International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 14, Issue 1 [January. 2025] PP: 134-144

Exploring the Role of Sustainable Energy in Achieving a Prosperous Future

Engr (Dr) Ekeinde, Evelyn Bose, Engr. Mamukuyomi, Julie Bemigho
Department of Petroleum and Gas Engineering, Federal University Otuoke, Federal University Otuoke, Bayelsa State, Nigeria

ABSTRACT
Understandings of rock mechanical properties under different environmental conditions become essential to multiple energy sector applications in sustainable energy development and the attainment of Sustainable Development Goals (SDGs) by 2030. The primary goal of this review investigates the effects temperature pressure and pore fluid have on rock mechanical characteristics. The improvement of drilling procedures together with enhanced hydrocarbon extraction and optimized reservoir management require this knowledge. The authors performed an extensive literature review which included systematic research selection to analyze studies focusing on rock mechanical properties influenced by temperature, pressure and pore fluids. Research papers alongside field measurements and theoretical platform constructs build the foundation for comprehensive understanding of this subject domain. Temperature elevation substantially impacts rock strength properties and deformation characteristics while increased pressure modifies pore structures and fluid movement patterns and different pore fluids affect rock mechanical characteristics. The theoretical and experimental findings reveal intricate links between environmental variables and rock responses which generate vital data to enhance drilling along with production operations. The current understanding of rock mechanical properties under temperature pressure and pore fluid conditions receives an extensive review overview in this paper. Congruent findings demonstrate why engineers must assess these variables to improve efficiency alongside safety measures. Future investigations should create evolved modeling tools together with experimental procedures to study how these factors combine in real-world operations.
KEYWORDS: *Rock Mechanical Properties; Temperature; Pressure; Pore Fluid; Sustainable Energy Development; Drilling Optimization; Reservoir Management; Hydrocarbon Recovery*.

Date of Submission: 16-01-2025 Date of acceptance: 31-01-2025

I. Introduction

Energy stands as the foundation of our future development. Modern civilization depends on energy to provide our basic needs as well as the luxurious way of life we currently enjoy. The worldwide adoption of an energy-based system exists as an optimal concept. Global well-being advancement requires deliberate attention to wide-ranging energy security conditions and resource consumption patterns which differ among various regions. We face the imperative of addressing extensive environmental consequences resulting from how we obtain our energy supply. Our current energy consumption methods unambiguously generate major climate change effects by emitting greenhouse gases into atmospheric layers (Yalew et al., 2020). Energy production makes destructive marks that extend beyond what the environment confronts. Traditional energy technology creation results in major local pollution and simultaneously consumes high volumes of freshwater while fundamentally changing land management patterns (Shahzad et al., 2021). Consequently, ensuring that our energy provision aligns with societal goals necessitates a significant acceleration of innovation and the widespread deployment of sustainable, equitable, and environmentally friendly energy technologies (Xue et al., 2022). By embracing these advancements, we can forge a future where energy serves as a catalyst for progress, benefiting both current and future generations (Norouzi et al., 2020). Innovating and deploying sustainable energy will involve many technological, societal, and economic challenges. It will mean, for example, accelerating not merely the deployment of electric vehicles that must displace the internal combustion engine, but also the manufacture and recycling of their materials and promoting vehicle use in the face of increasing urbanization and the demand for energy-intensive services such as mobility (Nastasi et al., 2022). It will involve reformulating our societies' relationships with the natural world, with each other, and with technology. At stake is not simply the health and well-being of billions of people, but also the remarkable diversity of life and culture on Earth (Sovacool et al., 2022). Achieving a beneficial future will depend upon designing innovative systems for a sustainable energy system for all (Söderholm, 2020; Li et al., 2023).

The Importance of Sustainable Energy

Energy is central to society because it plays an immensely crucial role in meeting the most fundamental needs of individuals. It provides the warmth required for comfort, ensuring good health and nourishment. Additionally, energy powers lighting systems, enabling people to engage in activities even during the darkest hours. The energy infrastructure supports communication networks which enable distant people to share ideas while connecting them through their locations. Energy serves as a power source for different transportation systems to create greater mobility that helps people discover new places in the world. Users who have access to energy obtain essential needs while receiving an abundance of beneficial social advantages. Through empowered industries businesses benefit from economic development. The creation of new job opportunities fosters better living conditions which benefits economic development alongside community progress. The benefits of enhanced well-being spread across society when energy enables better quality living (Khan et al., 2021). Energy maintains significance which goes beyond personal goals and daily requirements. _platforms containing critical infrastructure systems maintain a direct connection to the energy sector which provides fundamental support for both economic development and societal well-being._ Networks which distribute water need energy to function because clean water distribution depends on it. Energy operates waste management facilities through which appropriate waste treatment and disposal processes become possible. Energy sector plays a fundamental role in sustaining food transportation and storage which allows food products to reach multiple communities (Ahmad & Zhang, 2020).

The way economies organize their activities and the arrangement of societal systems has been fundamentally shaped by energy deployment. The diverse employment of energy throughout many industrial sectors and daily activities and agricultural practices and service operations has reshaped how both work and daily activities occur. Historic human evolution relied on sufficient and cost-effective energy until human civilization attained its current state (Molotoks et al., 2021). The growing global population along with society's modernization requires substantial future increases in energy demand. Developing countries lead the worldwide increase in energy demand because of fast population growth and rising economic strength. The increasing development creates multiple negative effects against the environment while giving rise to economic and social challenges. The main problem today involves using conventional energy resources that produce damaging air pollutants. Local and worldwide environmental threats stem from these pollutants which produce both air pollution and climate change effects. The extended impacts of these difficulties extend across multiple areas to harm energy safety standards while creating public health problems and reducing future generations' life quality (Santamouris and Vasilakopoulou, 2021).

The urgent situation requires dedicated efforts toward solving related obstacles and hazards alongside continuous improvement of energy sector environmental performance. Moving toward clean sustainable energy requires both novel innovative technology development and implementation of advanced practices. To create healthier and more sustainable circumstances for the future we must take measures which alleviate negative energy consumption effects (Thirunavukkarasu et al., 2022).

Definition and Concepts

The world community adopted sustainable development as a solution because it became clear that continuing established patterns of industrial development could not preserve ecological equilibrium on the planet. The combined pressure to protect the environment and fight global warming created an elevated interest in sustainable energy systems. A complete method which seeks low greenhouse gas emission outcomes through a series of tactical approaches defines sustainable energy. The energy sector employs two key strategies by utilizing broad energy efficiency deployments for minimizing energy waste together with installing environment-friendly reliable renewable energy systems (Suman, 2021).

