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Zuzana DZILSKÁ
Ekonomická univerzita v Bratislave

ASSESSMENT OF BLACKOUT RISK IN THE DIGITAL ECONOMY

POSÚDENIE RIZIKA VÝPADKU ELEKTRICKEJ ENERGIE V DIGITÁLNEJ EKONOMIKE

ABSTRACT
The global energy crisis represents one of the most urgent challenges of the 21st century. The power systems are in some regions obsolete and the aging infrastructure is facing global climate change. As a result, vulnerability is regarded as a potential threat to economies. In this context, the recent large-scale blackouts occurring in Europe, including the blackout in Spain and Portugal on 28 April 2025 or in Prague on 4 July 2025, emerge not only as a technological concern but also as a concern regarding continuity in achieving ambitious goals which may require shift in energy paradigms. The e-commerce logistics market in Europe has undergone a transformative shift recently. This has been driven by the growth of online shopping and evolving consumer expectations. E-commerce businesses across Europe continue to strive to meet the increasing demands and delivery expectations. This paper focus on the analysis of the net electricity productivity, the rising demand for electricity and the unstable market situation which may be greatly impacted by electricity outages in the recent digital era.

ABSTRAKT
Globálna energetická kríza predstavuje jednu z najnaliehavejších výziev 21. storočia. Energetické systémy sú v niektorých regiónoch zastarané a čelia globálnej zmene klímy, čím je infraštruktúra vystavovaná klimatickým zmenám. Z tohto dôvodu sa zraniteľnosť považuje za potenciálnu hrozbu pre ekonomiky. V tejto súvislosti sa nedávne rozsiahle výpadky prúdu v Európe, výpadok prúdu v Španielsku a Portugalsku 28. apríla 2025 alebo v Prahe 4. júla 2025, javia nielen ako technologický problém, ale aj ako problém týkajúci sa kontinuity pri dosahovaní náročných cieľov, ktoré si môžu vyžadovať zmenu energetických paradigiem. Trh v Európe v poslednom čase prešiel transformačným posunom. Transformácia bola poháňaná rastom online nakupovania a vyvíjajúcimi sa očakávaniami spotrebiteľov. Podniky elektronického obchodu v celej Európe sa naďalej snažia uspokojiť rastúci dopyt a očakávania týkajúce sa dodávok. Výpadok prúdu však môže výrazne ovplyvniť dodávateľské reťazce. Táto práca sa zameriava na analýzu produktivity čistej elektriny, rastúci dopyt po nej a nerovnomernú situáciu na trhu, ktorá môže byť výrazne ovplyvnená poklesom dodávok elektriny v nedávnom digitálnom období.

KEY WORDS
blackout, electricity production, electricity demand

KĽÚČOVÉ SLOVÁ
blackout (výpadok elektriny), produkcia elektriny, dopyt po elektrine

1. INTRODUCTION

Aging electricity infrastructure is becoming a new challenge in many countries, in certain regions the infrastructure is reaching the end of service life and could pose a further problem. Much of the power infrastructure is more than 40 years old, some even significantly older. This means that an extensive renewed energy source would have to be built ad hoc in order to maintain the existing level of operation and to cope with the increasing demand for electricity generation mainly driven by the vision of transitioning to more environmentally friendly operations for example in the transportation industry (Erlhofer & Saurugg, 2023). However, this is economically demanding and requires investments. At the same time, many reserves have been used in order to optimize the situation in the energy industry, thus not solving the problem but only maintaining the current situation in the short term. Due to increasing operating loads and irreversible aging processes, it can be foreseen that the market situation is unstable (Erlhofer & Saurugg, 2023). Power generation from renewable energy has naturally become a widely discussed subject recently and is considered a preferred resolution for the power market. Additionally, the costs of maintaining system stability in the European interconnected system have been rising for years (Erlhofer & Saurugg, 2023). Due to the above, the goal of the paper is to analyze the electricity market situation in the European Union Member States including the analysis of the production as well as demand for electricity since pre-pandemic period to the present.

It is crucial to maintain a balance between the power generation and its consumption with relatively small tolerance. If the balance cannot be maintained the system is easily at risk of collapse. It is a very sensitive market situation, the balance of which we are usually unaware (Erlhofer, 2023). Over the past years, a large part of the previously existing surpluses in power plant capacities have been continuously reduced due to the increasing demand and the increasing framework of the power market. The regulatory requirements for savings in grid operation have led to a situation where there are hardly any reserves available and parallel to the necessary further expansion, the renewal of the existing infrastructure is becoming more and more urgent (Erlhofer & Saurugg, 2023). Emerging drivers for demand of electricity include the electrification of transport including electric vehicles and building the supporting infrastructure such as charging stations, digitalization including development of AI, cloud computing, blockchain technologies and also lifestyle changes such as living in smart homes equipped with electronic devices connected to Wi-Fi and distributed energy such as solar panels for example. These are just a few examples of the structural increase in electricity demand.

Supply chain resilience is becoming a very important topic discussed in the context of growing globalization and increasing risks of disruption. An effective supply chain not only considers aspects of the logistics and distribution of goods, but also involves good governance in the social, economic and political dimensions to ensure the smooth flow of products, information and finance (Simanjuntak & Erwinsyah, 2020). The recent COVID-19 pandemic revealed the vulnerability of supply chain management. Apart from the macroeconomic impacts of the COVID-19 pandemic, there were several consequences for supply chain management including delays in deliveries, data breaches, impact on production lead time, impact on raw material supplies which may cause a domino effect and impact global sourcing (Maemunah, 2024).

Additionally, supply chain disruptions can arise from various sources, including natural disasters such as hurricanes, earthquakes, and floods, which damage infrastructure, disrupt transportation, and cause power outages. Cyber-attacks on suppliers or logistics providers can also disrupt the supply chain by causing delays, data breaches, or the loss of critical information. Moreover, technological failures such as power outages or equipment failures can cause production delays or transportation disruptions. The increasing pressure on the demand for electricity consumption together with the pressure on the transformation of the energy systems towards renewable sources can cause a blackout. A blackout is a total loss of electrical power in a geographical area for an extended period. Such a blackout can be fatal to production, logistics, and retail operations. Depending on the scope of the affected areas and the blackout duration, supply chains are impacted to different extents (Ivanov, 2022).

In order to avoid a blackout, energy security must be maintained. Energy security involves the availability of energy sources, diversification of sources whether renewable, nuclear, gas, coal or other. Apart from energy security, energy independence is also crucial and involves reducing dependence on electricity imports. Additionally, infrastructure resilience and the efficient use of the resources are also crucial to withstand disruptions and to reduce losses and optimize consumption (Fita et al., 2025).

Digitalization is one of the key trends nowadays which influences all parts of society. The Internet of Things (IoT) is becoming a part of every household with the basic household appliances such as washing machines or refrigerators being connected to Wi-Fi and the Internet to serve its users. This is a great technological improvement, however, it also brings about another increase in consumption as consumers want to be able to digitally communicate. There are already many Internet users and it is predicted that with such technological changes the number of internet users that apply network technology in their households will rapidly increase (Dzilská & Pollák, 2025). Additionally, it is not only individuals or households that implement digitalization, companies also implement IoT in their operations thus improving their factory systems and the entire industrial processes. As a result, electricity, the Internet and digitalization can no longer be viewed in isolation from one another but must be treated together in order to prevent blackout situations.

