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Energy Security in European Union -Opportunities and Challenges-

Dr. Ahmed Zitout[1] , Dr. Samir Ghouini[2]
[1]Ph.D., Faculty of economic sciences and commercial sciences and management sciences, University Ziane Achour Djelfa Algeria
Email: a.zitout@univ-djelfa.dz
[2]Ph.D., Faculty of economic sciences and commercial sciences and management sciences, University Ziane Achour Djelfa Algeria
Email: s.ghouini@univ-djelfa.dz

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Abstract:
The recent energy crisis affecting European Union (EU) countries highlighted significant vulnerabilities in the stable supply of energy, particularly due to reduced gas exports from Russia. This disruption threatened to undermine both the population's basic needs and the economic activities of EU nations. In response, EU member states have actively pursued a range of measures to mitigate the energy gap, focusing on diversifying energy sources, exploiting available renewable resources, and promoting energy efficiency.
Had these proactive measures not been implemented, the crisis could have severely impacted millions of EU residents, particularly during the winter months when demand for heating surges, as well as hindered economic activities related to production, distribution, and transportation. However, the swift actions taken by EU countries—particularly their solidarity and mutual assistance—played a key role in alleviating the immediate effects of the crisis.
This energy crisis underscores the critical need for the EU to diversify its energy sources and invest in sustainable, resilient energy systems. Such measures are essential to ensuring a stable and reliable energy supply in the face of both current and future external challenges.

Keywords: Diversification of energy sources, Energy crisis, Energy security, Energy efficiency, European Union (EU).

1. Introduction

Energy security is a critical issue for the European Union (EU), which faces growing energy demand while seeking to diversify its supply sources, reduce external dependencies, and meet its environmental goals. Historically, the EU has relied heavily on energy imports, particularly from neighboring countries such as Russia. However, recent geopolitical events, such as the war in Ukraine, have highlighted the vulnerability of Europe to supply disruptions and geopolitical tensions. These developments have sparked an urgent debate on the need to strengthen the resilience of Europe's energy system, diversify supply sources, and accelerate the transition to renewable energy.

Energy security encompasses not only supply reliability but also price stability, reducing dependency on external energy sources, and promoting technological innovation for a sustainable energy transition. To address these challenges, the EU has implemented strategies to secure its energy supply while also reducing greenhouse gas emissions and increasing energy autonomy. Initiatives such as the European Green Deal, the Fit for 55 package, and the REPowerEU plan reflect efforts to transform the European energy model into a more sustainable, resilient, and cooperative system.

As such, energy security in the EU sits at the intersection of managing immediate supply risks, pursuing a greener energy future, and balancing economic and social imperatives. The future of European energy security depends on continuous adaptation to global challenges, alongside enhanced internal and international cooperation.

2. Energy Production in European Union

Energy production in the European Union is rapidly evolving as the region shifts from fossil fuels to renewable sources like wind, solar, and biomass. This transition is driven by ambitious climate goals, including achieving net-zero emissions by 2050. The EU is focused on diversifying its energy mix, improving efficiency, and fostering innovation to ensure a sustainable, secure energy future.

2.1.Production ofPetroleum

The European Union is not a major producer of petroleum, as it relies heavily on imports to meet its oil demand. However, some EU countries, such as the United Kingdom and Denmark, have significant offshore oil fields in the North Sea, which contribute to the region’s production. Despite a decline in domestic production over the years, the EU continues to extract petroleum primarily from these sources, though it still imports the majority of its oil, particularly

from countries like Russia, Norway, and the Middle East. The production of petroleum within the EU faces challenges due to the depletion of local reserves and a growing shift toward renewable energy sources and climate goals that encourage reducing fossil fuel dependence.(European Commission, 2020)

Gross available energy in the European Union in 2022 decreased compared with 2021 (-4.5 %). Oil (crude oil and petroleum products) continued to be the most significant energy source for the European economy.