Sustainable development includes broad goals which extend past the preservation of long-term global ecosystem stability and health. Sustainable development expands beyond basic ecological preservation to include important elements which directly influence human health and welfare. The sustainable development discourse intensively explores how wealth distribution together with poverty alleviation functions as core societal issues. A sustainable future requires equitable resource access and quality-improving opportunities for all people to achieve fairness as a core component (Fawzy et al., 2020).

Sustainable development seeks equilibrium by providing satisfying current needs and sustaining future available resources. Our vision recognizes that Earth's resources are limited so we must follow sustainable consumption and production methods. Through this requirement we must adopt groundbreaking solutions to transform our frameworks which unite economic progress with societal advancement and ecological defense (Al-Shetwi, 2022). Nonetheless, the question remains: What operational methods exist for implementing abstract development concepts? Sustainable development requires a multi-dimensional implementation involving four main constituency groups including governments, businesses, civil society organizations and individual citizens. To achieve sustainable development we need broad transformative approaches which unite environmental conservation with economic development along with social impact improvements across widespread policymaking and daily operational activities. The successful implementation of sustainable development comes from supporting technologically advanced sustainability methods while creating strong legislation frameworks combined with citizen engagement and broad educational campaigns (Chien et al., 2021). By adopting sustainable development practices, we can foster a harmonious coexistence between human societies and the natural environment. It allows us to address the most pressing challenges of our time while securing a prosperous and equitable future for generations to come. Embracing sustainable development not only ensures the preservation of our planet's ecological integrity but also lays the foundation for a more resilient, just, and sustainable world (Abbass et al., 2022).

The focus of the energy chapter is based on the idea that control over energy supply will become a strategic element in all national development strategies. The argument is made that sustainable energy systems will only become a reality if a 'sustainable energy perspective' is adopted. What do we mean by a sustainable energy perspective? The common factor is the ethical concern for not only the long-term physical stability and integrity of the ecosystems that support life on Earth but also for the long-term well-being and survival of the population. The means of achieving this, however, will differ from country to country and culture to culture. Some precepts on how all of this might be done are advanced later in the energy chapter and throughout the remaining chapters (Ige et al., 2024; Borowski, 2021; Lu et al., 2020).

Environmental and Economic Benefits

There are numerous expected environmental and economic benefits to utilizing sustainable energy technologies, as thoroughly elucidated in the subsequent sections. The environmental benefits, which encompass a wide array of positive consequences, are often referred to as externalities within the economic system. It is crucial to note that investing in sustainable energy not only yields the generation of electricity but also holds within it an intrinsic value far beyond that. By embracing sustainable energy, we not only contribute to the reduction of environmental externalities linked to energy production but also alleviate the overall economic externality burden (Ekins & Zenghelis, 2021). These energy system externalities exert a significant influence on various government policies concerning energy. However, it is noteworthy that due to their perception as "free" commodities in the marketplace, they are not duly accounted for. Consequently, this circumstance gives rise to an excessive reliance on particular types of energy technologies, primarily those heavily reliant on externalities, such as oil (Belaïd et al., 2023). By using energy more wisely or by employing a wider spectrum of renewable energy sources, people can reduce their dependence on the ever-decreasing and expensive fossil sources. Reducing the need to import energy aids in lower costs, political stability, and energy security. Reduced fossil combustion also improves air quality and saves people from dealing with the annoying problems that litter their households and offices from polluted air and cheap disposable products (Kanwal et al., 2022). Switching fuels can also reduce the monetary flows outside the region, leading to a financial multiplier effect. This is briefly discussed with the jobs created and economic expansion inherent in the call for sustainable energy development. As communities address their energy weaknesses, they are less likely to want to build the needed energy infrastructure far from their communities (Munyanyi & Churchill, 2022).

Key Technologies in Sustainable Energy

The Switch outlines key technologies that will transform the energy landscape to enable a future of clean, abundant, low-cost energy. In this section**,** we provide an overview of the role of each of these key technologies. Solar-induced photosynthesis for fuel production is one of these key potential technologies. The sun is a bountiful source of renewable energy that provides more energy in one hour than the world economy uses in a year. The enormous energy potential has directed researchers to establish methods for obtaining cost-effective solar energy systems. Several solar technologies deserve careful examination. Solar photovoltaic panels supply direct electricity conversion through sunlight exposure explained by Schöniger et al. (2021). Scientists actively research a vital technological system which duplicates photosynthetic processes through converting water molecules alongside carbon dioxide exposure to sunlight to create oxygen molecules and sugar molecules. The biosphere depends on photosynthesis as its fundamental energy production method to obtain usable power that supports Earth's living organisms. Throughout its 3.5 billion year existence photosynthesis continues to revolutionize the Earth (Jacobson et al., 2022). Research in solar power as a clean renewable energy system has jumpstarted a scientific breakthrough. This work examines the advancements in modern energy technologies which will transform our energy systems by making clean abundant affordable power a reality. Solar-induced photosynthesis stands out as an intriguing fuel production concept in this chapter. Humanity enjoys an exceptional solar opportunity through the sun's unusual power to continuously generate renewable energy beyond measure. Because of solar energy's limitless potential and cost-effectiveness researchers in every corner of the world focus on developing innovative technological systems (Babajide & Brito, 2021). An examination of solar technologies reveals numerous technological potentials for the future. This book explores how photovoltaic solar panels transform incoming sunlight directly into usable electric power. The revolutionary solar technology breakthrough gives society reason to hope about future access to renewable power sources. This discussion investigates a crucial upcoming technology which could reshape the energy sector through artificial photosynthetic replication systems. The innovative approach intends to replicate nature-based photosynthesis by using it as its foundation. Scientists work to develop energy production methods based on water, carbon dioxide and light-driven sugar and oxygen transformation which nature achieves at an exceptional level according to Abbas et al. (2023). The research traces the significant role photosynthesis played during 3.5 billion years since the planet's inception. Photosynthesis started as a simple process and now maintains complete dominance while continuing to influence history from antiquity to today. The remarkable process creates sustainability for life on Earth and simultaneously creates the most foundational components of our biosphere. The exploration of solar-induced photosynthesis for fuel manufacturing has positioned humanity to start an energy revolution to create a prosperous sustainable future according to Peyvandi et al. (2023).

