

Global Transition to Renewable Energy: Challenges, Investments, and Future Outlooks in Electricity Grid Integration

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Abstract:

This study paper seeks to analyze the current shift towards renewable energy and its incorporation into global electrical systems. The study examines critical elements of this shift, encompassing the difficulties of incorporating variable renewable energy sources (such as solar and wind) into conventional networks, the technology innovations facilitating this integration, and the policies propelling change. The analysis examines worldwide investment trends in renewable energy infrastructure and compare expenditure patterns across regions to discover discrepancies and opportunities. The research evaluates previous alterations in the energy mix and offer projections based on prevailing patterns, emphasizing the anticipated progression of renewable adoption and its prospective effects on energy security, expenses, and emissions.

Keywords: Renewable energy ; Energy Investments; Grid Stability; Energy Storage.

Jel Classification Codes : Q40 ; Q42 ; L94.

Résumé:

Cette étude vise à analyser l'évolution actuelle vers les énergies renouvelables et leur intégration dans les systèmes électriques mondiaux. L'étude examine les éléments critiques de cette évolution, englobant les difficultés d'intégration de sources d'énergie renouvelables variables (telles que l'énergie solaire et l'énergie éolienne) dans les réseaux conventionnels, les innovations technologiques facilitant cette intégration et les politiques qui propulsent le changement. L'analyse examine les tendances mondiales en matière d'investissement dans les infrastructures d'énergie renouvelable et comparera les schémas de dépenses entre les régions pour découvrir les écarts et les opportunités. La recherche évalue les modifications antérieures du mix énergétique et proposera des projections basées sur les tendances actuelles, en mettant l'accent sur la progression prévue de l'adoption des énergies renouvelables et ses effets potentiels sur la sécurité énergétique, les dépenses et les émissions.

Mots clés: Energie renouvelable ; Investissements énergétiques ; Stabilité du réseau ; Stockage d'énergie

Jel Classification Codes : Q40 ; Q42 ; L94.

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I. Introduction

The integration of renewable energy sources into global energy systems is increasing, both in developed and developing countries. This integration contributes to the sustainability of existing technologies and the neutralization of risks (Barykina & Shao, 2023). Integrated approaches enable the provision of electricity, heat, cooling and mobility in an interconnected manner (Barykina & Shao, 2023).

In light of this, investments in renewable energy development technologies have increased significantly over the past decade. High growth rates in installed capacity of renewable energy plants are notable (Dzyuba & Semikolenov, 2023). In Australia, for example, public-private partnerships (PPPs) are facilitating the development of renewable energy generation infrastructure, which is essential for the national transition to renewable energy adoption (Li, Edwards, Hosseini, & Costin, 2020).

Looking ahead, long-term forecasts show that the capacity of renewable energy technologies, such as solar and wind, will continue to grow. Global average costs of photovoltaic energy are projected to decline from \$0.057/kWh to less than \$0.03/kWh by 2030 and to less than \$0.02/kWh by 2040 (Rozon, McGregor, & Owen, 2023). However, without direct interventions to accelerate the growth of wind energy production, the deployment of renewable energy technologies may not reach the capacities needed to meet climate change targets (Rozon, McGregor, & Owen, 2023).

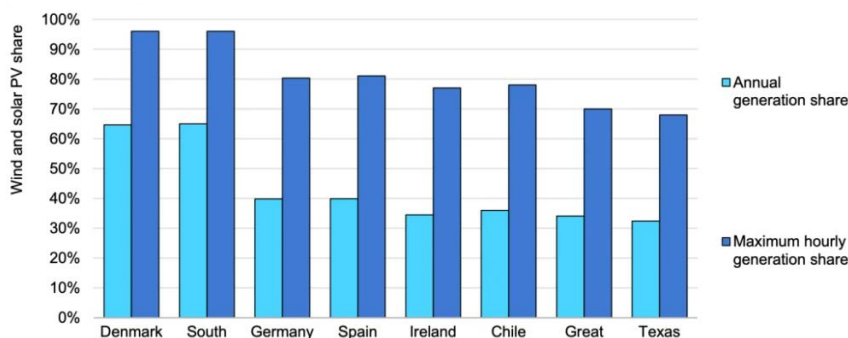
However, the shift towards a renewable energy-dominated grid is fraught with complexities. Technological barriers, regulatory frameworks, and economic considerations often hinder the seamless integration of these variable energy sources into traditional power systems. Issues such as grid stability, energy storage requirements, and the need for infrastructure upgrades necessitate a comprehensive understanding of the challenges involved. In this context, our study answers the following main question: ***"What are the key challenges and investment strategies for integrating renewable energy sources into existing electricity grids, and how can these strategies address the potential barriers to achieving a sustainable energy future?"*** The research objectives, based on the given question, are as follows :

- To comprehensively understand the challenges faced in the integration of renewable energy into electricity grids.
- To identify effective investment strategies that can mitigate these challenges.
- To provide a forward-looking perspective on how these integrations can shape the future of energy systems globally.

