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Electricity Price Analysis for Renewable Energy Dominated Electricity Markets under Extreme Scenarios

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Abstract

The COVID-19 pandemic, the energy crisis, the outbreak of the Russia-Ukraine war, and the rapid development of renewable energy electricity generation in European countries brought risks to electricity market operations, which are shown as high fluctuations in electricity prices. In order to explore the price risks of electricity markets in European countries, this paper studies the annual average electricity spot price and their fluctuations in each country, and compares them based on the renewable energy percentage of the country and inter-country power exchanges. It was found that under periods with extreme energy supply/consumption situations, a high proportion of hydropower generation may aggravate the price fluctuation of the electricity market. Meanwhile, electricity systems with high wind and solar generations are highly rely on natural gas, and hence be affected by gas/oil markets. Finally, cross-border electricity transactions might trigger electricity price fluctuations under extreme circumstances.

Keywords

Extreme scenarios, electricity market risk, electricity price fluctuation, high penetration renewable energy, cross-border electricity trading.

1. Introduction

Starting from the early 2020, the world and also electricity markets are affected by the COVID-19 pandemic. Subsequently, during the latter half of 2021, energy crisis occurred. The situation further aggravated in February 2022 with the start of the Russia-Ukraine conflict, leading to a substantial rise in natural gas prices. In part decades, to reduce carbon emissions and reach a low-carbon energy system, European nations are actively engaged in the development of different types of renewable energy electricity generation [1]. The intermittent and uncontrollable nature of renewable energy has brought challenges to the reliable operation of the power system [2].

Due to the extreme energy supply scenarios, pandemics, and high percentage renewable, European countries have experienced significant fluctuations in electricity prices. In 2020, due to the impact of the pandemic, social activities slowed down and electricity demand reduced, resulting in a sharp decline in electricity prices [3]. In the 2021 energy crisis, fuel costs rise, resulting in a sudden increase in electricity prices [4]. After the outbreak of the Russia-Ukraine war in 2022, Russia cut off natural gas supplies to the EU [5]. In this context, the situation has escalated. The electricity price was decreased until 2023.

With the extreme energy and social situations in recent years, it is obvious to observe the risk of the European electricity market. The electricity markets with high percentage intermittent renewables rely on fast-response gas turbines and hydropower to flatten the electricity price fluctuations [6]. How to enhance the reliability of the electricity market in the face of extreme scenarios has become a major challenge.

Before proposing relevant solutions to enhance market reliability, it is necessary to have a general reviewing of the risk tolerance of each country's electricity market under different extreme scenarios. Observing whether the increased proportion of renewable energy generation will elevate market risk.

This work studies the electricity price fluctuations in some countries with a high proportion of renewable energy generations to investigate their electricity market situations in recent years under various extreme scenarios. The data used in this paper is from 2018 to 2023, including Norway, Denmark, Sweden, Portugal, Spain, Finland, Germany and Ireland [7]. The contributions of the paper are mainly to interrelate the proportion of renewable energy generations

with the analysis of electricity market risk tolerance under extreme scenarios.

The paper is organized as the following. Section 2 presents the background information and literatures related to this work. Section 3 presents the recent electricity energy mixture and electricity price fluctuations in countries with high proportion of renewable energy generations. Their electricity markets are analysed by considering energy mixture, cross-border electricity trading and electricity price fluctuations, etc. Discussions about the analysis results are presented in Section 4. In the end, conclusions are drawn in Section 5.

2. Background and literature reviews

Recent literature focuses on the analysis of changes in national electricity supply and demand during the pandemic, as well as the analysis of the dependence of European electricity prices on natural gas price fluctuations during the energy crisis and the Russia-Ukraine war.

Ghiani et al. claimed that electricity consumption decreased by 37% and wholesale market price decreased by 30% in Italy during late March to early April in 2020 [8]. Gillingham et al. found that total electricity demand in the United States dropped by 10% compared with the same year between the second half of March and June 7 in 2020 [9]. Notably, the use of renewable energy has been outlined during the pandemic. Norouzi et al. found that the proportion of renewable energy electricity generation has increased through data analysis [10]. Bento et al. also compared the electricity price fluctuations, demand decreases, and energy mixture changes in the Iberian Peninsula with previous years to analyse the performance of the Spanish and Portuguese electricity markets during the pandemic [11].

