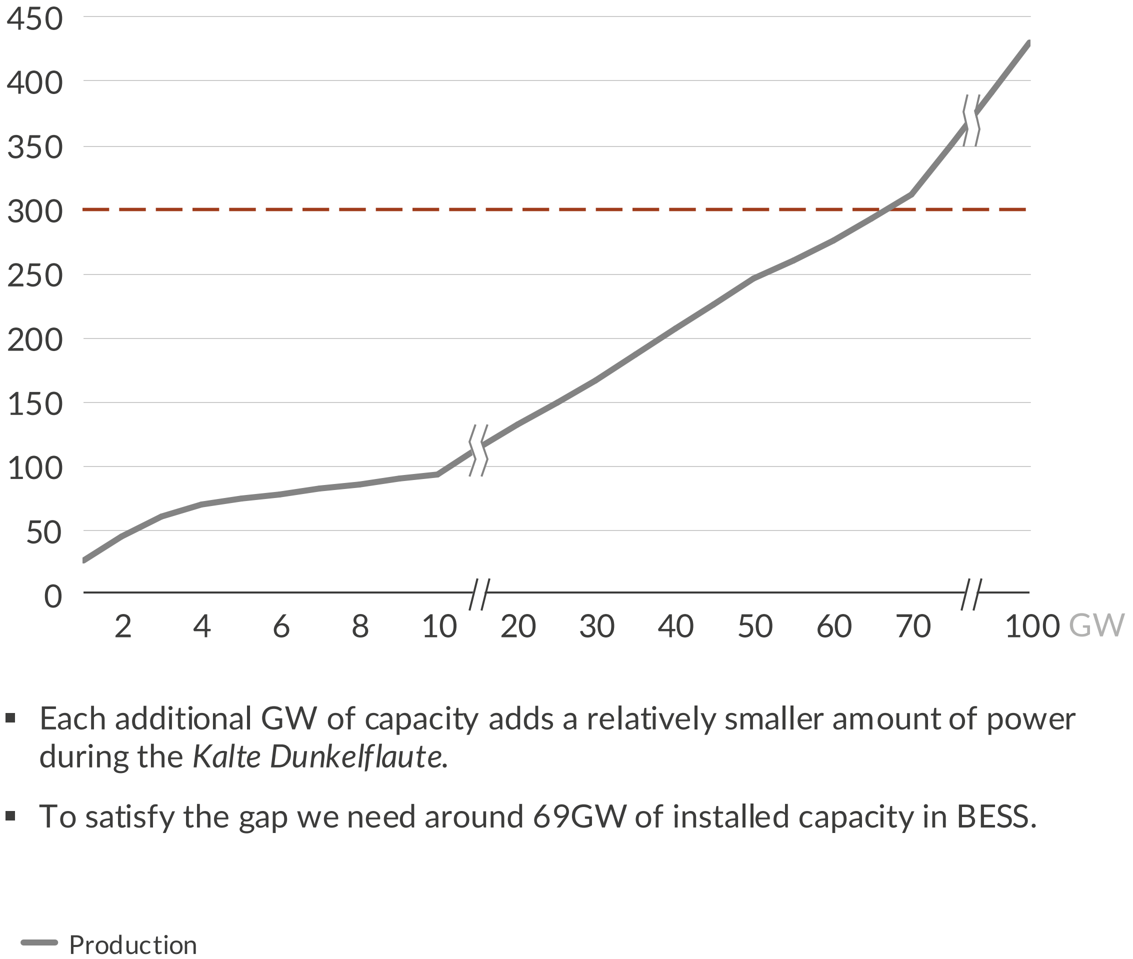
3 BESS faces a marginal availability dilemma, with each added unit, providing declining benefits

Behavior of 7.7GW of BESS during the *Kalte Dunkeflaute* event



- BESS is unable to satisfy the gap over *Kalte Dunkelflaute* due to the nature of its functioning. The gap amounts to 296GWh whereas BESS starts to flatline around 7GW of installed capacity to provide around 80GWh of power.
- This effect arises because batteries compete with one another, attempting to charge during periods of local price minima.

BESS production over *Kalte Dunkelflaute*



- Each additional GW of capacity adds a relatively smaller amount of power during the *Kalte Dunkelflaute*.
- To satisfy the gap we need around 69GW of installed capacity in BESS.