2.2. Production of Natural Gas in the EU

Natural gas production in the European Union is relatively limited, as the region is a net importer of gas. The largest producers within the EU are the Netherlands, the United Kingdom, and Norway (although Norway is not an EU member but is part of the European Economic Area). However, domestic production has been declining in recent years, particularly in the Netherlands, where the Groningen gas field, once one of the largest in Europe, is being phased out due to seismic activity and environmental concerns.

The EU's natural gas production still plays an important role in meeting regional demand, but this is increasingly supplemented by imports, primarily from Russia, Norway, and more recently, from the United States via liquefied natural gas (LNG) shipments. The geopolitical tensions, such as the Russia-Ukraine conflict, have underscored the EU's need for diversification in its gas supply sources to ensure energy security.

The EU is also exploring the role of natural gas as a "transition fuel" in its path toward decarbonization, balancing the need for a reliable energy source with efforts to reduce greenhouse gas emissions. Additionally, there are ongoing efforts to develop more sustainable alternatives, such as biogas and green hydrogen, to eventually reduce the EU's dependence on fossil fuels like natural gas.(European Commission, 2021)

natural gas remained the second largest energy source. When comparing 2022 with 2021, oil increased by 2.8 %, while natural gas decreased by 13.3 %. This decrease was mostly due to the demand-reduction measures taken as a consequence of the Russian war on Ukraine.

2.3. Production of Coal in the EU

Coal production in the European Union has significantly declined over the past few decades, as the EU has shifted towards cleaner and more sustainable energy sources in line with its climate goals. Historically, coal was a dominant energy source for electricity generation and industry in several EU countries, particularly in Poland, Germany, and the UK. However, the transition to renewable energy, stricter environmental regulations, and the EU's commitment to reducing greenhouse gas emissions have all contributed to a steady decline in coal production.(World Energy Council (WEC), 2022)

Poland remains the largest coal producer in the EU, relying heavily on coal for electricity generation and heating. However, even Poland has made steps toward reducing its dependence on coal, although the process is complex due to the socio-economic importance of the coal industry in certain regions. Germany, once a major coal producer, has committed to phasing out coal entirely by 2038 as part of its"Kohleausstieg" (coal exit) policy, aiming to reduce carbon emissions and meet its climate targets.

The overall trend in the EU is toward reducing coal production in favor of cleaner energy sources such as wind, solar, and natural gas. This transition is also supported by the EU’s Green Deal and the "Fit for 55" package, which aims to cut emissions by 55% by 2030. Despite this shift, coal remains a significant energy source in some EU countries, and its phase-out presents challenges, including addressing the impact on jobs and communities dependent on the coal industry.

In summary, while coal production in the EU is on the decline due to environmental policies and the rise of renewable energy, it remains an important issue in some member states as the region works toward a greener energy future.

2.4.Production of Wind Energy in the EU

Wind energy has become one of the most important and rapidly growing sources of renewable energy in the European Union. The EU is a global leader in wind power, both in terms of installed capacity and technological advancements. Wind energy plays a key role in the EU's strategy to reduce greenhouse gas emissions and achieve its climate goals, particularly the goal of reaching net-zero emissions by 2050.

The EU benefits from favorable geographical conditions, with significant wind resources, especially in coastal regions and on the open sea. Offshore wind farms, in particular, are a major area of development, with countries like the United Kingdom, Germany, Denmark, and the Netherlands leading the way in offshore wind installations. The North Sea, with its strong and consistent winds, is a focal point for these projects, which are expected to play a critical role in the EU's future energy production. (Sterling & Ziegler, 2023)

Onshore wind energy is also a significant contributor, with countries such as Spain, Germany, and France having large onshore wind farms that help meet national and regional energy needs. The EU has set ambitious targets for wind

energy, aiming to increase its share of total energy consumption and capacity in the coming decades. According to the European Commission's plans, wind energy could supply up to 30% of Europe's electricity by 2030.

