African Journal of Applied Research
Vol. 10, No. 1 (2024), pp. 374-386
http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.22

RENEWABLE ENERGY SOURCES IN THE CONTEXT OF EMISSIONS REDUCTION: GEOGRAPHICAL ASPECTS AND CHALLENGES FOR SUSTAINABLE DEVELOPMENT

Kovalskyi, M.[1], Duczmal, W.[2], Oleksiuk, M.[3], Skomorovskyi, A.[4], and Berezivskyy, Z.[5]
[1]*Department of Public Administration, Interregional Academy of Personnel Management, Kyiv, Ukraine.*
[2, 3, 4]*The Academy of Applied Sciences, Academy of Management and Administration in Opole, Opole, Poland.*
[5]*Department of Economics, Faculty of Management, Economics and Law, Lviv National Environmental University, Lviv, Ukraine.*
[1]*zyccompany@ukr.net*
[2] *w.duczmal@g.wszia.opole.pl*
[3] *m.oleksiuk@g.wszia.opole.pl*
[4] *a.skomorovskyi@g.wszia.opole.pl*
[5]*masterzenik@ukr.net*

ABSTRACT
Purpose: The study aims to provide a nuanced understanding of renewable energy sources' geographical aspects and challenges in reducing emissions and promoting sustainable development.
Design/Methodology/Approach: This study adopts a qualitative approach to investigate renewable energy sources in the context of emissions reduction, focusing on geographical aspects and challenges for sustainable development. The methodology is designed to gain in-depth insights and understand the complexities of deploying and utilising renewable energy across different geographical regions. Case studies provide detailed, context-specific insights into the practical implementation and challenges of renewable energy projects. The selection of case studies follows a purposive sampling method to ensure diversity in geographical settings, types of renewable energy, and stages of development. Reviewing project reports, policy documents, and environmental assessments related to each case study. The data was analysed by cross-verifying information from different data sources to enhance the reliability and validity of the findings.
Research Limitation/Implications: It justifies the immediate construction of a "green economy" in Ukraine, drawing on theory and the experience of advanced countries.
Findings: The diversity of renewable energy sources, geographical influences, technological advancements, policy and regulatory frameworks, and socio-economic impacts influenced their efforts to reduce emissions.
Social Implication: The modern global economy faces significant challenges such as energy security, sustainable development of society, and climate change.
Practical Implication: The paper identifies directions and outlines paths and mechanisms for accelerated development. Indeed, such a powerful carbon dioxide and methane emissions surge has never been observed.
Originality/ Value: Recently, the most pressing issue is the "carbon footprint", which refers to the total amount of carbon dioxide and methane emissions released into the environment due to human industrial activity. Measures to combat it will soon focus on modernising technologies to facilitate the transition to the sixth technological paradigm and minimise greenhouse gas emissions. Critical

ISSN: 2408-7920

technical solutions may involve harnessing the potential of hydrogen energy and immobilising or preventing greenhouse gas formation technologies. As an alternative direction, the authors consider research to solve some issues related to hydrogen production using metals.
Keywords: *Emissions. energy policy. geographical dimension. reduction. renewable*

INTRODUCTION

The international community has recognised the urgency of climate change and the need for legal, economic, and organisational measures to regulate the anthropogenic impact on the climate. Experts estimate that climate warming causes the global economy to lose over $1.2 trillion annually, equivalent to 1.6% of global GDP. Analysts acknowledge that climate change causes the deaths of nearly 400,000 people annually. An additional 4.5 million deaths are attributed to air pollution from fuel combustion, which is also linked to climate change issues.

The legal regulation in the climate sector can be improved through international treaties. The concept of sustainable development was adopted at the UN conference in Rio de Janeiro in 1992 (Zappa et al., 2019). The concept of sustainable development through a “green economy” was the third UN World Conference on Sustainable Development theme, Rio de Janeiro, 2012 (Rio+20). The main provisions of this concept are contained in the UNEP report “Green Economy: Pathways to Sustainable Development and Poverty Eradication”, 2011, prepared for Rio+20. The concept of the green economy incorporates innovative approaches and principles to tackle the multifaceted crises of the present.

The Paris Agreement, which replaced the Kyoto Protocol after 2020, highlighted a negative trend in emission growth. While some countries have made significant progress in transitioning to sustainable development, trends contrary to sustainable development have become dominant, exacerbating the crisis. According to the UNEP report, several crises have emerged or accelerated over the past decade, including climate change, war, biodiversity loss, fuel and food shortages, and water scarcity. Additionally, the financial system and economy have recently faced significant challenges. The current recession followed the financial economic crisis, and military conflicts continued without resolution.

This research investigates the role of renewable energy sources in reducing greenhouse gas emissions, specifically focusing on the geographical aspects and challenges associated with their deployment and integration into sustainable development frameworks. The objectives are to evaluate emissions reduction capabilities and identify the primary geographic challenges hindering the widespread adoption of renewable energy, such as land use conflicts, environmental impacts, and resource accessibility. Then, develop a framework for international cooperation and knowledge transfer to support regions with less favourable geographic conditions for renewable energy.