2. METHODOLOGY

This study aims to analyze the evolution of electricity generation, its sources and demand since the outbreak of the COVID-19 pandemic with a focus on the mitigation of the unstable market situation and resulting blackouts. The data for the purposes of this paper were obtained from various sources. The first source of data is Eurostat, the statistical office of the European Union.

In the first part of the research the data from Eurostat were taken from the report entitled “Gross and net production of electricity and derived heat by type of plant and operator” with the below criteria:

- Energy balance: net electricity production
- Geopolitical entity: European Union – 27 countries (from 2020)
- Operator trade: total
- Standard international energy product classification (SIEC): total

- Time: 2019 to 2024
- Time frequency: annual
- Type of plant: total
- Unit of measure: gigawatt-hour (GWh)

Annual data on quantities of electricity and renewables covering the full spectrum of the energy sector from supply through transformation to final consumption by sector and fuel type are collected. Annual import and export data of various energy carriers by country of origin and destination, as well as infrastructure information are consolidated by Eurostat. Energy data are submitted on the basis of energy questionnaires. Eurostat receives disaggregated data which are used to countercheck the results and to ensure consistency with the total amount of energy consumption (Eurostat, 2025).

For the preparation of Figure 2, the above-mentioned report from Eurostat was used as the data source with the following criteria:

- Energy balance: net electricity production
- Geopolitical entity: European Union – 27 countries (from 2020), Estonia, Germany, Czechia, Belgium, Italy, Bulgaria, France, Portugal, Romania, Sweden, Slovenia, the Netherlands, Austria, Ireland, Slovakia, Latvia, Poland, Cyprus, Hungary, Spain, Greece, Denmark, Malta, Finland, Luxembourg, Croatia and Lithuania
- Operator trade: total
- Standard international energy product classification (SIEC): total
- Time: 2019 and 2024
- Time frequency: annual
- Type of plant: total
- Unit of measure: gigawatt-hour (GWh)

In the following part, Figure 3 presents the analysis focused on net electricity production sources according to the Standard International Energy Product Classification. For this purpose, the following criteria were used:

- Energy balance: net electricity production
- Geopolitical entity: European Union – 27 countries (from 2020)
- Operator trade: total
- Standard international energy product classification (SIEC): Combustible fuels, Nuclear fuels and other fuels n.e.c., Hydro, Wind, Solar, Pumped hydro power
- Time: 2019 and 2024
- Time frequency: annual
- Type of plant: total
- Unit of measure: gigawatt-hour (GWh)

Consequently, to analyze the electricity demand, the analysis firstly focuses on the global electricity data as electricity is a commodity traded on the market. For this purpose, data from Ember, an independent global energy think tank that uses data and policy to accelerate the clean energy transition were used. Ember is the trading name of Ember Energy Research CIC held at the United Kingdom and European Union.

Ember publishes the Global Electricity Review on annual basis which provides a comprehensive overview of changes in global electricity generation. It presents the trends underlying them, and their likely implications for energy sources and power sector emissions in the near future. The report analyses electricity data from 215 countries, representing 93% of global electricity demand, as well as estimates for 2024 for all other countries. In addition to electricity generation data, the report uses weather and capacity data to uncover the underlying trends shaping the global power sector (Graham et al., 2025).

Additionally, to narrow down the global picture to the respective European country states, data from Eurostat was used from the report entitled “Supply, transformation and consumption of electricity” using the following criteria:

- Energy balance: Inland demand
- Geopolitical entity: European Union – 27 countries (from 2020)
- Standard international energy product classification (SIEC): electricity
- Time: 2019 to 2024
- Time frequency: annual
- Unit of measure: gigawatt-hour (GWh)

Based on the analysis of the collected data, the following research questions are addressed.

1. Is there an unstable (i.e. supply for electricity does not meet the demand) electricity market situation in the European Union among 27 Member States between 2019 and 2024?
2. Has the electricity market in European Union Member States shrunk since the outbreak of the COVID-19 pandemic?

In order to interpret the evolving market situation between 2019 and 2024, the interannual percentage change was calculated. As the data from both periods are available, the percentage change between the given years can be calculated. The result is expressed as a percentage and indicates the amount of change happening between the two selected years. It is calculated in the following way:

$$[(\text{Number in later period} / \text{number in earlier period})-1] * 100$$

Based on the above, the results of the interannual percentage change calculation are applied throughout the paper where appropriate.

The aim of this paper is to present the evolving trend in electricity demand compared to the electricity production and to analyze the electricity market situation since the COVID-19 pandemic. Furthermore, the analysis focuses on the recent blackout that occurred in the region of Spain and Portugal on 28 April 2025, which most probably resulted from the unstable market situation.

3. RESULTS

The global energy situation represents one of the biggest challenges of the 21st century. On the one hand, the demand for electricity is constantly increasing with the emerging shifts in the economies towards e-commerce while on the other hand, the capacity for electricity production seems to have reached its maximum unless there are new investments made into renewable electricity generation. Due to the recent blackout situation in Europe, the imbalance between the demand and supply, the topic of electricity blackouts has become widely discussed which may have a significant impact on e-commerce and supply chain management. In the subsections below, the separate topics such as electricity production, its sources, electricity demand and the drivers of the increasing demand are examined.

3.1. NET ELECTRICITY PRODUCTION IN EUROPE

Net electricity production in Europe increased steadily before the pandemic apart from one slight downturn in 2008 due to the global financial crisis. Since 2008, net electricity production in Europe observed both, increasing as well as decreasing trend. However, since 2021, electricity production trend has been shrinking, and the overall production has decreased. If one of the latest worldwide impacts, the COVID-19 pandemic is considered, it can be observed that the net electricity production has decreased compared with the pre-pandemic the year 2019 and data from 2024. The decrease is from 2 776 TWh to 2 718 TWh, or a decrease by 2.08%. Figure 1 below presents the evolution of net electricity production in Europe between 2019 and 2024 in TWh.