The growth of wind energy is supported by various EU policies, including the European Green Deal, which promotes the transition to clean energy, and the "Fit for 55" package, which aims to cut emissions and accelerate renewable energy deployment. The development of wind energy is also driving job creation and technological innovation within the EU, positioning Europe as a key player in the global renewable energy market. (Reiche, 2023)

In summary, wind energy production in the EU is a success story of renewable energy development, marked by rapid growth, technological leadership, and an important part of the EU's commitment to a sustainable and decarbonized energy system.

2.5.Production of Hydrogen in the EU

Hydrogen production in the European Union is gaining momentum as a key element in the transition to a low-carbon energy system. Hydrogen is seen as a versatile energy carrier that can decarbonize hard-to-electrify sectors such as heavy industry, transportation, and heating. The EU has identified hydrogen as a crucial part of its long-term energy strategy, with a focus on producing "green hydrogen" from renewable sources like wind and solar power, as well as "blue hydrogen" produced from natural gas with carbon capture and storage (CCS) technology.

Currently, most hydrogen produced in the EU is "grey hydrogen," made from natural gas without capturing the carbon emissions. However, the EU is making significant strides to increase the production of clean hydrogen. The European Commission's Hydrogen Strategy for a Climate-Neutral Europe, unveiled in 2020, aims to scale up the production of green hydrogen and build the necessary infrastructure to support its widespread use.(International Energy Agency (IEA), 2023)

Germany is a frontrunner in hydrogen production within the EU, with ambitious plans for hydrogen production and a clear focus on green hydrogen. The Netherlands, France, and Spain are also making significant investments in hydrogen production and infrastructure. The EU's goal is to produce 10 million tons of renewable hydrogen by 2030, while also importing another 10 million tons from regions with abundant renewable energy resources.

Hydrogen can be used in a variety of sectors, from industrial processes (such as steelmaking and chemicals production) to transportation (with hydrogen-powered trucks, buses, and trains), and even as an energy storage solution. It also holds potential for use in decarbonizing the heating sector, especially in areas where direct electrification is challenging.

Despite its promise, the production of hydrogen in the EU faces severalchallenges, including high production costs, the need for technological advancements, and the establishment of a reliable infrastructure for transportation and storage. Nonetheless, hydrogen is seen as a cornerstone of the EU's green transition and its efforts to achieve carbon neutrality by 2050. With continued investments and innovation, hydrogen could become a central player in Europe's clean energy future.

In summary, the production of hydrogen in the EU is rapidly evolving, with a strong push toward green and blue hydrogen as the region looks to decarbonize its economy, enhance energy security, and drive technological leadership in the global hydrogen market.

2.6.Production of Nuclear Energy in the EU

Nuclear energy remains a significant part of the European Union's energy production mix, particularly as a low-carbon source of electricity. Although the role of nuclear energy in the EU's energy landscape is a subject of ongoing debate, it continues to provide a substantial share of the region's electricity, especially in countries like France, Slovakia, and Hungary. Nuclear power offers a reliable, base load source of energy that helps reduce reliance on fossil fuels, contributing to the EU's efforts to decarbonize its energy system and meet climate goals.

France is the EU's largest producer of nuclear energy, with nuclear plants accounting for around 70% of the country's electricity generation. This makes France one of the most nuclear-dependent countries in the world. Other countries, such as Finland, the Czech Republic, and Bulgaria, also rely on nuclear power to meet a significant portion of their electricity needs. The EU overall generates approximately 25-30% of its electricity from nuclear energy.(Sullivan, 2023)

The role of nuclear power in the EU's energy transition is viewed differently across member states. Some countries, like Germany and Austria, have committed to phasing out nuclear energy in favor of renewable, citing concerns over safety, waste disposal, and the potential for catastrophic accidents. Germany, for example, is in the process of shutting down its nuclear reactors as part of its "Energiewende" (energy transition), which focuses on replacing nuclear and fossil fuels with renewable energy sources.