Literature Review

Numerous publications (Gao et al., 2020; Wang et al., 2011; Ye et al., 2019; Guo et al., 2018) have explored the hydrogenation of CO_2 using tandem catalysis, a chemical process that employs multiple catalysts (usually two) to produce a product that would be unattainable with a single catalyst. Tandem catalysis is based on two widely studied synthesis methods. The Fischer-Tropsch synthesis (FTS) and methanol synthesis are two processes used to produce hydrocarbons from CO_2. However, the mechanisms of initial C-C bond formation and C-O bond cleavage in tandem catalysts differ from those in traditional catalysts used in Fischer synthesis reactions.

In addition to carbon dioxide hydrogenation, valuable hydrocarbon products and energy resources can be obtained using secondary fuels. Hydrogen is the most promising of these fuels, as it is an environmentally friendly and practically inexhaustible energy carrier with low greenhouse gas emissions and pollutants when used. The countries that most intensively develop renewable energy technologies and markets should include the USA, EU countries (first of all, Sweden, Austria, Finland, Germany, Spain), Japan, and China. Recently, they have become more active in this in the direction of Brazil and India. The value of the shares of companies engaged in it is increasing NVDE. All this will make it possible to speed up the development of technologies and their introduction into industrial production.

Swedish scientists (Wegelius et al., 2018) have developed a new technology for converting solar energy into hydrogen using artificially synthesised enzymes. The method is based on achievements in synthetic biology and synthetic chemistry. Photosynthetic microorganisms, cyanobacteria, produce these artificial enzymes inside living organisms. Some scientific works by scientists and practitioners, particularly Sotnyk, Kurbatova, Trypolska, Sokhan, and Koshel (2023). At the same time, understudied, there are still issues related to the priority development of renewable energy sources in the context of state policies and their role in the development of the world economy. Renewable energy sources come from natural resources such as wind, sun, water (energy of sea tides and waves), heat of the Earth, and biomass (plants, various types of organic waste). There are such sources that are inexhaustible and environmentally safe.

Swiss scientists (Sinhamahapatra et al., 2018) developed efficient quantum dots based on indium for hydrogen production to address the issue of toxic catalysts. Quantum dots are objecting a few nanometers in size with tunable optical properties, facilitating the most efficient hydrogen synthesis. In their research, Professor Jong-Sung Yu and his team attempted to modify the most common photocatalyst, titanium dioxide. They cleaned the surface of the photocatalyst from oxygen molecules and then saturated it with hydrogen atoms obtained from the splitting of magnesium hydride. The resulting material was four times more active than photocatalysts made from titanium dioxide and remained stable for over 70 days under visible light.

Under Whittemore's guidance, Ohio researchers have developed an artificial molecule made of rhodium that can absorb sunlight from the entire visible spectrum. The molecule produces 50% more solar energy than current photovoltaic elements and acts as a catalyst for transforming solar energy into hydrogen.

The University of Cambridge researchers (Sokol et al., 2018) have developed a semi-artificial photosynthesis mechanism. They activated the hydrogenase of algae, which reduces protons to hydrogen, a process typically deactivated during photosynthesis. Combining it with photosynthesis

ISSN: 2408-7920

created a molecular machine that efficiently splits water into hydrogen and oxygen using sunlight. The mechanism captures much more solar radiation than natural photosynthesis.

MATERIALS AND METHODS

This study adopts a qualitative approach to investigate renewable energy sources in the context of emissions reduction, focusing on geographical aspects and challenges for sustainable development. The methodology is designed to gain in-depth insights and understand the complexities involved in the deployment and utilisation of renewable energy across different geographical regions.

Case studies are employed to provide detailed, context-specific insights into the practical implementation and challenges of renewable energy projects. The selection of case studies follows a purposive sampling method to ensure diversity in geographical settings, types of renewable energy, and stages of development. Reviewing project reports, policy documents, and environmental assessments related to each case study.

The data was analysed by cross-verifying information from different data sources to enhance the reliability and validity of the findings.

RESULTS

The findings from the literature review on renewable energy sources in the context of emissions reduction, focusing on geographical aspects and challenges for sustainable development, are organised into several key themes. These include the diversity of renewable energy sources, geographical influences, technological advancements, policy and regulatory frameworks, and socio-economic impacts.

Diversity of Renewable Energy Sources

The literature indicates that various renewable energy sources contribute to emissions reduction, each with unique advantages and challenges:

It was revealed by Zhang, Ren, Pu, and Wang (2020) that solar energy is widely regarded for its potential to generate electricity without emissions. However, its efficiency is highly dependent on geographical location, with regions having higher solar irradiance achieving better results.
A study by Roga, Bardhan, Kumar, and Dubey (2022) disclosed that wind energy is adequate in regions with consistent and robust wind patterns. Coastal areas and open plains are particularly suitable, but wind intermittency challenges consistent energy supply.

Hydropower provides significant emissions reduction benefits and reliable power generation, as indicated by Xiaosan, Qingquan, Iqbal, Manzoor, and Ur (2021). However, its highly site-specific feasibility requires suitable topography and water resources.