II. Integration of Renewable Energy into Electricity Grids

Until now, electricity grids have been built according to a relatively centralized production mode, but they are undergoing a profound transformation with the emergence of renewable energies. Indeed, the use of the latter as the main source of electricity production highlights unit production capacities ranging from a few KW (mainly residential solar panels) to several hundred MW for large solar or wind power plants (with the exception of hydroelectricity). In reality, there is a significant expansion in the profile of potential producers, subject to the pressure exerted by the new dynamic of sustainable development on a global scale, encouraged by the launch of many ambitious national programs in this area.

Fig.(01): Top Contributions (2023) to Solar PV and Wind Power Generation



Source: (Evwind, 2024)

The data (illustrated in figure 01) present the diverse renewable energy integration progress across several countries, with Denmark and South Korea leading the pack in terms of annual generation share, reaching around 95% and 90% respectively. Germany, Spain, Ireland, and Chile also exhibit substantial renewable energy penetration, with annual shares ranging from 70% to 80%. These nations have demonstrated their ability to rely heavily on renewable sources, as evidenced by their high maximum hourly generation shares, particularly in Denmark, South Korea, and Ireland. In contrast, Texas lags behind, with relatively lower annual and maximum hourly shares of renewables, indicating its greater reliance on non-renewable energy sources. This data underscores the varying strategies and capabilities of different countries in the global transition towards a more sustainable energy future.

Indeed, renewable energies, in particular solar and wind, are responsible for the main technical difficulties that hinder a massive integration of electricity production based on these energies into the electricity grid (esmap, 2019). Concerns about grid stability, protection, and energy quality due to the

integration of renewable energy have been largely addressed through technological advancements. In particular, progress in inverter technology, which controls energy flow exchanges, has played a key role. This area is now a dynamic field of research, merging electrical engineering and renewable energy, aimed at improving energy flow management on the grid. Additionally, the development of technical standards and network codes is helping ensure efficient integration of renewable resources (IRENA, 2019). The creation of technical standards or network codes is one of the most obvious consequences of the latter, promoting an optimal integration of renewable energies in the network while preserving its stability and the quality of the energy served. In this regard, the managers of the transmission (TSO) and distribution (GRD) networks have been reaffirmed thanks to the remarkable consolidation of knowledge in this field, which also continues to evolve in different directions (IRENA, 2019).

Table (01): An overview of the renewable energy landscape across different countries in 2024 (GW)

Country/Region	Solar PV Capacity	Wind Power Capacity
China	500+	400+
United States	270	150
India	70	40+
European Union	200+	250+
Germany	70	65
Brazil	20+	20+
Australia	30+	10+
United Kingdom	14	30+
Japan	80	5+
South Korea	20	2+

Source: Elaborated by the authors based on (Evwind, 2024)

In this perspective, the table 01 provides a comprehensive overview of the global renewable energy landscape in 2024, showcasing the leading countries and regions in solar PV and wind power capacity. China emerges as the dominant player, with over 500 GW of solar PV and more than 400 GW of wind power, cementing its position as the global renewable energy powerhouse. The United States follows as the second-largest market, with significant investments in both solar (270 GW) and wind (150 GW) power. India also maintains a strong presence, with 70 GW of solar and over 40 GW of wind capacity. The European Union as a whole boasts substantial renewable energy capacity, with over 200 GW of solar PV and more than 250 GW of wind power, with Germany standing out as a key contributor within the EU. Additionally, countries like Brazil, Australia, the UK, Japan, and South Korea have varying levels of renewable energy development, each with their own unique strategies and priorities. This

data underscores the global momentum towards renewable energy, with leading nations driving the charge and diversifying their energy mixes to achieve a more sustainable future.