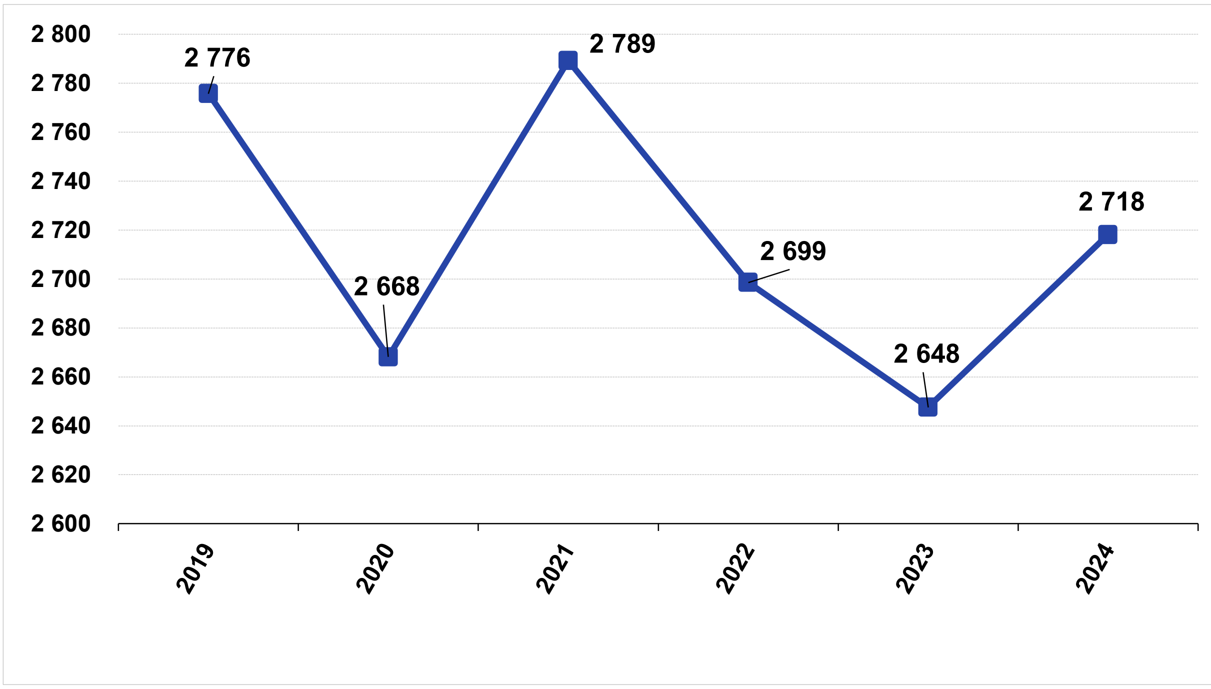

Figure 1: Net electricity production, EU, 2019–2024, in TWh

Moving away from a holistic perspective, the evolution of net electricity production in the European Union (EU) is examined at the level of individual Member States. For the purposes of the analysis, the specified period is defined from the year 2019 (pre pandemic) until 2024 (present). Every country shows a different evolution of net electricity production in recent years, which are affected by the COVID-19 pandemic to a great extent. In the selected period, 8 EU member states recorded a decrease in the net electricity production and 19 recorded increases. Estonia is the leading country among those that recorded a decrease, which is mainly driven by the downturn in oil shale electricity production. According to Helle Truuts, a leading analyst at Statistics Estonia, “the amount of electricity generated from oil shale fell by nearly 40% in a year, accounting only for a third of the total electricity production. In the previous year, 2022, more than half of the electricity was generated from oil shale," Truuts pointed out (Statistics Estonia, 2024). On the other hand, Lithuania recorded the largest increase in net electricity generation at 107%. This was achieved due to substantial investments in renewable power generation capacities. According to the International Energy Agency the electricity generation from renewable sources has nearly doubled in recent years. The transition is mainly driven by the expansion of wind and solar electricity generation (International Energy Agency, 2025). The percentage change for other EU Member States is presented in Figure 2. The average percentage point change of the EU is –2 points. Therefore, it can be assumed that the net electricity production in the EU decreased by 2% between the years 2019 (pre-pandemic period) compared to the present data from 2024, since the outbreak of the COVID-19 pandemic.

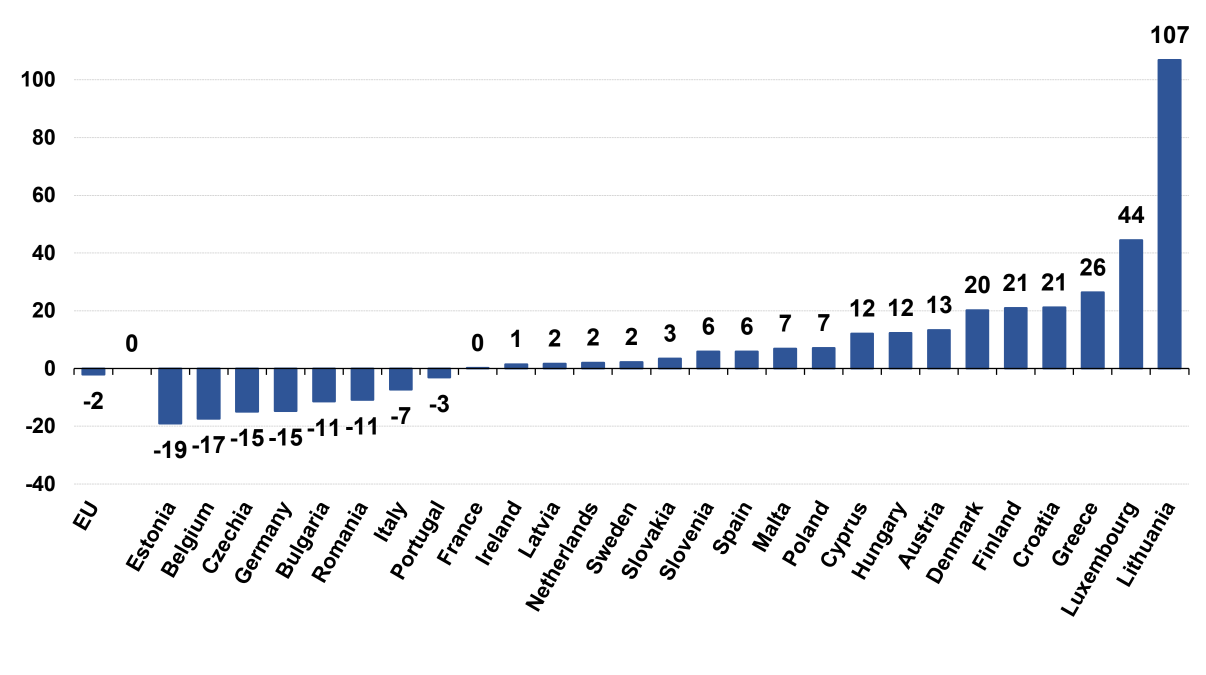

Figure 2: Overall change in net electricity generation, between 2019–2024 in % and based on GWh

3.2. NET ELECTRICITY PRODUCTION ACCORDING TO THE STANDARD INTERNATIONAL ENERGY PRODUCT CLASSIFICATION

The European Climate Pact (Green Deal) is an EU initiative to make Europe the first climate-neutral continent by 2050. The Green Deal sets the goal of achieving climate neutrality in Europe, meaning no net emissions of greenhouse gases by 2050. The European Green Deal has three primary goals: establishing the EU as a global leader in the green transition; transforming the EU's economy for a sustainable future and setting up a European Climate Pact. The target is that Europe will become the first continent in the world with zero climate impact by 2050 (Dzilská, 2024).

