EXPECTED IMPACTS ON THE PAN-EUROPEAN DAY AHEAD POWER MARKET IN THE YEAR 2040 DUE TO THE INTRODUCTION OF LARGE-SCALE OFFSHORE WIND FARMS [1]

Matthias OBERMAIR[1], Gustav RESCH[2]

Introduction

To reach the goals set by the European Union with regard to renewable energy expansion and climate neutrality, the market uptake of offshore wind farms is an essential component. This means including large-scale units with volatile production curves in the European power grid and market. Major implications on the current system are expected. This article investigates the impact of the ambitious large-scale offshore wind energy expansion plans, and thus decentralized feed-in of large amounts of energy, on the European electricity market and transmission grid by simulating future scenarios for the year 2040. The growth of other renewable energy sources, namely onshore wind, photovoltaic, and hydro, is considered as well.

Key objectives and research questions

The investigated topics are:

- Research and overview of expansion plans in the area of offshore wind farms. This includes research into whether and which studies have already been carried out on this topic.
- A comparison with fundamental simulations, which are carried out by Transmission System Operators (TSOs) with other tools, is done [2]. Those, in contrast to the planned market simulations, usually have a pure grid focus.
- The existing European grid topology is extended by the planned offshore wind farms. This is used to carry out various market simulations regarding production profiles, installed capacity, and changed grid capacities. For offshore wind farm production profiles, different climate models will be considered. As an additional factor, the demand for electricity is modified considering planned electrification and flexibility.
- Based on the simulation results, possible accompanying measures to get these selective energy feed-ins under control are suggested. Among those are facilitating grid expansion, flexibility provision, and the expansion of large-scale storage units.

Method

In total four different scenarios are simulated for the whole year 2040 based on original market and grid capacity data from the base year 2024. Using the original Day Ahead Market Coupling Algorithm EUPHEMIA [3] and historical market data as a basis, they are developed based on the National Trends+ and Distributed Energy Scenarios from ENTSO-E's Ten Year Network Development Plan (TYNDP) [4] and climate models SSP2-4.5 and SSP5-8.5 [5]. For all additionally assumed energy infeed the study introduces offshore bidding zones and models their integration into the European grid topology. EUPHEMIA aims to optimize social economic welfare throughout the EU plus Norway. To achieve this goal, implicit auctions are conducted.

Results

The results show significant regional disparities in market clearing prices, with Central Northern European countries experiencing negative prices due to oversupply, while prices in remote regions like Ireland and Greece remain at a higher level (see Chart 1).

[1] Austrian Power Grid AG, Wagramerstraße 19, 1220 Wien, matthias.obermair@apg.at
[2] Austrian Institute of Technology, Giefinggasse 6, 1210 Vienna, gustav.resch@ait.ac.at

While this general trend is confirmed over all scenarios, within the scenarios the extent of negative prices and the roles of the countries transform. Thus, for example within the scenarios using projections from the Distributed Energy scenario, France is the main exporter of Europe, with Germany importing energy. On the other hand, for the National Trend+ based scenarios, Germany becomes the largest energy exporter of the region. In general, while the choice of climate model does not show big differences for the TYNDP scenarios, the indication is given that choosing a coordinated transition at the European level, as in the Distributed Energy scenario, results in more sustainable prices for the whole continent.

If the challenges accompanying the expansion of offshore wind farms in relation to the electricity market are not addressed, this will also have a significant impact on the pricing in the offshore bidding zones and thus on the revenues of asset owners. This could lead to a reluctance to make the urgently needed investments in the expansion of renewable energies.

These disparities underscore the importance of coordinated grid expansion and reinforcement as well as the deployment of large-scale storage systems, such as offshore hydrogen projects, to balance supply and demand on a European scale. This will allow to mitigate price volatility and ensure equitable access to renewable energy throughout Europe. Furthermore, the introduction of offshore bidding zones has been shown to be an effective mechanism for integrating offshore wind energy into the market.

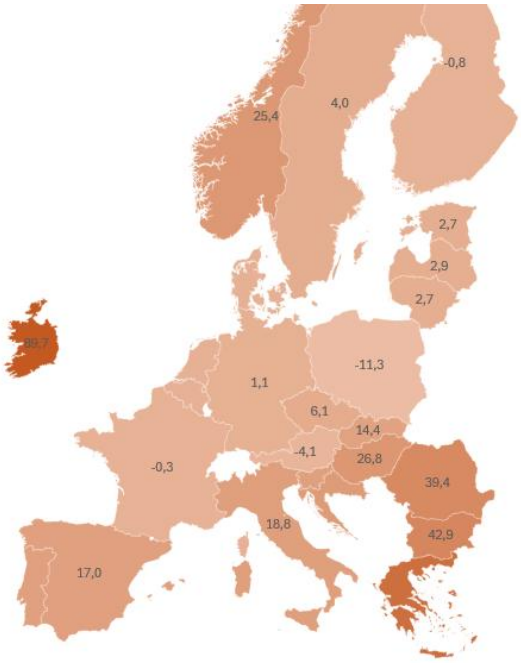

Chart 1: Illustration of the mean value of the MCP [e] for each country in the year 2040 according to the Distributed Energy combined with the SSP2-4.5 climate model for offshore wind energy production rates scenario.

References

[1] Matthias Obermair: Expected impacts on the pan-European Day Ahead power market in the year 2040 due to the introduction of large-scale offshore wind farms, Master Thesis, Wien 2025.

[2] ENTSO-E: Ten-year network development plan (TYNDP), https://www.entsoe.eu/outlooks/tyndp/2024, 2025 (Accessed: 15.07.2025).

[3] PCR NEMOs: Euphemia public description: PCR market coupling algorithm. Technical report, Price Coupling of Regions (PCR), August 2024 (Accessed: 27.07.2025).

[4] ENTSO-E and ENTSOG: Ten-year network development plan 2024 scenarios. https://2024.entsos-tyndp-scenarios.eu, 2024 (Accessed: 18.07.2025).

[5] Copernicus Climate Change Service (C3S). Climate and energy related variables from the pan-European climate database (PECD). https://cds.climate.copernicus.eu/datasets/sis-energy-pecd, 2024 (Accessed: 15.07.2025).