# *MARKET DESIGNS FOR HIGH SHARES OF RENEWABLE ENERGY IN THE UK*

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## Overview

The world has embarked upon a major energy transition to tackle climate change, which will change the ways electricity is generated, distributed, and consumed. Renewable energy is at the core of this transition, powered by decreasing costs and technology progress. However, the energy transition needs to happen faster to reach the climate goals. The electricity sector will continue to bear the significant share of the economy decarbonization, which will in turn require even higher shares of renewable energy, use of interconnection, hydro resources, and new battery technologies.

The United Kingdom (UK) as well as Europe, in general, have made remarkable progress in creating liberalized and competitive wholesale markets (Newbery et al., 2018). Beginning in the 90s, the liberalization process was complemented by large-scale private investment in conventional power generation and an hourly price market for matching supply and demand, leading to an increase in generation investment in some countries. However, the development of renewable energy, with high upfront investment and low short-run costs, reduced the market role in inducing investment. Current policies give privilege to subsidies and capacity mechanisms to support new investment and meet reliability standards. Generous subsidies and priority to dispatch allowed the UK to increase remarkably the share of renewables in the electricity production to 40% in 2022 (Jaynes, 2023).

Accelerating the energy transition requires a rethinking of the current market design in many aspects, where the support of higher shares of renewable energy and backup capacity is fundamental (IRENA, 2017; Newbery et al., 2018; Strielkowski (Ed.), 2020). In this paper, we review the international experience with electricity market design and support policies. Given the international experience in this matter, our aim is to present a market design and policy support package that allows the UK to meet its 2040 investment targets in an efficient manner and is robust against future increases in the level of renewable generation capacity.

## Methods

In our analysis, we employ the electricity market model EuroMod. EuroMod is a bottom-up model of the European interconnected power system, covering 27 countries. It minimizes total system costs with respect to dispatch, storage, and interconnectors. For each hour of the year, demand and supply of electricity is matched and a clearing price is determined. Individual generation and storage technologies are explicitly modelled. Demand fluctuates exogenously and it is perfectly price-inelastic. The model is subject to a set of technical constraints related to demand and supply balance, combined heat and power, cycling of thermal plants, and operational constraints on hydro. Trading between bidding zones or countries is subject to net transfer capacity, and it takes place until arbitrage possibilities are exploited or capacity constraints become binding. Unit commitment of individual power stations and optimal load flow are not modelled.

Markets are not assumed to be competitive by proposing two enhancements to the total system cost function:

1. to allow generators to bid or to sell electricity at prices which deviate from their marginal cost, and
2. to apply a linear transformation on the resulting modelled prices so that they better reflect the volatility of prices seen in real power markets.

The resulting market-clearing price resembles the equilibrium price on European wholesale electricity markets (Mendes et al., 2022).

Our goals are to:

1. Review international experience with electricity market design and support policy.
2. Use EuroMod to model efficient prices for energy and assess a range of future market and support policy designs such as: contract for differences (CFDs), premiums, capacity markets and negative bidding designs.
3. Select and promote a market design and support mechanism that offers the best prospects for cost-effective decarbonisation of the UK power sector.

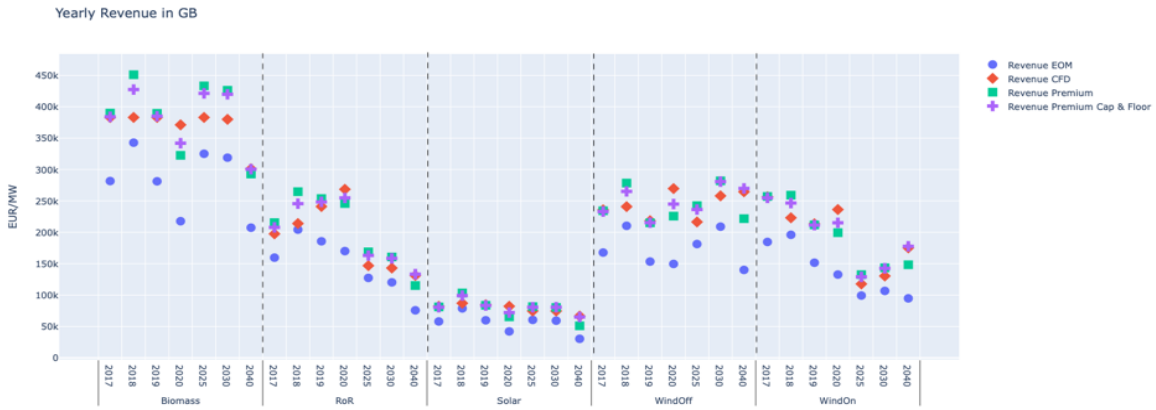


Figure 1: Yearly Revenues in GB by support scheme in EUR/MW

## Results

This is a work-in-progress and the results presented here are still preliminary. We are currently in an advanced modelling stage and the results are expected to be finalised beginning of May and will be therefore included in the paper draft submitted to the IAEE Milan conference. Figure 1 presents the revenues of four technologies in the UK (biomass, run-of-river, solar, wind onshore and wind offshore), considering different renewable support schemes (CFDs, premium, and premium with cap and floor) and comparing them to the energy-only-market (EOM). Preliminary results show that, while premium is the support scheme that provides higher revenues to renewable energy in the future, EOM shows the lowest revenues, as expected. In years with lower prices, either due to higher RES generation or lower demand (e.g., 2020 and 2040), CFDs and premiums with cap and floor are the support schemes that bring more revenues to renewable generators, leading to a total system cost of 0.95 Mio EUR/MW for premium with cap and floor, followed by CFDs with a total cost of 0.94 Mio EUR/MW. Premium is the support scheme that brings less burden to the electricity system in years with higher renewable generation with a total system cost of 0.83 Mio EUR/MW. As indicated in the methods section, we expect to simulate more support schemes such as CFDs with cap, capacity mechanisms for conventional technologies, and negative bidding. This analysis will highlight market designs that help the UK to meet their decarbonization targets in an efficient and robust way against the risks associated with increasing shares of renewable generation.

## Conclusions

The rise of renewable generation under the current market design brings several problems that can be traced back to issues of "missing money" and "missing markets". Various support mechanisms used to bring investment in generation capacity have been applied in different countries over the years with different results. Our objective is to explore different market designs and determine the market design and policy support package that allows the UK to meet its 2040 investment targets efficiently and considering the future role of renewable energy in the electricity market. To reach this goal we apply the EuroMod model to several future market designs. The model new features make it a suitable tool for exploring the impacts of price volatility and price spreads in the market. This is of relevance as an inadequate representation of electricity price volatility in current models can lead to an underestimation of the revenue available to renewable and storage technologies, and thus the optimal amount of investment in them. The model framework allows us to investigate the importance of price variation on arbitrage earnings and price cannibalisation of different technologies, providing better market signals regarding future revenues to support investment decision on key technologies to support the current energy transition.

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