In this subsection, the analysis moves from the holistic view of the European net electricity generation and presents a breakdown based on Standard International Energy Product Classification (SEIC). For the purposes of this analysis, the sources of electricity generation which present a smaller percentage share than 0.5 are excluded from the graph. These include, for example, geothermal, batteries, tidal and wave ocean electricity generation sources. As can be seen in Figure 3, there is a shift within the EU towards generating electricity from renewable sources, the solar electricity generation has increased from 4.36% in 2019 to 11.13% in 2024; hydro increased from 12.21% to 14.56%; wind increased from 12.98 % to 17.59%; and pumped hydro power increased from 0.90 % to 1.24%. On the other hand, net electricity generation from combustible fuels decreased from 43.44% to 32.95 and nuclear fuels decreased as well from 26.11% to 22.53. Due to these changes, it can be interpreted that according to the SEIC, net electricity generation recorded a shift between 2019 and 2024 towards renewable sources.

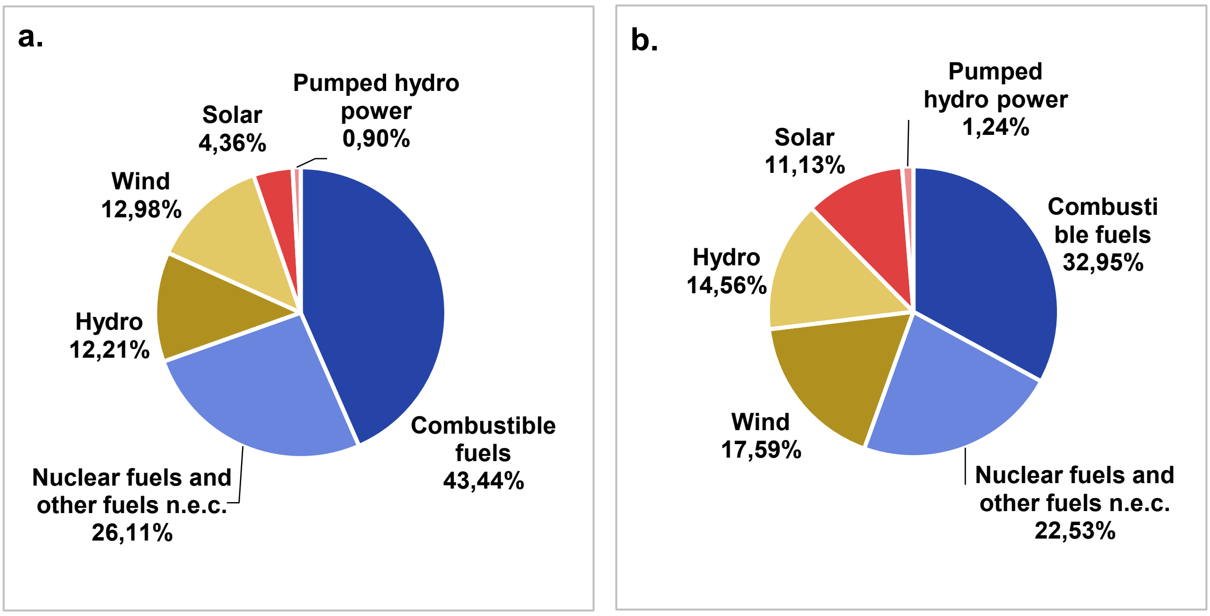

Figure 3a: Net electricity generation by source, EU, 2019 in % (based on GWh)
Figure 3b: Net electricity generation by source, EU, 2024 in % (based on GWh)

3.3. EMERGING DRIVERS OF ELECTRICITY DEMAND AND ITS GROWTH

As electricity is a commodity traded on the energy market, this section firstly provides an overview of global electricity demand followed by an analysis of the demand in Europe. Global electricity demand had an increasing trend between 2019 and 2024, with a slight decrease in 2020 which may have been affected by the economic slowdown due to the COVID-19 pandemic. As can be seen in Figure 4, the evolution of demand in TWh is displayed in Figure 4a. and the change in the demand in absolute terms (in TWh) and in percentage change is shown on Figure 4b.

In general, there is an increasing trend in the electricity demand apart from a slight decrease in 2020. This was most probably caused by government restrictions introduced due to pandemic situation which caused an economic slowdown and thus resulted in lower electricity demand. The most significant increase both in absolute and percentage change was noted between 2020 and 2021, with an increase of 1 531 TWh which represents an increase of 5.73% between 2020 and 2021. This may be due to the post COVID-19 pandemic recovery of economies and an increase of overall economic activity. In the following years, a further increase was recorded, in 2022 of 2.33%, in 2023 of 2.58% and in 2024 of 4.22%.

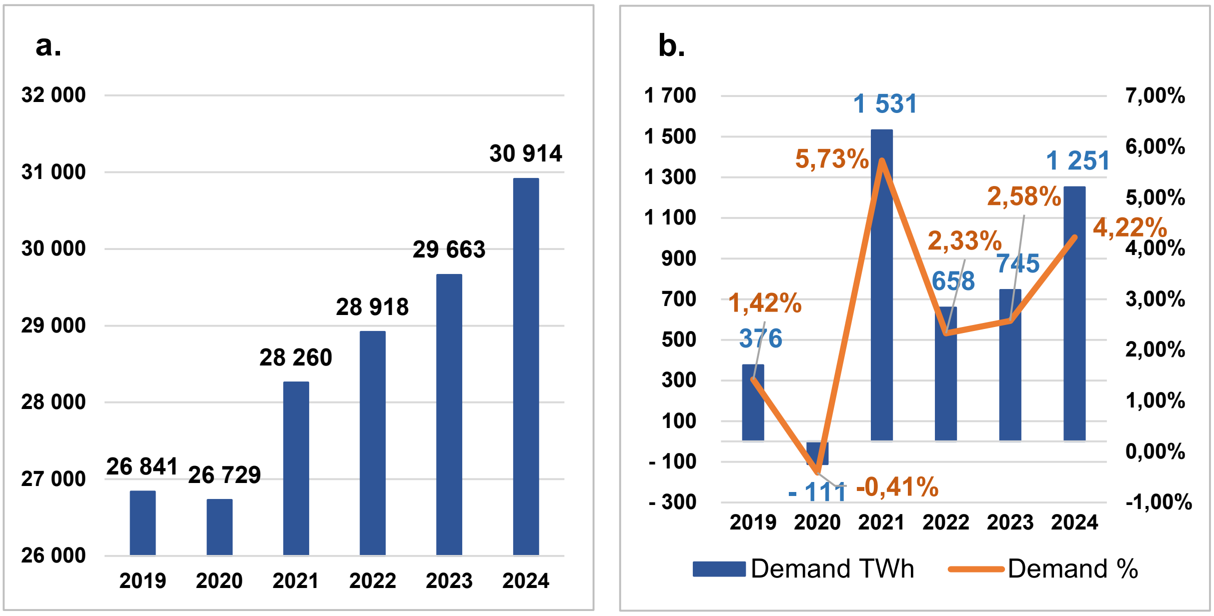

Figure 4a: Global electricity demand, between 2019 and 2024, in TWh
Figure 4b: Global change in electricity demand, EU, between 2019 and 2024, in TWh and in %

In the following section, the analysis is narrowed to the electricity demand in 27 EU Member States. The electricity demand has had an increasing trend in the pre pandemic period. The COVID-19 pandemic represented an economic shock which was reflected in a drop in the demand between 2019 and 2020. The demand decreased from 2 741 TWh to 2 639 TWh which represents a drop of 102 TWh in the absolute value or a drop by 3.72%. In the following year, 2021, most probably due to release of government restrictions, the demand started to increase again to 2 755 TWh, the demand was slightly higher than in 2019, in pre-pandemic period. However, in 2022 and 2023, there was a consecutive drop to 2 586 TWh, so in total, the decrease in electricity demand between 2019 and 2023 is 155 TWh in absolute terms and 5.68%. These data are visually presented in Figure 5. It can be added to the data presented in the figure below that demand showed an increasing trend 2024 according to the data available from Eurostat.