However, other EU countries view nuclear energy as essential to meeting both energy demand and climate goals. Nuclear power is considered a reliable, low-carbon energy source that can complement intermittent renewable energies like wind and solar, providing stable electricity when renewable generation is low. The EU's long-term climate and energy strategies, such as the European Green Deal and Fit for 55 package, include nuclear energy as part of a diversified energy

mix.

In addition to existing nuclear plants, there are ongoing discussions about new nuclear technologies. Small Modular Reactors (SMRs) are gaining attention as a potential innovation in nuclear energy, offering safer, more flexible, and potentially more cost-effective solutions compared to traditional large-scale reactors. Research and development into next-generation nuclear technologies, such as thorium reactors and fusion energy, also hold promise for the future. (Kostov, 2022)

In summary, nuclear energy in the EU plays a crucial role in electricity generation, offering a low-carbon alternative to fossil fuels. While some EU countries are moving away from nuclear energy, others continue to rely on it as part of a balanced energy mix. The future of nuclear power in Europe will likely depend on technological innovation, safety considerations, and how it aligns with the EU's broader energy and climate objectives.

3. Energy Dependence and External Suppliers in the EU

Energy dependence on external suppliers is a significant challenge for the European Union (EU), as the region imports a substantial portion of its energy needs, particularly fossil fuels. This reliance creates vulnerabilities in the face of geopolitical tensions, supply disruptions, and price volatility. Understanding the EU's energy dependence on external suppliers—and the associated risks—is key to addressing energy security challenges.

3.1. Dependence on Energy Imports

The EU is highly dependent on imports for its energy supply. Around 60% of the EU's energy is imported, with fossil fuels—namely oil, natural gas, and coal—making up the largest share of these imports. The EU's reliance on external suppliers varies by country, but overall, it faces several key challenges:

- Natural Gas: The EU imports more than 70% of its natural gas, with major suppliers including Russia, Norway, and increasingly the United States (via liquefied natural gas, or LNG). Russia has historically been the largest supplier, accounting for over 40% of EU gas imports prior to the geopolitical tensions that arose following the 2022 invasion of Ukraine. This dependency on a single supplier has raised concerns about supply security, especially during times of political or economic conflict. (European Council, 2022)

- Oil: The EU imports around 90% of its crude oil, with major suppliers including Russia, the Middle East, and Norway. While the EU has made strides toward reducing oil dependence by diversifying its supply sources, the volatility of global oil markets still presents a challenge for long-term energy security.

- Coal: Though coal production in the EU has decreased significantly, some countries—such as Poland and Germany—still rely on imports of coal for electricity generation and heating. Coal is mainly imported from countries like Russia, the United States, and Australia.

3.2. Geopolitical Risks and Supply Vulnerabilities

The EU's reliance on external suppliers exposes it to a range of geopolitical risks that can affect the security, affordability, and reliability of its energy supply. Some key issues include:
- Political Instability: The EU is vulnerable to disruptions caused by political tensions or conflicts in energy-supplying regions. For example, Russia's annexation of Crimea in 2014 and the subsequent Ukraine conflict in 2022 raised significant concerns about gas supply security in Europe. The EU's dependence on Russian gas made it susceptible to political leverage and supply cuts during times of geopolitical conflict.

- OPEC and Oil Price Volatility: The EU is also exposed to price volatility in global oil markets, particularly due to decisions made by the Organization of the Petroleum Exporting Countries (OPEC) and other key producers. Price fluctuations, which can be influenced by geopolitical tensions or changes in global demand, can lead to instability in energy prices within the EU.

- Energy Supply Disruptions: Energy supply disruptions due to natural disasters, accidents (such as pipeline explosions), or infrastructure failures are also a risk. The EU's dependence on pipelines and other infrastructure, such as LNG terminals, makes it vulnerable to supply chain interruptions.

3.3. The Russia Factor: A Special Case

Historically, Russia has been the EU's largest supplier of natural gas, oil, and coal, which has resulted in significant energy dependence. However, the geopolitical implications of this reliance have become particularly evident

in recent years:

- Russia's Energy Leverage: Russia has historically used its energy exports as a tool for political influence, which has made the EU's energy security precarious. Russia has previously reduced gas exports to the EU in response to political disputes, most notably during the "gas wars" with Ukraine.

