[*COMPARATIVE ANALYSIS OF THE ELECTRICITY PRICES IN FRANCE, ITALY AND GERMANY, 2015-2024*]

[Charron Kallia, EDF Lab Saclay, +33601858546, kallia.charron@edf.fr]
[Girard Alexandre, EDF Lab Chatou, , alexandre.girard@edf.fr]
[Florea Alina Alexandra, EDF Lab Saclay, +33666024775, alina-alexandra.florea@edf.fr]

Overview

The countries of the European Union share the goal of reaching carbon neutrality for 2050, set out in the European Green Deal in 2019 and written into the European Climate Law (Fit for 55 Package) in 2023 [1].The Fit for 55 law package also includes the revised Renewable Energy Directive (REDII), which sets a minimum 42.5% of renewable energy sources in the energy mix by 2030 [2]. Yet, considering the dissimilar initial energy mixes and local constraints, the energy transition and its transcription into the national laws take on various shapes depending on the country. This paper focuses on three neighbouring and interconnected countries, displaying very contrasted energy mixes [3]: France, Germany and Italy.
Those policy trends combined with other conjunctural parameters – geopolitics, climate-related incidents and others –, lead to contrasted and at times volatile electricity prices. Indeed, the observed prices in Italy over the past two years (2023-2024) are in average 55% higher than in France (117.75 €/MWh compared to 76.06 €/MWh) and 38% than in Germany (85.67 €/MWh) [3]. In addition, both Germany and France have seen an increase in null and negative prices in recent years, representing up to 5.8% of the hourly day-ahead prices in Germany in 2024 (3.7% in 2023) and 6.2% in France (2.1% in 2023). Germany day-ahead electricity prices also presents a much higher standard deviation (46.97 €/MWh in 2023-2024) than those in Italy (32.78 €/MWh) and France (40.93 €/MWh) [3].
This paper proposes an analysis of exogenous conditions under which the electricity prices in each country behave in a predictable manner, thus identifying price regimes. Investigation of electricity price regimes is used in the field of electricity price forecasting (EPF) for regime switching [9] or regime jumping models [7] [8]. Such models would often explain price regimes through the seasonality of the demand. Yet, with the increase of the share of renewable energy sources in the electricity mix, the renewable production has been shown to play an increasingly important role in determining price regimes [5] [6]. The observations in this paper confirm an evolution in this regard, the prices spectrum being much more similar to the demand spectrum at the beginning of the period (2015-2018) than in recent years (2023-2024).
This paper is structured in four sections. First, a review of the literature on the topic of electricity price signal analysis and price regimes in the field of electricity prices forecasting. The second section consists in a spectrum analysis of the day-ahead electricity price signal in the three countries for the time period 2015-2024. The third section focuses on a feature-based clustering analysis. The final section cross-examines the results in order to conclude on the evolution of the number and nature of electricity price regimes identified in each country.

Methods

This paper compares the results of two econometric approaches, a spectrum analysis and a feature-based clustering analysis. Both approaches were applied using the hourly electricity day-ahead prices and power load hourly data in each country from 2015 to 2024, retrieved from the ENTSOE Tansparency platform [3].

A preliminary intensity graphic representation showed strong daily patterns in both the prices and load, depending on the hour of the day. Therefore, we chose to decompose each time serie in 24 time series, each one giving the value for a chosen hour throughout the year.

The spectrum analysis consists in a spectrum decomposition using a Fast Fourier Transform (FFT). We chose to apply an FFT to the autocorrelation of the time-series for improved precision. The obtained spectrums provide insights on the evolution of the price and demand over the years for each hour of the day.

The feature-based cluster analysis was performed using the Euclidian distance between the electricity prices and the kmeans method. We build two to ten clusters for each year and country between 2015 and 2024 and for the 2-years time periods 2018-2019 and 2023-2024. Then we compared silhouette scores to determine the optimal number of clusters. This method was used to compare the obtained numbers between the countries and highlight evolutions.

Results

The spectrum analysis shows a clear recent evolution in the patterns of the electricity prices. At the beginning of the time period (2016-2017), the prices price and the load display similar spectrums and patterns. In recent years however, while the load remained fairly similar, new spikes appeared on the price spectrum. This is especially verified during the night hours, which may be due to wind production. Indeed, low prices and negative prices can occure at times of high wind production coïnciding with low night-time demand, and higher prices can also occure when the production is lower than anticipated.

The cluster analysis illustrates the contrasted situations between the three countries.

Conclusions

This paper provides insights on the electricity prices in three European countries and the evolution of their correlation with the load. It is meant to support the parametering of an electricity price forecasting model, such as a regime-switching model, and the interpretation of the results given by such an econometric model.

References

[1] European Commission, «European Climate Law,» 2024. [En ligne]. Available: https://climate.ec.europa.eu/eu-action/european-climate-law_en.

[2] *Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023,* 2023.

[3] European Commission - Eurostat, «Simplified energy balances,» 16 Décembre 2024.

[4] ENTSOE, «Energy prices,» 2025. [En ligne]. Available: https://newtransparency.entsoe.eu/market/energyPrices.

[5] C. Lagarde et F. Lantz, «How renewable production depresses electricity prices: Evidence from the German market,» *Energy Policy,* vol. 117, pp. 263-277, 2018.

[6] M. J. Maticka et T. S. Mahmoud, «Unlocking market secrets: Revealing wholesale electricity market price dynamics with a novel application of spectrum analysis,» *The Electricity Journal,* vol. 36, 2023.

[7] R. Weron, «Electricity price forecasting: A review of the state-of-the-art with a look into the future,» *International Journal of Forecasting,* vol. 30, pp. 1030-1081, 2014.

[8] R. Weron, M. Bierbrauer et S. Trück, «Modeling electricity prices: jump diffusion and regime switching,» *Physica A: Statistical Mechanics and its Applications,* vol. 336, n° %11-2, pp. 39-48, 2004.

[9] R. Huisman et R. Mahieu, «Regime jumps in electricity prices,» *Energy Economics,* vol. 25, p. 425–434, 2003.