Regard the energy crisis and Russia-Ukraine war, the impact on the electricity market mainly comes from the increase in natural gas prices. This is determined by the electricity market pricing mechanism. Natural gas units are relatively flexible and have high costs. The operating costs of natural gas units are often used as the uniform market price. The increase in natural gas prices has become the trigger for the surge in electricity prices in European countries, which is caused by the uniform price. Uribe et al. and Chuli´a et al demonstrated direct spillover effects between natural gas prices and electricity prices [6, 12]. They used quantile regression to process natural gas and electricity prices in European countries during the energy crisis and the Russia-Ukraine War. It proves that in times of distress, the spillovers is stronger.

Our study comprehensively analyses the sudden declines in electricity prices due to the reduction in demand caused by the pandemic and the raise in electricity prices because of the increase in energy prices caused by the energy crisis and war. By comparing the fluctuations of electricity prices, we correlate the energy mixture and cross-border electricity trading with the price fluctuations of the electricity market in the selected countries.

3. The interactions between price fluctuation, energy mixture and cross-border electricity trading

Data on electricity prices and energy mixture are obtained from the International Energy Organization (IEA) [7] for Norway, Denmark, Sweden, Portugal, Spain, Finland, Germany and Ireland from 2018 to 2023. What we discuss here are prices in the spot market, in order to better observe the price of the energy part and exclude costs such as transportation and taxes.

We present a summary of the electrical spot price (see Appendix Table A) [7]. Among them, the electricity price in 2020 is defined as being affected by COVID, the electricity price in 2021 is affected by the energy crisis, and the electricity price in 2022 is affected by the Russia-Ukraine war.

The average annual electricity spot price of each country in the past five years is used here. We compare the spot electricity prices of adjacent years in each country to obtain the annual electricity price fluctuations. We then observe the proportion of the difference in the electricity spot price of the previous year to obtain the percent changes. We obtain the annual electricity price fluctuations in each country from the data provided (see Appendix Table A) and calculate the percent changes. In this paper, the analysis is based on yearly data. Therefore, the difference between the average annual spot electricity prices in adjacent years and the size of the percent change are considered to determine the level of volatility of each country's electricity market in the current year. The level of market volatility is directly related to the risk tolerance of the market.

Price Fluctuations is specified as Eq. (1)

$$D_n = P_n - P_{n-1} \tag{1}$$

Percent Changes is specified as Eq. (2)

$$C_p = \frac{D_n}{P_{n-1}} \times 100\% \tag{2}$$

where P_n is the electricity spot price of current year, P_{n-1} is the electricity spot price of adjacent previous year.

Figure 1 shows the changes in electricity prices in the selected countries. The fluctuations on electricity price (2018-2023) over the past five years. Combined with the proportion of renewable energy, from left to right they are Norway (NO), Denmark (DK), Sweden (SE), Portugal (PT), Spain (ES), Finland (FI), Germany (DE) and Ireland (IE). From the perspective of total renewable energy electricity generation, there seems to be no direct connection with electricity price fluctuations. We will conduct the analysis on the proportion of hydro energy, wind energy and the fluctuations in electricity prices. Appendix Table 2 and Appendix Table 3 presents the proportion of hydropower and wind power generation in each country, respectively, in the past five years (because the energy mixture in 2023

has not yet been published, only data before 2022 is analysed here).

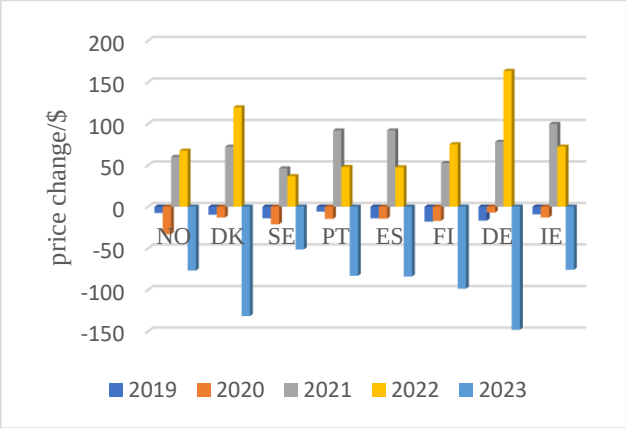

Figure 1. The fluctuations on electricity price (2018-2023)
Source: Illustration based on Appendix Table A

In 2018-2019, as a normal year, Table 1 and Table 2 shows electricity price fluctuations and percent changes in each country, respectively, and arranges them according to the proportion of hydropower and wind power generation in each country.