II.1 Storage management

The problem of large-scale storage of electrical energy is clearly posed by the intermittent nature of renewable energies (IRENA, 2019). The establishment of infrastructures to adequately guarantee this functionality therefore becomes an essential element of planning to improve the efficiency of electricity production from renewable resources. The system responsible for managing the grid will in fact be easier to support the latter, by providing it with a regulatory lever that allows it to constantly adjust production to demand, which remains an essential objective for the stability of the whole. In this regard, all approaches are being studied in order to achieve adequate solutions for mass storage of electrical energy, which remains the final step towards directly addressing the problems related to the intermittency of renewable resources and their integration into the electricity grid. It is important to emphasize that many financial and other resources are being invested in this path throughout the world, especially in pioneer countries, because this would actually represent a major event due to the economic stakes that arise in the future. In this way, different technologies are being examined that can guarantee mass storage of electrical energy (ifpen, 2024) (Table. 02).

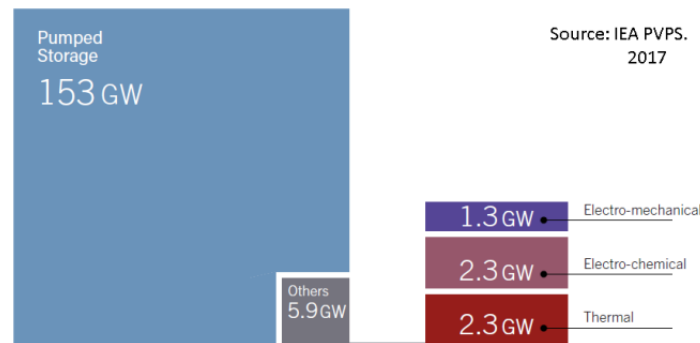
Table (02): Energy storage technologies and their power capacities (MW)

Technology	Power Storage Capacity
Heat	10
CAES - AA-CAES	10
Hydrogen	1
Flow batteries	10
Some lead and NaS batteries	1

Source: Elaborated by the authors based on (ifpen, 2024)

As of 2017, the predominant method, accounting for 96% of capacities, is based on Pumped Storage Energy Transfer Stations (PSETs), as introduced in Figure 02. Although this option exhibits low efficiency attributed to multiple energy conversion stages, it possesses the significant advantage of employing reliable and controlled techniques characteristic of hydroelectric power plants.

Fig.(02): Storage capacities by technology in the world (2017)



Source: (CEREFE, 2020)

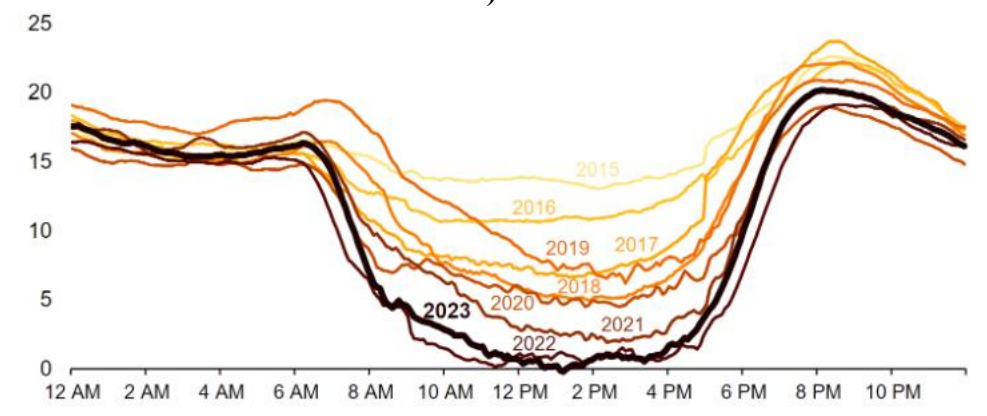
Other storage methods that make it possible to synchronize large powers with acceptable autonomy, such as CAES (Compressed Air Energy Storage) and flow batteries, are still in the experimental phase before being deployed on a large scale. As for hydrogen, it has not yet reached the industrial stage for its use as a means of storing renewable electricity. However, its various applications as an energy vector (Power to Gas, Power to X, or transformation of electricity produced from solar or wind energy into molecules, hydrogen, ammonia, etc.) are developing rapidly, particularly as a clean fuel in some countries (CEREFE, 2020).