Solar Energy

The sun is the cleanest and most abundant source of energy on Earth and has been important to human beings since the beginning of civilization. Solar energy can be converted into thermal or electrical energy, depending on the method used. Solar thermal technologies utilize sunlight to thermally convert heat from the sun into mechanical or thermal energy used for various applications. Solar thermal systems currently possess many advantages that enable their deployment for both concentrated and distributed power generation. Solar thermal power generation plants are also more compatible with existing power generation and grid support infrastructure than other renewable energy sources, and they are currently considered by many involved with energy systems to be a 'bridge' technology to bridge the gap between large-scale fossil fuel-driven power generation and the future envisaged large Solar photovoltaic technologies use photovoltaic systems to convert light into electricity. The photovoltaic effect is the basic process that powers ordinary solar cells and requires only a small fraction of incident sunlight to liberate photons from atoms and create electrical current, while the remaining energy is usually lost as heat. e-scale contribution of wind or other renewable energy sources (Rickerson et al., 2024). The global potential for solar energy is enormous, exceeding the total global use equivalent of 12% of all energy consumed today. It is more than 5000 times greater than the energy consumption of the entire world. In principle, cities, villages, industries, or even individual dwellings far from a power grid in both developed and developing countries could be powered by an adequate solar energy conversion system. The potential for market penetration measured in energy consumption is even greater. Small islands or regions have limited access to electricity, and it is in the interests of developing countries to consider all options, including solar, for renewable energy as the most practical solution (Kumar et al., 2023).

Wind Energy

Although wind has a relatively low energy density compared to hydrocarbons, the collection area of a wind turbine array is much larger. This provides a sufficient effective capacity to make a valuable contribution to both the volatility and balance markets. The area density values of wind turbines are consistently above 60 MW/rpm, which is quite impressive (Hu et al., 2021). When examining the subject of wind, there are several interesting subtleties that can be observed. One of these is the sensitivity to geographical dispersion. Wind turbine effectiveness depends heavily on their geographical positioning in relation to other wind power plants (Xu et al., 2020). Understanding the duration of wind variability impacts the resulting photovoltaic power system design strategy. Stochastic behavior refers to unpredictable patterns in wind energy production. Concentration, especially within the predominant outlook zone, serves as a source of effective spatial dispersion. Wind production gains greater effectiveness by deploying distinctive turbine operations based on land and offshore locations as offshore resource usage continues to expand. Wind turbine performance optimization and environmental impact reach their full potential when we spread turbines across different regions (Ren et al., 2021).

Wind production economics relies heavily on selecting the suitable duration when characterizing wind behavior as stochastic. Ramp frequency and duration probabilities stand as the main economic elements for wind production systems. The duration of stochastic wind characterization affects ramping frequency and duration probabilities at different degrees. Frequency response ramping services become less profitable as the length of characterization becomes shorter. Regardless of whether market participants require continuous response or not, it is clear that the profitability of frequency response and ramping services are negatively impacted by shorter time frames. Therefore, it is essential to consider the longer-term perspective when assessing the potential profitability of wind energy initiatives. By doing so, we can ensure the sustainability and success of wind power projects (Zhou et al., 2021).

Hydroelectric Power

Water is the basis of hydroelectric energy, and it is transformed into electricity by the force of falling water. The movement of kinetic energy is responsible for transforming the water into mechanical energy, which is then transformed into electrical energy. On the earth's surface, water exists in one form or another, and in permanent rivers alone, its volume is 15,904 km³ per annum. Therefore, the volume wasted at natural lowers is huge, and hydroelectric power is an effective means of generating energy. Humans have been harnessing mechanical energy from moving water for many years, and a horizontal water wheel became available during the early industrial revolution to take advantage of rivers of free water. Hydroelectric plants come in two distinct structures, namely, high and low height, with the former making use of a substantial containment reservoir where water is stored and used to produce energy. Higher performance is found in these plants, with energy saving being the main advantage by reinforcing the power reserve (Xiaosan et al., 2021). Most plants are, however, of low power and are remnants of rapid flows of rivers and low skid resistance. Their flaws, such as necessary heavy maintenance and the creation of environmental habitats, have led to the expansion of this means of alternative power not being suitable for meeting the global demand for electricity in the next century (Farghali et al., 2023).

Policy and Regulatory Frameworks

Fragile, incomplete, or inconsistent policy and regulatory frameworks are among the most significant barriers to increasing the role of sustainable energy in the broader effort to safeguard and improve the state of our world. Tackling these barriers makes an essential leadership agenda for legislators and regulators, as well as for leaders across business, civil society, academia, and other stakeholders. The removal of these barriers is an indivisible part of a broader climate leadership agenda. It is important to clarify that the accuracy of the policies and regulations that are needed in many of the areas is more important than the presence of something that is formally labeled as such (Shah & Longsheng, 2022). Toward a contemporary vision for energy legislators and regulators, there are several compelling reasons for questioning the conventional vision for legislators and regulators with responsibilities for energy. Some of the reasons are specific to the energy system; others relate to the broader agendas driven by reason of state, encouragement for values that are precious to society, or broader energy-related challenges. Such considerations are long-standing, but they are intensified in interesting ways by wave after wave of transformational change (Norouzi et al., 2022). Our collective futures and the legacy that is left for those who come after us in short, our prosperity depend in part on the contemporary performance of institutions that regulate and govern energy policy frameworks. The advancement towards a contemporary vision for energy legislators and regulators holds tremendous significance in shaping the future of sustainable energy. Leaders in various sectors are obliged to solve environmental barriers after understanding how policy frameworks affect planetary well-being according to Bai et al. (2023). The vital agenda exists independently of legislators and regulators because individuals across businesses and civil society and academia along with multiple stakeholder groups all hold responsibility to drive sustainable energy initiatives (Nilashi et al., 2023). A complete climate leadership framework requires the urgent removal of all identified barriers before progress toward sustainability can happen. Constructing a sustainable energy future requires first destroying policy and regulatory frameworks containing unstable structures and incomplete rules and inconsistent frameworks. Effectiveness rates above existence of categorized regulatory approaches as the accuracy of these measures within their defined areas turns them into effective instruments. The need to reevaluate the conventional vision for energy legislators and regulators arises from numerous compelling factors. While some reasons pertain directly to the energy system, others extend to broader agendas driven by the state, the promotion of societal values, or the ever-growing challenges in the energy sector (Chen et al., 2024). These considerations have been present for a long time, but they gain even more significance in light of the continuous waves of transformational changes sweeping across the industry. We must recognize that our shared future and the legacy we leave behind for future generations, ultimately influencing our prosperity, heavily rely on the contemporary performance of energy policy frameworks and the governing institutions responsible for their implementation (Haldar et al., 2023).

