PENINSULA PUBLISHING LLC

ESTIDAMAA
Vol. **(2024)**, 2024, **pp**. 30-35
ISSN: 3078-428X

MEDAAD ESTD 2024 PENINSULA PUBLISHING

Research Article

The Role of Green Technologies in Mitigating Carbon Footprints in Industrial Sectors

Israa Ibraheem Al Barazanchi [1,2,*] , Dima Haider Rasheed [3]

[1] *College of Computing and Informatics, Universiti Tenaga Nasional (UNITEN), 43000 Kajang, Selangor, Malaysia.*

[2] *College of Engineering, University of Warith Al-Anbiyaa, Karbala, Iraq*

[3] *Department of Cyber Engineering Technologies, Ashur University, Baghdad 10001, Iraq*

ARTICLE INFO

Article History

Received 20 Des 2023

Revised: 6 Feb 2024
Accepted 5 Mar 2024
Published 27 Mar 2024

Keywords

Green Technologies,

Carbon Footprints,

Industrial Sustainability,

Renewable Energy,

Carbon Capture and Storage (CCS).

ABSTRACT

Due to energy-intensive processes, dependence on fossil fuels and poor waste management, industry is among the largest contributors to global carbon emissions This environment this growing environmental problem highlights the urgent need for sustainable solutions to reduce carbon emissions. This study examines the role of green technologies in addressing these challenges, focusing on renewable energy systems, carbon capture and storage (CCS), circular economic practices, and digital products on the other hand. The main objective is to assess how these technologies can reduce greenhouse gas emissions and increase energy efficiency and potentially increase the industrial sustainability of resources activities in the field. Findings show that integrating green technologies can lead to a 25% reduction in energy consumption, 85% efficiency in carbon capture, and greenhouse gas emissions has decreased by 50% in a decade Furthermore, sustainable materials and energy efficiency solutions promise to reduce waste and improve the relative quality of infrastructure use Display results. Despite constraints such as high start-up costs and technical barriers, the study highlights the significant potential of green innovation to transform technology It provides a call to action for businesses , policy makers and consumers to embrace this technology as a means to achieve global sustainability goals ends.

1. INTRODUCTION

Whole-atmosphere carbon emissions have reached unprecedented levels, leading to climate change and environmental degradation. Industries, including manufacturing, construction, and energy-intensive industries, are one of the largest sources of greenhouse gases. According to a report by the International Energy Agency (IEA), industry is responsible for about 24% of global CO2 emissions, as a result of over-reliance on fossil fuels for energy production, inefficient roads and industrial waste generation Regarding severe and extensive weather environmental degradation In a growing crisis, the need for actions sustainability in industries has become more urgent than ever[1]. If we aim to achieve global climate goals, as outlined in the Paris Agreement, traditional production methods and energy sources must shift to cleaner technologies and efficiency to reduce the environmental impact of the industrial sector[2]. Idle work threatens not only environmental health but economic stability and public welfare, as businesses face increasing pressure from governments, consumers and investors to take action a green one does not apply This paper seeks to explore how green technologies can meet these challenges and play an important role in reducing the available carbon footprints of industrial projects[3]. By looking at the current state of industrial emissions, advances in green technologies and efficiency, this study aims to provide insights into how businesses can get policies going so that it will remain forever[4]. The aim is to highlight flexible and economically viable solutions that can be applied across sectors to effectively reduce carbon emissions Green technologies represent a transformative approach to industrial development in[5]. From renewable energy systems to carbon capture storage (CCS) processes, these technologies offer the potential to significantly reduce emissions while increasing operational efficiency and as businesses adapt to in this new paradigm not only can regulatory requirements be met but also competitive advantage can be achieved [6].This paper shows that green technology Provides a practical path towards sustainable industrial practices on a regular basis, providing scalable, efficient and economical solutions to one of the most pressing challenges of our time[7].