II.2 The flexibility of the electricity grid

Grid flexibility refers to the ability of the system to balance supply and demand while managing the uncertainty and variability of variable renewable energy (VRE), while ensuring system security and reliability (Hadi, 2022). To improve this flexibility, several solutions are being implemented. Infrastructure investments play a key role, with a planned increase in VRE capacity to 44%, the addition of 1000 MW of transmission lines and the installation of 200 MW of battery storage (Zaheb, 2023). In addition, innovations in flexible coal and gas power plants, energy storage, and transmission and distribution networks contribute to enhancing this flexibility. On the demand side, domestic energy management, including heat pumps in the residential sector, the use of energy management systems for household appliances and electric vehicles, and consumption optimization in the industrial, commercial and agricultural sectors (such as supermarket refrigerators and irrigation pumps) play a crucial role (Golmohamadi, 2022). In addition, market policies and strategies are adopted, such as the development of new market frameworks for the purchase of reserve capacity to manage overloads and the introduction of time-based tariffs to provide economic incentives for consumers to adjust their consumption

(Takeshita, 2021). Furthermore, The graph (presented in Figure 03) depicts the fluctuations in electricity prices over the course of a day, showcasing the hourly changes from 12 AM to 10 PM across multiple years. The data reveals a distinct pattern, with prices generally peaking during the afternoon and evening hours, likely reflecting increased energy demands during those times.

Fig.(03): Conventional power plants in the California electricity grid (2015-2023)



Source: (AEI, 2023)

The graph also highlights significant year-over-year variations, with certain years, such as 2019 and 2020, exhibiting more pronounced price spikes compared to other years. This volatility in electricity prices underscores the dynamic nature of energy supply and demand, and the importance of understanding and managing these fluctuations to ensure the reliability and affordability of the electricity grid. The data provides valuable insights for energy stakeholders, policymakers, and consumers in their efforts to optimize energy usage and plan for the future.

III. Investments and Expenditure Trends in Renewable Energy

Previous studies on global trends in the development of different technologies related to the exploitation of renewable resources have mainly been based on the evolution of installed capacities worldwide. From this perspective, it appears that hydropower, wind and solar alone represent nearly 2400 GW, which represents 95% of all renewable energy resources used in 2019 worldwide. However, only wind and solar photovoltaic are by far the most significant, with average annual rates of around 10% and 25% respectively between 2015 and 2019 (Table 3).

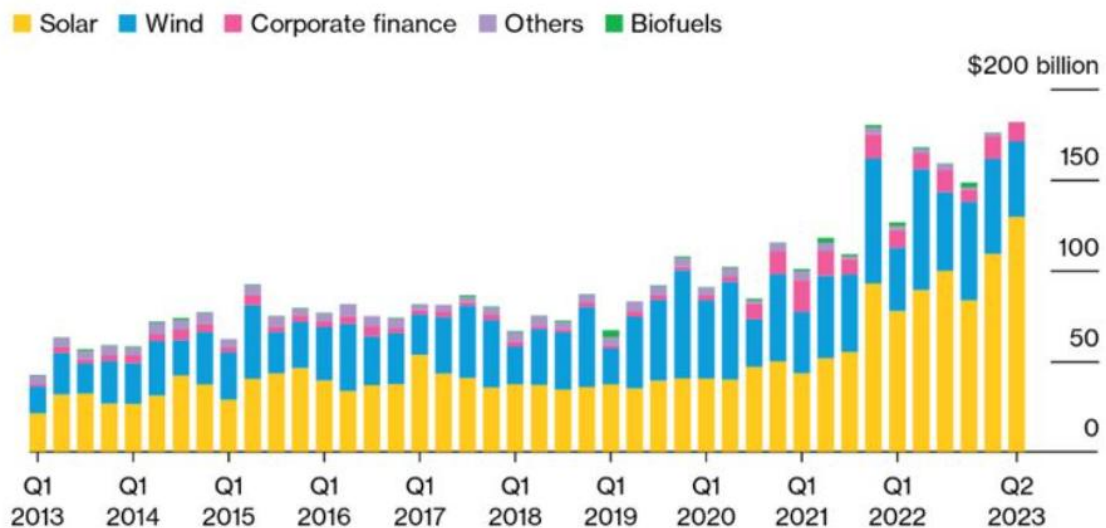
Table (03): Electricity production capacities (in GW) based on renewable resources over the last five years

Primary renewable source	2015	2016	2017	2018	2019
Hydroelectricity	1099,00	1129,00	1156,00	1177,00	1189,00
Wind (On and Offshore)	416,00	467,00	514,00	564,00	623,00
Solar (CSP + PV)	222,00	296,00	389,00	489,00	586,00
Biomass	97,00	105,00	111,00	117,00	124,00
Geothermal	12,00	12,00	13,00	14,00	15,00
Total	1846,00	2009,00	2183,00	2361,00	2537,00