International Agreements

Most countries have signed international agreements regarding climate change. Such international agreements are believed to be critical in mitigating climate change. These agreements may promote renewable energy by providing a signal that climate policies will be adopted and creating the global conditions necessary to innovate and reduce the costs of production of renewable energy. Therefore, these agreements create incentives for countries to adopt renewable energy so that they can achieve compliance with low carbon dioxide emission targets. Then, countries that have more restrictive targets and need to achieve them may buy some Certified Emission Reductions from countries that have less restrictive targets (Naser & Pearce, 2022; Dechezleprêtre et al., 2022). The international price of carbon allows for the propagation and implementation of a comprehensive incentive mechanism for the sequestration and effective reduction of CO2 emissions. These international agreements play a pivotal role in fostering and facilitating widespread international cooperation among nations, with the overarching aim of safeguarding the invaluable global public good universally recognized as the environment. It is imperative for every single country to actively engage and partake in these agreements, ensuring their complete involvement and commitment in order to realize the most significant and substantial reduction in their emissions levels. While it is understandable that developing nations may initially display some reservations or reluctance to fully participate in these agreements, they are often compelled to eventually sign on, recognizing the urgent need to substantially curtail their own emissions of greenhouse gases for the greater benefit of our planet (Green, 2021; Gür, 2022).

National Policies

There are nearly as many different approaches to the direct promotion of renewable energy as there are elements identified in national policy strategies for the promotion of sustainable energy. These include, inter alia, partial or full taxation relief, investment grants, long-term loans, and various other forms of financial intervention; the establishment of special funds or research programs for the development of cost-effective technologies; modification of appropriate technology standards or environmental objectives or consumer protection standards; and regulation of prices, rates of return, or set-offs against subsidies (Yasmeen et al., 2023). Some countries also promote specialty products from renewable energy by means of export credits or contributions to their expenses. The use of these and other promotional measures can be influenced significantly by particular features of a country's legal system, its institutional infrastructure, or its pattern of public expenditure (Xie & Jamaani, 2022).

Simple direct taxes can be used to encourage the development and utilization of technology in general or particular types of renewable energy technologies by reducing the tax base treated as cost, the time period over which profits are calculated, or the rate at which profits are taxed. It is also possible, however, to neutralize taxes that would otherwise be collected. By contrast, if the national budget is in surplus or there is a low demand for public services, grants to approved projects or progressively increasing funds can be awarded. Nonetheless, it is difficult, when dealing with a lack of demand for investment, to determine the economic merits of public grants without an in-depth analysis of the particular managerial, financial, and post-operation position of the company, bank, and government (Sharif et al., 2023).

Case Studies of Successful Implementation

In the last decade, Indonesia, recognizing the importance of sustainable energy, actively engaged in power sector reform. The objective of this reform was to create a cleaner, more reliable, and affordable energy landscape with the active participation of the private sector. The strategic implementation and joint work of energy service companies with renewable energy source utilization allowed Indonesia to fully exploit its sustainable energy potential. A combined method established solid improvements across infrastructure growth and service delivery which provided various advantages to Indonesia's population (Setyowati & Quist, 2022). The Philippine case study presents exemplary guidance through investments and governance initiatives which produced impressive enhancements in infrastructure and service execution. Through strategic use of renewable energy resources the Philippines built its energy capacity which sealed the path toward reliable and sustainable energy provision. This success resulted from the groundbreaking partnership between private sector corporations and energy service companies. The findings of this case study highlight that partnerships with responsible investments in sustainable resources should drive current progress while advancing renewable energy objectives (Setyowati, 2021). The Kenya case study demonstrates considerable insights regarding how sustainable energy systems revolutionize off-grid regions. The combination of sustainable energy solutions with typically neglected spaces led to significant job market growth coupled with thriving small business formation in areas previously considered marginalized. The empowering shift brought both an end to poverty conditions while creating an environment filled with hope and vitality for local communities. The Kenya case study demonstrates sustainably powered societies as key drivers of development at both economic and social levels in areas without traditional access (Hapsari 2023).

These carefully analyzed case studies provide essential directions which help countries select appropriate fundamental elements when building sustainable energy markets All countries need specific solutions because each nation has distinctive energy systems and national specifics. Decision-makers who examine these case studies discover their best-fit energy solutions by understanding what approaches will work best for their particular circumstances. These case studies provide countries with tools to develop their journey toward sustainable energy system while ensuring present well-being and building a future forward energy approach (Lilasari & Siallagan, 2023; Halimatussadiah et al., 2024).

Scandinavian Countries

The Scandinavian region, in the northern part of Europe, with a total population of at least 24 million, encompasses four nations: Norway, Sweden, Denmark, and Finland. These countries have a history of making a swift transition toward renewable and affordable energy resources starting in the late 19th century. The objective then was to increase citizens' prosperity and make room for industrial growth. Fossil and hydropower for electrical energy, and later biofuels for heating, have played a central role in achieving these goals. The more recent interest in increasing the use of efficient, eco-friendly energy around the world makes this region even more special as it reveals many of the issues and roadblocks taken into account when tapping the advantages of efficient renewable energy systems (Hansen & Moe, 2022). Today, they encompass some of the most advanced local and regional large-scale and energy-efficient systems of concurrently used renewable energy points. As heuristic forecasting should more properly evaluate new or particularly important architectural and unique statewide achievements in renewable energy fields, it is interesting to analyze in detail what the drivers and roadblocks of this revitalization were, how these projects could be affected, and what these countries have to say about the large restructuring of the energy system likely to be performed on a worldwide basis (Ranta et al., 2020). Their policing and regulatory units embarked on active professional recruitment and preparation to get ready for brand-new situations through their handling. Actually, they were among the initial to position themselves, establishing experience-structured policing devices, a National Renewable Energy unit making real progress, and a formulary to relax the difficult position that renewable energy hardware gets interconnected to the electrical grid. Finally, all four nations show important moves into what could be labeled as fifth-generation rapidly localized socio-energy systems, with the substantial elongation of wind energy production and the symbiotic development of extremely differentiated and cyclical forms of electrosynthesis (Juszczyk et al., 2022; Hassan et al., 2024).

Germany's Energiewende

Germany's 'energy transition', or 'Energiewende', aims to transform the energy system to an efficient, largely carbon-neutral, renewables-based one. In its current formulation, it was introduced in 2010 and coordinates phasing out nuclear power by 2022 and an increase in the share of renewable energy to at least 80% by 2050. By positioning itself as a forerunner in sustainable energy, environmental protection, and thus economic growth, the German government also aimed to boost the German economy and create jobs; original targets included an expansion of renewable energy technology and exports. Public support for the transition and the related policies has varied but has recently been both strong in terms of maintaining the renewables policies and skeptical as to their contribution to mitigating climate change, particularly among the working class and other economically affected demographics (Traber et al., 2021; Abuzayed & Hartmann, 2022).