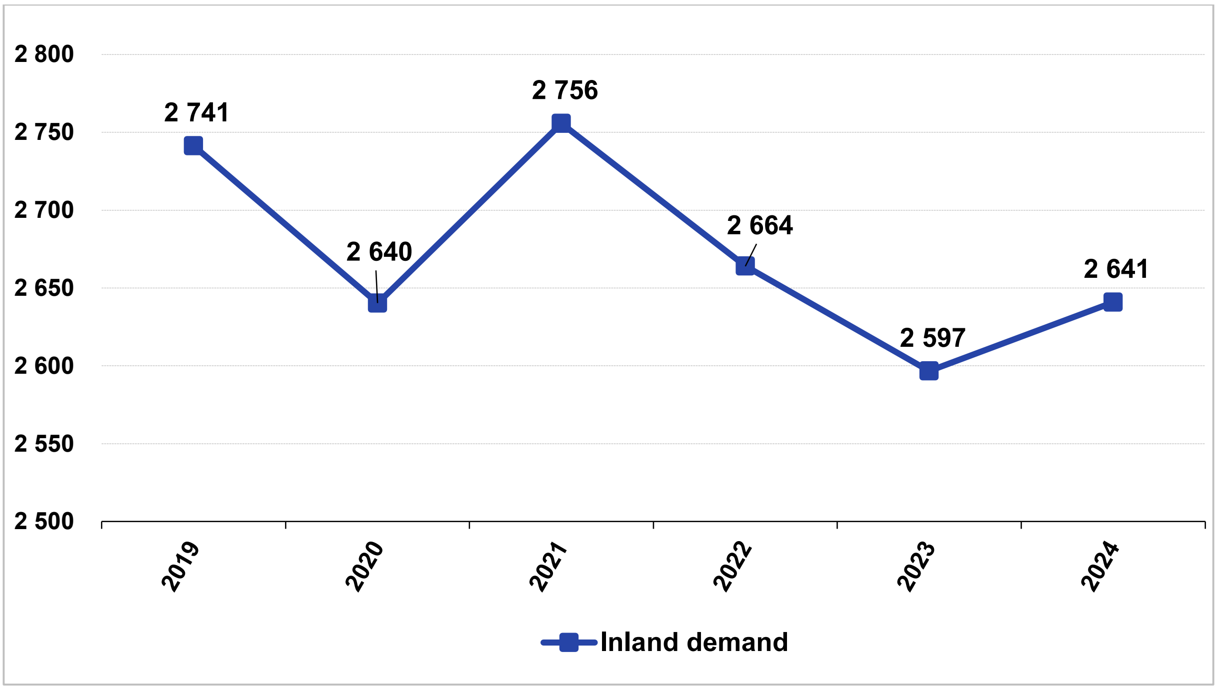

Figure 5: Electricity demand, EU, between 2019–2024, in TWh

Moving away from a holistic perspective, the evolution of electricity demand in the European Union (EU) is examined at the level of individual Member States. For the purposes of the analysis, the specified period is defined from 2019 (pre- pandemic period) until 2024 (the present). Every country shows a different evolution of electricity demand, but in general the EU average is –3.7%. In the selected period, 13 EU Member States recorded a decrease in the electricity demand and 6 recorded increases. As can be seen in Figure 6, Slovakia is the leading country with a –14.7% decrease in the demand between 2019 and 2024. This can be caused by the increased energy prices which have caused several large industrial companies such as SLOVALCO, the country's largest aluminum producer, to reduce their consumption which at the end was forced to close the company operations in August 2022 due to a substantial increase in energy prices. According to the Energy Policy Review published by the International Energy Agency, the demand forecast assumes that those industries which reduced their electricity demand in 2024 will not regain their original consumption before the pandemic. Additionally, it is assumed that a shortage of generation capacity could proceed faster than expected which would lead to increased import dependence among the EU Member States over the period to 2040 (International Energy Agency, 2024). On the other hand, there are few countries which record an increase in the electricity demand between 2019 and 2024 among which Ireland recorded a largest increase. As presented in Figure 6, Ireland noted a 15.8% increase, which may be caused by various factors such as increasing adoption of electric vehicles or an increase in the commercial services sector which depends on data center or other.

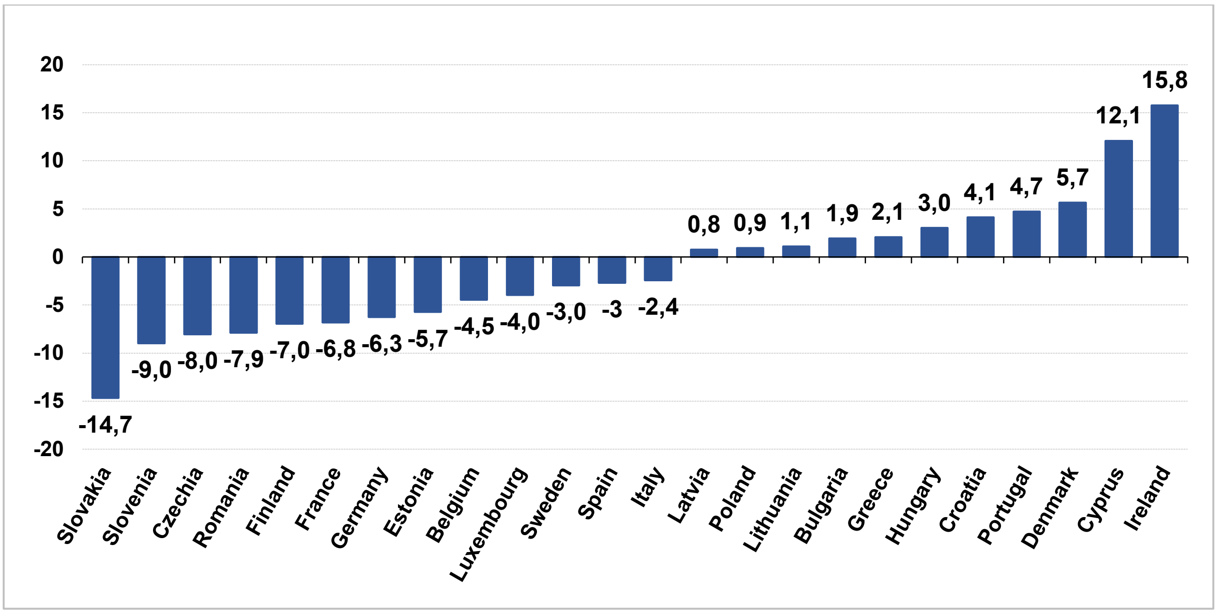

Figure 6: Overall change in electricity demand, between 2019–2024 in % (based on GWh)

3.4. MITIGATING THE UNEVEN DEMAND VS SUPPLY OF ELECTRICITY

In case there is an unstable market situation, in which electricity demand is increasing and supply cannot meet the increasing demand, blackouts can occur. A blackout is a complete loss of electrical power in a given area and has a major impact on economic operations including the digital supply chains. As a result, vulnerability is seen as a potential threat which can also be seen on the example of the recent blackout in Spain and Portugal on 28 April 2025.

