

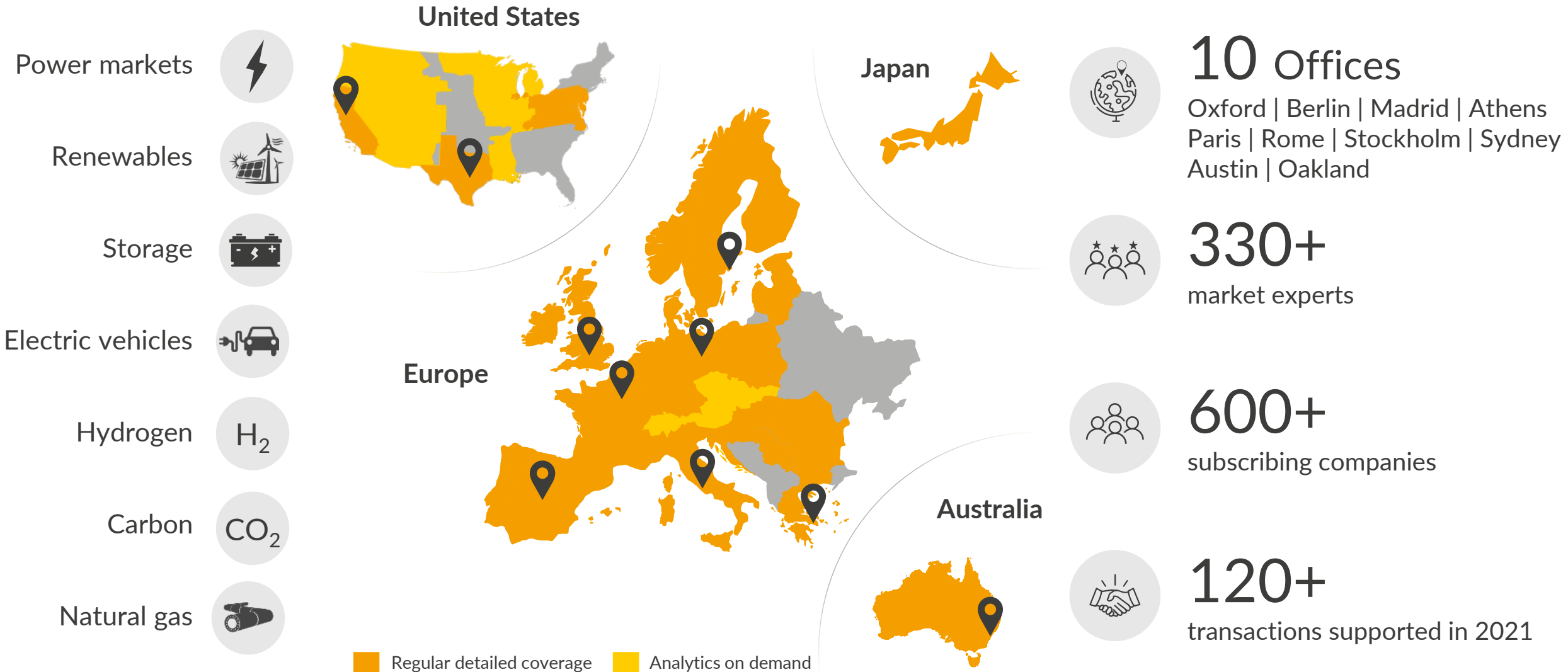
The Economics of Batteries in Poland

Public Report

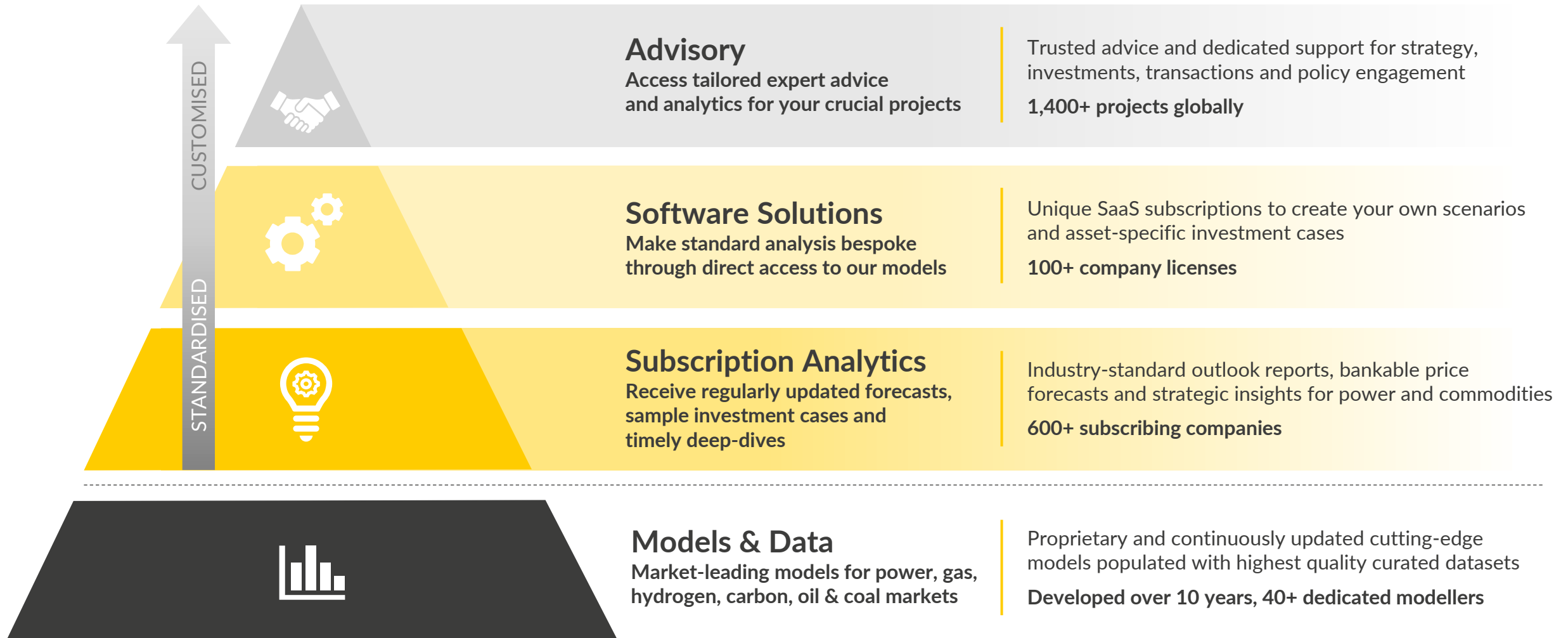


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Aurora's offerings

For more information on the Polish flexible energy market, the economics of battery projects, battery business cases and their optimisation, please contact Anna Donczew-Salawa, Senior Commercial Associate – Central Europe.

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To discuss speaking partnership opportunities with our team experts, please contact Lucy Sovetova, Marketing Coordinator

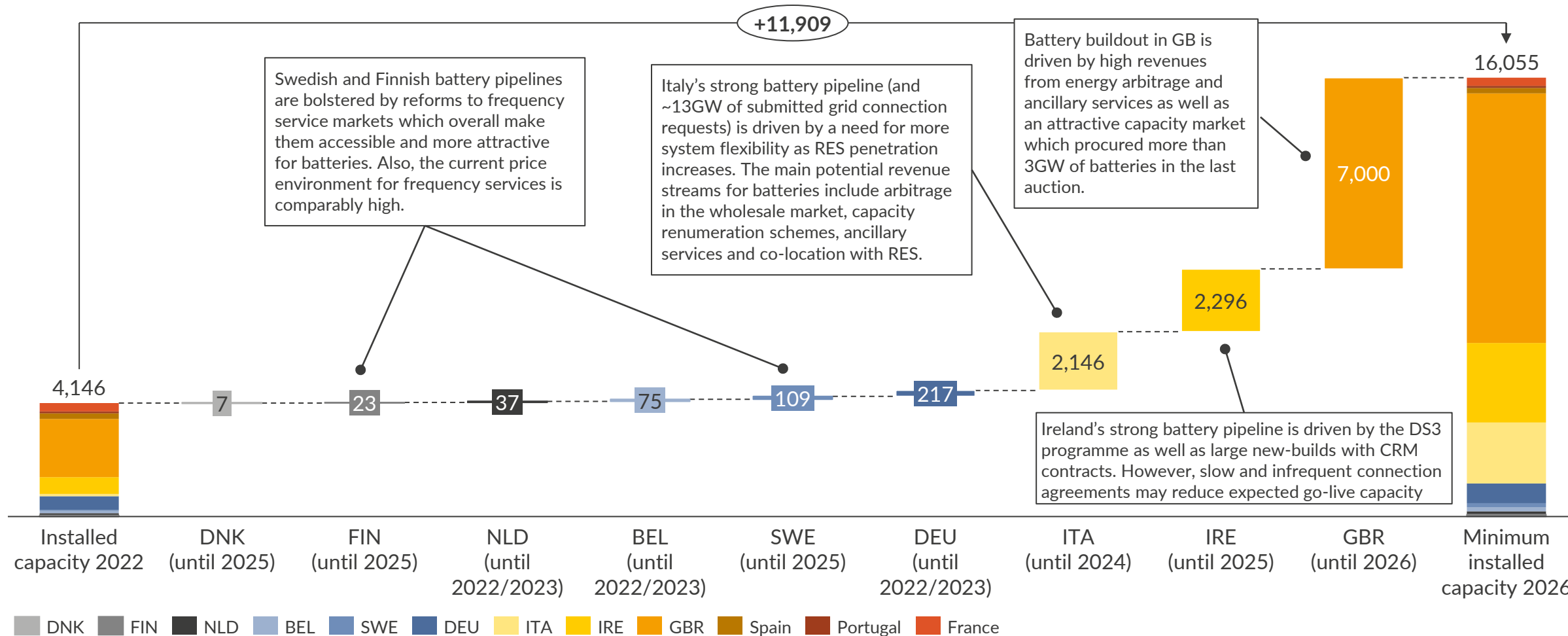
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1. Introduction to batteries in Poland
2. Wholesale market opportunities
3. Capacity market
4. Ancillary services and optimising battery business
5. Closing remarks