There have been some criticisms against the strategy and scale of the energy transition. Participants in an open workshop on the issue in Berlin criticized the way energy policies have been implemented: they believe that Germany has chosen the wrong energy sectors to prioritize and has adopted the wrong tools. There are doubts as to whether Germany's GHG emissions will be in line with these goals, considering that they are not decreasing in line with the targets and stated goals. Investment plans for cracking and synthetic fuel production should play a role in the energy mix plan also because natural gas and biogas production and distribution systems are ready to speed up the energy transition (Stechemesser et al., 2024; Liu & Raftery, 2021).

Challenges and Future Directions

Challenges and Future Directions: Sustainable development requires the need to balance between the goals of sustaining a high quality of life with access to modern energy services on one hand and the goals of a vibrant economy on the other, and at the same time not compromising the well-being of future generations. Expanding the use of modern energy services in the developing world, while reducing the environmental and social impacts of the systems used to provide these services, is a key challenge facing the world today. Moving in the direction of internationally agreed sustainability goals remains the challenge for all countries in the world. Effective long-term, transparent policy frameworks can help steer the energy sector towards sustainability. Creating the enabling environment for energy services is essential for moving from automated, growth-driven energy development to a more holistic, sustainable energy services approach (Nguyen et al., 2021; Ang et al., 2022).

The full potential of renewable energy technologies must be exploited to achieve the high priority benefits of global, diversified, and durable energy service. Viewed in the context of policy development, the renewable energy sector spawn’s numerous important policy issues not connected to energy supply, environmental or oil import vulnerabilities, and innovative new fuel sources, such as first-mover access to advanced energy exports. Their employment practicality is a fundamental example of their policy importance. Boosting a poorly designed or unaligned renewable strategy could give a country's nascent renewable industries such an economically unstable start that they develop a reputation for being too expensive and impractical, a reputation that takes time to overcome in future renewable strategies (Tan et al., 2021; Olabi et al., 2022).

Technological Challenges

Sustainable and reliable energy supply is crucial for the stability and prosperity of any country. However, global demographic, economic, and political changes present a number of significant challenges to our ability to supply energy sustainably. This section explores these challenges and how they might affect our ability to develop and implement environmentally favorable energy technologies. Energy will be one of the main issues to be addressed by the G8 summit. As reported in the announcement of the meeting, the question on the table will be the development of multilateral strategies to provide the necessary investments and technologies to increase our supply of affordable and clean energy (Chen et al., 2024; Kabeyi & Olanrewaju, 2022).

Thus, while there is some optimism that solutions might be found to the supply and environmental problems of the next fifty years, it is clear that not all energy issues will be resolved through technical or economic fixes. Moreover, demand, resource, and technology create complex interdependencies that we must understand to fully comprehend the energy problems we are facing. This section examines these problems and how technology might be used to address them. Although it takes a somewhat pessimistic view, it also indicates that it might be possible to identify a few positive trends. These trends might, if nurtured and developed through concerted action, encourage sustainable development, reduce the probability of international conflicts, and reduce the risk of irreversible environmental impact (Demestichas & Daskalakis, 2020; Allam et al., 2022).

Financial Barriers

Investment barriers are often synonymous with financial barriers, as funds can be drawn from internal or external sources (Ahmed et al., 2022). Various barriers restrict money flow, including lack of collateral, creditworthiness issues, and internal resistance to change. Credit constraints typically arise from lenders' inability to accurately evaluate project risks and sponsors' challenges in providing loan security or demonstrating project viability (Moradi et al., 2021). Potential barriers to risk capital formation include inadequate early-stage high-risk finance, absent venture capital markets, and limited pre-competitive financing bridging cost gaps (Giri, 2021). Financing for technology transfer and capacity building remains exceptional, with large investments often postponed due to perceived research and development needs (Huhta, 2020).

Local investors struggle to compete with outside private financiers, while international lenders may hesitate due to contextual preferences and different cost-benefit evaluation criteria (Jowitt & McNulty, 2021). Financial market imperfections can influence foreign direct investment, with tipping point perceptions affecting investment pace (Vanstapel et al., 2023). Investment challenges extend beyond direct financial constraints. Domestic imperfections like weak intellectual property rights protection can retard investments (Newman & MacDougall, 2021). The fragility of local financial institutions further discourages investment, while unsatisfactory monetary and fiscal policies create unequal market opportunities (Suryaningsi, 2020). Notably, unrealistic interest rates and market interventions can impede credit access and compromise the potential for sustainable economic development (Schünemann et al., 2020).

Greenhouse gas emission reductions are often treated as a by-product of optimization rather than a primary objective (Aripin et al., 2023). Attracting finance requires robust data, analytical capabilities, and transparency, with a crucial need to establish links between technology, risk, and environmental considerations (Demin, 2020).

II. Conclusion

Projections of global energy consumption point to a marked increase over the coming years. Simply put, providing the necessary energy supplies to the global population without exacerbating temperature changes is one of the major challenges of the 21st century. Against this backdrop, analysing sustainable energy options in a consistent and encompassing framework cannot be overemphasized. The role of sustainable energy in achieving a prosperous future was outlined by three case studies. Planning and implementing the development of sustainable energy technologies, together with enabling policy frameworks, is part of the solution to these challenges. By examining developments in the three case studies, we found that an increased share of renewable resources in sustainable energy makes a significant contribution to a sustainable and more secure energy system. However, the fact that geographically and climatically the potential of different renewable resources for host countries varies greatly, and that other non-technical barriers and drawbacks can occur, should be taken into account. Despite the different projects encountered in the case studies, our work also highlighted that the lack of a comprehensive indicator framework together with the lack of international support significantly hinders success. As a result, the development of sustainable energy tends to be biased towards certain, more mature, and less capital-intensive technologies such as hydropower.