Geothermal Energy offers a stable and continuous power supply but is limited to regions with accessible geothermal resources, such as volcanic areas (Gong et al., 2020).

African Journal of Applied Research
Vol. 10, No. 1 (2024), pp. 374-386
http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.22

Geographical Influences

Geographical aspects play a crucial role in the feasibility and efficiency of renewable energy projects. Local climate conditions heavily influence solar and wind energy potentials (Jung, & Schindler, 2020). Regions with high solar irradiance and intense wind patterns are more suitable for these technologies. The physical landscape affects the implementation of renewable energy projects. Hydropower and wind farms require specific topographical features to maximise efficiency.

The presence of natural resources, such as biomass feedstock and geothermal activity, dictates the suitability of specific renewable energy sources in different regions. Geographical factors also influence land use decisions and environmental impacts, with renewable energy projects needing to balance energy production and the conservation of natural habitats.

Technological Advancements

Advancements in technology have significantly improved the efficiency and viability of renewable energy sources:

Technological innovations have increased the efficiency of photovoltaic cells, making solar energy more competitive with traditional energy sources. Advances in turbine design and materials have enhanced the performance and reduced wind energy costs. The development of advanced energy storage technologies, such as batteries and pumped hydro storage, addresses the intermittency issues of solar and wind energy, enabling a more reliable power supply.

Innovative grid technologies and improved grid infrastructure facilitate the integration of renewable energy sources, enhancing their contribution to the overall energy mix.

Regulatory Frameworks

The success of renewable energy projects is closely linked to supportive policy and regulatory frameworks (Clausen & Rudolph, 2020). Government incentives, subsidies, and tax breaks are critical in promoting the adoption of renewable energy technologies. Clear and stable regulatory frameworks provide the necessary assurance for investors and developers of renewable energy projects. Global commitments, such as the Paris Agreement, drive national policies towards reducing emissions and increasing the share of renewable energy in the energy mix.

Socio-Economic Impacts

The deployment of renewable energy sources has significant socio-economic implications. Renewable energy projects create manufacturing, installation, and maintenance jobs, contributing to local economies. Renewable energy can improve access to electricity in remote and underserved areas, promoting social and economic development. Successful projects often involve community participation and ownership, ensuring that local needs and concerns are addressed. We need to ensure that renewable energy's benefits are equitably distributed, avoiding negative impacts on marginalized communities.

Reducing CO_2 emissions to minimise environmental impact is crucial for environmental safety, especially in light of climate change. The outlook for global and national energy development beyond

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 1 (2024), pp. 374-386
http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.22

2030 indicates a rising global demand for energy, particularly in non-Organisation for Economic Co-operation and Development countries. Although renewable energy technologies are growing and developing, fossil fuels still dominate the world's energy balance. It is necessary to transition from high-carbon to low-carbon fuels to reduce CO2 emissions, which are a major contributor to the intensification of the greenhouse effect. However, a rapid abandonment of oil, natural gas, and coal is unlikely feasible without severe disruption to the global economy.

According to Ampah et al. (2020), stabilising the level of CO_2 in the atmosphere requires a reduction of approximately 20 billion tonnes of emissions annually. Khoja et al. (2020) anticipate that carbon sequestration could reduce emissions by 5-10 billion tonnes per year by storing CO_2 in various geological formations. Aquifers are the most numerous underground formations with significant storage capacity. When storing CO_2 in aquifers, it is crucial to consider various parameters. These include acceptable storage capacity, CO_2 migration rate, rock impermeability, geological characteristics of the aquifer formation, caprock structures, potential leakage from the reservoir, and wells.

Comprehensive analysis of natural experimental research and computer modelling can facilitate the effective use of carbon dioxide in aquifers. This analysis aims to better understand the physical and chemical processes that occur in underground formations during sequestration and underground storage. As CO_2 is a relatively stable molecule, significant energy is required to break molecular bonds for its conversion to CO. The urgent problem of increased anthropogenic environmental load requires new models.

The "Green Economy" concept has emerged as a new development model. It aims to transition from carbon-intensive, "brown" energy production and unsustainable resource use to a "green" sustainable development economy with rational resource use. The green economy model is proposed to the global community as a solution to the multifaceted global crisis. While we agree with the principles and main provisions of sustainable development, we believe that the concept of the green economy is distinguished by its focus on the structural transformation of the economy as a leading factor in the transition to sustainable development, poverty eradication, and increasing social justice. The objective of the "green economy" is to promote reforms across.

For instance, in Sweden, the introduction of a tax on nitrogen oxide emissions has led to a significant expansion of the use of existing emission reduction technology. Before the tax, only 7% of companies utilised the technology, but the year following its introduction increased to 62%. Several municipalities in India have implemented property tax discounts for those who use solar water heaters. These discounts can reach up to 6-10% of the property tax, which falls under the exemption for fixed assets, reducing taxable income.