Table 1. Price fluctuations based on hydro power proportion (2018-2019)

Country	Hydro power proportion	Price Fluctuation	Percent Change
Norway	93%	-7.65	-15%
Sweden	36%	-9.63	-18%
Portugal	19%	-13.94	-21%
Finland	19%	-5.82	-11%
Spain	10%	-13.96	-21%
Germany	4%	-17.97	-30%
Ireland	4%	-16.76	-23%
Denmark	0.06%	-9.2	-17%

Source: The authors' calculations

Table 2. Price fluctuations based on wind power proportion (2018-2019)

Country	Wind power proportion	Price Fluctuation	Percent Change
Denmark	55%	-9.2	-17%
Ireland	32%	-16.76	-23%
Portugal	26%	-13.94	-21%
Germany	21%	-17.97	-30%
Spain	20%	-13.96	-21%
Sweden	11%	-9.63	-18%
Finland	9%	-5.82	-11%
Norway	4%	-7.65	-15%

Source: The authors' calculations

Figure 2 and Figure 3 shows the relationship of hydro energy percentage, wind energy percentage and the percent change of electricity prices in each country. It can be seen from the figure that in normal years, countries with a high proportion of hydropower, such as Norway, generally have smaller electricity price percent change which is at -15%. Countries with a high proportion of wind power, such as Ireland, have relatively high electricity price percent change which is at -23%. The most special country is Denmark. Denmark is mainly based on wind power generation, supplemented by other renewable energy sources and fossil fuel power generation. However, the percent change is only at -17%. Denmark imports a large amount of cheap hydropower from Norway every year, which smoothing the electricity price fluctuations. Zakeri et al.'s investigated the electricity markets in European countries which found that electricity prices in Denmark were determined by hydropower prices in Norway 62% of the time in 2019 [13].

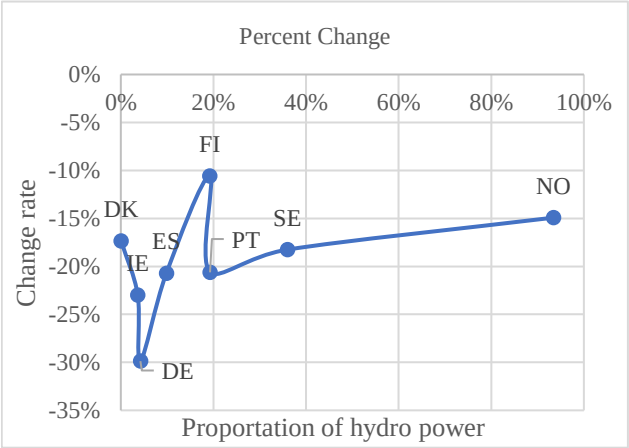

Figure 2. The fluctuations on electricity price (2018-2019)

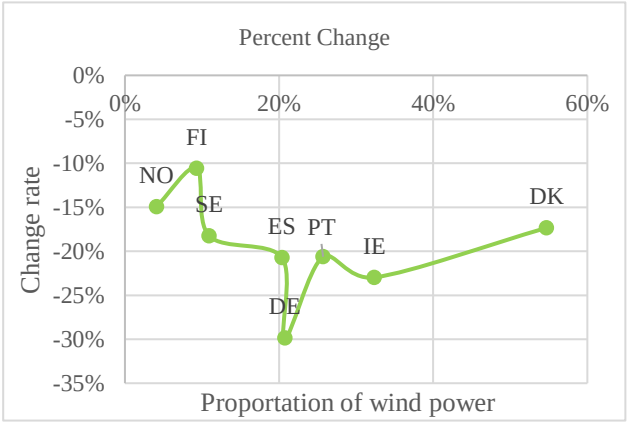

Figure 3. The fluctuations on electricity price (2018-2019)

Second, in 2019-2020, affected by the COVID-19 pandemic, Table 3 and Table 4 shows the country's electricity price fluctuations and percent change respectively, and arranges them according to the proportion of hydropower and wind power generation in each country.