References:

[1]. Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. Environmental Science and Pollution Research, 29(28), 42539-42559. springer.com

[2]. Abbas, J., Wang, L., Belgacem, S. B., Pawar, P. S., Najam, H., & Abbas, J. (2023). Investment in renewable energy and electricity output: Role of green finance, environmental tax, and geopolitical risk: Empirical evidence from China. Energy, 269, 126683. academia.edu

[3]. Abuzayed, A. & Hartmann, N. (2022). MyPyPSA-Ger: Introducing CO2 taxes on a multi-regional myopic roadmap of the German electricity system towards achieving the 1.5° C target by 2050. Applied Energy. sciencedirect.com

[4]. Ahmad, T. & Zhang, D. (2020). A critical review of comparative global historical energy consumption and future demand: The story told so far. Energy Reports. sciencedirect.com

[5]. Ahmed, Z., Ahmad, M., Murshed, M., Shah, M. I., Mahmood, H., & Abbas, S. (2022). How do green energy technology investments, technological innovation, and trade globalization enhance green energy supply and stimulate environmental sustainability in the G7 countries?. Gondwana Research, 112, 105-115. [HTML]

[6]. Allam, Z., Sharifi, A., Bibri, S. E., Jones, D. S., & Krogstie, J. (2022). The metaverse as a virtual form of smart cities: Opportunities and challenges for environmental, economic, and social sustainability in urban futures. Smart Cities. mdpi.com

[7]. Al-Shetwi, A. Q. (2022). Sustainable development of renewable energy integrated power sector: Trends, environmental impacts, and recent challenges. Science of The Total Environment. [HTML]

[8]. Ang, T. Z., Salem, M., Kamarol, M., Das, H. S., Nazari, M. A., & Prabaharan, N. (2022). A comprehensive study of renewable energy sources: Classifications, challenges and suggestions. Energy Strategy Reviews, 43, 100939. sciencedirect.com

[9]. Aripin, Z., Agusiady, R., & Saepudin, D. (2023). POST COVID: WHAT LESSONS CAN BE LEARNED FOR THE BANKING AND MSME INDUSTRY. Journal of Economics, Accounting, Business, Management, Engineering and Society, 1(1), 25-36. kisainstitute.com

[10]. Babajide, A. & Brito, M. C. (2021). Solar PV systems to eliminate or reduce the use of diesel generators at no additional cost: A case study of Lagos, Nigeria. Renewable Energy. sciencedirect.com

[11]. Bai, W., Zhang, L., Lu, S., Ren, J., & Zhou, Z. (2023). Sustainable energy transition in Southeast Asia: Energy status analysis, comprehensive evaluation and influential factor identification. Energy. [HTML]

[12]. Belaïd, F., Al-Sarihi, A., & Al-Mestneer, R. (2023). Balancing climate mitigation and energy security goals amid converging global energy crises: The role of green investments. Renewable Energy. [HTML]

[13]. Borowski, P. F. (2021). Digitization, digital twins, blockchain, and industry 4.0 as elements of management process in enterprises in the energy sector. Energies. mdpi.com

[14]. Chen, M., Chen, C., Jin, C., Li, B., Zhang, Y., & Zhu, P. (2024). Evaluation and obstacle analysis of sustainable development in small towns based on multi-source big data: A case study of 782 top small towns in China. Journal of Environmental Management, 366, 121847. sciencedirect.com

[15]. Chen, W., Alharthi, M., Zhang, J., & Khan, I. (2024). The need for energy efficiency and economic prosperity in a sustainable environment. Gondwana Research. [HTML]

[16]. Chien, F., Kamran, H. W., Albashar, G., & Iqbal, W. (2021). Dynamic planning, conversion, and management strategy of different renewable energy sources: a sustainable solution for severe energy crises in emerging economies. International Journal of Hydrogen Energy, 46(11), 7745-7758. researchgate.net

[17]. Dechezleprêtre, A., Fabre, A., Kruse, T., Planterose, B., Chico, A. S., & Stantcheva, S. (2022). Fighting climate change: International attitudes toward climate policies (No. w30265). National Bureau of Economic Research. nber.org

[18]. Demestichas, K. & Daskalakis, E. (2020). Information and communication technology solutions for the circular economy. Sustainability. mdpi.com

[19]. Demin, A. V. (2020). Certainty and Uncertainty in Tax Law: Do Opposites Attract? Laws. mdpi.com

[20]. Ekins, P. & Zenghelis, D. (2021). The costs and benefits of environmental sustainability. Sustainability Science. springer.com

[21]. Farghali, M., Osman, A. I., Chen, Z., Abdelhaleem, A., Ihara, I., Mohamed, I. M., ... & Rooney, D. W. (2023). Social, environmental, and economic consequences of integrating renewable energies in the electricity sector: a review. Environmental Chemistry Letters, 21(3), 1381-1418. springer.com

[22]. Fawzy, S., Osman, A. I., Doran, J., & Rooney, D. W. (2020). Strategies for mitigation of climate change: a review. Environmental Chemistry Letters, 18, 2069-2094. springer.com

[23]. Giri, S. (2021). Water quality prospective in Twenty First Century: Status of water quality in major river basins, contemporary strategies and impediments: A review. Environmental Pollution. [HTML]

[24]. Green, J. F. (2021). Does carbon pricing reduce emissions? A review of ex-post analyses. Environmental Research Letters. iop.org

[25]. Gür, T. M. (2022). Carbon dioxide emissions, capture, storage and utilization: Review of materials, processes and technologies. Progress in Energy and Combustion Science. [HTML]

[26]. Haldar, S., Peddibhotla, A., & Bazaz, A. (2023). Analysing intersections of justice with energy transitions in India-A systematic literature review. Energy Research & Social Science. sciencedirect.com

[27]. Halimatussadiah, A., Kruger, W., Wagner, F., Afifi, F. A. R., Lufti, R. E. G., & Kitzing, L. (2024). The country of perpetual potential: Why is it so difficult to procure renewable energy in Indonesia? Renewable and Sustainable Energy Reviews, 201, 114627. ssrn.com

[28]. Hansen, S. T. & Moe, E. (2022). Renewable energy expansion or the preservation of national energy sovereignty? Norwegian renewable energy policy meets resource nationalism. Political Geography. sciencedirect.com

[29]. Hapsari, I. (2023). Clean Power for Indonesia: Leading the Way in the Energy Transition. First published in 2023 by BRIN Publishing Available to download free: penerbit. brin. go. id, 147. researchgate.net

[30]. Hassan, Q., Viktor, P., Al-Musawi, T. J., Ali, B. M., Algburi, S., Alzoubi, H. M., ... & Jaszczur, M. (2024). The renewable energy role in the global energy Transformations. Renewable Energy Focus, 48, 100545. [HTML]

[31]. Huhta, K. (2020). Anchoring the energy transition with legal certainty in EU law. Maastricht Journal of European and Comparative Law, 27(4), 425-444. sagepub.com