The implementation of renewable energy technologies is facilitated by price support and net metering for electricity (Figure 1). Private investors require long-term certainty, often provided through subsidies or price regulation to ensure market prices for specific goods or services. Feed-in tariffs are the most widely used approach to promote the adoption and improvement of renewable energy production technologies. In addition, many countries incentivise small-scale energy production based

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 1 (2024), pp. 374-386
http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.22

on renewable sources through net metering. Net metering is a common practice in the USA and is implemented in Mexico and Thailand. The operating conditions for these reactions in acidic and alkaline solutions typically range from room temperature to below 100°C and atmospheric pressure. Only a few studies have been conducted at temperatures up to 160°C and pressures of around 10 bar.

In the USA, there is extensive research into a method of hydrogen production based on using alcohols such as methanol, ethanol, and bioethanol as a source of hydrogen and energy to support electrolysis. Methanol and ethanol better suit low-temperature (<80°C) electrolysis systems. According to Xia et al. (2022), the cost of hydrogen production using water electrolysis with methanol (MAWE) could be approximately half that of conventional water electrolysis, even when considering the cost of methanol. Another method of hydrogen production from hydrocarbons is through their thermal decomposition, as shown in the following reaction: $C_mH_n = {}_mC + n/2H_2$. Methane can be decomposed into carbon and hydrogen through thermal or thermocatalytic means at temperatures ranging from 500-700°C. This process does not result in the formation of CO or CO_2. One notable benefit of the thermocatalytic reaction of methane is the production of carbon nanomaterials, including carbon nanotubes. Nickel catalysts are among the most effective catalysts for methane dissociation.

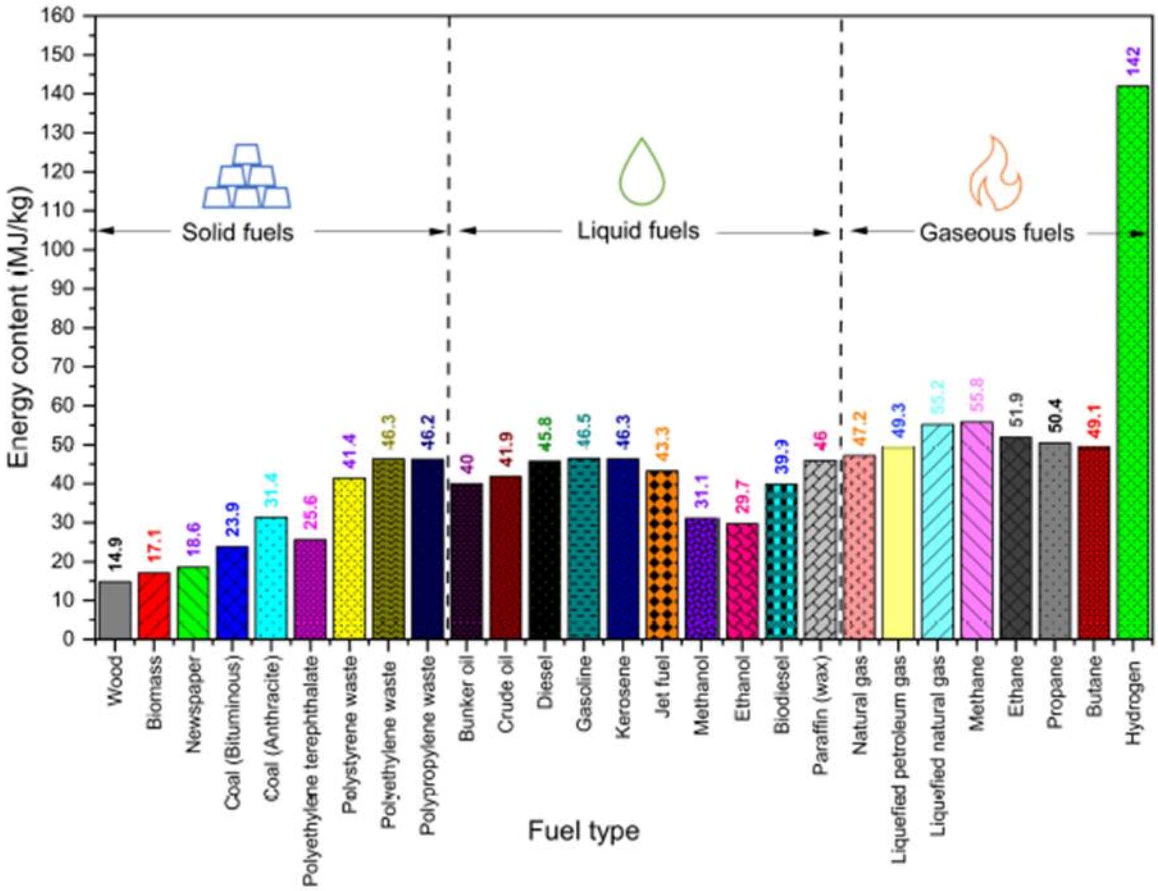

Figure 1: Energy intensity of different fuel types, including hydrogen
Source: Compiled by author

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 1 (2024), pp. 374-386
http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.22

The economic benefits of developing and actively using green technologies are evident not only in addressing the issue of population employment. Germany is one of the world leaders in this field, with 23% of all patented technologies in ecology and over 30% in the field of solar and wind energy owned by German companies. This trend is expected to continue.