- Impact of the Ukraine Conflict: The 2022 Russian invasion of Ukraine has dramatically highlighted the EU's vulnerability to Russian energy cuts. In response to the invasion, the EU imposed sanctions on Russian energy exports, and Russia in turn reduced or halted its gas exports to Europe. This led to skyrocketing energy prices and triggered the EU's urgent push to find alternative energy sources, diversify its supply chains, and invest in renewables.

3.4. Diversification of Energy Suppliers and Routes

In response to its energy dependence and the vulnerabilities associated with reliance on a small number of external suppliers, the EU has been taking measures to diversify its energy sources and suppliers. This strategy is aimed at reducing dependency and increasing energy security:

- Increasing LNG Imports: The EU has been working to increase its imports of liquefied natural gas (LNG) from alternative suppliers, particularly from the United States, Qatar, and other LNG-exporting countries. The development of new LNG terminals and the expansion of existing infrastructure has been a priority, especially in countries like Germany, Spain, and the Netherlands.

- Diversifying Pipeline Supply Routes: To reduce reliance on Russian pipelines, the EU has been investing in new pipeline projects and alternative gas supply routes. For example, the Southern Gas Corridor (linking Azerbaijan to Italy via Georgia and Turkey) and the Baltic Pipe (connecting Poland to Norway) are key projects aimed at diversifying natural gas imports. The Trans-Adriatic Pipeline (TAP), which is part of the Southern Gas Corridor, is another key infrastructure project that allows the EU to bring gas from the Caspian region.(Zander & Huber, 2023)

- Renewable Energy: The EU's push to diversify its energy mix with renewable energy sources—wind, solar, hydro, and biomass—also contributes to energy security. By reducing the need for fossil fuel imports, renewable energy lessens the EU's dependence on external suppliers and enhances resilience.

3.5. The Role of Energy Efficiency and Demand Reduction

Another important part of the EU's strategy for reducing dependence on external suppliers is increasing energy efficiency and reducing overall energy demand. This is being achieved through:

- Energy Efficiency Directives: The EU has set ambitious targets for improving energy efficiency in buildings, transportation, and industry. Improving efficiency reduces overall demand and the reliance on energy imports.

- Demand Response and Smart Grids: Technologies like smart meters and demand response systems enable consumers to better manage their energy consumption, helping to reduce peak demand and avoid reliance on imported energy during times of high usage.

3.6.The Energy Transition and Long-Term Energy Security

As the EU transitions to a low-carbon economy, energy security concerns remain at the forefront. The EU is focusing on both energy diversification and decarbonization to ensure that energy security is maintained in a cleaner and more sustainable way.(European Court of Auditors, 2022) This includes:

- Renewable Energy Expansion: Increased investments in renewable energy sources, such as offshore wind, solar, and geothermal energy, which reduce dependence on fossil fuel imports.

- Green Hydrogen: The EU is exploring hydrogen as a potential game-changer in energy security. Green hydrogen, produced from renewable electricity, can serve as a clean energy carrier and help store energy from intermittent renewable sources.

- Battery Storage: Enhanced energy storage technologies, such as advanced battery systems, will allow the EU to store excess renewable energy, further reducing the need for imports.

4.Conclusion

Balancing energy security and sustainability in the EU is a delicate and evolving process. The EU's ambitious climate policies and renewable energy targets are critical to achieving a low-carbon future, but they must be carefully managed to ensure that they do not compromise the availability, affordability, or reliability of energy. Through diversification of energy sources, technological innovation, infrastructure development, and regional cooperation, the EU is working to meet both its energy security and sustainability objectives. Ultimately, the successful integration of these goals will depend on continued investment in clean energy solutions, smart grid technologies, and the collaboration of all EU member states in ensuring a secure, sustainable, and affordable energy future.

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