Source: (CERFE, 2020)

As detailed in table 3, hydroelectricity remains the dominant renewable source, with its capacity growing steadily from 1,099 GW in 2015 to 1,189 GW by 2019. Wind power has also seen substantial growth, increasing from 416 GW in 2015 to 623 GW in 2019, showcasing the rapid expansion of both onshore and offshore wind energy. Solar power, including concentrated solar power (CSP) and photovoltaics (PV), has experienced the most remarkable expansion, more than doubling its capacity from 222 GW in 2015 to 586 GW in 2019, highlighting the accelerating adoption of solar energy globally. Biomass and geothermal energy have also maintained consistent growth, albeit at a slower pace compared to the more prominent renewable sources. The overall trend indicates a significant increase in the total installed capacity of primary renewable energy sources, rising from 1,846 GW in 2015 to 2,537 GW by 2019, reflecting the global shift towards sustainable energy generation.

Fig.(04): Renewable energy investments between 2013 and 2023



Source: (BloombergNEF, 2023)

Regarding the investment expenditure related to wind and solar photovoltaics, the graph (illustrated in figure 04) presents the quarterly investment trends across various renewable energy sectors from 2013 to 2023. The data shows that solar energy has consistently been the largest recipient of investments, with a significant uptick in recent years, reaching over \$90 billion in the second quarter of 2023. Wind energy investments have also seen substantial growth, with fluctuations but a general upward trend, reaching around \$50 billion in the same period. Corporate finance has emerged as an increasingly important source of funding for renewable energy projects, while investments in biofuels and other categories have remained relatively stable. The overall trend indicates a steady increase in renewable energy investment, with solar and wind power leading the charge as the energy transition accelerates globally. This data highlights the growing confidence and commitment of investors in the renewable energy sector as it becomes an increasingly viable and attractive alternative to traditional fossil fuel-based energy generation.

Despite the generally encouraging investment trends, issues like supply chain interruptions, legal restrictions, and the intermittent nature of renewable energy sources continue to exist (Anvari, Lohmann, Wächter, & Milan, 2016). However, there are plenty of chances to get beyond these obstacles and quicken the global energy transition thanks to developments in energy storage technologies, grid infrastructure, and legislative frameworks (Jiang, Liu, & Peng, 2024).

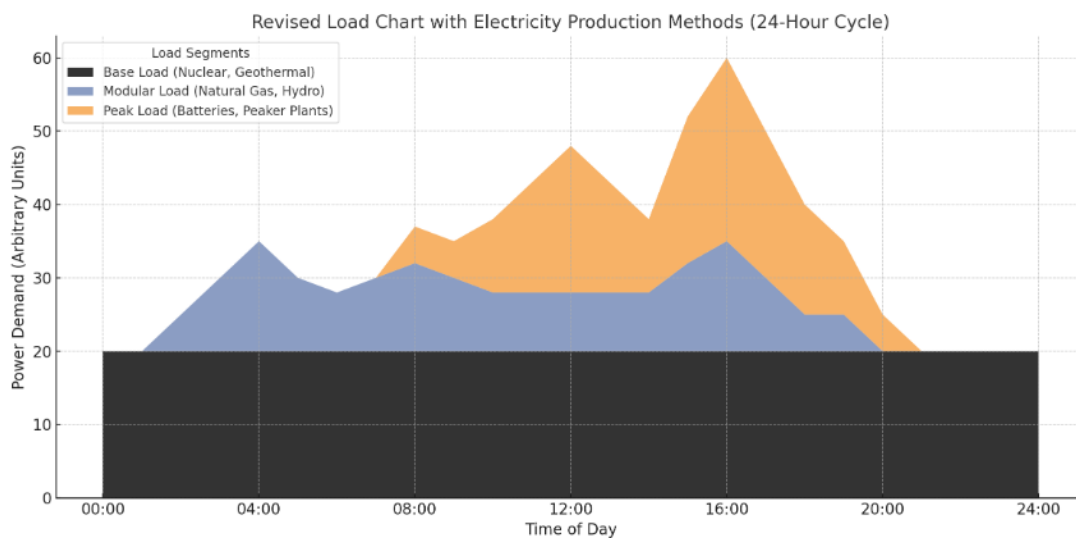
An important step toward a cleaner, more sustainable energy landscape is the consistent rise in investments in renewable energy, especially in solar and wind power. The renewable energy industry is positioned to become the foundation of global energy systems, propelling economic growth, lowering greenhouse gas emissions, and promoting energy security as long as technology keeps improving and public awareness keeps rising.