In Ukraine, implementing four blocks of the "green economy" has already begun despite the ongoing war. These blocks include using renewable energy sources, increasing energy efficiency and conservation, constructing waste recycling plants, and developing low-carbon, specifically the carbon emissions trading market (Mikhno, 2023). Economic mechanisms to stimulate the development of the "green economy" in Kyiv and the Kyiv region include state funding for projects and government procurement.

Implementing the Smart Grid concept in Ukraine will have the following advantages. It will provide the following significant fundamental technological changes in the electricity sector compared to traditional power systems:

- transition from centralised energy generation and delivery systems to distributed ones, with the ability to control generation and network topology at any point, including the consumer.
- transition from centralised demand forecasting to an active consumer who becomes an element and subject of the management system.
- the transition from rigid dispatch regulation (control) to a different level of coordination among all grid entities.
- transition to intelligent technologies for monitoring, accounting and diagnostics of assets, which allow for self-healing and self-healing of assets and ensure their efficient functioning, pricing and operation.
- Creating high-performance information and computing infrastructure as a key element of the energy system.
- creating preconditions for introducing new technological equipment that increases the manoeuvrability of energy sources, superconductivity, etc.
- Recently, along with the Smart Greed concept, the Smart home subsystem has been successfully used, see Figure 2.

African Journal of Applied Research
Vol. 10, No. 1 (2024), pp. 374-386
http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.22

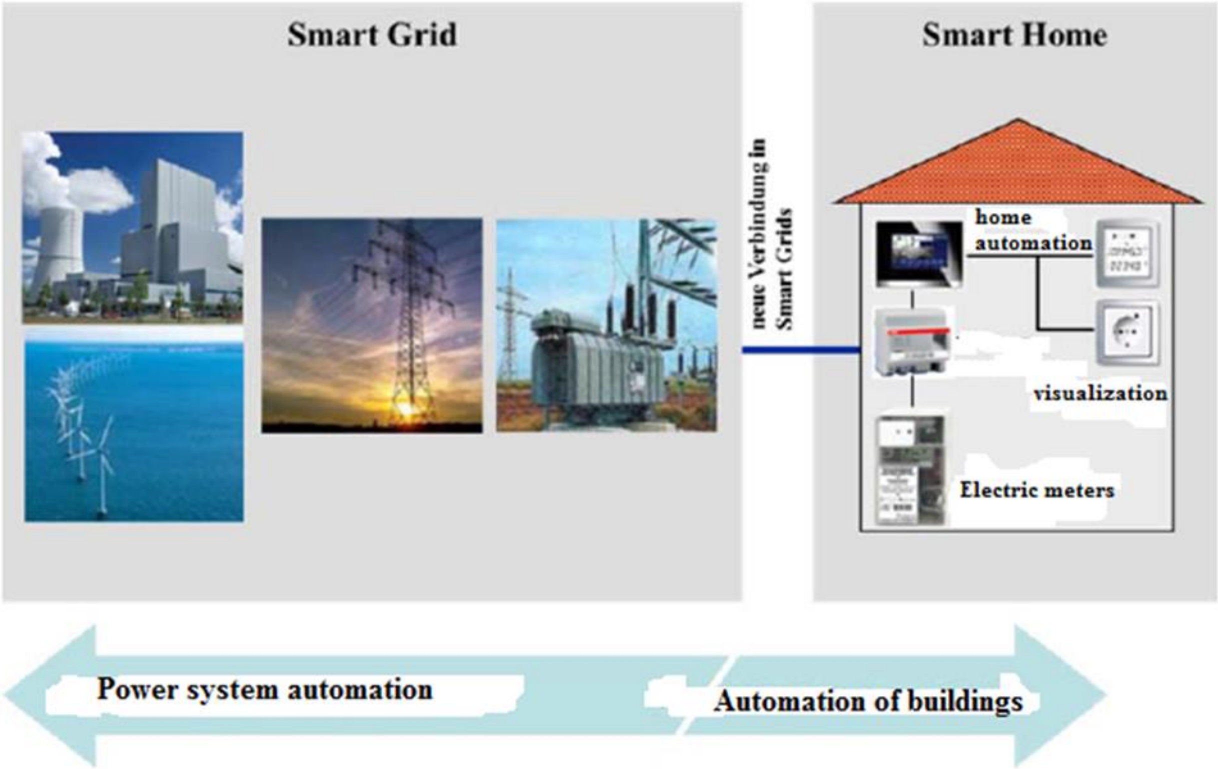

Figure 2: Interaction between Smart grid and Smart Home systems
Source: Compiled by author

The Strategy for Ukraine's Transition to a Green Economy mandates the adoption of global priorities, such as transitioning to new indicators of sustainable economic development and greening taxation. This ensures a unified approach to new norms of natural resource use, environmental standards, and incentive measures, creating a system to motivate businesses to enter the green economy sector. Several regions of Ukraine are already implementing "green" projects within the framework of the Government's alternative energy development plan.