As can be seen in Figure 7, net electricity demand in Spain and Portugal noted a significant decrease in 2020 and showed signs of recovery in the following years. In case of Spain the demand did not reach the pre-pandemic volumes, and in case of Portugal the demand showed an increasing trend year after year.

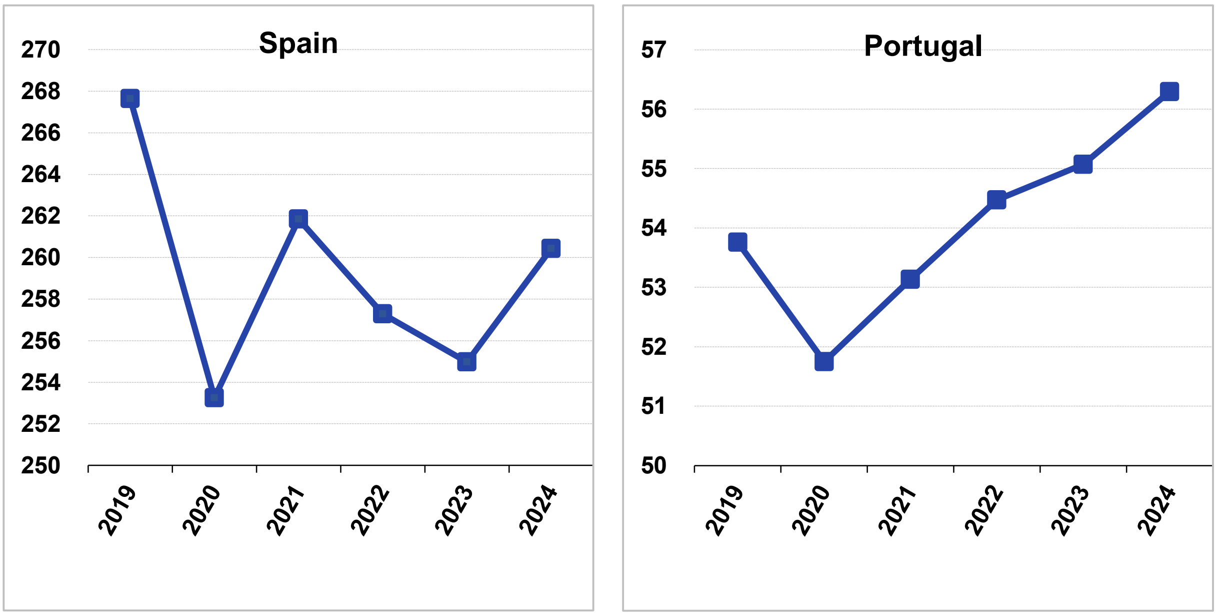

Figure 7: Electricity demand in Spain and Portugal, between 2019–2024, in TWh

Additionally, it is vital to have an understanding of the shift that these two countries experienced between the studied years. A shift towards cleaner energy sources in both countries was observed. If net electricity generation from the two countries is aggregated, a decrease in the main source of electricity generation, from combustible fuels, can be observed from 43.71% in 2019 to 23.27% in 2024. A decrease was also noted in nuclear fuels by 1.79%. Other sources recorded an increase, wind energy generation by 1.26%, solar energy generation by 14.50% and hydro power generation by 6.22%.

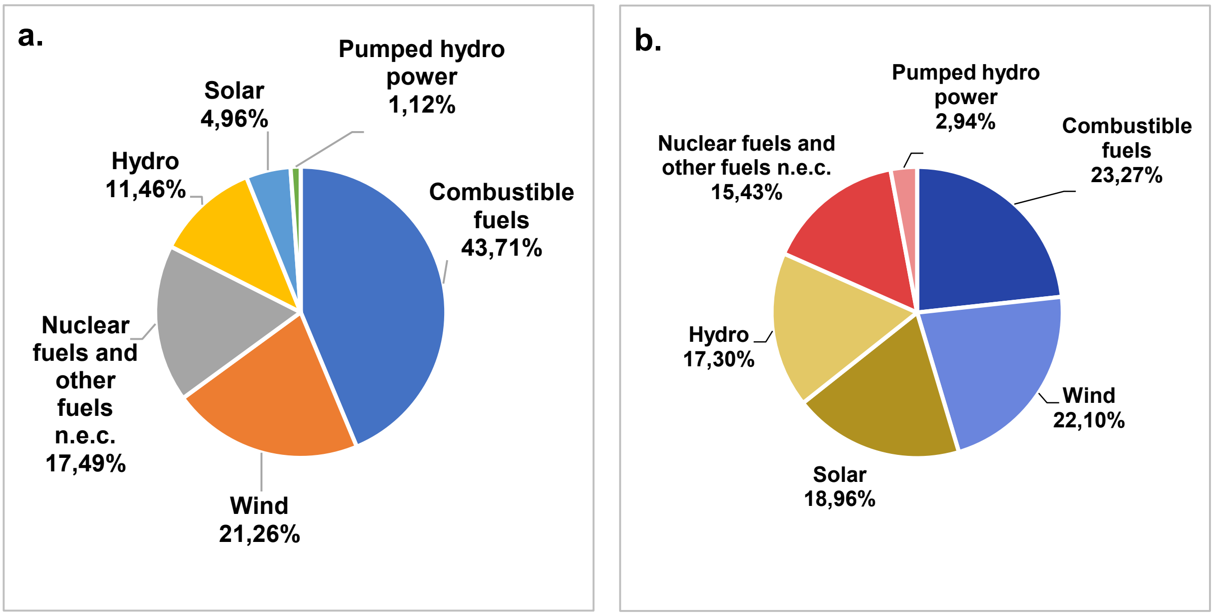

Figure 8a: Net electricity generation by source in Spain and Portugal in 2019 in % (based on GWh)
Figure 8b: Net electricity generation by source in Spain and Portugal in 2024 in % (based on GWh)

On 28 April 2025, at 12:33 CEST, the power systems of Spain and Portugal experienced a blackout affecting the entire Iberian Peninsula and a small area in France, close to the border with Spain. The area in France was affected for a limited duration. The power was restored in Portugal at 0:22 CEST on 29 April 2025 and around 4:00 CEST in Spain. The blackout lasted roughly 12 hours in Portugal and 16 hours in Spain. The geographic representation of the area is presented in Figure 9.