The pipeline of advanced European battery projects will quadruple installed capacity to at least 16 GW by 2026

Near-term project pipeline large-scale batteries¹

MW, nameplate



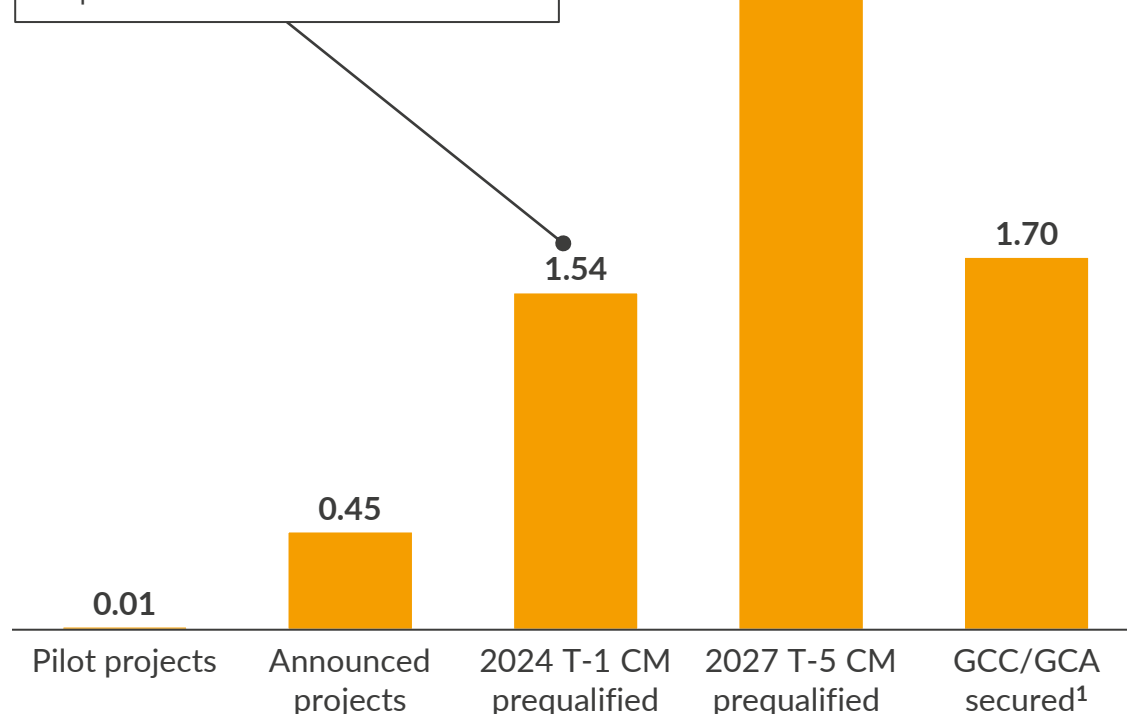
1) Includes projects with agreed connections and CRM contracts, includes projects with granted planning permissions. 2) Nameplate capacity presented i.e. capacity before any de-rating factor is applied

Project announcements and Capacity Market prequalification indicate a strong pipeline of projects exists in Poland

Polish battery project pipeline

GW, nameplate

Projects which are prequalified for 2027 T-5 auction but which are at an advanced enough stage of development to be able to compete for short-term contracts in 2024



Pilot projects



- A number of small-scale pilot projects are operating in Poland, mostly exploring the role batteries can play in improving grid stability. The largest is a 6 MW, 27.3 MWh battery developed jointly by Energa, PSE and BME

Announced projects



- PGE recently announced that it has received a concession for a large-scale battery storage system. The development at Żarnowiec will be a 205 MW, 820 MWh battery which is planned to work in coordination with the existing pumped storage system at the site



- Columbus Energy announced that it is planning to develop a 133 MW, 532 MWh battery storage system in the south of Poland. The investment is expected to be completed between 2024 and 2026






- Green Capital has received grid connection conditions for a 110 MW, 440 MWh battery storage project in southern Poland. The project will cost 850 mln PLN and is due to be completed by 2025

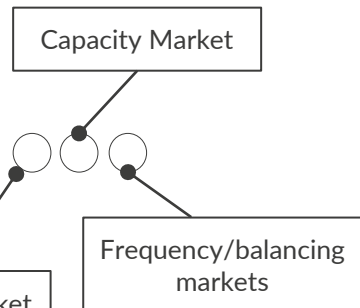
1) Grid Connection Conditions/Grid Connection Agreements as published by TSO and DSOs

Across Europe, balancing services and frequency regulation markets are the key revenue streams for battery business cases

Most valuable market for batteries

Rating

-  Primary revenue stream
-  Secondary revenue stream
-  Minimal to zero revenue



In more mature markets frequency services become saturated over time. Energy arbitrage between the wholesale and balancing markets becomes crucial

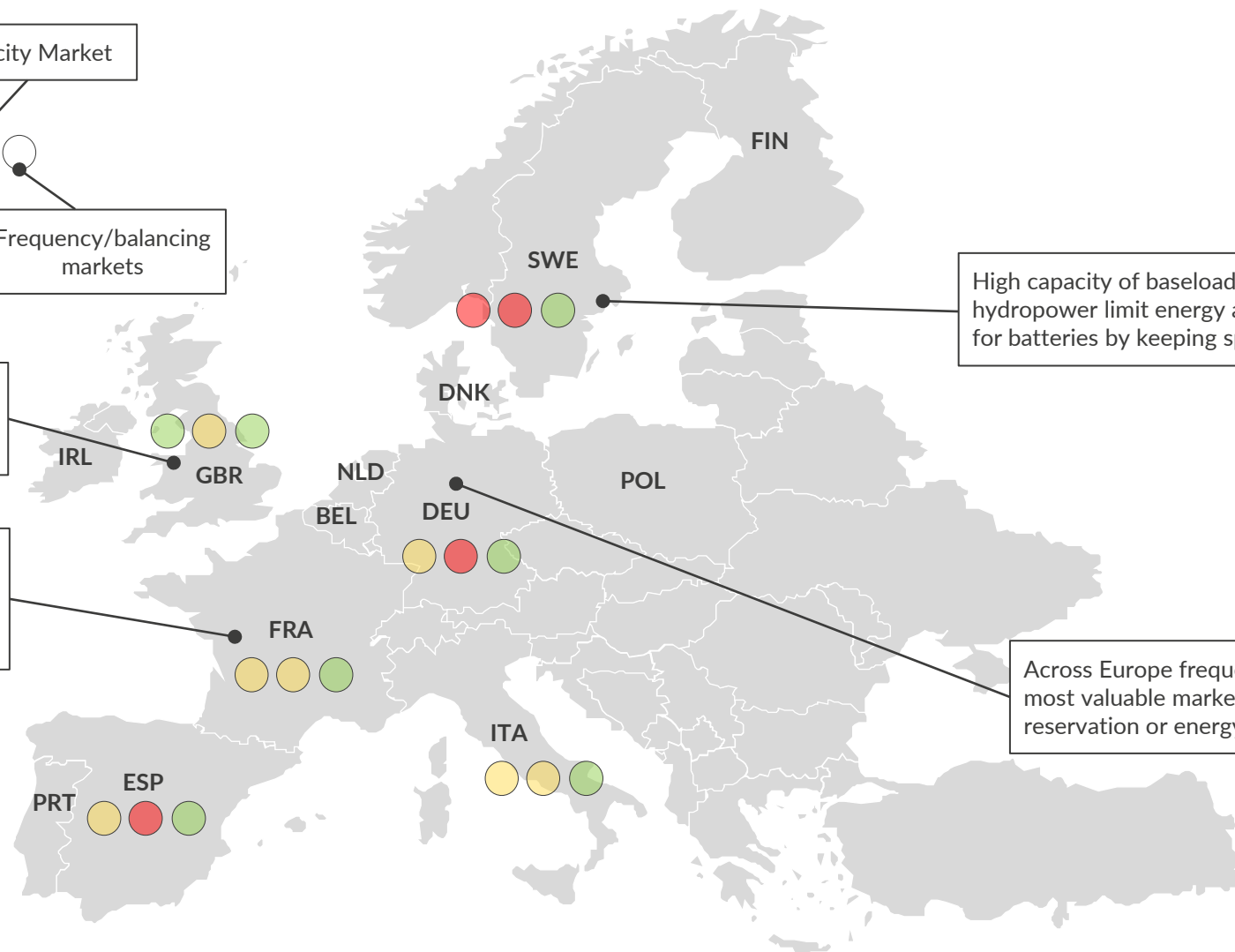
Newbuild capacities in France can secure 7-year contracts. Longer-term contracts are available in GB (15 years) and Ireland (10 years) and are an important bankable revenue stream