Challenges for Sustainable Development

The literature highlights several challenges that need to be addressed to achieve sustainable development through renewable energy. Securing sufficient investment for large-scale renewable energy projects remains a significant challenge, particularly in developing regions (Lema et al., 2021). Despite advancements, some renewable energy technologies still face technical limitations that hinder widespread adoption. Inadequate infrastructure, especially in remote and rural areas, hinders the deployment of renewable energy. Renewable energy projects must balance energy production with conserving natural resources and ecosystems.

Discussion

Hydrogen is considered a clean energy carrier and a key direction for sustainable development. However, technical, cost-related, and institutional challenges hinder the widespread adoption of hydrogen energy. The methods of hydrogen production from fossil fuels do not eliminate CO_2

emissions. Less than 4% of hydrogen production currently comes from “carbon-neutral” electrolysis, which involves hydrogenation and nuclear energy. The options for tackling the challenges of large-scale production of “green” hydrogen (where no CO_2 emissions occur during production) at the current stage of technological development are limited. One option is to use energy from nuclear and hydroelectric power plants or to explore new, affordable, and environmentally friendly sources. One potential approach to hydrogen production involves using carbon dioxide capture methods based on the Sabatier and Boudouard reactions. Despite advancements, hydrogen energy still faces challenges that are difficult to resolve. These issues include the explosion and fire hazards associated with this environmentally friendly energy carrier's production, storage, and transportation.

Experimental studies by authors (Gao et al., 2020; Wang et al., 2011; Ye et al., 2019; Guo et al., 2018) are also directed to the consolidation of efforts in search for solutions to the affected problems for substantiation of carbon dioxide utilisation technologies with simultaneous generation of helpful energy carriers - hydrogen and hydrocarbons. Developing countries actively express concerns about transitioning to the “green economy”. They fear that the concept of the “green economy” may lead to the creation of new trade barriers and reduce the competitiveness of their goods. This, in turn, could hinder the achievement of development goals. Developing countries believe that the “green economy” should only be considered in the context of sustainable development and poverty alleviation.

Photocatalytic conversion of carbon dioxide is also a relatively difficult task, so most of the research is focused on understanding the mechanism connecting the adsorption of dioxo-carbon dioxide, activation of carbon dioxide, desorption of the product and the possible reaction mechanism. Because the photoconversion of carbon dioxide requires a considerable amount of input to be developed, renewable approaches energy (wind energy, solar energy and hydroelectric triple energy) for the effectiveness of such technologies. In addition, it is possible to improve the photoconversion characteristics formation of carbon dioxide, which allows efficient but accumulated light, as well as separate photo-genera-charged charge carriers. Many conversion methods, such as catalytic hydrogenation, mineralisation, electrochemical biological, thermochemical, plasma and enzymatic transformation, were adapted to transform carbon dioxide into valuable chemicals. Recent international discussions have highlighted the need for a clear definition of the “green economy” concept and a comprehensive analysis of measures for its implementation that consider the interests of all countries.

CONCLUSION

One promising direction in carbon dioxide utilisation is producing environmentally friendly energy carriers by converting carbon dioxide into valuable products or synthesising hydrocarbons. From the point of view of cost, coal or carbon are the most efficient active sources of this process, available in large quantities. There is limited global evidence of successful industrial implementation of such technologies. This is due to the requirement for a long service life for catalyst modifications, ensuring high carbon dioxide conversion rates with selectivity for desired reaction products. Furthermore, a stable source of hydrogen remains a significant issue. The scientific community proposes obtaining hydrogen through water electrolysis using electricity generated by solar, wind, or other renewable energy sources, as well as water splitting using photocatalytic, photoelectrochemical, and other photochemical processes as a rational solution to these problems. However, these methods' high energy consumption and cost constrain their use.

Scientific activity focuses on obtaining and using renewable energy sources, such as solar, wind, hydroelectric, and geothermal, to reduce dependence on fossil fuel-based energy sources. However, these sources often require significant initial investments, and the cost of electricity production can be high. In addition, the fluctuation of renewable energy sources and their reliance on environmental conditions emphasises the importance of reducing costs.

REFERENCES

Abbasi, K., Lv, K., Nadeem, M. A., Khan, A., & Shaheen, R. (2020). Agricultural and manufacturing sector determinants consumption, price, and real GDP from Pakistan of electricity. North American Academic Research, 3, 21–44. http://dx.doi.org/10.5281/zenodo.3604943

Adams, S., Klobodu, E. K. M., & Apio, A. (2018). Renewable and non-renewable energy regime type and economic growth. Renewable Energy, 125, 755–767. http://doi.org/10.1016/j.renene.2018.02.135

Ahmed, K., Farrok, O., Rahman, M. M., Ali, M.S., Haque, M. M., & Azad, A. K. (2020). Proton Exchange Membrane Hydrogen Fuel Cell as the Grid Connected Power Generator. Energies, 13, 6679. https://doi.org/10.3390/en13246679