Figure 9: Geographic area impacted by the blackout of 28 April 2025 (ENTSO-E, 2026)

Understanding the exact causes of the blackout is rather complex and is still under investigation as it is one of the most recent examples of a blackout. Understanding events of this scale and complexity requires time and a rigorous technical and scientific approach. However, it is known that this is not the only case of a blackout, similar situations happened in the Czech Republic on 4 July 2025, in Turkey on 31 March 2015, and in Germany on 4 November and also before.

Power blackouts not only interrupt electricity services, but also disrupt supply-chain flows, create cascading production losses across tiers, and can generate lasting changes in sourcing patterns and inventory policies. The power outage in Spain and Portugal lasted more than 12 hours, and caused a disruption to global supply chains, resulting in an outage. Spain and Portugal serve as vital gateways connecting Europe, Africa, and the Americas, enabling the smooth movement of goods across continents. Spain serves as one of Europe's largest logistics markets, supported by extensive rail networks and a coastline of more than 8 thousand kilometer long. On the other hand, Portugal disposes with vital logistics hubs near Lisbon and Porto which link Atlantic trade routes and European markets. Due to this, these two countries represent an important trade corridor, and the blackout posed several threats to the supply chains including:

- Oil refineries had to stop refueling the ships transporting goods between the continents,
- Car manufacturers had to adapt to the situation and needed to communicate potential overseas delays,
- Major car manufacturers with plants located in these countries needed to interrupt their production such as Iveco with its plant located in Madrid, other example included Ford or SEAT,
- Among others, the food industry suffered as well due to fresh products that could not be refrigerated during the power outage. It is estimated that the loss reached up to EUR 200 million (Ilgar, 2025).

4. DISCUSSION

As can be seen from the results, both, the demand and supply indicate a decrease among the EU Member States between 2019 and 2024. In terms of net electricity production and thus electricity supply, there was a drop from 2 776 TWh in 2019 to 2 718 TWh in 2024, which is a decrease by 58 TWh in absolute terms or a drop by 2.08%. In terms of demand, there was also a drop from 2 741 TWh in 2019 to 2 641 TWh, which is a decrease of 100 TWh or 3.64%. Due to the above, the first research question can be answered: "Is there an uneven (i.e. supply of electricity does not meet the demand) electricity market situation in the European Union among the 27 Member States between 2019 and 2024?" Based on the collected data it is clear that the supply sufficiently covers the demand at the level of the EU Member States.

Additionally, is it important to mention that electricity is a commodity that can be traded on the market and thus global data on electricity demand were presented as well. However, these are excluded from the answer to the research question due to the specified geographic region to Europe as a criterion. Nevertheless, from a global perspective, the demand is increasing which can be driven by several emerging drivers. These include electrification of transport including electric vehicles and building the supporting infrastructure such as charging stations, digitalization including development of AI, cloud computing, but also lifestyle changes such as living in smart homes including electronic devices connected to Wi-Fi and distributed energy with solar panels for example.

Due to the above, it can only be assumed that the unstable electricity market situation in Europe is not the main cause of power blackout. Other aspects which were not part of this study, also need to be taken into account, as they play an important role in power systems. Another aspect to be considered is the fact that Europe is heading towards clean electricity production, focusing on wind, hydro or solar electricity sources which require investment and infrastructure development. This has been improving in some of the European countries, however, not all Member States have the economic potential to utilize such investments in the recent turbulent economic times.

To answer the second research question, “Did the electricity market in the European Union Member States shrink since the COVID-19 pandemic outbreak?” the data presented in the research part of the paper can be reviewed, indicating that the market has shrunk. As mentioned earlier, the production decreased by 5.27% and the demand by 5.68%. Additionally, it can be observed that there is a shift towards cleaner electricity production as electricity production from combustible fuels dropped by 7.28% and electricity production from nuclear fuels by 7.28%. At the same time, an increase can be seen in cleaner electricity production such as solar increased by 5.00%, followed by wind with 4.72% increase, hydro 1.19% increase and lastly pumped hydro power which increased by 0.26%. All the data are available at the level of 27 European Member States, between 2019 and 2024. As a result, not only a shrinking of the electricity market in Europe but also a shift towards cleaner energy can be observed.

In the case of the blackout in Spain and Portugal, a significant shift towards cleaner electricity production can be observed between 2019 and 2024 with a 20.21% drop in the main source of electricity generation, from combustible fuels in 2024. On the other hand, cleaner electricity sources recorded an increase, wind energy generation increased by 1.26%, solar energy generation by 14.50% and hydro power generation by 6.22%. Also, it can be observed that the demand have an increasing trend in both countries, whereas the demand in Spain did not reach the pre-pandemic volumes while Portugal exceeded them.

As can be seen from the results, both, the demand and supply indicate a decrease among the EU Member States between 2019 and 2024. In terms of net electricity production and thus electricity supply, there was a drop from 2 776 TWh in 2019 to 2 718 TWh in 2024, which is a decrease by 58 TWh in absolute terms or a drop by 2.08%. In terms of demand, there was also a drop from 2 741 TWh in 2019 to 2 641 TWh, which is a decrease of 100 TWh or 3.64%. Due to the above, the first research question can be answered: “Is there an uneven (i.e. supply of electricity does not meet the demand) electricity market situation in the European Union among the 27 Member States between 2019 and 2024?” Based on the collected data it is clear that the supply sufficiently covers the demand at the level of the EU Member States.

Additionally, is it important to mention that electricity is a commodity that can be traded on the market and thus global data on electricity demand were presented as well. However, these are excluded from the answer to the research question due to the specified geographic region to Europe as a criterion. Nevertheless, from a global perspective, the demand is increasing which can be driven by several emerging drivers. These include electrification of transport including electric vehicles and building the supporting infrastructure such as charging stations, digitalization including development of AI, cloud computing, but also lifestyle changes such as living in smart homes including electronic devices connected to Wi-Fi and distributed energy with solar panels for example.

Due to the above, it can only be assumed that the unstable electricity market situation in Europe is not the main cause of power blackout. Other aspects which were not part of this study, also need to be taken into account, as they play an important role in power systems. Another aspect to be considered is the fact that Europe is heading towards clean electricity production, focusing on wind, hydro or solar electricity sources which require investment and infrastructure development. This has been improving in some of the European countries, however, not all Member States have the economic potential to utilize such investments in the recent turbulent economic times.

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5. CONCLUSION

Modern supply chains rely heavily on technological improvements and digitalization systems in which electricity plays an inevitable role. If a blackout occurs, it can have a serious consequence for the supply chain patterns depending on its duration and scope. Uneven electricity demand vs. supply is one of the core challenges of modern power systems. This paper provides an overview of the power market situation and the decreasing production potentials of electricity in the recent years, and at the same time, increasing demand mainly driven by newly emerging drivers of higher consumption.

The blackout recently experienced in Spain and Portugal is also described together with its consequences for supply chain patterns.

This paper provides an analysis based on the data available from Eurostat and Ember and does not reflect other possible aspects that may affect the electricity industry. There may be other aspects that also influence the electricity production or consumption such as EU government regulations which require a shift towards more renewable sources of electricity generation. These are not included in this paper and may be perceived as limitations of this study. From another perspective, these aspects may represent an area for examination and potential future research.