High capacity of baseload generation or hydropower limit energy arbitrage opportunities for batteries by keeping spreads low

Across Europe frequency services tend to be the most valuable market for batteries due to high reservation or energy payments

Our flexibility market forecasts and analytics help to build successful battery business cases. Learn more about subscription options from **Anna Donczew-Salawa, Senior Commercial Associate – Central Europe**

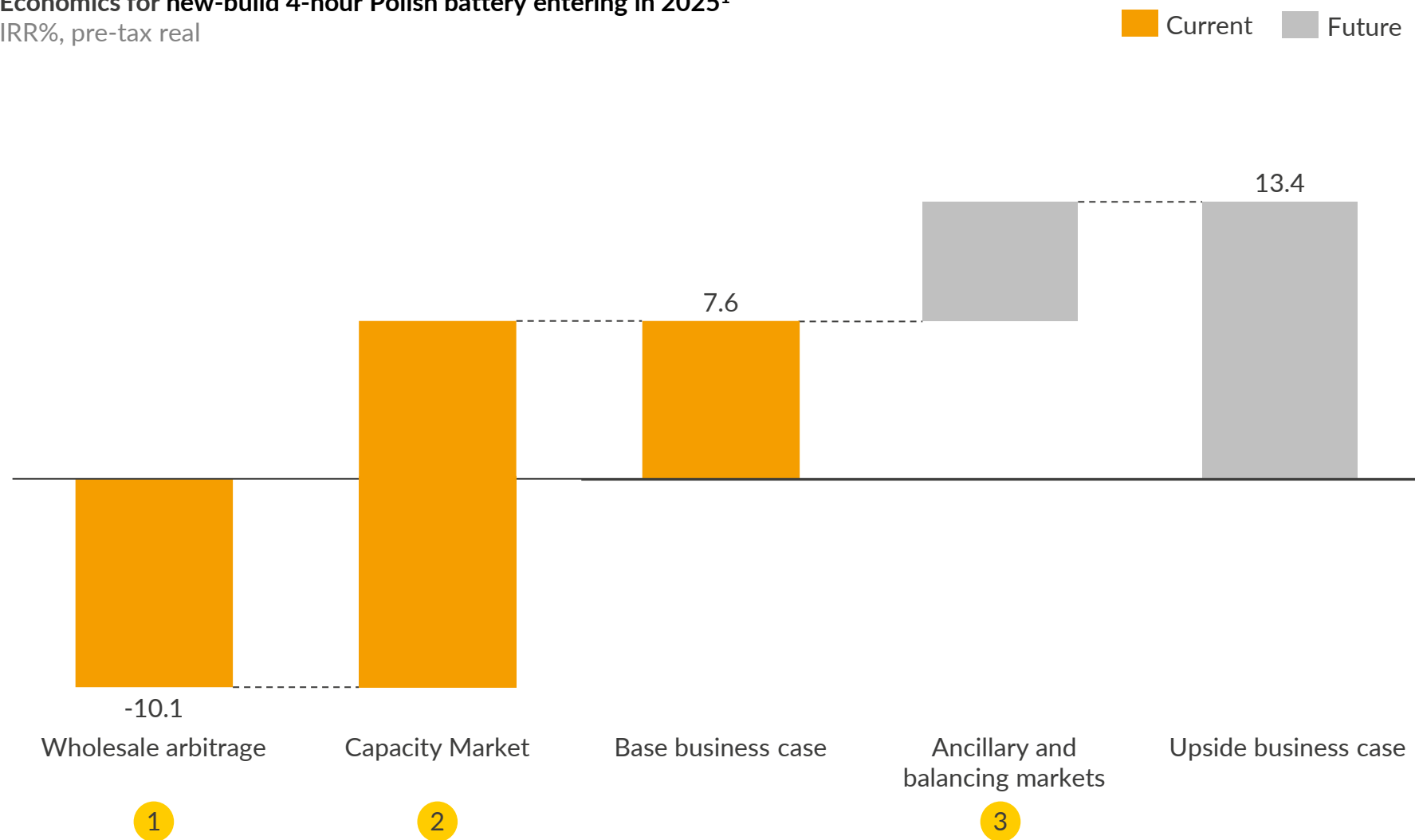
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In this report we review the available revenue streams and look at the potential business cases for batteries in Poland

Economics for new-build 4-hour Polish battery entering in 2025¹

IRR%, pre-tax real



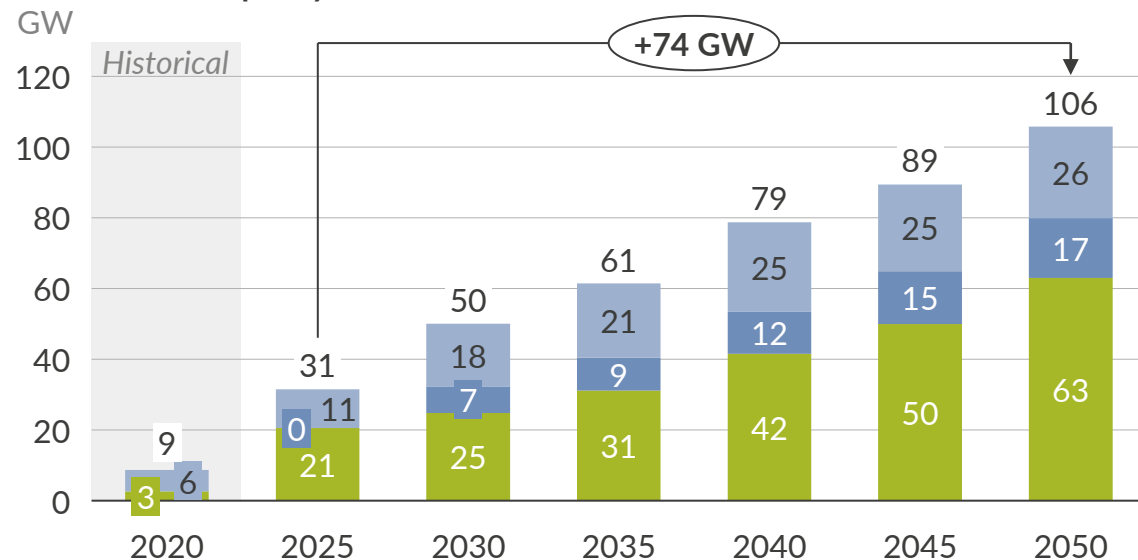
- 1 Wholesale market volatility is rising due to high commodity prices, fast renewable buildout and capacity tightness. Understanding the value of arbitrage is the first step to evaluating business cases
- 2 High prices and bankability mean Capacity Market contracts are key to current thinking around battery investments in Poland
- 3 The opening of liberalised frequency control markets in H1 2023 will provide additional revenue streams. Experiences from other markets show that optimal dispatch between markets can offer a large upside to battery revenues

1) Lifetime of 20 years.

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Rapidly increasing installed capacity of intermittent renewables will lead to growing volatility in the day-ahead market

Installed RES capacity



RES share of demand

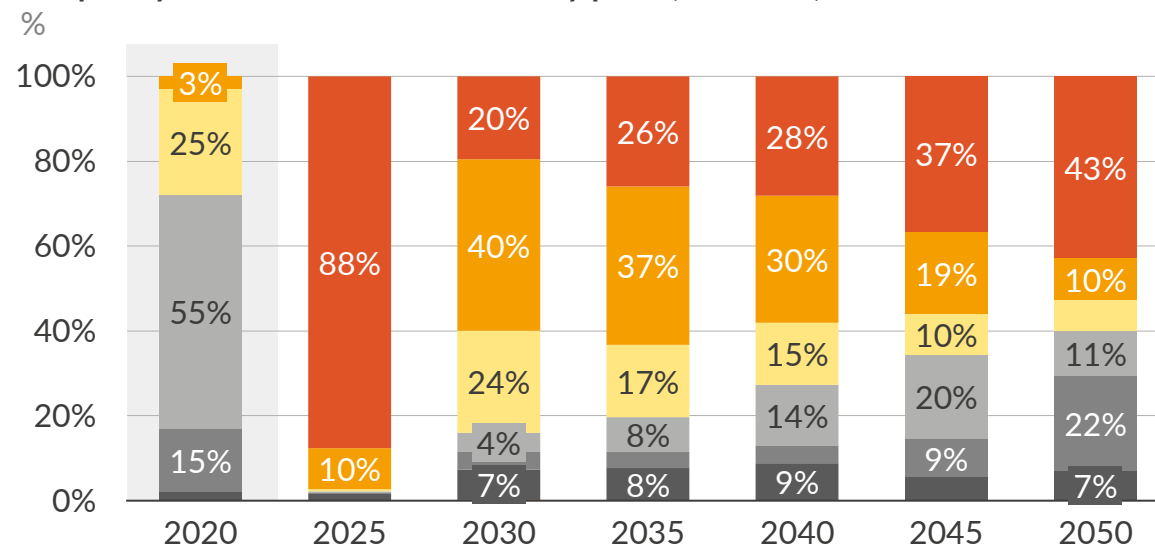


- Renewable capacity rapidly grows by 74 GW in the next three decades. Initially buildout is subsidy-driven but onshore wind is built on a fully merchant basis from 2026 and solar from the early 2030s
- This rapid growth of renewable capacities, paired with a rapid coal exit sees the RES share of demand grow to 55% by 2030 and 78% by 2050

