Offshore Market Design in Integrated Energy systems: A Case Study on the North Sea Region towards 2050

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Offshore wind can have an important role to achieve a cost-effective energy transition in Europe. Part of the offshore wind power development is likely to take place as part of integrated offshore grids. Considering the vast potential of offshore wind in the North Sea, it is important to investigate the influence that offshore grids can have on the energy markets (not only the electricity one), and how different market designs influence such impact.

We try to gain insight into the influence of different offshore electricity market designs, especially zonal configurations, on the operation of day-ahead markets in integrated energy systems towards 2050, and quantify the costs of the required congestion management. Three offshore market designs are investigated: Offshore Nodal Pricing (ONP), Offshore Zonal Pricing (OZP), and No Offshore Pricing (NoOP). The influence of the overall development of the offshore grids on these previous aspects is also analysed by creating two scenarios with very different offshore hydrogen generation volumes. We do this through an advanced optimisation process using the open-source energy system model Balmorel.

Overall, we find the impact of different market designs is highly dependent on the overall configuration of the offshore grid, as well as the availability of hydrogen generation. Higher flexibility in offshore grids and in the rest of the system might reduce the spread between the designs and thus help mitigate implications of suboptimisation.

Because of ignoring parts of the electricity grid and having larger market assets/liquidity, OZP and NoOP designs generally lead to cheaper electricity prices in day-ahead markets compared to the offshore nodal pricing design. Ignoring part of the electricity grid and possible bottlenecks leads to a reduction in congestion rent when using alternative market designs to ONP that ranges from 14-33%.

Despite leading to more expensive day-ahead prices, the most cost-effective market design is still found to be ONP, which results in, compared to alternative market designs, final operational cost savings of 0.2-1.6 bEUR/year and CO_2 emission reduction of 0.6-5.6 Mton/year. OZP and NoOP lead to higher costs and emissions because of the additional cost and emissions incurred in the energy system linked to congestion management. The congestion management costs of alternative market designs to ONP range from 0.6-2.6 bEUR/year.

The results highlight that when designing offshore markets in integrated energy systems, it is key to identify the hub-connected interconnectors that are likely to experience high congestion, so they are accounted for in day-ahead markets.

Our results confirm that nodal pricing in offshore grids is preferable over price zones or no offshore pricing at all. Choosing this market configuration can thus contribute to pave the way for a cost-effective energy transition to carbon neutrality in Europe in 2050.

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