Figure 1 illustrates how the various environmental factors carbon footprint, energy footprint, water footprint, and nitrogen footprint are interconnected which, when combined, contribute to the overall environmental impact of the industrial sector

*Corresponding author email: israa.albarazanchi2023@gmail.com
DOI: https://doi.org/10.70470/ESTIDAMAA/2024/005

[8]. Each step represents a specific level of resource consumption and environmental pressures, highlighting the complexity of achieving sustainable development. Carbon footprint involves the emissions of industrial activities, such as manufacturing, transportation, manufacturing, consumption and directly or indirectly reflects the total amount of greenhouse gases generated by these processes thus, highlighting the need for energy efficiency and a clean fuel source [9]. It considers waste consumption, changes in land use, natural resource use, identifies the importance of shifting towards renewable energy and improves energy management and has reduced environmental pressures and underlines the critical importance of sustainable mitigation water resources management [10]. The nitrogen footprint results from the use of nitrogen-based products, which are generally associated with industrial activities such as agriculture and land use [11]. The use of large amounts of nitrogen can damage ecosystems and contribute to issues such as water vapor and greenhouse gas emissions [12]. Together, these steps constitute a comprehensive environmental step that highlights the interdependence of natural resource use and environmental sustainability It is emphasized in the audit that addressing a single step is not enough An integrated holistic approach is essential for meaningful environmental development [13].