Onshore wind Offshore wind Solar

1) Analysis based on our July 2022 Power Market Forecast

Frequency distribution of the electricity price (real 2021)¹



Standard deviation

PLN/MWh (real 2021)

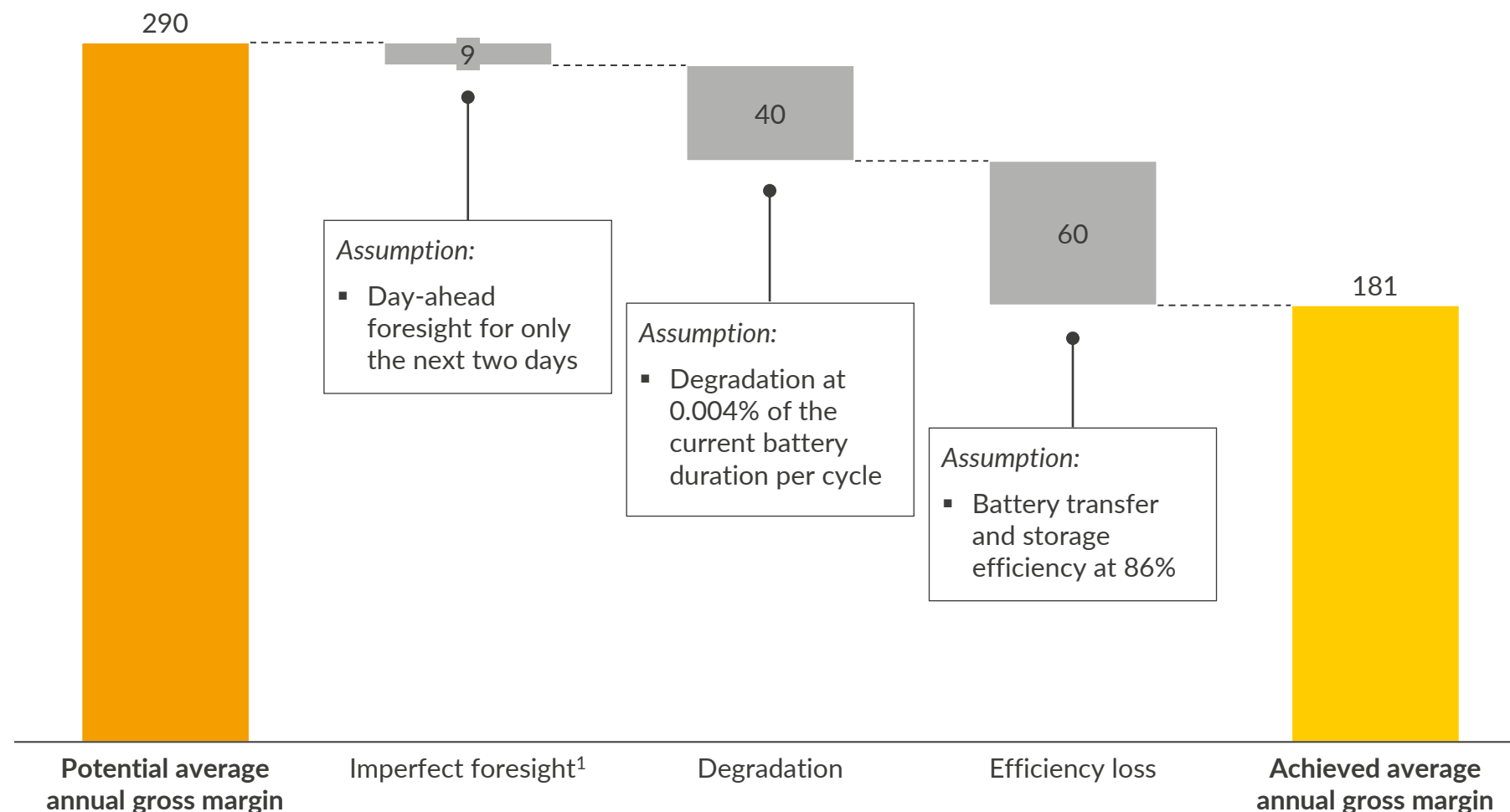


- The rapid growth in renewables from 2025 drives increasing volatility in wholesale prices with the occurrence of very high and very low prices increasing in frequency

>400 320-400 240-320 160-240 80-160 0-80 <0

Resulting gross margins can only be partially realised, as there are limiting factors to the value on offer in the wholesale market

Value achieved in wholesale arbitrage for an exemplary 4-hour, 1-daily cycle battery starting in 2025
PLN/kW



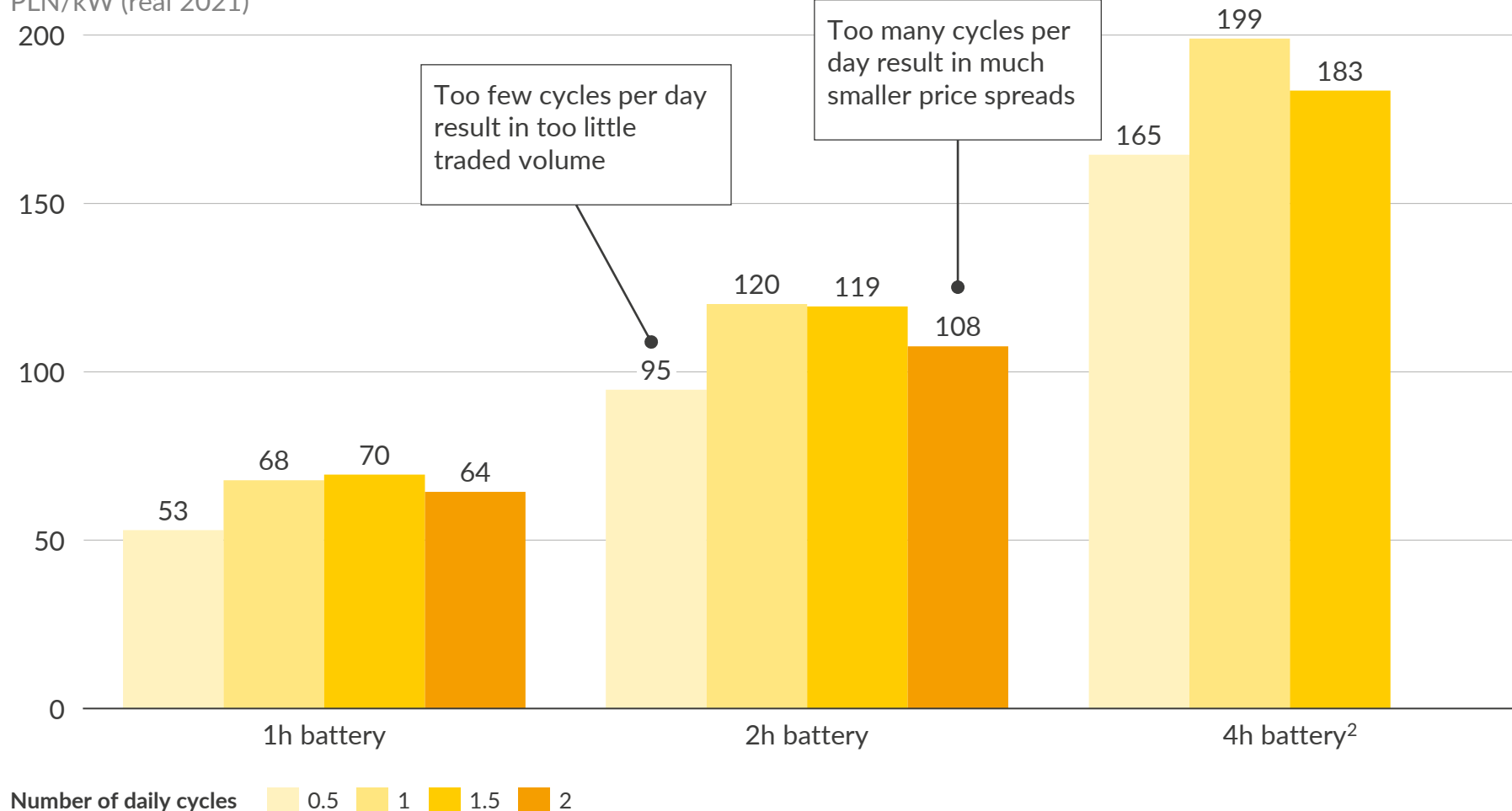
- Based on the daily spreads, a battery could achieve up to 290 PLN/kW simply through DAM arbitrage
- But actual wholesale gross margins are limited by three factors:
 - Imperfect foresight – is a restriction on the foresight of prices on the DAM and therefore on trading strategy
 - Degradation – is a reduction in battery duration as a function of the number of cycles
 - Efficiency loss – is a reduction in the volume of energy sold representing the loss in both transferring and storing energy. In our modelling it is already reflected in the volume purchased