III.3 Wholesale electricity sales

The deregulation of the electricity generation industry in some developed countries towards the end of the last century, such as in Great Britain from the early 1990s, led to the introduction of wholesale markets dedicated to electrical energy, with the aim of creating some competition in the sector. However, since the quantity of electricity used in the transactions in question (futures, spot contracts, etc.) is impossible to store on a large scale with current technologies, at least at acceptable costs, it is necessary to adjust it almost in real time to meet demand. Given that the latter is random and can fluctuate considerably throughout the day, not to mention seasonal variations, it would be easier to find a balance between supply and demand by using fast capacities, especially during

peak hours. Since such a performance criterion is highly influenced by the technologies used, the mentioned peculiarity of the electricity market lies in the fact that the market value of the product in question is not only linked to its intrinsic quality, but also to the means used for its marketing. This also arouses the interest of the main customers, namely the electricity grid managers, who must ensure the optimization of the mix of resources to be mobilized in order to meet the imposed consumption at the lowest cost. In this perspective, it is necessary to vary the production fleet to respond appropriately to different situations, depending on the level of demand and the flexibility requirements (Fig. 05).

Fig.(05): Load charter and appropriate electricity production methods



Source: (CEREFEE, 2020)

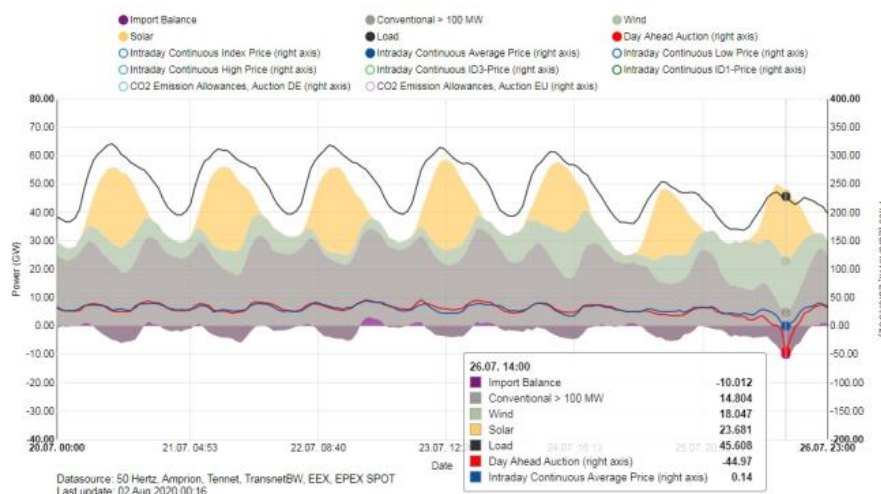
In actuality, various purchasing characteristics exist within the wholesale energy markets, among which we may particularly distinguish: First, long-term acquisitions are conducted to guarantee the fulfillment of the persistent fundamental demand on the network. They entail the delivery of continuous power year-round, predicated on long-term contracts, typically established equitably. Second, balancing purchases refer to the acquisition of flexible power capable of accommodating fluctuations in demand, typically assessed in the short term (such as the following day) and occasionally in the immediate short term (such as the following hour). In this context, acquisitions are conducted on-site to ensure availability at certain times, typically the following day or within hours.

III.4 Renewable energies, spot markets and low prices

Electricity generation from intermittent renewable sources, including wind and solar photovoltaic, does not adequately fulfill the criteria necessary for integration into dedicated wholesale or spot markets, such as demand availability and controlled variability. They do not require this support as they benefit from

prior commitments to purchase their production over extended periods, typically ranging from 20 to 25 years, established through tenders at specialized public auctions. Their indirect influence on electricity market prices has become more pronounced alongside the increase in installed capacities. The support mechanisms provided to them, such as purchase obligations and priority access to the network, enable indirect influence over market prices in specific instances. Concerning solar photovoltaic and wind power, it is probable that periods of high energy production (such as sunny spring days and favorable winds) coincide with times of low electricity demand. This is especially relevant for public holidays in developed nations, where industrial and service sector electricity consumption is minimized, in contrast to peak usage during operational days. Consequently, any potential overproduction relative to demand necessitates a mandatory reduction in the equivalent capacity allocated to the operational conventional power plants. If the imbalance is significant, the necessary reduction in the production regime for certain units may lead to operations below a technical minimum, resulting in financial losses. Temporary shutdowns introduce various risks, including minimum incompressible shutdown duration and restart costs. In this context, the producer may opt to sell its production on the spot market at a calculated negative price to avoid incurring even greater losses. The situations outlined in the presented scenario have become more frequent in recent years, especially in certain European wholesale electricity markets. The most compelling evidence is the comprehensive data presentation available on the Fraunhofer Institute for Solar Energy Systems ISE website, which focuses on the German electricity market.