1) The *Kalte Dunkelflaute* is a period in 22-28.01.2029 in WY 2013 of our Central GM scenario.

Sources: Aurora Energy Research

Agenda

I. Introduction

II. What has shaped Poland’s dispatchable capacity?

III. Weather variability and strain events

IV. Maintaining security in energy transition

V. Considerations for policy makers

VI. Key takeaways

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Earlier deployment of gas assets would reduce the system costs by up to 6bn zł, depending on choice of technology

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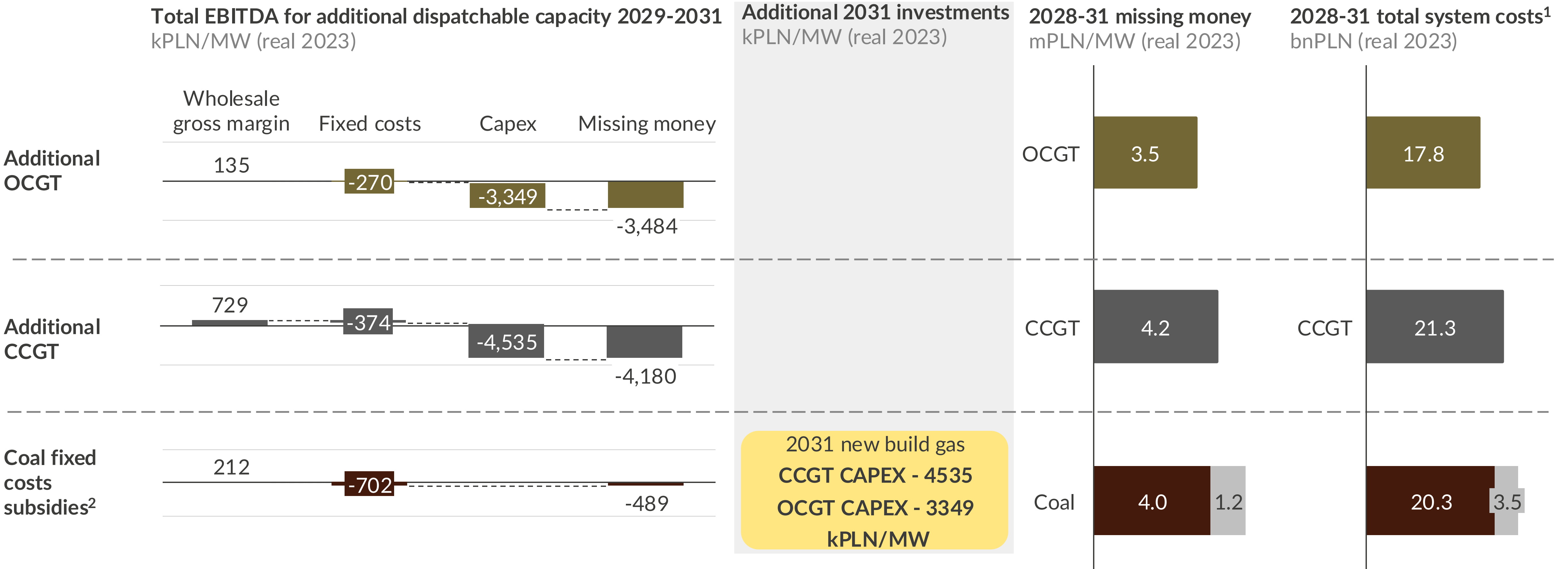

- Extending Coal units until 2031 is feasible considering the age of existing assets. However, a longer extension requires significant modernisation investment[3] as some of them exceed their preliminary lifetime.
- Additional investments in the modernization of coal, can increase asset reliability and flexibility. Modernised coal plants would however remain uneconomic to operate.

1) In line with the identified scarcity gap of 4400MW. 2)Based on combination of remaining coal assets, at 1.4GW coal and 3GW of lignite. 3) Potential grid investments are not considered

Sources: Aurora Energy Research

A dual-track approach would resolve the competition between gas and batteries in the Polish Capacity Market

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	Dispatchable capacity mechanism	Flexible capacity mechanism
Objective	**System Security** ▪ Requires **high-availability** technologies, that can operate for extended time, regardless of weather patterns. ▪ Currently, these capacities cannot enter the system amidst high investment risks.	**System Flexibility** ▪ The primary function is load shifting and network stability; continuous availability is secondary. ▪ Capacities with rapid activation time are required within a system that is highly reliant on RES generation.
Technologies	▪ Gas and H2 CCGT/OCGT, CHP plants, nuclear.	▪ BESS, DSR.