1) This was modelled under the assumption of perfect foresight for the next two days, the cost will increase with more uncertainty

Gross margins for various batteries depends heavily on the number of cycles that each battery will undergo on daily basis

Average annual wholesale gross margin, non-degraded (2025-2050)¹

PLN/kW (real 2021)



- Wholesale gross margins are a cross section of the volume traded and the price spreads captured in each cycle
- Too few cycles daily result in too little traded volume, whereas too many cycles daily forces batteries to buy and sell at inopportune hours, lowering price spreads
- Degradation is not taken into account here to provide a comparison for all batteries irrespective of the buildout date
- However, degradation has a negative effect on wholesale gross margins, and it increases with more battery cycles

Interested in our Polish Flexible Energy Market Service? Please contact **Anna Donczew-Salawa**, Senior Commercial Associate – Central Europe

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1) The average annual revenues of a battery including the cost of arbitrage, efficiency loss, and imperfect foresight. 2) 2 cycles per day for 4h batteries resulted in very small price spreads that did not incentivize plants to operate above 1.5 cycles

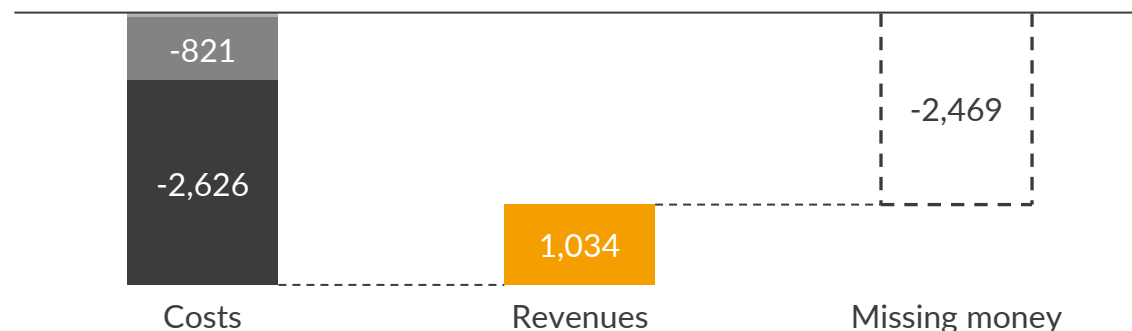
Sources: Aurora Energy Research

Battery revenues from the Polish wholesale market alone do not suffice for an investable business case

1 Wholesale arbitrage for a 2-hour battery, 1 cycle per day, entering in 2025

Present value of cashflows¹

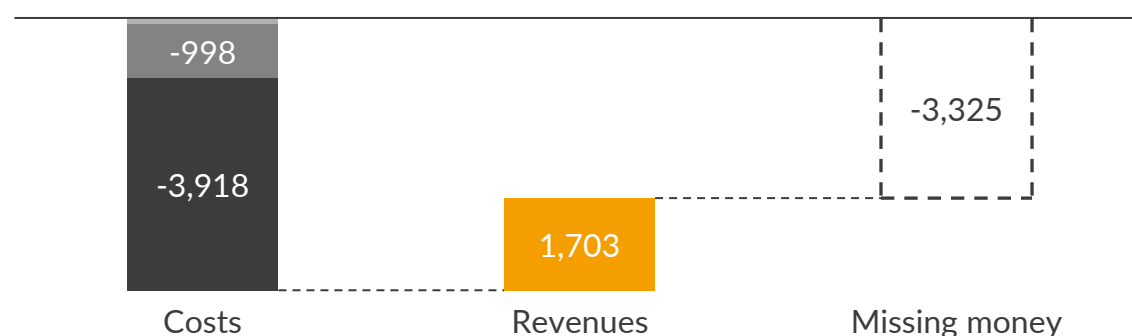
PLN/kW, real 2021



2 Wholesale arbitrage for a 4-hour battery, 1 cycle per day, entering in 2025

Present value of cashflows¹

PLN/kW, real 2021



■ CAPEX ■ FOM ■ Grid costs ■ WM revenues² □ Missing money

NPV by battery duration, entry year and number of cycles per day
PLN/kW, real 2021

Year of entry	2-hour battery			4-hour battery	
	1 cycle	1.5 cycles	2 cycles	1 cycle	1.5 cycles
2025	1 - 2,469	-2,494	-2,649	2 -3,325	-3,483
2027	- 2,359	-2,391	-2,532	-3,126	-3,302
2030	-2,239	-2,291	-2,434	-2,921	-3,135

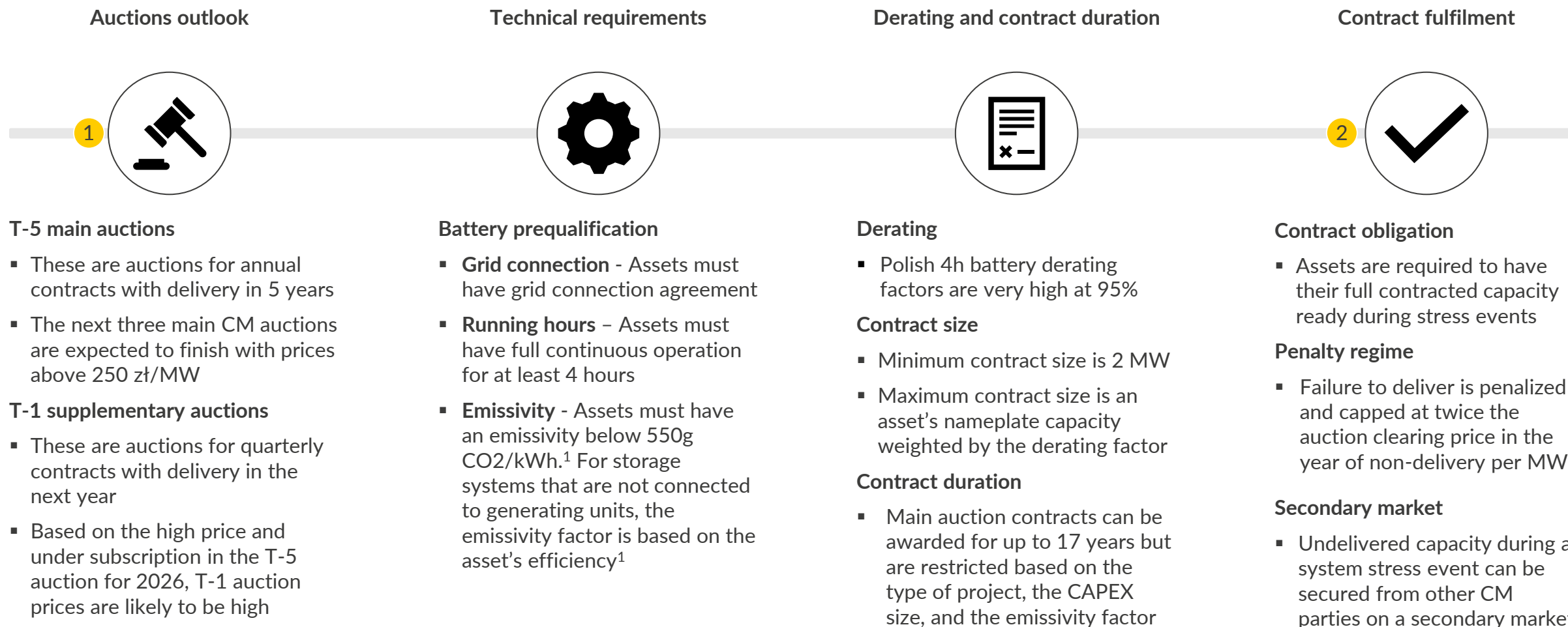
■ NPV < -3000 ■ -3000 ≤ NPV < -2500 ■ -2500 ≤ NPV

1) All revenues and costs discounted at 9%; 2) Wholesale market revenues included costs of arbitrage, efficiency loss, degradation and imperfect foresight

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Batteries can participate in both supplementary and main CM auctions, securing even over 19 years of additional support

 Deep dive on next slide



1) The 2027 auction will require a single cycle efficiency of at least 55.9% for batteries