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REFERENCES

Dzilská, Z. (2024). Renewable energy generation and its sources in Germany. In *Generic, convergence and model approaches of environmental production and logistics in business development in Slovakia II: Proceedings of scientific papers* (pp. 26 – 35). Vysoká škola evropských a regionálních studií.

Dzilská, Z., & Pollák, F. (2025). Internet of Things in the context of digital online revolution in marketing of Bosch campaign LikeABosch. *Acta Mechanica Slovaca, 29*(1), 50 – 57. https://doi.org/10.21496/ams.2025.012

ENTSO-E. (2026, March 20). *28 April 2025 Blackout.* https://www.entsoe.eu/publications/blackout/28-april-2025-iberian-blackout/

Erlhofer, P. (2023). *Blackbox blackout – Fragen zur Komplexität von Stromausfällen – Wege zur Resilienz.* Geistkirch Verlag.

Erlhofer, P., & Saurugg, H. (2023). *The European electricity supply system in transition and possible consequences of a major European disruption ("blackout").* Gesellschaft für Krisenvorsorge. https://www.researchgate.net/publication/374557800_The_European_Electricity_Supply_System_in_Transition_and_possible_consequences_of_a_major_European_disruption_blackout

European Union. (2024). *EU energy in figures: Statistical pocketbook 2024.* Publications Office of the European Union.

Eurostat. (2025). Energy statistics – quantities. https://ec.europa.eu/eurostat/cache/metadata/en/nrg_quant_esms.htm

Fita, N. D., Utu, I., Marcu, M. D., Pasculescu, D., Mila, I. O., Popescu, F. G., Lazar, T., Schiopu, A. M., Muresan-Grecu, F., & Cruceru, E. A. (2025). Global Energy Crisis and the Risk of Blackout: Interdisciplinary Analysis and Perspectives on Energy Infrastructure and Security. *Energies, 18*(16), 4244. https://doi.org/10.3390/en18164244

Graham, E., Fulghum, N., & Altieri, K. (2025). *Global electricity review 2025.* Ember. https://ember-energy.org/app/uploads/2025/04/Report-Global-Electricity-Review-2025.pdf

Ilgar, O. (2025, May 6). *Spain-Portugal blackout: Lessons learned amid supply chain shockwaves.* Forbes. https://www.forbes.com/sites/sap/2025/05/06/spain-portugal-blackout-lessons-learned-amid-supply-chain-shockwaves/

International Energy Agency. (2024). *Slovak Republic 2024: Energy policy review.* https://iea.blob.core.windows.net/assets/d2f59c8b-1344-4b98-8a00-52ef074cfa06/Slovak_Republic_2024.pdf

International Energy Agency. (2025). *Lithuania 2025.* https://iea.blob.core.windows.net/assets/0f37fbed-856d-4fde-8f2b-4db10d9bfd2a/Lithuania2025.pdf

Ivanov, D. (2022). Blackout and supply chains: Cross-structural ripple effect, performance, resilience and viability impact analysis. Annals of Operations *Research, 348,* 1127 – 1143. https://doi.org/10.1007/s10479-022-04754-9

Maemunah, S. (2024). Supply chain resilience: Strategies for mitigating disruptions and building adaptive networks. *Management Studies and Business Journal (PRODUCTIVITY), 1*, 421 – 431. https://doi.org/10.62207/xcrh2f10

Simanjuntak, A., & Erwinsyah, R. (2020). Kesejahteraan petani dan ketahanan pangan pada masa pandemi Covid-19: Telaah kritis terhadap rencana megaproyek Lumbung Pangan Nasional Indonesia. *Sosio Informa, 6*(2), 184 – 204. https://doi.org/10.33007/inf.v6i2.2332

Statistics Estonia. (2024, September 6). *Oil shale electricity production decreased last year.* https://stat.ee/en/news/oil-shale-elctricity-production-decreased-last-year

RESUME

This paper provides an overview of electricity production and consumption among the 27 EU Member States. The provided analysis is based on the data available from Eurostat and Ember. There are 2 study questions analyzed:

1. *Is there an uneven (i.e. electricity supply does not meet demand) electricity market situation in the European Union among the 27 Member States between 2019 and 2024?*
   Based on the data presented in the empirical section of the paper, it is clear that the supply sufficiently covers the demand at the level of the EU Member States. As a result, it can only be assumed that the uneven electricity market situation in Europe is not the main cause of the power blackout. To be able to better understand this issue, an analysis of other aspects would need to be taken, which play important role in the power systems. Additionally, as can be seen on Figure 3a. and b., Europe is moving towards clean electricity production, focusing on wind, hydro or solar electricity sources which require investments and infrastructure development.

2. *Did electricity market in the European Union Member States shrink since the COVID-19 pandemic outbreak?*
   As mentioned in the empirical part of the paper, production shrunk by 2.08% and the demand by 5.68%. Additionally, a shift towards cleaner electricity production can be observed, as electricity production from combustible fuels dropped by 7.28% and in the nuclear fuels also decreased by 7.28%. At the same time, an increase can be seen in the cleaner electricity production with solar energy increasing by 5.00%, followed by wind energy with a 4.72% increase, hydropower with a 1.19% increase and lastly pumped hydro power with an increase of 0.26%.

RESUMÉ
Článok poskytuje prehľad o výrobe a spotrebe elektriny v 27 členských štátoch EÚ. Analýza je založená na údajoch dostupných v Eurostate a Ember. Analyzujú sa dve výskumné otázky:

1. *Existuje nerovnomerná (t. j. ponuka elektriny neuspokojuje dopyt) situácia na trhu s elektrinou v Európskej únii medzi 27 členskými štátmi v rokoch 2019 až 2024?*
   Z údajov uvedených v empirickej časti práce je zrejmé, že ponuka dostatočne pokrýva dopyt na úrovni členských štátov EÚ. V dôsledku toho možno len predpokladať, že nerovnomerná situácia na trhu s elektrinou v Európe nie je hlavnou príčinou výpadku prúdu. Pre lepšie pochopenie témy by bolo potrebné vykonať analýzu ďalších aspektov, ktoré zohrávajú dôležitú úlohu v energetických systémoch. Okrem toho, ako vidieť na obrázku 3a a 3b, Európa smeruje k čistej výrobe elektriny so zameraním na veterné, vodné alebo solárne zdroje elektriny, ktoré si vyžadujú investície a budovanie infraštruktúry.

2. *Zmenšil sa trh s elektrinou v členských štátoch Európskej únie od vypuknutia pandémie COVID-19?*
   Ako sa uvádza v empirickej časti práce, produkcia sa znížila o 2,08 percenta a dopyt o 5,68 percenta. Okrem toho vidíme posun k čistejšej výrobe elektriny, keďže poklesla výroba elektriny z horľavých palív o 7,28 percenta a jadrových palív o 7,28 percenta. Zároveň došlo k nárastu výroby čistejšej elektriny, ako je solárna energia (o 5,00 percenta), nasledovaná veternou energiou s nárastom o 4,72 percenta, vodnou energiou s nárastom o 1,19 percenta a nakoniec prečerpávacou vodnou energiou s nárastom o 0,26 percenta.

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KONTAKT
zuzana.dzilska@euba.sk