Table 3. Price fluctuations based on hydro power proportion (2019-2020)

Country	Hydro power proportion	Price Fluctuation	Percent Change
Norway	92%	-33.1	-76%
Sweden	44%	-21.3	-49%
Portugal	26%	-14.63	-27%
Finland	23%	-17.11	-35%
Spain	13%	-14.45	-27%
Germany	4%	-7.08	-17%
Ireland	4%	-13	-23%
Denmark	0.06%	-13.11	-30%

Source: The authors' calculations

Table 4. Price fluctuations based on wind power proportion (2019-2020)

Country	Wind power proportion	Price Fluctuation	Percent Change

Denmark	57%	-13.11	-30%
Ireland	36%	-13	-23%
Portugal	23%	-14.63	-27%
Germany	23%	-7.08	-17%
Spain	21%	-14.45	-27%
Sweden	17%	-21.3	-49%
Finland	12%	-17.11	-35%
Norway	6%	-33.1	-76%

Source: The authors' calculations

Figure 4 and Figure 5 shows the changes in the proportion of hydro energy, wind energy and the percent change of electricity prices in each country. It can be seen from the figure that countries with a higher share of hydropower, such as Norway, have percent change that fluctuate dramatically to -76%. Countries with a higher share of wind power, such as Ireland, have a low fluctuation in electricity prices, which is at -23%. This phenomenon is because in an situation where social activities have been cut and power demand has reduced due to the pandemic, countries with a large amount of controllable renewable energy electricity generation, such as hydropower in Norway, are affected by the marginal cost pricing mechanism (merit-order effect) [14]. Marginal units have to be the hydropower unit most of the time. They are all extremely low-cost generating units and the cost is close to zero. Since demand has reduced, sellers in the market will offer lower prices in order to be prioritized for sale. This has aggravated the decline in electricity prices during the pandemic. For countries with a high proportion of wind power generation, in most cases they need to rely on fossil fuel units for frequency regulation [15]. Because the operating costs of fossil fuel units are high, their roles as marginal units result in a relatively smaller drop in electricity prices. Denmark, which is quite special, uses Norway's flexible hydropower for frequency regulation. Affected by fluctuations in electricity prices in Norway, the decline in electricity prices has also increased.

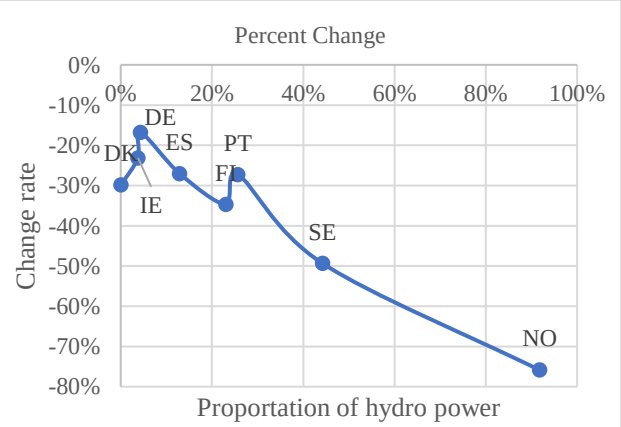

Figure 4. The fluctuations on electricity price (2019-2020)

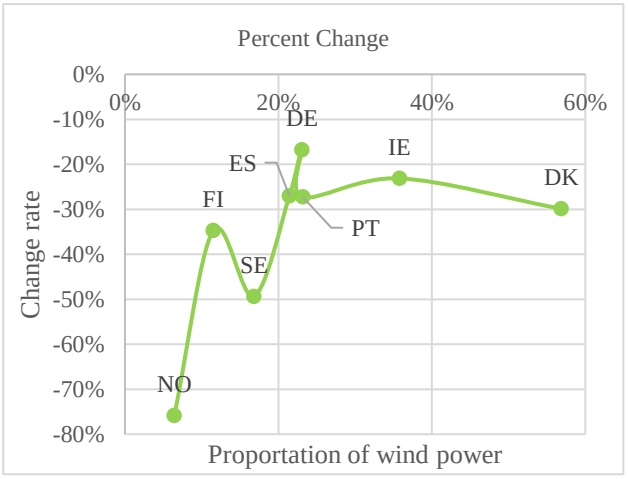

Figure 5. The fluctuations on electricity price (2019-2020)

From the perspective of cross-border electricity transactions, according to IEA data, in 2020, hydropower in Norway and Sweden, where electricity prices fluctuate greatly, had very limited trading volume with countries like Germany [7], which mainly rely on fossil fuel power generation. This also explains why electricity prices in these countries fluctuated greatly during the pandemic.