1 A rapid coal exit in the mid 2020s will ensure high demand for capacity in Poland through the CM

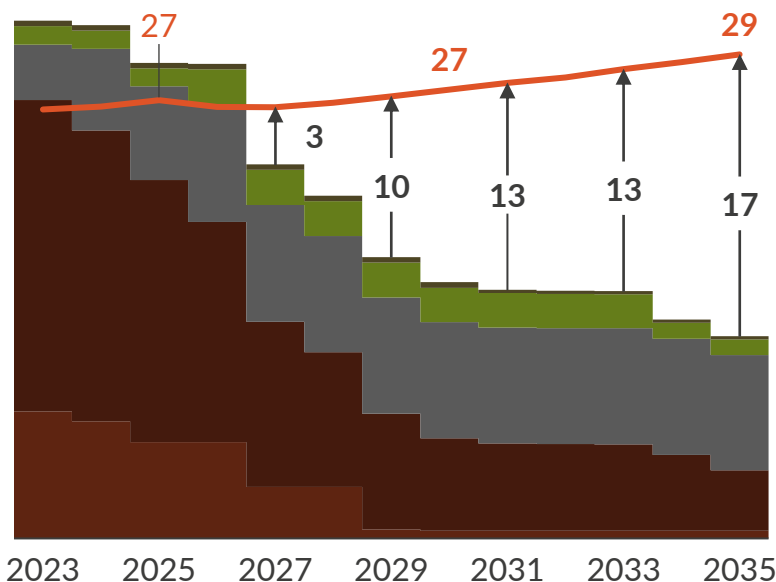
Expected evolution of security of supply requirements in Poland

1 With a rapid coal exit from 2026, driven by its exclusion from the Capacity Market (CM), Poland faces a large capacity gap in peak demand periods

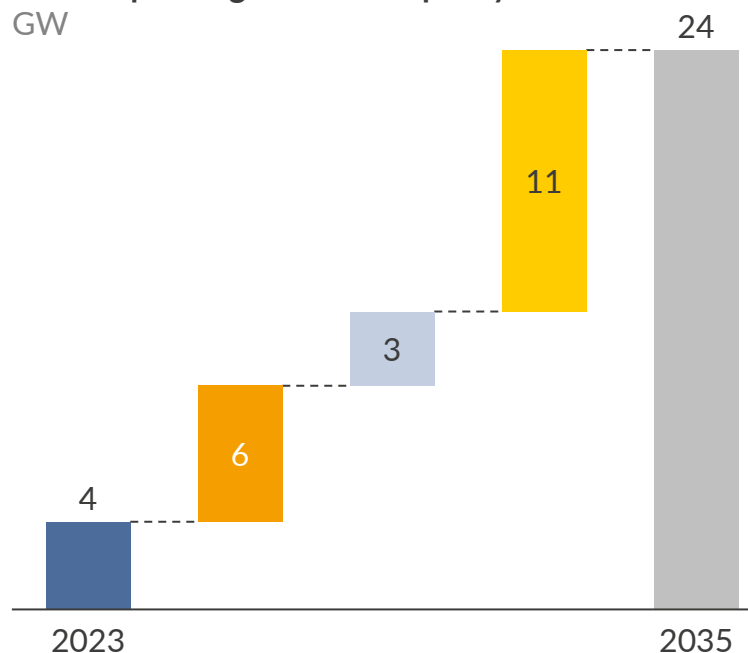
2 In order to ensure security of supply, the CM will need to secure at least 17 GW of additional flex capacity, with gas as the main contender

3 High demand for capacity on the CM is likely to keep prices above 250 zł/kW/year for the next three auctions

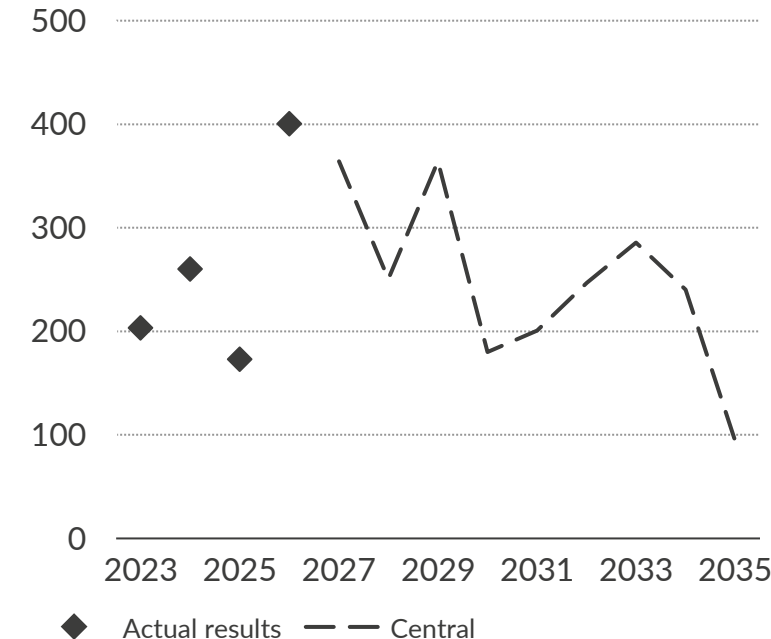
Total installed capacities and peak residual demand¹ GW



Flexible power generation capacity GW



Capacity market clearing price PLN/kW/year (real 2021)



1) Demand not covered by renewable generation between 7am and 7 pm excluding weekends

Together with capacity payments, wholesale arbitrage can make a viable battery business case in Poland

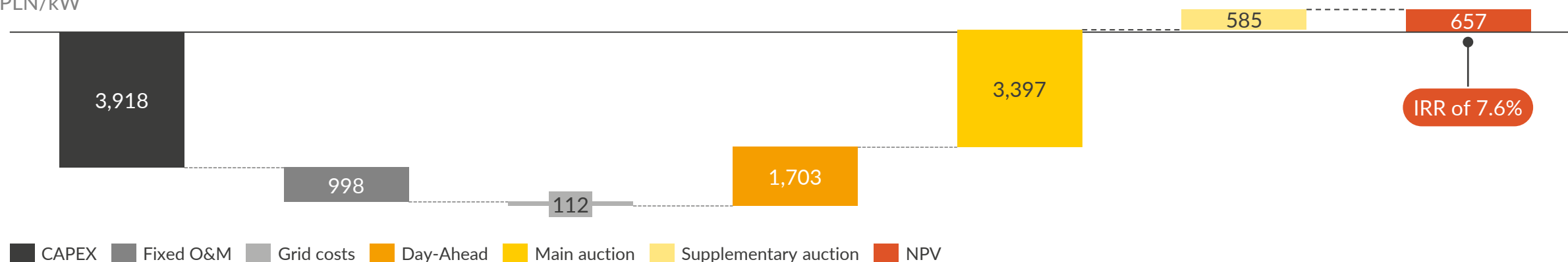
1 Assuming activity in wholesale markets and the capacity market...

Battery parameter	▪ 4h duration, 20 year lifetime and targeting 1 cycle/day
Entry year	▪ 2025
Successful wholesale market participation	▪ Battery participates in wholesale market with all of its capacity and is awarded a bid in 2926 hours of the year in 2025
Successful Capacity Market participation	▪ Battery wins a 17-year main CM contract for 2027 with a price of 364 PLN/kW/year ▪ Battery also wins supplementary CM contracts for delivery in 2025 and 2026 at 333 and 345 PLN/kW, respectively

2 ... arbitrage paired with CM payments make a strong battery business case

- If batteries can only participate in wholesale markets, they use their cycles to make profit on the Day-Ahead
- Even though the battery can fully concentrate on doing arbitrage, the volatility on wholesale markets alone is not high enough to make a strong business case, considering the imperfect foresight of the batteries
- However, capacity payments, primarily from the main auction contract, add the largest bulk of battery earnings in Poland
- Therefore, the full expected revenues are higher than the costs, making the battery's NPV positive with a value of 657 PLN/kW and an IRR² of 7.6%

NPV¹ for Polish battery resulting from wholesale and capacity market participation
PLN/kW