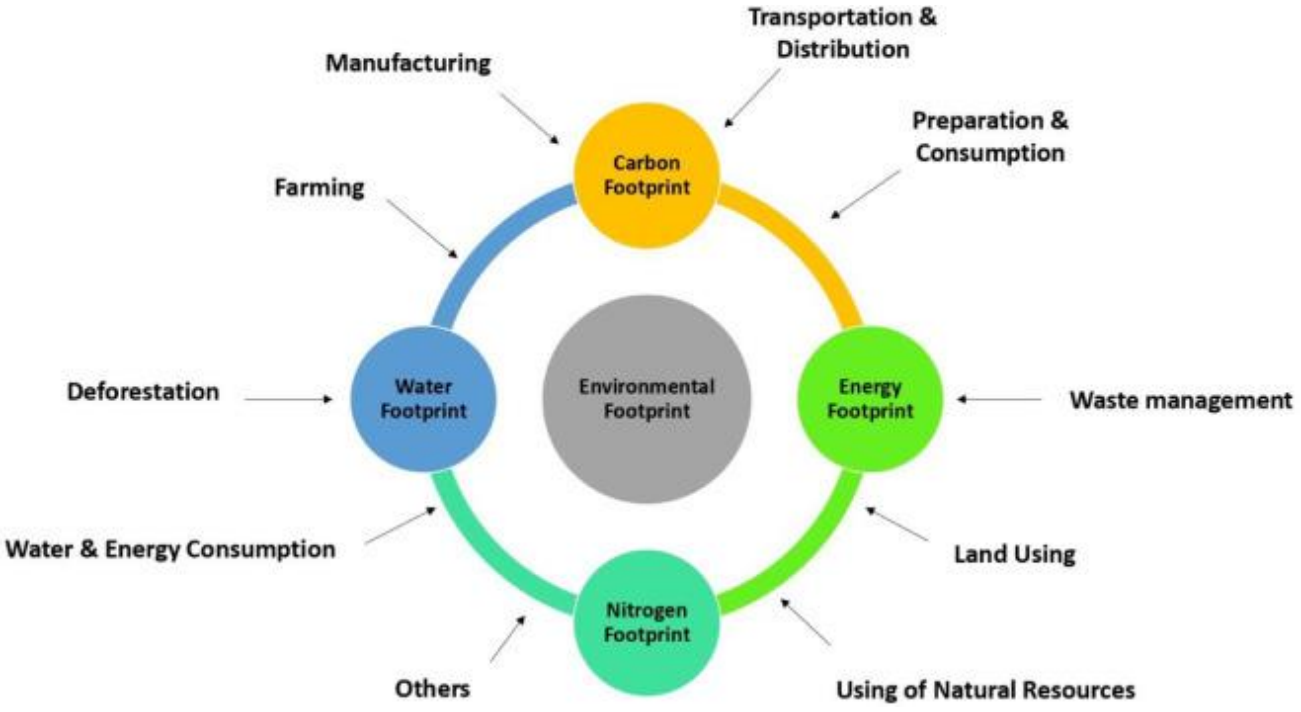

Fig 1. Interconnected Environmental Footprints in Industrial Activities

2. RELATED WORK

The concept of carbon footprint refers to the emissions of greenhouse gases (GHGs), particularly carbon dioxide (CO2), caused directly and indirectly by human activities Technically, a carbon footprint represents emissions from manufacturing, energy consumption, transport income and waste management[14]. Understanding carbon footprints is important for companies, as they identify the most carbon-intensive activities and are strategies to reduce their impact on the environment Industrial carbon footprints are especially important because the company contributes to global warming a large proportion of disposal, which consumes many resources that rely on fossil fuels - and is driven by actions[15]. Industrial emissions are caused by many factors, with energy-intensive industries being the main culprit. Industries such as steel, cement and chemicals are particularly notorious for their high energy demands and heavy reliance on fossil fuels, resulting in significant CO2 emissions As, global carbon emissions account for about 8% of cement production only internally, through chemicals involved -Transportation and logistics of processes and required-energy plays an important role, since fossil fueled vehicles are widely used in raw materials, finished goods and industrial equipment, increasing the region's overall carbon emissions[16]. In addition, industrial waste, including the disposal, incineration, and handling of hazardous materials, contributes significantly to greenhouse gas emissions through methane emissions and roads inefficient recycling The impact of industrial emissions goes beyond environmental damage[17]. In the environment, increased GHGs increase global temperatures, with serious consequences such as sea level rise, extreme weather, ecosystems loss of income, etc.—such as

infrastructure damage, supply disruption, and legal penalties—are significantly placing burdens on businesses and governments on[18]. These results highlight the urgent need for companies to manage their carbon footprints through sustainable practices, including the adoption of green technologies and energy-efficient solutions. Companies can help meet global climate goals by reducing emissions and ensuring long-term viability and competitiveness in a rapidly growing economy[19].

Table I lists the major methods currently used to reduce carbon footprints in technology, highlighting their implications, limitations, and special application areas[20]. These strategies range from technological solutions such as carbon capture and storage (CCS), renewable energy integration and hydrogen technologies to policy strategies such as circular economic practices and energy waste management although any form for large-scale emission reduction potential limitations often hinder their adoption such as high initial costs, technical difficulties and infrastructure requirements[21]. Application areas, including energy-intensive industries, construction, waste management, and transportation, present opportunities to apply these solutions in a variety of sectors This comprehensive overview emphasize the importance of overcoming the barriers associated with unlocking the full potential of these processes in achieving sustainable technologies practices[22].

TABLE I. CURRENT METHODS, LIMITATIONS, AND APPLICATIONS IN REDUCING INDUSTRIAL CARBON FOOTPRINTS

Method	Description	Limitations	Application Areas
Energy Efficiency Improvements	Upgrading machinery and processes to reduce energy consumption.	High upfront costs for upgrading equipment; requires technical expertise for implementation.	Manufacturing, steel production, chemical plants, and energy-intensive industries.
Renewable Energy Integration	Using solar, wind, geothermal, or biomass energy to replace fossil fuels.	Intermittency of renewable sources; significant investment in infrastructure and storage systems.	Power generation, industrial plants, and transportation systems.
Carbon Capture and Storage (CCS)	Capturing CO_2 emissions from industrial processes and storing them underground.	High cost of installation and operation; limited storage sites; not widely adopted on a large scale.	Cement, steel, oil and gas, and chemical industries.
Circular Economy Practices	Recycling, reusing, and reducing waste in production processes.	Limited availability of recycling technologies; challenges in scaling up waste reduction efforts.	Manufacturing, packaging, electronics, and waste management sectors.
Smart Grids and IoT	Using digital tools to monitor and optimize energy use.	High dependence on digital infrastructure and cybersecurity challenges.	Industrial automation, logistics, and energy management.
Sustainable Materials	Developing and using eco-friendly materials such as bio-based plastics.	Limited availability and higher production costs compared to conventional materials.	Construction, automotive, and packaging industries.
Electrification	Replacing fossil-fuel-driven equipment with electric alternatives.	Requires clean electricity sources to be effective; infrastructure challenges for implementation.	Transportation (e.g., EVs), industrial machinery, and heating systems.
Waste-to-Energy (WTE)	Converting industrial waste into usable energy.	Risk of emissions during conversion; high initial investment and regulatory challenges.	Waste management, manufacturing plants, and urban industrial hubs.
Hydrogen Technologies	Using green hydrogen as a clean energy source for industrial processes.	High cost of production and limited hydrogen infrastructure.	Steelmaking, energy storage, and transportation sectors.
Forestation and Carbon Offsetting	Planting trees and investing in offset projects to counteract emissions.	Limited effectiveness in offsetting emissions from high-emission industries.	Heavy industries, energy production, and supply chains.