[32]. Hu, S., Xiang, Y., Zhang, H., Xie, S., Li, J., Gu, C., Sun, W., & Liu, J. (2021). Hybrid forecasting method for wind power integrating spatial correlation and corrected numerical weather prediction. Applied Energy. bath.ac.uk

[33]. Ige, A. B., Kupa, E., & Ilori, O. (2024). Analyzing defense strategies against cyber risks in the energy sector: Enhancing the security of renewable energy sources. International Journal of Science and Research Archive, 12(1), 2978-2995. researchgate.net

[34]. Jacobson, M. Z., von Krauland, A. K., Coughlin, S. J., Dukas, E., Nelson, A. J., Palmer, F. C., & Rasmussen, K. R. (2022). Low-cost solutions to global warming, air pollution, and energy insecurity for 145 countries. Energy & Environmental Science, 15(8), 3343-3359. [HTML]

[35]. Jowitt, S. M. & McNulty, B. A. (2021). Geology and mining: mineral resources and reserves: their estimation, use, and abuse. SEG Newsletter. [HTML]
[36]. Juszczyk, O., Juszczyk, J., Juszczyk, S., & Takala, J. (2022). Barriers for renewable energy technologies diffusion: Empirical evidence from Finland and Poland. Energies. mdpi.com
[37]. Kabeyi, M. J. B. & Olanrewaju, O. A. (2022). Sustainable energy transition for renewable and low carbon grid electricity generation and supply. Frontiers in Energy research. frontiersin.org
[38]. Kanwal, S., Mehran, M. T., Hassan, M., Anwar, M., Naqvi, S. R., & Khoja, A. H. (2022). An integrated future approach for the energy security of Pakistan: Replacement of fossil fuels with syngas for better environment and socio-economic development. Renewable and Sustainable Energy Reviews, 156, 111978. sciencedirect.com
[39]. Khan, I., Hou, F., & Le, H. P. (2021). The impact of natural resources, energy consumption, and population growth on environmental quality: Fresh evidence from the United States of America. Science of the Total Environment. [HTML]
[40]. Kumar, C. M. S., Singh, S., Gupta, M. K., Nimdeo, Y. M., Raushan, R., Deorankar, A. V., ... & Nannaware, A. D. (2023). Solar energy: A promising renewable source for meeting energy demand in Indian agriculture applications. Sustainable Energy Technologies and Assessments, 55, 102905. [HTML]
[41]. Lilasari, L. L., & Siallagan, M. (2023). Navigating Upstream Indonesia's Oil and Gas (O&G) Services Industry Amidst the Cleaner Energy Transition Era with A Scenario Planning Framework. European Journal of Business and Management Research, 8(4), 192-201. ejbmr.org
[42]. Liu, P. R. & Raftery, A. E. (2021). Country-based rate of emissions reductions should increase by 80% beyond nationally determined contributions to meet the 2 C target. Communications earth & environment. nature.com
[43]. Li, X., Raorane, C. J., Xia, C., Wu, Y., Tran, T. K. N., & Khademi, T. (2023). Latest approaches on green hydrogen as a potential source of renewable energy towards sustainable energy: Spotlighting of recent innovations, challenges, and …. Fuel. [HTML]
[44]. Lu, Y., Khan, Z. A., Alvarez-Alvarado, M. S., Zhang, Y., Huang, Z., & Imran, M. (2020). A critical review of sustainable energy policies for the promotion of renewable energy sources. Sustainability, 12(12), 5078. mdpi.com
[45]. Molotoks, A., Smith, P., & Dawson, T. P. (2021). Impacts of land use, population, and climate change on global food security. Food and Energy Security. wiley.com
[46]. Moradi, E., Jafari, S. M., Doorbash, Z. M., & Mirzaei, A. (2021). Impact of organizational inertia on business model innovation, open innovation and corporate performance. Asia Pacific Management Review, 26(4), 171-179. sciencedirect.com
[47]. Munyanyi, M. E. & Churchill, S. A. (2022). Foreign aid and energy poverty: Sub-national evidence from Senegal. Energy Economics. ssrn.com
[48]. Naser, M. M., & Pearce, P. (2022). Evolution of the International Climate Change Policy and Processes: UNFCCC to Paris Agreement. In Oxford Research Encyclopedia of Environmental Science. [HTML]
[49]. Nastasi, B., Markovska, N., Puksec, T., Duić, N., & Foley, A. (2022). Renewable and sustainable energy challenges to face for the achievement of Sustainable Development Goals. Renewable and Sustainable Energy Reviews, 157, 112071. [HTML]
[50]. Newman, J. & MacDougall, P. (2021). Increasing DER integration through discrete intraday settlements. The Electricity Journal. sciencedirect.com
[51]. Nguyen, H. T., Le, D. M. D., Ho, T. T. M., & Nguyen, P. M. (2021). Enhancing sustainability in the contemporary model of CSR: a case of fast fashion industry in developing countries. Social responsibility journal, 17(4), 578-591. academia.edu
[52]. Nilashi, M., Keng Boon, O., Tan, G., Lin, B., & Abumalloh, R. (2023). Critical data challenges in measuring the performance of sustainable development goals: Solutions and the role of big-data analytics. Harvard Data Science Review, 5(3), 3-4. pubpub.org
[53]. Norouzi, F., Hoppe, T., Elizondo, L. R., & Bauer, P. (2022). A review of socio-technical barriers to Smart Microgrid development. Renewable and Sustainable Energy Reviews, 167, 112674. sciencedirect.com
[54]. Norouzi, N., de Rubens, G. Z., Choupanpiesheh, S., & Enevoldsen, P. (2020). When pandemics impact economies and climate change: Exploring the impacts of COVID-19 on oil and electricity demand in China. Energy research & social science, 68, 101654. nih.gov
[55]. Olabi, A. G., Obaideen, K., Elsaid, K., Wilberforce, T., Sayed, E. T., Maghrabie, H. M., & Abdelkareem, M. A. (2022). Assessment of the pre-combustion carbon capture contribution into sustainable development goals SDGs using novel indicators. Renewable and Sustainable Energy Reviews, 153, 111710. [HTML]
[56]. Peyvandi, M., Hajinezhad, A., & Moosavian, S. F. (2023). Investigating the intensity of GHG emissions from electricity production in Iran using renewable sources. Results in Engineering. sciencedirect.com
[57]. Ranta, T., Laihanen, M., & Karhunen, A. (2020). Development of the bioenergy as a part of renewable energy in the Nordic Countries: A comparative analysis. Journal of Sustainable Bioenergy Systems, 10(3), 92-112. scirp.org
[58]. Ren, Z., Verma, A. S., Li, Y., Teuwen, J. J., & Jiang, Z. (2021). Offshore wind turbine operations and maintenance: A state-of-the-art review. Renewable and Sustainable Energy Reviews, 144, 110886. ntnu.no
[59]. Rickerson, W., Gillis, J., & Bulkeley, M. (2024). The value of resilience for distributed energy resources: An overview of current analytical practices. osti.gov
[60]. Santamouris, M., & Vasilakopoulou, K. (2021). Present and future energy consumption of buildings: Challenges and opportunities towards decarbonisation. e-Prime-Advances in Electrical Engineering, Electronics and Energy, 1, 100002. sciencedirect.com
[61]. Schöniger, F., Thonig, R., Resch, G., & Lilliestam, J. (2021). Making the sun shine at night: comparing the cost of dispatchable concentrating solar power and photovoltaics with storage. Energy Sources, Part B: Economics, Planning, and Policy, 16(1), 55-74. tandfonline.com
[62]. Schünemann, H. J., Santesso, N., Vist, G. E., Cuello, C., Lotfi, T., Flottorp, S., ... & Akl, E. A. (2020). Using GRADE in situations of emergencies and urgencies: certainty in evidence and recommendations matters during the COVID-19 pandemic, now more than ever and no matter what. Journal of clinical epidemiology, 127, 202-207. nih.gov
[63]. Setyowati, A. B. & Quist, J. (2022). Contested transition? Exploring the politics and process of regional energy planning in Indonesia. Energy Policy. sciencedirect.com
[64]. Shahzad, U., Radulescu, M., Rahim, S., Isik, C., Yousaf, Z., & Ionescu, S. A. (2021). Do environment-related policy instruments and technologies facilitate renewable energy generation? Exploring the contextual evidence from developed economies. Energies, 14(3), 690. mdpi.com
[65]. Shah, S. A. A., & Longsheng, C. (2022). Evaluating renewable and sustainable energy impeding factors using an integrated fuzzy-grey decision approach. Sustainable Energy Technologies and Assessments, 51, 101905. [HTML]
[66]. Sharif, A., Kartal, M. T., Bekun, F. V., Pata, U. K., Foon, C. L., & Depren, S. K. (2023). Role of green technology, environmental taxes, and green energy towards sustainable environment: insights from sovereign Nordic countries by CS-ARDL approach. Gondwana Research, 117, 194-206. [HTML]
[67]. Söderholm, P. (2020). The green economy transition: the challenges of technological change for sustainability. Sustainable Earth. springer.com