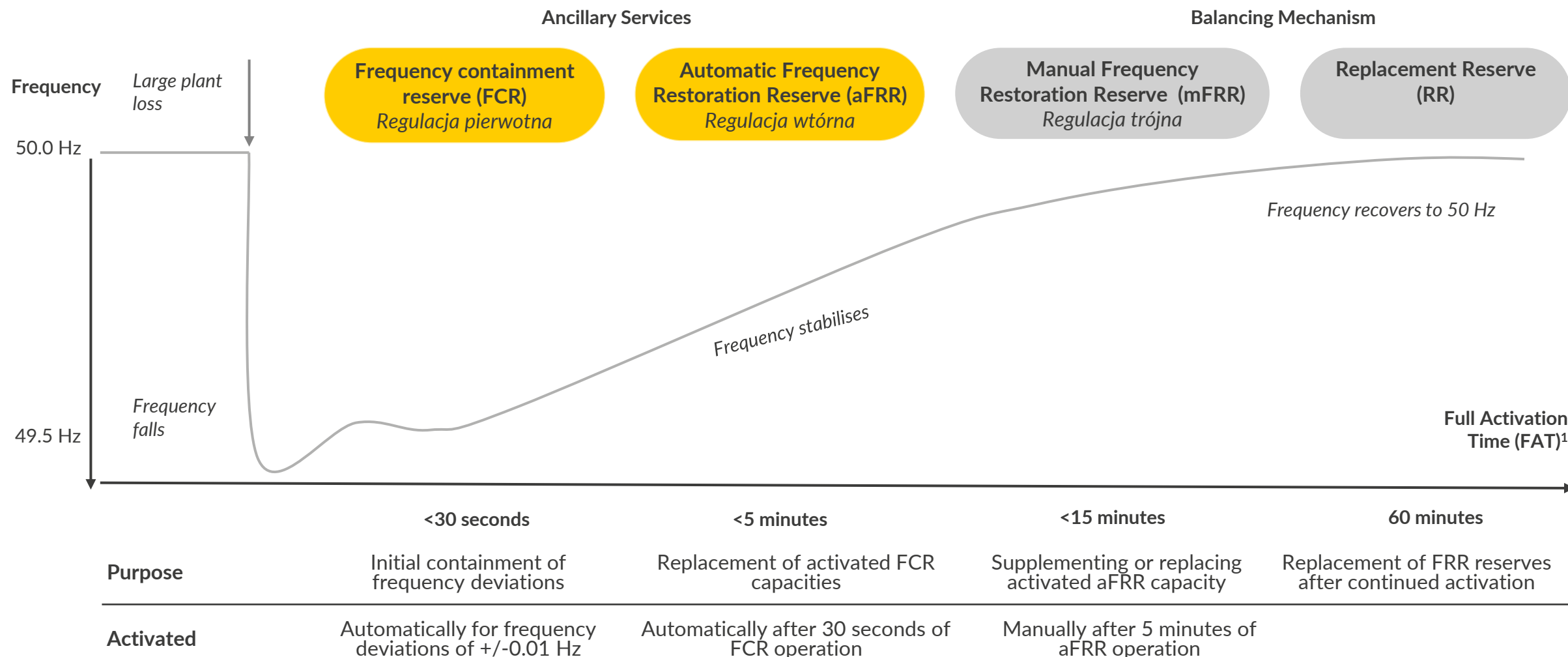


1) Net Present Value, assuming a 9% real hurdle rate for everything apart from the main CM auction which has an assumed 6% hurdle rate; 2) Real, pre-tax Internal Rate of Return

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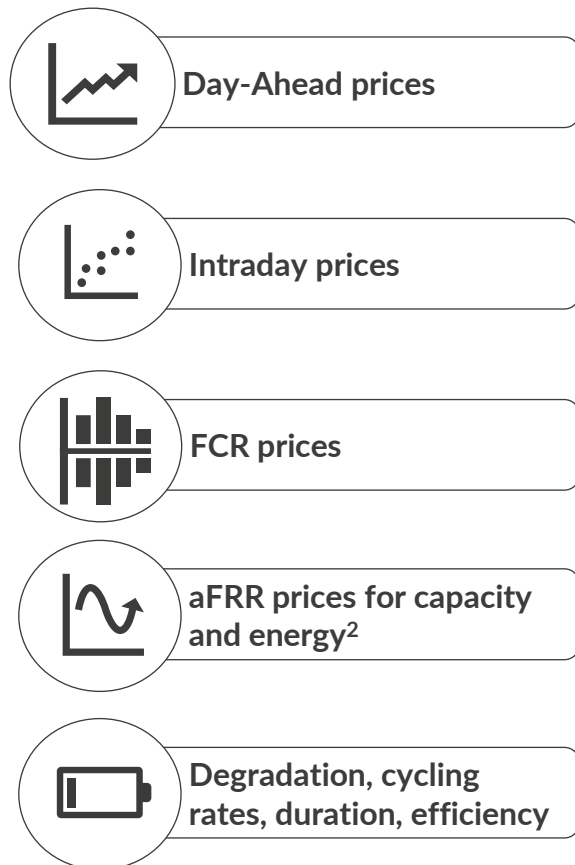
A full suite of liberalised frequency response markets will be introduced by PSE in H1 2023 to balance deviations between production and demand



1) Full Activation Time is defined as the maximum allowed duration for the full activation or deactivation of an energy bid

Battery trading strategies seek to optimise between the available markets; this is simulated by our imperfect foresight dispatch model

Flexibility markets and battery parameters¹



Imperfect foresight battery dispatch model

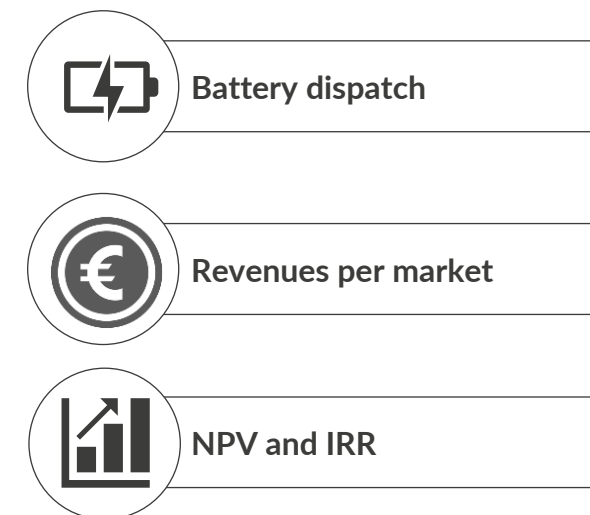
1 Optimisation process for day-ahead markets

- Optimisation of markets that take place day-ahead (Day-Ahead and FCR markets)
- We assume perfect foresight of one day
- The model solves for actions in these markets simultaneously

2 Dispatch based on real-time knowledge

- Batteries have limited foresight into Intraday prices (until next committed Day-Ahead trade)³
- Battery gains insight into aFRR energy markets in real time
- Based on results of stage 1, battery charges or discharges if within-day market prices are more attractive than planned actions
- Model accounts for upcoming commitments and applies penalties for missed actions

Results



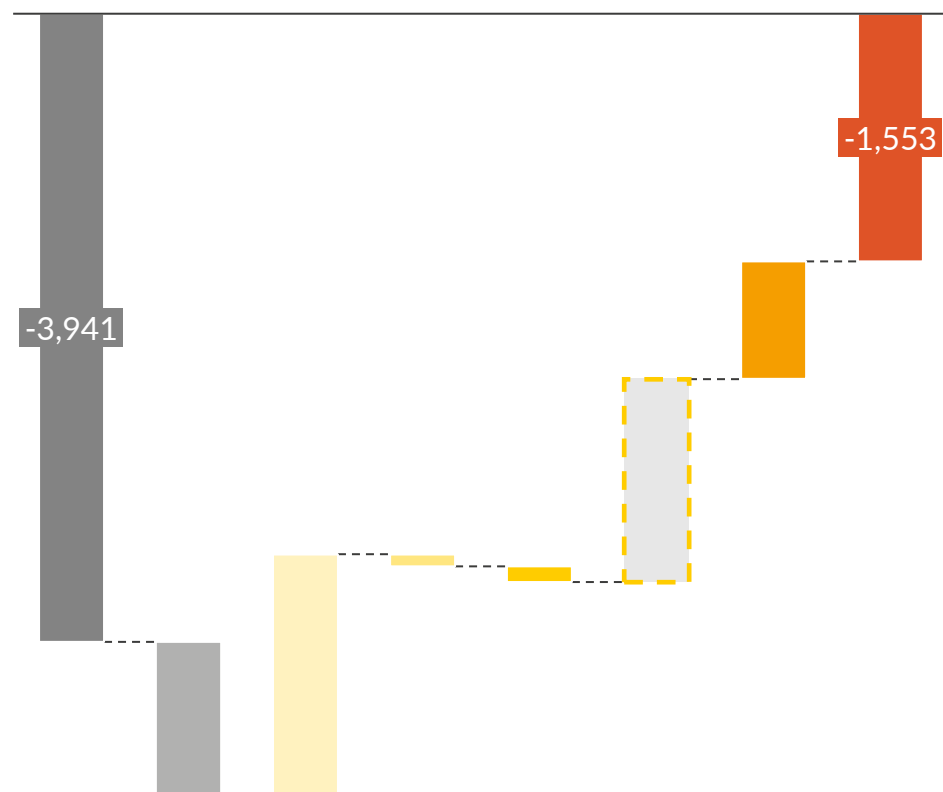
Improve your business strategy with our flexibility market offerings. For more information, please contact **Anna Donczew-Salawa**, Senior Commercial Associate – Central Europe