Fig.(06): Electricity prices in Germany market (week of 20 to 27 July 2020)



Source: (CEREF, 2020)

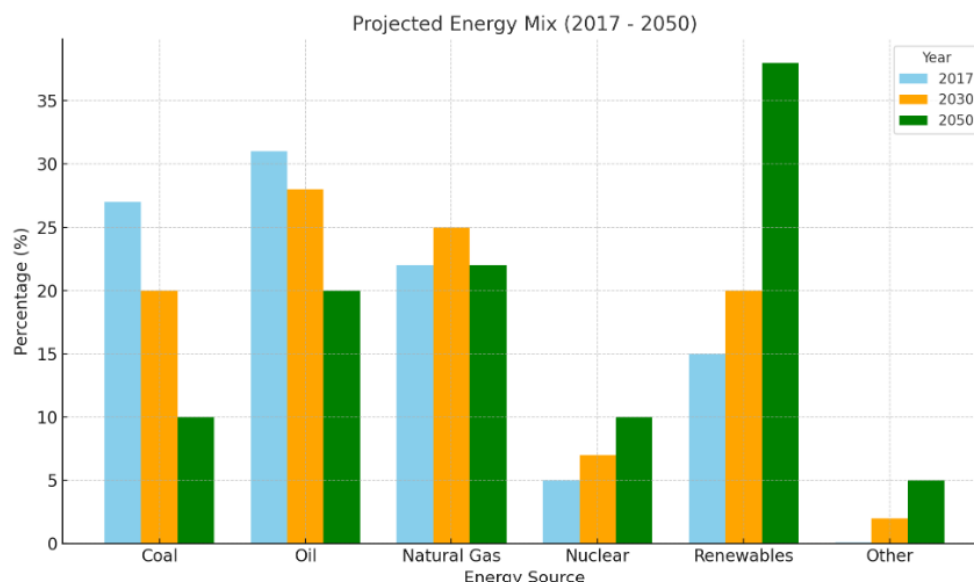
Indeed, this detailed energy market data (presented in figure 06) visualizes the intricate relationships between electricity prices, CO2 emission allowance trading, renewable wind power generation, and overall system capacity and demand. The graph demonstrates the significant volatility in electricity prices,

reflecting the dynamism of supply and demand, as well as the fluctuating nature of renewable energy sources like wind power. The emissions trading data further highlights the market's responses to factors influencing the supply and demand for carbon credits. Underlying these trends are the broader energy system dynamics, including the balance of imports and exports, as well as the conventional generation capacity and overall electricity load. This comprehensive data set provides valuable insights for stakeholders navigating the complexities of the evolving global energy landscape.

IV. Global Energy Shifts and Future Projections

Energy transition action plans began in the 1980s, driven by crises in the global energy market, growing environmental awareness, and the rise of renewable energy. Technological advancements shaped the future of energy, depending on each country's capacity and goals for energy security, independence, and local development. These transitions required careful, long-term planning to avoid disruptions in key sectors. Regulatory frameworks were put in place to guide the shift, with laws aimed at liberalizing electricity production and embracing decentralized renewable sources, which became integral to future energy mixes. (IRENA, 2019).

Fig.(07): Projections (IEA) concerning the global energy mix (2017-2050)



Source: (AEI, 2023)

As illustrated in figure 07, the projected global energy mix from 2017 to 2050 indicates a significant shift towards renewable energy sources, which are expected to more than double their share from around 5% in 2017 to over 30% by 2050. This growth in renewables is accompanied by a decline in the reliance

on coal, from 27% to 15%, and a moderate reduction in oil's share, from 27% to 20%. Natural gas and nuclear energy are projected to maintain relatively stable roles, with natural gas ranging from 22% to 24%, and nuclear staying around 5-6% of the mix. Other emerging energy sources, like geothermal and hydrogen, are also anticipated to see a slight increase in their contributions over this period, reflecting the overall transition towards a more diversified and sustainable global energy system.