3. METHOD

Green technology refers to innovative solutions and practices designed to reduce environmental impact, promote sustainability, and mitigate climate change. This technology is characterized by increasing energy efficiency, reducing greenhouse gas emissions, and providing outstanding resource efficiency. Some of the most prominent green technologies include renewable energy, carbon capture and storage (CCS) systems, and circular economic practices. Renewable energy sources, such as solar, wind and geothermal, use natural resources to generate energy that does not consume fuel with limited fossil fuels or carbon emissions it is unlikely that these energy systems are sustainable not only permanently available but also highly suitable for different scales and soil types, making it technologically revolutionary green importance components. CCS technologies, on the other hand, are focused on capturing carbon dioxide from industrial products before they reach the atmosphere and generate electricity, store it safely underground or recycle it in industrial Hence, circular economic practices is aimed at recycling, recycling and efficient use of materials materials and processes can be designed to minimize waste, thereby reducing the environmental burden of industrial activities The successful role of these green technologies in achieving sustainable resources is multifaceted. One of their main contributions is to reduce reliance on fossil fuels, a major source of carbon emissions and environmental damage[23]. By using renewable energy and efficient technologies, businesses can move away from carbon-intensive energy, significantly reducing their carbon footprint Moreover, green technologies force energy consumption encourage efficiency by reducing industrial efficiency and energy consumption, reducing operating costs and operating costs Furthermore, circular economy practices reduce waste and wear resources encouraging recycling, thereby conserving natural resources and reducing environmental pollution, create a closed-loop

system These technologies jointly address environmental challenges of industrial activity various causes address and pave the way for sustainable development Strong explanation They build[24].
Table II lists the main green technologies, their limitations, and applications for environmental reduction. These strategies include innovations such as renewable energy, carbon capture and storage (CCS), circular economy practices, green hydrogen and waste energy systems etc. Although these technologies offer great potential to reduce carbon a is thrown at it and has encouraged sustainable development although high initial costs, infrastructure limitations , . Challenges such as technological barriers often prevent widespread adoption The table also highlights their different uses, including manufacturing and construction transportation and waste management, indicating their importance in terms of technological development a in a continuous process. Addressing these challenges through innovation and policy support is essential to maximize the impact of these green technologies[25].

TABLE II. OVERVIEW OF GREEN TECHNOLOGY METHODS, LIMITATIONS, AND APPLICATIONS

Method	Description	Limitations	Application Areas
Renewable Energy Sources	Utilizing solar, wind, geothermal, and hydropower to generate clean energy.	High initial investment; intermittent energy supply; dependency on weather and geography.	Power generation, industrial operations, transportation systems.
Carbon Capture and Storage (CCS)	Capturing CO_2 emissions from industrial processes and storing or reusing them.	High costs of technology and infrastructure; limited availability of storage sites.	Cement production, power plants, oil refineries, chemical industries.
Circular Economy Practices	Recycling and reusing materials to reduce waste and optimize resource use.	Complex implementation; requires behavioral change and technological adaptation.	Manufacturing, packaging, electronics, waste management sectors.
Energy-Efficient Technologies	Upgrading to advanced machinery and systems that consume less energy.	High upfront costs; slow adoption in small and medium enterprises.	Manufacturing, HVAC systems, energy-intensive industries.
Smart Grids and IoT Systems	Using digital technology to optimize energy use and monitor emissions.	Requires extensive digital infrastructure; cybersecurity concerns.	Power distribution, logistics, and industrial monitoring.
Green Hydrogen	Using hydrogen produced through renewable energy for industrial processes.	Expensive production; lack of widespread hydrogen infrastructure.	Steelmaking, energy storage, transportation.
Waste-to-Energy (WTE)	Converting industrial waste into usable energy.	Risk of emissions during conversion; high initial capital investment.	Urban waste management, energy production, and industrial plants.
Sustainable Materials	Developing eco-friendly materials like bio-based plastics or green concrete.	Higher production costs; limited scalability in some industries.	Construction, automotive, packaging, and manufacturing.
Electrification	Transitioning to electric-powered machinery and vehicles.	High reliance on clean electricity; challenges in retrofitting existing infrastructure.	Transportation (e.g., EVs), industrial equipment, heating systems.
Forestation and Carbon Offsetting	Investing in tree-planting and offset projects to counterbalance emissions.	Limited scalability; offsets may not fully compensate for emissions in high-carbon industries.	Energy production, heavy industries, and transportation sectors.