Third, in 2020-2021, affected by the energy crisis in Europe, Table 5 and Table 6 shows the country's electricity price fluctuations and percent change respectively, and arranges them according to the proportion of hydropower and wind power generation in each country.

Table 5. Price fluctuations based on hydro power proportion (2020-2021)

Country	Hydro power proportion	Price Fluctuation	Percent Change
Norway	91%	59.94	569%
Sweden	42%	46.11	211%
Portugal	26%	91.81	235%
Finland	22%	52.51	163%
Spain	10%	91.75	235%
Germany	4%	78.04	222%
Ireland	3%	99.66	231%
Denmark	0.05%	72.28	235%

Source: The authors' calculations

Table 6. Price fluctuations in based on wind power proportion (2020-2021)

Country	Wind power proportion	Price Fluctuation	Percent Change
Denmark	49%	72.28	235%
Ireland	30%	99.66	231%
Portugal	26%	91.81	235%
Germany	19%	78.04	222%
Spain	19%	91.75	235%
Sweden	16%	46.11	211%
Finland	11%	52.51	163%
Norway	7%	59.94	569%

Source: The authors' calculations

Figure 6 and Figure 7 shows the changes in the proportion of hydro energy, wind energy and the percent change of electricity prices in each country. It can be found from the figure that during the period when natural gas prices rose due to the energy crisis, the percent change in each country

was almost the same. The fluctuations in countries dominated by hydropower generation are generally slightly smaller than those in countries dominated by wind power generation. This is also determined by the fact that natural gas is often used as a marginal unit in pricing electricity prices in these countries [15]. The changes in electricity prices in Norway become particularly unique during this period. Its percent change reached an exaggerated 569%. One of the reasons for this situation is that due to the impact of the pandemic in 2020, Norway's annual average spot electricity price is at an extremely low level. Another reason is more frequent cross-border power transactions with Germany and the UK.

From the perspective of cross-border electricity transactions, according to Reuters, starting in mid-2021, a new cross-border power trading line that connecting Norway and Germany was operating, promoting price-driven imports of Norwegian hydropower by Germany [16]. This has led to exaggerated electricity price increases in Norway in 2021.

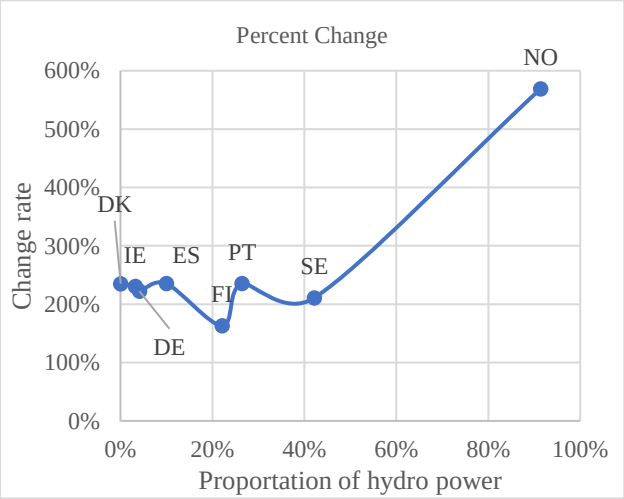

Figure 6. The fluctuations on electricity price (2020-2021)