Firm capacities are held in the system via availability and CfD payments. Flexibility support is more varied, and may combine CAPEX support, reduced charges and BM revenue.

- **Centralized strategic reserve** for emergency supply (firm capacity), supported by activation[1] and availability payments.
- **Flexible assets support available via CAPEX subsidies**. Grid transmission fees are substantially reduced for Flexible capacities.

- Technology Neutral Capacity Market supplemented by:
  - **Generation Strategic Reserve (SGR):** Contracts with existing power plants that are kept out of the market to be available during peak times.
  - **DSR Strategic Reserve (SDR)**: Engages large consumers to participate in DSR, remuneration based on availability and activation[1].

- **Direct support for H_2-Convertible Gas Plants** – subsidies in the form of direct investment grants and CfD payments for gas plants with planned transition to H2 between 2035-2040.
- **Grid fee reductions** for battery storage and **regional funding programs**, including CAPEX subsidy.

1) Activation payments are additional incentives paid when an asset is called upon to provide power or reduce consumption. Unlike capacity payments, which reward availability, activation payments compensate for actual energy delivered or response actions performed.

Sources: Aurora Energy Research, Elia, Tennet,Tesvolt

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Key takeaways

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1 Driven by an ageing fleet and deteriorating economics, Poland's coal fleet will decline to **5 GW by 2030.** The pace of coal phase-out will impact the security of supply in Poland, however **support opportunities for coal are limited, and the pipeline for gas assets remains insufficient to bridge the emerging supply gap.** Instead, BESS assets have been far more successful, with a potential **12 GW by 2030**.

2 Retaining coal assets to fill the capacity gap is not a long-term solution. **Extending the operational lifespan of coal assets will cost at least 163 kzł/MW/year for a total of 489 kzł/MW assuming Aurora's coal extension expectations.** Accounting for modernization and refurbishment costs this amount may be even higher. However, their early retirement may lead to load shortages, with a projected 4.1GW capacity gap in a prolonged *Kalte Dunkelflaute*.

3 Recent Capacity Market auctions have demonstrated that BESS can outcompete gas plants based on the required level of support, but **BESS assets do not offer the same level of supply security as thermal power plants.** In an extreme weather year, **up to 69GW of BESS would be required to ensure system stability by 2029, compared to 4.4GW of thermal capacities**.

4 Gas investments are the most feasible solutions to the Polish capacity gap, but **large CCGT investments remain constrained due to high capital requirements. Gas reciprocating engines and OCGTs can offer viable short-term alternatives.** Their lower investment thresholds result in 115-200 zł/kW/year lower CM clearing price than CCGTs and their operational flexibility makes them well-suited for addressing supply fluctuations.

5 **Most EU countries approach capacity reserves with a technology-neutral strategy, yet differentiation between flexible and dispatchable sources is emerging.** While dispatchable assets are rewarded for availability, flexible resources may benefit from alternative incentives such as reduced grid costs, CAPEX support, or dedicated reserve mechanisms for rapid flexibility shifts.

Sources: Aurora Energy Research

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Solarplaza
Warszawa

13 March 2025

13 May 2025

Group Meeting:
Policy outlook and a nuclear scenario for Poland

Battery Forum
Warszawa

20-22 May 2025

26-27 May 2025

Kongres PV
Warszawa

PSEW
Świnoujście

4-6 June 2025

November 2025

Group Meeting:
One year of liberalised balancing markets - learnings and forecast

LONDON 2025

WEDNESDAY 21 & THURSDAY 22 MAY

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Aurora's suite of software products for the Polish market

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ORIGIN
for markets

Our **market-level model** enables you to create your own market scenarios within hours and quantify market risks and upsides from policy, commodity, demand and supply changes.

AMUN
for wind

Our **software tool for asset-specific modelling of a wind farm's** financial performance that delivers bankable asset-specific revenue forecasts for wind assets within minutes.

LUMUS
for PPAs

Our **contracts valuation engine** lets you price and analyse Power Purchase Agreements, fully consistent with Aurora's view of the market.

Details and disclaimer

Plugging the gap: security of supply in Poland

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