Ampah, J. D., Afrane, S., Agyekum, E. B., Adun, H., Yusuf, A. A., & Bamisile, O. (2022) Electric vehicles development in Sub-Saharan Africa: Performance assessment of standalone renewable energy systems for hydrogen refuelling and electricity charging stations (HRECS). Journal of Cleaner Production, 376, 134238. http://dx.doi.org/10.1016/j.jclepro.2022.134238

Anwar, A., Siddique, M., Eyup, D., & Sharif, A. (2021). The moderating role of renewable and non-renewable energy in environment income nexus for ASEAN countries: evidence from Method of Moments Quantile Regression. Renewable Energy, 164, 956–967. https://doi.org/10.1016/j.renene.2020.09.128

Azad, K., Rasul, M., Halder, P., & Sutariya, J. (2019). Assessment of Wind Energy Prospect by Weibull Distribution for Prospective Wind Sites in Australia. Energy Procedia, 160, 348–355. https://doi.org/10.1016/j.egypro.2019.02.167

Clausen, L. T., & Rudolph, D. (2020). Renewable energy for sustainable rural development: Synergies and mismatches. Energy Policy, 138, 111289.

Doppalapudi, A., Azad, A., & Khan, M. (2023). Advanced strategies to reduce harmful nitrogen-oxide emissions from biodiesel-fueled engines. Renewable and Sustainable Energy Reviews, 174, 113123. https://doi.org/10.1016/j.rser.2022.113123

Doppalapudi, A., Azad, A., & Khan, M. (2021). Combustion chamber modifications to improve diesel engine performance and reduce emissions: A review. Renewable and Sustainable Energy Reviews, 152, 111683. https://doi.org/10.1016/j.rser.2021.111683

Dvigun, A., Datsii, O., Levchenko, N., Shyshkanova, G., Platonov, O., & Zalizniuk, V. (2022). Increasing ambition to reduce the carbon trace of multimodal transportation in the conditions of Ukraine’s economic transformation towards climate neutrality. Science and Innovation, 18(1), 96-111. https://doi.org/10.15407/scine18.01.096

Gao, X., Atchimarungsri, T., Ma, Q., Zhao, T.-S., & Tsubaki, N. (2020). Realizing efficient carbon dioxide hydrogenation to liquid hydrocarbons by tandem catalysis design. EnergyChem, 2(4), 100038. https://doi.org/10.1016/j.enchem.2020.100038

Gong, F., Guo, T., Sun, W., Li, Z., Yang, B., Chen, Y., & Qu, Z. (2020). Evaluation of geothermal energy extraction in Enhanced Geothermal System (EGS) with multiple fracturing horizontal wells (MFHW). *Renewable Energy*, *151*, 1339-1351.

Guo, L., Sun, J., Ge, Q., & Tsubaki, N. (2018). Recent advances in direct catalytic hydrogenation of carbon dioxide to valuable C2+ hydrocarbons. Journal of Materials Chemistry A, 6, 23244-23262. https://doi.org/10.1039/C8TA05377D

Jung, C., & Schindler, D. (2020). Introducing a new approach for wind energy potential assessment under climate change at the wind turbine scale. Energy conversion and management, 225, 113425.

Khoja, A., Azad, A., Saleem, F., Khan, B., Naqvi, S., Mehran, M., & Amin, N. (2020) Hydrogen Production from Methane Cracking in Dielectric Barrier Discharge Catalytic Plasma Reactor Using a Nanocatalyst. Energies, 13, 5921. https://doi.org/10.3390/en13225921

Ma, Y., Zhang, J., Huang, Y., & Cao, J. (2018). A novel process combined with flue-gas desulfurization technology to reduce lead dioxide from spent lead-acid batteries. Hydrometallurgy, 178, 146–150. https://doi.org/10.1016/j.hydromet.2018.04.006

Mazhar, A., Khoja, A., Azad, A., Mushtaq, F., Naqvi, S., Shakir, S., Hassan, M., Liaquat, R., & Anwar, M. (2021). Analysis of TiO2-Modified Co/MgAl2O4 Catalyst for Dry Reforming of Methane in a Fixed Bed Reactor for Syngas (H2, CO) Production. Energies, pp. 14, 5921. https://doi.org/10.3390/en14113347

Mehrjerdi, H. (2020). Modeling and optimization of an island water-energy nexus powered by a hybrid solar-wind renewable system. Energy, 197, 117217. https://doi.org/10.1016/j.energy.2020.117217

Mikhno, I., Ihnatenko, N., Cherniaiev, O., Vynogradnya, V., Atstaja, D., Koval, V. (2023). Construction waste recycling in the circular economy model IOP Conference Series: Earth and Environmental Science, 1126(1). https://doi.org/10.1088/1755-1315/1126/1/012003

Rahman, M., Chowdhury, S., Zayed, N. M., Imran, M. A., Hanzhurenko, I., & Nitsenko, V. (2022). Does globalization trigger an ecological footprint? A time series analysis of bangladesh. Rocznik Ochrona Srodowiska, 24, 141-162. https://doi.org/10.54740/ros.2022.011

Rej, S., Bandyopadhyay, A., Murshed, M., Mahmood, H., & Razzaq, A. (2022). Pathways to decarbonization in India: the role of environmentally friendly tourism development. Environmental Science and Pollution Research, 29, 1–22. https://doi.org/10.1007/s11356-022-19239-2

Roga, S., Bardhan, S., Kumar, Y., & Dubey, S. K. (2022). Recent technology and challenges of wind energy generation: A review. *Sustainable Energy Technologies and Assessments*, *52*, 102239.