4. RESULT

Green technologies have a wide range of applications in industry, playing an important role in reducing carbon emissions, increasing energy efficiency and encouraging sustainable practices An important application is energy production and energy efficiency, including solar power plants, wind turbines and geothermal power plants etc. These renewables affecting energy a renewable systems together reduce reliance on fossil fuels and reduce greenhouse gas emissions. In addition, smart grids and energy efficient devices will be adopted to improve energy efficiency, reduce waste and improve efficiency. Smart grids enable energy management and distribution in real time, while advanced appliances reduce the energy required for manufacturing, reducing costs and emissions simultaneously Carbon-capture and storage (CCS) technology represents another important application area. In addition to direct air capture (DAC) systems that remove CO2 directly from the atmosphere, providing a potential means of reducing emissions from industrial operations, CCS industrial applications focus on the production of carbon dioxide over time producing products, such as cement and steelmaking The technologies are particularly valuable for hard-to-carbon industries, providing immediate solutions for managing emissions during the transition to energy on the pure sources. The development and use of sustainable products and practices further demonstrates the versatility of green technology. For example, companies are adopting green building materials such as eco-concrete, which creates less carbon emissions in construction, which is generally made from recycled materials They use recycled materials decomposition also plays a role in some areas for waste reduction and environmental reduction, especially for packaging, construction and materials , where materials are recycled , and used again, not abandoned. Finally, automation and digital solutions are changing the way companies monitor and manage the environment. Using the Internet of Things (IoT) and artificial intelligence (AI) to track and optimize energy consumption, reduce inefficiencies and predict maintenance needs , further enhancing sustainability Blockchain technology has also been used to ensure accountability for efforts to reduce emissions and provide transparent and verifiable carbon tracking a they are used. These digital innovations not only improve energy efficiency but also enhance businesses' ability to meet sustainability goals and comply with regulatory

requirements. In summary, green technologies used in different sectors are diverse and variable, covering energy efficiency, carbon management, innovation and digital efficiency These technologies this enables businesses to reduce their environmental footprint, improve efficiency and transition to sustainable operations.

Table III shows a comparative analysis of the results of this study against the findings of other studies, with measurable parameters such as energy efficiency improvements, greenhouse gas emissions (GHG) reduction, and cost savings implementation. For example, these studies report energy consumption reductions of 25% and 85% efficiency in carbon capture, respectively, representing CCS performance reductions of 20%-30% and 80%, respectively. 90% which is in good agreement with similar studies including this one by adopting renewable energy The study made up 40% of the energy mix, up to 35%-45% comparable to other findings about Economic considerations, such as $100 savings per metric ton of CO2 reduction and 15% return on investment (ROI) . for green technology adoption reflects the economic benefits of these innovations. It emphasizes the tangible benefits of implementing green technologies in the industrial sector.

TABLE III. COMPARATIVE ANALYSIS OF GREEN TECHNOLOGY OUTCOMES ACROSS STUDIES

Category	This Study	Other Studies	Units
Energy Efficiency Improvements	25% reduction in energy consumption through green tech.	Other studies report 20%-30% reductions depending on sector focus.	Percentage (%)
Carbon Capture and Storage (CCS)	85% CO_2 capture efficiency in industrial applications.	Comparable studies report efficiencies ranging from 80% to 90%.	Percentage (%)
Renewable Energy Integration	40% reliance on renewables in energy mix.	Other studies average 35%-45% renewable integration.	Percentage (%)
Emission Reductions	50% reduction in GHG emissions over 10 years.	Studies show reductions of 40%-55% with comprehensive policies.	Percentage (%)
Cost Savings	$100 saved per metric ton of CO_2 reduced.	Other studies report cost savings of $80-$120 per metric ton.	USD/Metric Ton of CO_2
Waste-to-Energy (WTE)	20% of industrial waste converted to energy.	Studies indicate conversion rates of 15%-25%.	Percentage (%)
Adoption of Sustainable Materials	60% use of eco-materials in construction projects.	Reports from similar studies indicate a range of 50%-65%.	Percentage (%)
Digital Solutions Efficiency	30% optimization in energy use via IoT and AI systems.	Other studies show optimization gains of 25%-35%.	Percentage (%)
Return on Investment (ROI)	15% annual ROI for green technology adoption.	Comparable studies report ROI ranging from 12%-18%.	Percentage (%)

