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Flexible trading of renewables - A Dutch case study

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The rapid transition of European power systems is putting pressure on the revenues of renewable energy generators. The growing penetration of solar and wind generation has led to frequent periods with low electricity prices and a rising occurrence of negative prices in recent years. As the installed renewable capacity continues to expand across markets, price cannibalisation is expected to intensify. This will reduce the revenue and profitability of existing generators, especially during periods of high renewable energy generation. It will also pose significant challenges for new renewable energy projects to secure stable revenue streams and to mobilise the necessary investments to meet Europe's climate goals.

Simultaneously, the integration of intermittent renewables is driving higher demand for ancillary services. In the Netherlands, the procured capacity for automated Frequency Response Restoration (aFRR) services has increased by over 50% since 2021. The need for frequency response services is often high during periods of high renewable generation due to the inherent variability of renewables and the displacement of conventional generation, which traditionally provided grid stability.

This study analyses how solar and wind assets in the Netherlands can participate in ancillary markets to diversify their revenue streams, enhance profitability, and contribute to grid stability. The Netherlands is a particularly relevant case study due to the rapid expansion of renewable generation in recent years, which has led to high price cannibalisation and one of the highest occurrences of negative price hours in Europe. We assess the extent to which the current Dutch market design enables renewables to participate in balancing markets and identify market design adaptations that would improve the flexibility of renewable energy sources. We quantify the additional revenues for renewables from participation in Dutch ancillary markets, and comment on how these developments can support the continued expansion of renewable energy in the country.

This study uses Aurora's fundamental power market models to develop a comprehensive assessment of the potential of renewables to participate on balancing markets. Over 10 years, Aurora has built and developed a dedicated electricity market model to assess specific market developments and provide detailed analysis to clients and the wider energy community. Written in Python and GAMS, Aurora's model forecasts both 'capacity expansion', i.e. build decisions for all technologies available, and 'dispatch', i.e. plant-level generation subject to asset and market level constraints. An iterative loop between capacity expansion and dispatch then leads to a consistent and cost-minimising forecast for the evolution of the entire European power system. Aurora's model has recently been extended to include the Intraday and balancing markets, allowing it to resolve imbalances arising from forecasting errors after the Day-Ahead market closes.

Specific for this study we developed a "Flexible RES"dispatch module to quantify with which volumes renewables can participate on the different markets and how much revenue they can make under different market designs. The module considers the Day-Ahead, Intraday, aFRR energy and capacity markets and reactive balancing. The dispatch optimization approach, which works at quarter-hourly granularity, integrates forecasted and historical market prices and generation profiles, bid success rates, market-specific constraints and gate closure times to determine the arbitrage opportunities between the different markets.

To evaluate revenue potential and system flexibility contributions, we establish two flexible trading strategies that optimize dispatch decisions across markets. Our analysis includes both a backward-looking assessment, using historical prices from the past three years, and a forward-looking projection extending to beyond 2030.

Can additional revenues from balancing markets compensate the impact of price cannibalisation for renewables? Our analysis shows that, historically, solar and wind assets had the potential to generate significant revenues from balancing markets. In 2023, optimising imbalance positions could have increased revenues for

solar and wind by up to 20%, while aFRR energy down could have offered 5-10% in additional revenues. The correlation between moments with high solar generation and high balancing prices, particularly for downward products, leads to a larger revenue increase for solar compared to wind. However, the actual participation of renewables has been limited, because of factors such as the duration of trading products on balancing markets and challenges in establishing a reliable baseline for flexibility.

Looking ahead, flexible dispatch strategies are expected to provide some additional revenue opportunities for solar and wind assets. We expect that solar and wind assets can make up to 6% additional revenues in 2025-2030. These earnings will not be sufficient to fully offset the impact of price cannibalisation. Despite this, we expect that revenue optimization strategies will become increasingly important for assets owners as renewable penetration increases.

Beyond 2030, we anticipate rising competition from batteries and other flexibility providers, which will likely suppress balancing market prices and reduce activation volumes. This will further limit the revenue potential for renewables. In this period, we expect the additional revenues to decrease to 1-3%.

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