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STRUCTURAL NON-LINEARITY AND NEGATIVE ELECTRICITY PRICES: AN OPERATIONAL RISK MANAGEMENT APPROACH FOR RENEWABLE ASSETS

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Extended Abstract

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Abstract Summary

This research addresses the shifting landscape of European electricity markets, where the rapid growth of intermittent renewable energy has made negative price episodes a structural reality. In 2024, the frequency of these episodes reached a historical peak, directly threatening the profitability of renewable assets governed by Power Purchase Agreements. To combat this uncertainty, the study introduces a predictive structural non-linear model based on a system stress variable that balances carbon-free supply against net demand. Unlike traditional black-box machine learning approaches, this method offers economic interpretability by identifying specific thresholds where market flexibility reaches saturation and negative price regimes take over.

The model is validated through an operational simulation on thirteen wind farms, where it successfully identifies critical stress thresholds, including a primary point at 2,677 MWh. While the model exhibits a conservative bias by predicting a higher frequency of negative prices than what has actually occurred, this functions as a valuable safety margin for risk-averse operators. The primary economic finding is that this non-linear approach generates a positive net monetary gain across the entire portfolio of sites, whereas traditional models often fail to trigger timely curtailment actions.

The study concludes that understanding structural non-linearity is more important for operational success than simple average forecast accuracy. These findings provide a quantitative foundation for calibrating grid flexibility and refining investment signals for long-duration storage. By integrating these predictive signals into future contracts, operators can mitigate the "cannibalization effect" and turn negative price risks into strategic opportunities for charging storage units, ultimately securing the long-term financing of the energy transition.

Presenting Author Biography

Marc Baudry serves as Professor of Economics at the University of Paris-Nanterre (France), where he is also Deputy Director of the Faculty of Economics, Management, Mathematics, and Computer Sciences. He is also a Senior Research Fellow at the EconomiX research center and heads the 'CO2 price and low carbon innovation' program at the Climate Economics Chair. Internationally, he teaches 'EU climate change economics and policy' as a Visiting Professor at the College of Europe (Belgium), with further invited professorships at Radom University (Poland) and Heilongjiang University (China). His research focuses on environmental economics and the economics of innovation.