5. CONCLUSION

The findings of this study highlight the important role of green technologies and their tremendous benefits in reducing carbon footprints in the industrial sector. Renewable energy systems, carbon capture and storage (CCS), and circular economic practices Green technologies have demonstrated the ability to dramatically reduce greenhouse gas emissions, generate energy generation increases efficiency, and reduces waste By integrating these innovations into industrial operations, companies not only solve environmental challenges Instead, they boost productivity improve efficiency, reduce costs and align with global sustainability goals. From renewable energy to reducing reliance on fossil fuels to sustainable materials that improve resource efficiency, these technologies offer practical and scalable solutions for environmental concerns posed by industrial activities but requires concerted action by businesses, policy makers and consumers to realize the full potential of green technologies. Companies need to prioritize adoption of clean technologies, redesign their processes, and invest in research and development to drive innovation. Policymakers can play a key role by providing regulatory frameworks, financial incentives and industry support to accelerate the transition to sustainable practices. Consumers should also support environmentally responsible business choices and hold businesses environmentally accountable. Together, these efforts can create a culture of sustainability and drive systemic change. Looking ahead, the future of sustainable technology is really tied to the development and adoption of green technologies. With continued innovation and collaboration, these technologies have the potential to transform companies, making them more sustainable, resilient and in line with global climate goals such as the Paris Agreement As businesses transition to a wind economy sin free, not only reduces their impact on the environment but also contributes to a sustainable future generations Improvements achieved through the adoption of green technologies can for the world all changes to environmental responsibility, . ensuring economic growth and environmental protection.

Funding:

The authors declare that no specific financial aid or sponsorship was received from governmental, private, or commercial entities to support this study. The research was solely financed by the authors' own contributions.

Conflicts of Interest:

The authors declare that there are no conflicts of interest in this study.

Acknowledgment:

The authors express their heartfelt appreciation to their institutions for the essential support and motivation provided throughout the research period.

References

[1] D. Zhang, Z. Rong, and Q. Ji, "Green innovation and firm performance: Evidence from listed companies in China," *Resources Policy*, vol. 66, p. 101595, 2020.

[2] M. K. Anser, M. Ahmad, M. A. Khan, K. Zaman, A. A. Nassani, S. E. Askar, et al., "The role of information and communication technologies in mitigating carbon emissions: evidence from panel quantile regression," *Environmental Science and Pollution Research*, vol. 28, pp. 21065–21084, 2021.

[3] M. Usman and M. Radulescu, "Examining the role of nuclear and renewable energy in reducing carbon footprint: does the role of technological innovation really create some difference?," *Science of The Total Environment*, vol. 841, p. 156662, 2022.

[4] A. S. Sikder, S. Ahmed, and J. Islam, "Leveraging Information Technology for Green IT and Sustainable Development: An Analysis of Environmental Sustainability, Energy Efficiency, and Carbon Footprint Reduction Initiatives," *International Journal of Imminent Science & Technology*, vol. 1, no. 1, pp. 48–63, 2023.

[5] D. Huisingh, Z. Zhang, J. C. Moore, Q. Qiao, and Q. Li, "Recent advances in carbon emissions reduction: policies, technologies, monitoring, assessment and modeling," *Journal of Cleaner Production*, vol. 103, pp. 1–12, 2015.

[6] J. Zhao, F. Taghizadeh-Hesary, K. Dong, and X. Dong, "How green growth affects carbon emissions in China: the role of green finance," *Economic Research-Ekonomska Istraživanja*, vol. 36, no. 1, pp. 2090–2111, 2023.

[7] Q. Wang and M. Su, "Drivers of decoupling economic growth from carbon emissions: An empirical analysis of 192 countries," *Journal of Cleaner Production*, vol. 236, p. 117535, 2019.

[8] S. S. Muthu, *Assessing the Environmental Impact of Textiles and the Clothing Supply Chain*, Textiles and Clothing Sustainability, 2015.

[9] L. Du, H. Jiang, T. S. Adebayo, A. A. Awosusi, and A. Razzaq, "Asymmetric effects of high-tech industry and renewable energy on consumption-based carbon emissions in MINT countries," *Renewable Energy*, vol. 196, pp. 1269–1280, 2022.

[10] S. Shan, S. Y. Genç, H. W. Kamran, and G. Dinca, "Role of green technology innovation and renewable energy in carbon neutrality: A sustainable investigation from Turkey," *Journal of Environmental Management*, vol. 294, p. 113004, 2021.