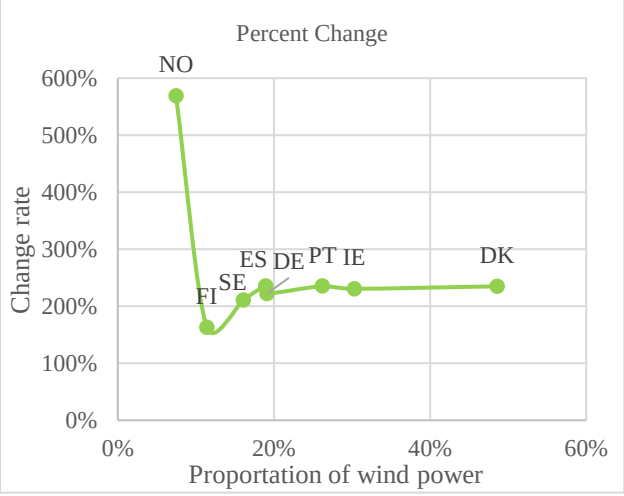

Figure 7. The fluctuations on electricity price (2020-2021)

Finally, in 2021-2022, Russia-Ukraine war breaks out completely, Table 7 shows the country's electricity price fluctuations and percent change respectively. From the table, the fluctuation of electricity prices in each country does not have direct correlation with the energy mixture of each country. Therefore, the countries in the table are arranged according to fluctuation rate.

Table 7. Price fluctuations (2021-2022)

Country	Percent Change	Price Fluctuation
Germany	145%	163.53
Denmark	116%	119.6
Norway	96%	67.42
Finland	89%	75.14
Sweden	54%	36.7
Ireland	51%	72.25
Portugal	37%	47.79
Spain	36%	47.47

Source: The authors' calculations

From the Table 7, The highest percent change is seen in Germany, Denmark and Norway, which the percent changes reached 145%, 116% and 96% respectively. The Russia-Ukraine war has caused electricity prices to continue to rise in countries that originally relied heavily on natural gas power generation as a marginal generation unit, such as Germany. But why countries like Norway and Denmark, which have high percentages of renewable electricity generations, are also experiencing such high price fluctuations?

According to data released by GOV.UK, the UK's electricity imports from France are significantly reduced from 15.15 TWh in 2021 to 2.74 TWh in 2022 [17]. The same situation occurs in Germany, which imports a large amount of French electricity. This is mainly due to the large number of decommissioned nuclear power stations in France. This phenomenon becomes more significant in 2022. According to data from RTE, France's nuclear power generation losses 82 TWh in 2022 compared with 2021 [18]. As France's electricity production shrunk, according to IEA, Germany and the United Kingdom increased their imports of electricity from Norway [7]. Directly affected by the electricity price spikes in Germany, Norwegian electricity prices and their fluctuations remain at a high level after 2021. Ireland, Portugal and Spain experienced less percent change because they have relatively simple cross-border energy connections with other countries in the European electricity market and are therefore less affected.

4. Discussions

The contribution of this work to the existing relevant literature is to combine the impact of renewable energy generation mixture and cross-border power trading with price fluctuations to explore the risk tolerance of European countries' electricity markets in the time of distress.

From the results, in a normal year like 2019, with the exception of Denmark, countries such as Ireland and Germany that are dominated by wind power generation have slightly higher electricity price fluctuations than countries that are dominated by hydropower generation. In 2020, under the extreme circumstances of a reduction in power demand due to the impact of the pandemic,

electricity prices in countries like Norway that mainly rely on hydropower have fluctuated more dramatically.

In 2021, under the influence of the energy crisis, energy prices have risen. The electricity spot price in every country has been affected, and the price fluctuation is almost the same. Only Norway experienced exaggerated price fluctuation due to a combination of cross-border power trading and lower demand in the previous year.

In 2022, geopolitical conflicts caused Russia to completely cut off natural gas supplies. Countries with electricity prices that are highly dependent on natural gas, such as Germany, have the highest price fluctuation. Because France's electricity production has shrunken, Germany has increased cross-border transactions with other neighbouring countries, such as Norway and Denmark. This makes the electricity prices of the two countries more affected by Germany's fluctuations than others. For Ireland, Portugal and Spain, the price fluctuation is the smallest due to their simple power connection structures with other countries.