The shift towards renewables has far-reaching implications for industries and economies worldwide. It promises to create new opportunities in clean energy jobs, drive innovation in storage and grid technologies, and reduce greenhouse gas emissions. However, it also poses challenges for fossil fuel-dependent industries and regions, requiring a just transition to mitigate economic and social disruptions.

Ultimately, the projected energy mix from 2017 to 2050 highlights a pivotal shift towards a cleaner, more diversified energy system. While challenges remain, this transformation underscores a global commitment to addressing climate change and fostering a sustainable energy future. The coming decades will be crucial in ensuring that these transitions are equitable, efficient, and impactful.

IV. Conclusion

The integration of renewable energy into global energy systems is expanding, supported by increasing investments and enabling policies. Moreover, projections show continued increases in capacity and reductions in the costs of renewable technologies, although however, additional interventions are needed to meet climate targets. In fact, global trends indicate continued interest in renewable resources and increased energy efficiency to reduce the environmental impact of energy production.

On the one hand, the integration of renewable resources presents significant opportunities for sustainable economic growth and reducing environmental impacts. On the other hand, it faces technical, financial and regulatory challenges. To address these, solutions include developing innovative financial models, improving energy storage technologies and establishing enabling regulatory frameworks. Furthermore, these combined efforts can facilitate a more efficient and resilient energy transition.

In brief, the increase of the integration of renewable energy sources is being pushed by the increasing investments, favorable regulations, and reducing costs of technology. Nevertheless, further measures will be necessary in order to achieve the chosen climate goals. The move to renewable energy sources has a number of problems; nevertheless, it also presents a number of major benefits.

These benefits can be realized through an all-encompassing approach that addresses the technological, economical, and regulatory constraints.

IV. References:

- AEI. (2023, 07 05). *californias electricity duck curve is deepening*. Retrieved from pv magazine: <https://pv-magazine-usa.com/2023/07/05/californias-electricity-duck-curve-is-deepening/>
- Barykina, Y., & Shao, Y. (2023). Integration of renewable energy sources into energy systems. *IOP Conference Series: Earth and Environmental Science, Volume 1212*. Tajikistan.
- BloombergNEF. (2023). *renewable-energy-investment-hits-record-breaking-358-billion-in-1h-2023*. Retrieved from BloombergNEF: <https://about.bnef.com/blog/renewable-energy-investment-hits-record-breaking-358-billion-in-1h-2023/>
- CEREFÉ. (2020). *Transition Energétique*. CEREFÉ.
- Dzyuba, A., & Semikolenov, A. (2023). RESEARCH OF GLOBAL ENERGY TRENDS AIMED AT THE DEVELOPMENT OF ACTIVE ENERGY COMPLEXES. *Bulletin of Udmurt University. Series Economics and Law*.
- esmap. (2019). *annual report 2019*. Retrieved from esmap: <https://annualreport.esmap.org/>
- Evwind. (2024, 09 23). *evwind*. Retrieved from windreve: <https://www.evwind.es/2024/09/23/chart-how-much-photovoltaic-or-wind-power-dominate-renewable-energy-in-different-countries/101152>
- Golmohamadi, H. (2022). Demand-Side Flexibility in Power Systems: A Survey of Residential, Industrial, Commercial, and Agricultural Sectors. *Sustainability*.
- Hadi, M. M.-A. (2022). A Comprehensive Review on Power System Flexibility: Concept, Services, and Products. *IEEE Access*, 10.
- ifpen. (2024). *stockage-denergie-accompagner-deploiement-des-energies-renouvelables*. Retrieved from ifpen: <https://www.ifpenergiesnouvelles.fr/enjeux-et-prospective/decryptages/climat-environnement-et-economie-circulaire/stockage-denergie-accompagner-deploiement-des-energies-renouvelables>
- IRENA. (2019). *Innovation landscape brief: Future role of distribution system operators*. Abu Dhabi: International Renewable Energy Agency.
- Li, H., Edwards, D., Hosseini, M., & Costin, G. (2020). A review on renewable energy transition in Australia: An updated depiction. *Journal of Cleaner Production*, 242.



- Rozon, F., McGregor, C., & Owen, M. (2023). Long-Term Forecasting Framework for Renewable Energy Technologies' Installed Capacity and Costs for 2050. *Energies*.
- Takeshita, T. A. (2021). Assessment of utilization of combined heat and power systems to provide grid flexibility alongside variable renewable energy systems. *Energy*, 214, 118951.
- Zaheb, H. A. (2023). Optimal Grid Flexibility Assessment for Integration of Variable Renewable-Based Electricity Generation. *Sustainability*.