[68]. Sovacool, B. K., Newell, P., Carley, S., & Fanzo, J. (2022). Equity, technological innovation and sustainable behaviour in a low-carbon future. Nature human behaviour. columbia.edu

[69]. Stechemesser, A., Koch, N., Mark, E., Dilger, E., Klösel, P., Menicacci, L., ... & Wenzel, A. (2024). Climate policies that achieved major emission reductions: Global evidence from two decades. Science, 385(6711), 884-892. science.org

[70]. Suman, A. (2021). Role of renewable energy technologies in climate change adaptation and mitigation: A brief review from Nepal. Renewable and Sustainable Energy Reviews. academia.edu

[71]. Suryaningsi, S. (2020). Legal Certainty Of Mining Management After The Enactment Of Indonesian Law On Local Government No. 23 Of 2014. Solid State Technology. unmul.ac.id

[72]. Tan, K. M., Babu, T. S., Ramachandaramurthy, V. K., Kasinathan, P., Solanki, S. G., & Raveendran, S. K. (2021). Empowering smart grid: A comprehensive review of energy storage technology and application with renewable energy integration. Journal of Energy Storage, 39, 102591. [HTML]

[73]. Thirunavukkarasu, G. S., Seyedmahmoudian, M., Jamei, E., Horan, B., Mekhilef, S., & Stojcevski, A. (2022). Role of optimization techniques in microgrid energy management systems—A review. Energy Strategy Reviews, 43, 100899. sciencedirect.com

[74]. Traber, T., Hegner, F. S., & Fell, H. J. (2021). An economically viable 100% renewable energy system for all energy sectors of Germany in 2030. Energies. mdpi.com

[75]. Vanstapel, F. J., Orth, M., Streichert, T., Capoluongo, E. D., Oosterhuis, W. P., Çubukçu, H. C., ... & Neumaier, M. (2023). ISO 15189 is a sufficient instrument to guarantee high-quality manufacture of laboratory developed tests for in-house-use conform requirements of the European In-Vitro-Diagnostics Regulation: Joint opinion of task force on European regulatory affairs and working group accreditation and ISO/CEN standards of the European Federation of Clinical Chemistry and Laboratory Medicine. Clinical Chemistry and Laboratory Medicine (CCLM), 61(4), 608-626. degruyter.com

[76]. Xiaosan, Z., Qingquan, J., Iqbal, K. S., Manzoor, A., & Ur, R. Z. (2021). Achieving sustainability and energy efficiency goals: assessing the impact of hydroelectric and renewable electricity generation on carbon dioxide emission in China. Energy Policy. [HTML]

[77]. Xie, P. & Jamaani, F. (2022). Does green innovation, energy productivity and environmental taxes limit carbon emissions in developed economies: Implications for sustainable development. Structural Change and Economic Dynamics. [HTML]

[78]. Xue, C., Shahbaz, M., Ahmed, Z., Ahmad, M., & Sinha, A. (2022). Clean energy consumption, economic growth, and environmental sustainability: what is the role of economic policy uncertainty? Renewable Energy. uni-muenchen.de

[79]. Xu, Y., Li, Y., Zheng, L., Cui, L., Li, S., Li, W., & Cai, Y. (2020). Site selection of wind farms using GIS and multi-criteria decision-making method in Wafangdian, China. Energy. [HTML]

[80]. Yalew, S. G., van Vliet, M. T. H., Gernaat, D. E. H. J., & Ludwig…, F. (2020). Impacts of climate change on energy systems in global and regional scenarios. Nature Energy. ucl.ac.uk

[81]. Yasmeen, R., Zhang, X., Tao, R., & Shah, W. U. H. (2023). The impact of green technology, environmental tax and natural resources on energy efficiency and productivity: Perspective of OECD Rule of Law. Energy Reports. sciencedirect.com

[82]. Zhou, M., Wang, B., Guo, S., & Watada, J. (2021). Multi-objective prediction intervals for wind power forecast based on deep neural networks. Information Sciences. [HTML]