In response to the abnormal situation of sudden reduction in power demand, electricity markets such as Norway and Sweden, which are dominated by stable hydropower generation, are with relatively higher risk. For the abnormal situation of rising natural gas prices, power markets such as Germany, Ireland, Portugal and Spain, where have high proportion of wind power generation and electricity prices are highly dependent on natural gas prices, are with higher risk. However, under the influence of cross-border electricity transactions, its own electricity prices are affected by the fluctuations of electricity prices in neighbouring trading countries. Therefore, the electricity markets in Norway and Denmark which are close to Germany are also considered to be risky under such extreme circumstances.

The unusual performance of traditional pricing mechanism in the electricity market in countries with a high proportion of renewable energy generation under a low demand period, and high dependence on natural gas in countries transitioning to renewable energy generation, as well as cross-border electricity trading during the time of distress. Together they aggravate the fragility of the European electricity market. Therefore, in the future of accelerated development of renewable energy, it is imperative to make appropriate intervention policies for different extreme situations.

5. Conclusions

In this paper, we have studied the electricity spot prices of several European countries with high renewable energy percentage during 2019-2022, which have experienced Covid pandemics, energy crisis and Russia-Ukraine war. The extreme situations affect energy supply-demand and electricity prices. We tried to study how an electricity market with high percentage renewable energy generation can stand for such extreme social situations. The major conclusions are found as following:

- Although the electricity market dominated by hydropower generation does not often experience interruptions and uncontrollability like wind and solar energy, it still shows strong electricity price instability when electricity demand reduced.
- The electricity market, dominated by wind and solar power generation, has highly dependence on natural gas at this stage.
- Due to the cross-border electricity trading, the countries with relatively less-fluctuating electricity prices, are affected by fluctuations of electricity prices in neighbouring countries during the time of distress.

Reference

[1] European Commission, "Energy Union and Climate." europa.eu. Available: https://ec.europa.eu/commission/priorities/energy-union-and-climate_en (accessed Aug. 15, 2024).

[2] M. Götz *et al.*, "Renewable power-to-gas: A technological and economic review," *Renewable Energy*, vol. 85, pp. 1371-1390, 2016, doi: 10.1016/j.renene.2015.07.066.

[3] D. Çelik, M. E. Meral, and M. Waseem, "The progress, impact analysis, challenges and new perceptions for electric power and energy sectors in the light of the COVID-19 pandemic," *Sustainable Energy, Grids and Networks*, vol. 31, p. 100728, 2022, doi: 10.1016/j.segan.2022.100728.

[4] M. Fulwood, "Surging 2021 European gas prices–why and how," *The Oxford Institute for Energy Studies*, pp. 1-8, 2022.

[5] European Council, Council of the European Union, "Infographic -Energy price rise since 2021," europa.eu. Available: https://www.consilium.europa.eu/en/infographics/energy-prices-2021/ (accessed Aug. 15, 2024).

[6] H. Chuliá, T. Klein, J. A. Muñoz Mendoza, and J. M. Uribe, "Vulnerability of European electricity markets: A quantile connectedness approach," *Energy Policy*, vol. 184, p. 113862, 2024, doi: 10.1016/j.enpol.2023.113862.

[7] International Energy Agency, "Real-time Electricity Tracker." iea.org. Available: https://www.iea.org/data-and-statistics/data-tools/real-time-electricity-tracker.

[8] E. Ghiani, M. Galici, M. Mureddu, and F. Pilo, "Impact on electricity consumption and market pricing of energy and ancillary services during pandemic of COVID-19 in Italy," *Energies*, vol. 13, no. 13, p. 3357, 2020.

[9] K. T. Gillingham, C. R. Knittel, J. Li, M. Ovaere, and M. Reguant, "The short-run and long-run effects of Covid-19 on energy and the environment," *Joule*, vol. 4, no. 7, pp. 1337-1341, 2020, doi: 10.1016/j.joule.2020.06.010.

[10] N. Norouzi, G. Zarazua de Rubens, S. Choupanpiesheh, and P. Enevoldsen, "When pandemics impact economies and climate change: Exploring the impacts of COVID-19 on oil and electricity demand in China," *Energy Research & Social Science*, vol. 68, p. 101654, 2020, doi: 10.1016/j.erss.2020.101654.