Sinhamahapatra, A., Lee, H-Y., Shen, S., Mao, Y., & Yu, J.-S. (2018). H-doped TiO2-x prepared with MgH2 for highly efficient solar-driven hydrogen production. Applied Catalysis B: Environmental, 237, 613-621. http://dx.doi.org/10.1016/j.apcatb.2018.06.030

Sokol, K. P., Robinson, W. E., Warnan, J., Kornienko, N., Nowaczyk, M. M., Ruff, A., & Reisner, E. (2018). Bias-free photoelectrochemical water splitting with photosystem II on a dye-sensitized photoanode wired to hydrogenase. Nature Energy, 3, 944–951. https://ui.adsabs.harvard.edu/link_gateway/2018NatEn.3..944S/doi:10.1038/s41560-018-0232-y

Sotnyk, I., Kurbatova, T., Trypolska, G., Sokhan, I., & Koshel, V. (2023) Research trends on development of energy efficiency and renewable energy in households: A bibliometric analysis. Environmental Economics, 14(2), 13-27. http://dx.doi.org/10.21511/ee.14(2).2023.02

Sumets, A., Tyrkalo, Y., Popovych, N., Poliakova, J., & Krupin, V. (2022). Modelling of the environmental risk management system of agroholdings considering the sustainable development values. Agricultural and Resource Economics, 8(4), 244-265. https://doi.org/10.51599/are.2022.08.04.11

Tymoshenko, Y., Kyslenko, D., Kuzmichova-Kyslenko, E., Leonenko, I., & Servetsky, I. (2022). Features of the pre-trial investigation of air pollution. Environment and Ecology Research, 10(2), 133-145. https://doi.org/10.13189/eer.2022.100203

Wang, W., Wang, S., Ma, X., & Gong, J. (2011). Recent advances in catalytic hydrogenation of carbon dioxide. Chemical Society Reviews, 40, 3703-3727. https://doi.org/10.1039/C1CS15008A

Wegelius, A., Khanna, N., Esmieu, C., Barone, G. D., Pinto, F., Tamagnini, P., … & Lindblat, P. (2018). Generation of a functional, semisynthetic [FeFe]-hydrogenase in a photosynthetic microorganism. Energy & Environmental Science, 11, 3163-3167 https://doi.org/10.1039/C8EE01975D

Whittemore, T. J., Xue, C., Huang, J., Gallucci, J., & Turro, C. (2020). Single-chromophore single-molecule photocatalyst for the production of dihydrogen using low-energy light. Nature Chemistry, 12, 180-185. https://doi.org/10.1038/s41557-019-0397-4

Xia, W., Apergis, N., Bashir, M., Ghosh, S., Dogan, B., & Shahzad, U. (2022) Investigating the role of globalization, and energy consumption for environmental externalities: Empirical evidence from developed and developing economies. Renewable Energy, 183, 219–228. http://dx.doi.org/10.1016/j.renene.2021.10.084

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, 155, 112332.

Ye, R. R, Ding, J., Gong, W., Argyle, M. D., Zhong, Q., Wang, Y., …, & Yao, Y. G. (2019). CO2 hydrogenation to high-value products via heterogeneous catalysis. Nature Communications, 10, 5698. https://doi.org/10.1038/s41467-019-13638-9

Yu, S., Fan, X-B., Wang, X., Li, J., Zhang, Q., Xia, A., …, & Patske, G. (2018). Efficient photocatalytic hydrogen evolution with ligand engineered allinorganic InP and InP/ZnS colloidal quantum dots. Nature Communications, 9(1), 4009. https://doi.org/10.1038/s41467-018-06294-y

Zappa, W., Junginger, M., & van den Broek, M. (2019) Is a 100% renewable European power system feasible by 2050? Applied Energy, 233–234, 1027–1050. https://doi.org/10.1016/j.apenergy.2018.08.109

Ziegler, M.S., Mueller, J.M., Pereira, G.D., Song, J., Ferrara, M., Chiang, Y.-M., & Trancik, J.E. Storage Requirements and Costs of Shaping Renewable Energy Toward Grid Decarbonization. Joule, 3, 2134–2153. https://doi.org/10.1016/j.joule.2019.06.012

Zhang, Y., Ren, J., Pu, Y., & Wang, P. (2020). Solar energy potential assessment: A framework to integrate geographic, technological, and economic indices for a potential analysis. Renewable Energy, 149, 577-586.