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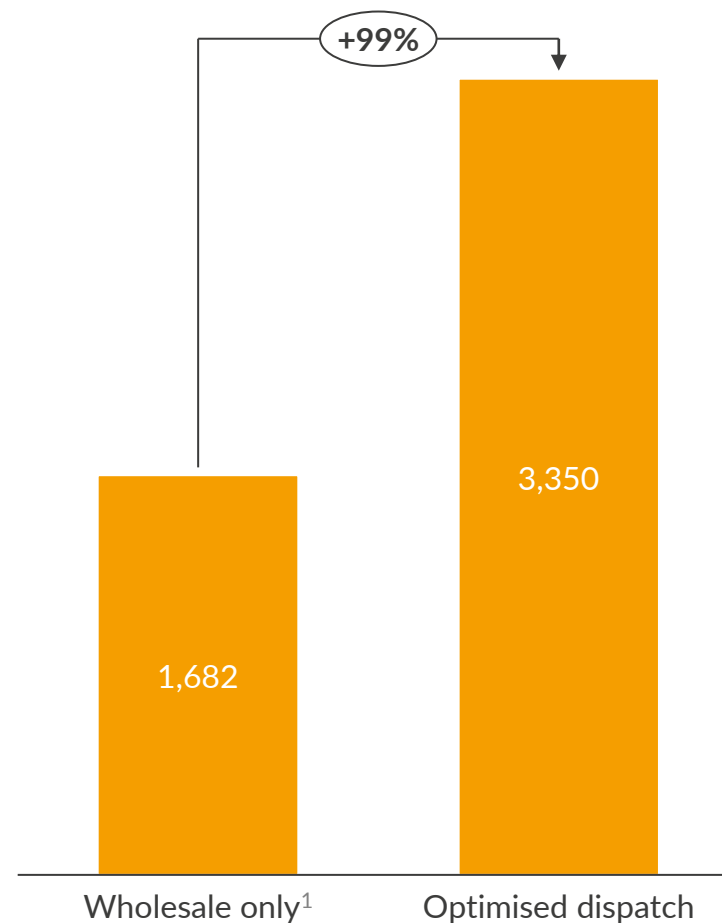
1) Preliminary, all prices have hourly time granularity; 2) aFRR capacity markets are not yet included; 3) Limited Intraday forecast based on the assumption that battery needs to optimise state of charge with regard to upcoming committed trades, i.e. in the Day-Ahead market.

Optimal dispatch doubles the Present Value of 4-hour battery revenues in Germany compared to DAM arbitrage

Economics for new-build 4-hour German battery entering in 2025
Net Present Value¹ PLN/kW (real 2021)



Revenue of 4-hour German battery entering in 2025
Present Value¹ PLN/kW (real 2021)



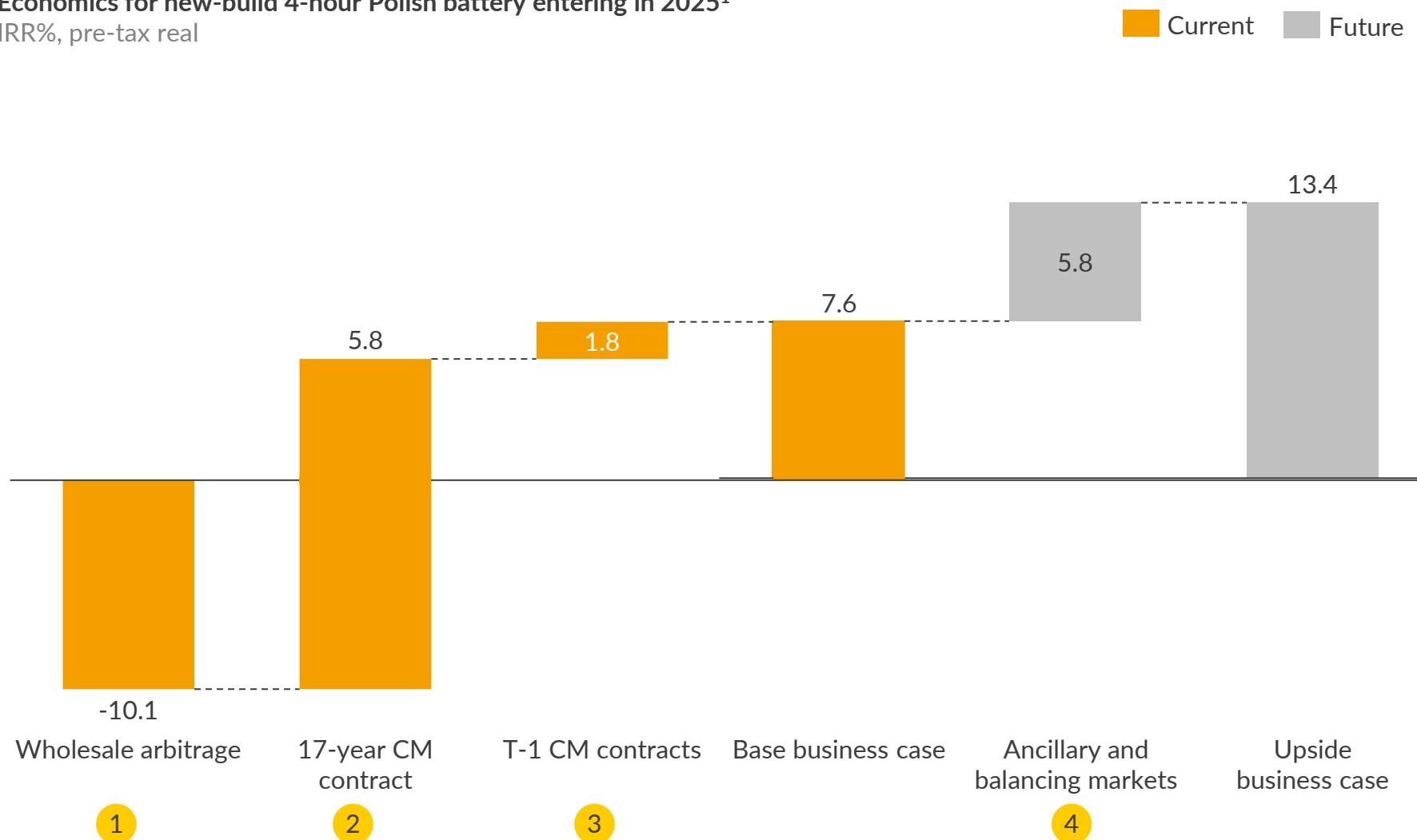
- An optimally dispatching battery will split its time between energy trades in the DAM, Intraday and aFRR and participation in frequency control capacity markets
- Capacity payments for aFRR and FCR are a key revenue stream and allow lower cycling
- aFRR is especially beneficial as it allows simultaneous trading on the aFRR energy market
- While an optimally dispatched 4-hour battery in Germany still can't reach a 9% hurdle rate, it sees a Present Value on revenues which is 99% higher than that of a battery dispatching only in the DAM
- Batteries in Germany don't benefit from Capacity Market contracts

■ CAPEX ■ Fixed O&M ■ Day-Ahead arbitrage ■ Intraday arbitrage ■ aFRR energy ■ aFRR capacity ■ FCR ■ NPV ■ CM

1) Assumed discount rate of 9% for all cash flows and a lifetime of 15 years or 8,500 cycles; 2) Dispatch in day-ahead market only

A similar upside from dispatch optimisation in Poland would mean 4-hour batteries achieving IRRs of 13%

Economics for new-build 4-hour Polish battery entering in 2025¹
IRR%, pre-tax real



- 1 A 4-hour battery sees 91% of the Present Value from DAM arbitrage revenues compared to the German market, but this results in negative returns
- 2 High prices and 17 year CM contracts improve revenue, but investment milestones require an early capital commitment which reduces IRRs
- 3 Securing quarterly T-1 CM revenues before long-term contracts start brings the project IRR above an average investor's hurdle rate
- 4 A revenue upside from dispatch optimisation in line with that seen in Germany would mean a 58% increase in IRR. Market volatilities are correlated and frequency market fundamentals are strong, indicating a similar upside is available in Poland

1) Lifetime of 20 years.

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Key take-aways

- 1** Rising renewable penetration and volatile prices provide good opportunities for battery arbitrage in the wholesale market. Depending on battery duration, spreads will remain around **200-250 PLN/MWh** and the **optimal number of daily cycles will be between 1 and 1.5**
- 2** The Capacity Market provides a significant boost to the economics of battery projects. **4-hour batteries** can secure **up to 19 years** of capacity contracts in the main and supplementary auctions, with high derating factors and prices consistently **above 250 PLN/kW/year**
- 3** The base business case of 4h battery entering market in **2025** and stacking capacity market and wholesale arbitrages revenues proves to be economically feasible with an **IRR of 7.6 %**
- 4** Balancing market reform will be introduced in 2023 and **liberalise Polish ancillary services**. The structure of the markets will be in line with those across western Europe, indicating that they should provide strong upside opportunities for batteries
- 5** New ancillary service markets will bring additional complexity and enable the optimisation of battery dispatch decisions. Indicative benchmarking to the German market suggests this could bring a **two-fold increase** in battery revenues and **boost IRRs to over 13%**

Access detailed power market analysis and investment case data for batteries with our Polish **Flexible Energy Market Service**

Flexible Energy Market Service

Forecast Reports & Data



Technology and Market Development Reports

- Overview of regulatory framework for batteries
- Revenue stacking models for batteries
- Projections for battery CAPEX and OPEX by delivery year
- Reports and datasets follow the same format with content tailored to specific markets



Forecast Data

- Central case forecast prices provided at hourly granularity until 2050:
 - Wholesale power prices
 - Balancing market prices
 - Capacity market prices
 - FCR and aFRR market prices

Investment Cases



Standalone battery

- Multiple investment cases per country or zone including:
 - Arbitrage of wholesale market and balancing market
 - Focused participation in frequency control market (if applicable)
- Annual project margins to 2050; IRR and NPV for multiple entry years

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