[11] P. M. R. Bento, S. J. P. S. Mariano, M. R. A. Calado, and J. A. N. Pombo, "Impacts of the COVID-19 pandemic on electric energy load and pricing in the

Iberian electricity market," *Energy Reports*, vol. 7, pp. 4833-4849, 2021, doi: 10.1016/j.egyr.2021.06.058.
[12] J. M. Uribe, S. Mosquera-López, and O. J. Arenas, "Assessing the relationship between electricity and natural gas prices in European markets in times of distress," *Energy Policy*, vol. 166, p. 113018, 2022, doi: 10.1016/j.enpol.2022.113018.
[13] B. Zakeri *et al.*, "The role of natural gas in setting electricity prices in Europe," *Energy Reports*, vol. 10, pp. 2778-2792, 2023, doi: 10.1016/j.egyr. 2023.09.069.
[14] F. Sensfuß, M. Ragwitz, and M. Genoese, "The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany," *Energy Policy*, vol. 36, no. 8, pp. 3086-3094, 2008, doi: 10.1016/j.enpol.2008.03.035.
[15] M. M. Kamal, I. Ashraf, and E. Fernandez, "Optimal sizing of standalone rural microgrid for sustainable electrification with renewable energy resources," *Sustainable Cities and Society*, vol. 88, p. 104298, 2023, doi: 10.1016/j.scs.2022.104298.
[16] V. Eckert and T. Sims, "Even in Crisis, Germany Extends Power Exports to Neighbours." financialpost. com. Available: https://financialpost.com/pmn/business-pmn/even-in-crisis-germany-extends-power-exports-to-neighbors (accessed Aug. 15, 2024).
[17] "Energy Trends." gov.uk. Available: https://www.gov.uk/government/collections/energy-trends (accessed Aug. 15, 2024).
[18] "Annual Electricity Review 2022." rte-france.com. Available: https://analysesetdonnees.rte-france.com/en/electricity-review-keyfindings (accessed Aug. 15, 2024).

Appendix

Table A. Summary of electricity spot price (2018-2023)

Country	Electricity Price						Units
	2018	2019	2020	2021	2022	2023	
	Normal	Normal	COVID	Energy Crisis	War	After war	
Norway	51.28	43.63	10.53	70.47	137.89	61	$/MWh
Denmark	53.07	43.87	30.76	103.04	222.64	90.86	$/MWh
Sweden	52.78	43.15	21.85	67.96	104.66	53.17	$/MWh
Portugal	67.59	53.65	39.02	130.83	178.62	95.41	$/MWh
Spain	67.4	53.44	38.99	130.74	178.21	94.13	$/MWh
Finland	55.12	49.3	32.19	84.7	159.84	61.05	$/MWh
Germany	60.16	42.19	35.11	113.15	276.68	128.38	$/MWh
Ireland	72.97	56.21	43.21	142.87	215.12	139.15	$/MWh

Source: International Energy Agency (2023)

Table B. The proportion of hydro power (2018-2022)

Country	The proportion of hydro power in total power generation				
	2018	2019	2020	2021	2022
Norway	94.98%	93.43%	91.79%	91.38%	88.12%
Germany	3.73%	4.23%	4.34%	4.12%	4.00%
Denmark	0.05%	0.06%	0.06%	0.05%	0.05%
Finland	18.93%	19.17%	23.04%	22.10%	18.69%
Sweden	38.11%	35.97%	44.22%	42.19%	40.59%
Portugal	22.48%	19.27%	25.68%	26.45%	18.07%
Spain	13.41%	9.84%	12.91%	9.99%	7.59%
Ireland	2.99%	3.66%	3.79%	3.25%	2.82%

Source: International Energy Agency (2023)

Table C. The proportion of wind power (2018-2022)

Country	The proportion of wind power in total power generation				
	2018	2019	2020	2021	2022
Norway	2.64%	4.09%	6.43%	7.45%	10.09%
Germany	17.17%	20.74%	23.07%	19.10%	21.25%
Denmark	45.78%	54.70%	56.83%	48.58%	53.94%
Finland	8.31%	9.30%	11.51%	11.40%	16.65%
Sweden	10.18%	10.92%	16.80%	16.08%	19.10%
Portugal	20.81%	25.71%	23.17%	26.20%	27.28%
Spain	18.54%	20.37%	21.43%	18.93%	21.55%
Ireland	27.75%	32.36%	35.77%	30.29%	33.08%

Source: International Energy Agency (2023)