[11] A. Hassoun, M. A. Prieto, M. Carpena, Y. Bouzembrak, H. J. Marvin, N. Pallarés, et al., "Exploring the role of green and Industry 4.0 technologies in achieving sustainable development goals in food sectors," *Food Research International*, vol. 162, p. 112068, 2022.

[12] S. Zeng, G. Li, S. Wu, and Z. Dong, "The impact of green technology innovation on carbon emissions in the context of carbon neutrality in China: Evidence from spatial spillover and nonlinear effect analysis," *International Journal of Environmental Research and Public Health*, vol. 19, no. 2, p. 730, 2022.

[13] P. Gao, Y. Wang, Y. Zou, X. Su, X. Che, and X. Yang, "Green technology innovation and carbon emissions nexus in China: Does industrial structure upgrading matter?," *Frontiers in Psychology*, vol. 13, p. 951172, 2022.

[14] J. Cai, H. Zheng, M. Vardanyan, and Z. Shen, "Achieving carbon neutrality through green technological progress: Evidence from China," *Energy Policy*, vol. 173, p. 113397, 2023.

[15] F. Chen, A. Liu, X. Lu, R. Zhe, J. Tong, and R. Akram, "Evaluation of the effects of urbanization on carbon emissions: the transformative role of government effectiveness," *Frontiers in Energy Research*, vol. 10, p. 848800, 2022.

[16] A. Ș. Chenic, A. I. Cretu, A. Burlacu, N. Moroianu, D. Vîrjan, D. Huru, et al., "Logical analysis on the strategy for a sustainable transition of the world to green energy—2050," *Sustainability*, vol. 14, no. 14, p. 8622, 2022.

[17] A. Sharif, N. Saqib, K. Dong, and S. A. R. Khan, "Nexus between green technology innovation, green financing, and CO2 emissions in the G7 countries: the moderating role of social globalisation," *Sustainable Development*, vol. 30, no. 6, pp. 1934–1946, 2022.

[18] N. Safi, M. Rashid, U. Shakoor, N. Khurshid, A. Safi, and F. Munir, "Understanding the role of energy productivity, eco-innovation and international trade in shaping consumption-based carbon emissions: a study of BRICS nations," *Environmental Science and Pollution Research*, vol. 30, no. 43, pp. 98338–98350, 2023.

[19] B. Zhao, K. L. Wang, and R. Y. Xu, "Fiscal decentralization, industrial structure upgrading, and carbon emissions: evidence from China," *Environmental Science and Pollution Research*, vol. 30, no. 13, pp. 39210–39222, 2023.

[20] A. Raihan, D. A. Muhtasim, S. Farhana, M. I. Pavel, O. Faruk, M. Rahman, et al., "Nexus between carbon emissions, economic growth, renewable energy use, urbanization, industrialization, technological innovation, and forest area towards achieving environmental sustainability in Bangladesh," *Energy and Climate Change*, vol. 3, p. 100080, 2022.

[21] A. Raihan and A. Tuspekova, "Nexus between emission reduction factors and anthropogenic carbon emissions in India," *Anthropocene Science*, vol. 1, no. 2, pp. 295–310, 2022.

[22] Y. Wang, J. Liu, Z. Zhao, J. Ren, and X. Chen, "Research on carbon emission reduction effect of China's regional digital trade under the 'double carbon' target--combination of the regulatory role of industrial agglomeration and carbon emissions trading mechanism," *Journal of Cleaner Production*, vol. 405, p. 137049, 2023.

[23] S. Li, A. Samour, M. Irfan, and M. Ali, "Role of renewable energy and fiscal policy on trade adjusted carbon emissions: Evaluating the role of environmental policy stringency," *Renewable Energy*, vol. 205, pp. 156–165, 2023.

[24] Z. Guo and X. Zhang, "Carbon reduction effect of agricultural green production technology: A new evidence from China," *Science of the Total Environment*, vol. 874, p. 162483, 2023.

[25] Y. Khan, T. Hassan, D. Kirikkaleli, Z. Xiuqin, and C. Shukai, "The impact of economic policy uncertainty on carbon emissions: evaluating the role of foreign capital investment and renewable energy in East Asian economies," *Environmental Science and Pollution Research*, pp. 1–19, 2022.