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THE ROLE OF DIGITAL AND SCIENTIFIC TECHNOLOGY IN COMPLIMENTING GLOBAL LEGAL FRAMEWORK TOWARDS CLEAN ENERGY TRANSITION

Paul Atagamen Aidonojie*, Oluwaseye Oluwayomi Ikubanni**, Adesoji Kolawole Adebayo***, Olusola Joshua Olujobi**** and Mundu M. Mustafa

ABSTRACT

The global environment is endowed with several natural resources including energy sources such as biomass, hydro, and the potential for gas and oil production. However, the exploration of these energy sources is considered essential for economic development and growth global. However, harnessing and utilizing some of these energy sources such as biomass fuel products and fossil fuels are regarded as unfriendly to climate earth. This is concerning the fact that recent climate change and global warming are deemed to be associated with toxic chemical waste as a result of the exploration activities from harmful energy sources which often reduce the environment to a deplorable and vulnerable state. Hence, there is need for incorporating technology and scientific discoveries such as the metaverse concept, nanotechnology and biotechnology, towards clean energy transition. The study adopts a doctrinal method of study, the data obtained from primary and secondary sources were analysed through analytical and descriptive methods. The study found that, although fossil fuel, traditional biomass, thermal power, and nuclear power are essential for economic development and growth. However, they are considered a greater threat given their unfriendly nature to climate earth. Although there are global laws and agreements (such as Kyoto Protocol, United Nations Framework Convention on Climate Change) concerning curtailing the use of harmful energy sources, there seems to be a high demand for these energy sources, thereby leading to severe climate change. The study further reveals that current technological and scientific discoveries such as metaverse concept, nanotechnology and biotechnology could aid in clean energy transition. The study therefore concludes and recommends that, given the harmful nature of conservative energy sources to climate earth, there is a need for a global shift toward promoting sustainable technology and scientific discoveries such as metaverse concept, nanotechnology and biotechnology toward a cleaner energy transition

Keywords: Climate change, Climate earth, Economic development, Energy transition, Global warming.

1. INTRODUCTION

The energy sector is a critical and integral aspect of the global economy considering that it is responsible for the provision of energies that powers the activities of various industries, transportation[1], major infrastructures, and so on[2]. The vast majority of the fuel consumption across the globe is derived from traditional fossil fuels such as crude oil, natural gas, and coal.[3] To this end, there have been concerns that the global reliance on these conventional sources of energy would occasion the exhaustion of these fossil fuels due to increasing rates of exploitation and a decline in the replenishment rates[4]. Furthermore, the exhaustion of fossil fuels due to excessive demand and the ongoing war between Russia and Ukraine indicates the chances for high energy demand globally.[5]

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1 Dominik Franjo Dominkovic and others, 'The Future of Transportation in Sustainable Energy Systems: Opportunities and Barriers in a Clean Energy Transition' (2018) 82(2) Renewable and Sustainable Energy Reviews 1823-1838.

2 Ekrem Alagoz and Yaser Alghawi, 'The Energy Transition: Navigating the Shift Towards Renewables in Oil and Gas Industry' (2023) 12(2) Journal of Energy and Natural Resources 21-24, 21.

3 Naeem AbassRaza A. Kalair, and Nasrullah Khan, 'Review of Fossil Fuels and Future Energy Technologies' (2015) 69 Futures 31-39.

4 Paul Atagamen Aidonojie and others, 'The Legal Challenges and Effect Concerning the Environmental Security in Nigeria: A Lesson from International Perspective' (2022) 9(1) Journal of Commercial and Property Law 110-120.

5 Amira Nemmour, Abrar Inayat and others, 'Green Hydrogen-based E-Fuels (E-methane, E-methanol, E-ammonia) to Support Clean Energy Transition: A Literature Review' (2023) 48(75) International Journal of Hydrogen Energy 29011-29033.

The over-reliance of countries across the globe on liquid fossil fuels has been a major threat to sustainable energy globally. For instance, in the area of transportation, the vehicles that dominate various countries are mostly internal combustion engine vehicles (ICEVs) that emit carbon dioxide (CO_2) that threaten sustainable energy and provoke climate change[6]. The most fundamental problem of these conventional sources of energy is the greenhouse gas emissions that lead to the destruction of the environment and necessitate climate change which today remains a major driver of the call for a transition to clean and sustainable energy.[7] It is observable that industries across the globe including the transportation sector and major enterprises are assiduously concerned about the need to reduce greenhouse gas emissions to "net zero"[8]. That is, to ensure a decrease in greenhouse gas emissions and its negative impact on society.

The acceleration in the global reliance on fossil fuels, its adverse effect on climate due to the upsurge in greenhouse gas emissions, and the necessity to enhance the sustainability of the environment buttress the urgent need for a transition to clean energy[9]. This accounts for the adoption of technologies to transition to clean energy including electric vehicles (EVs), photovoltaic panels (used for producing electricity through sunlight), and wind turbines.[10] Energy transition remains highly fundamental to the reduction of the hazardous environmental impact of fossil fuel usage[11]. There are concerns

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6 Martino Tran and others, 'Realizing the Electric-Vehicle Revolution' (2022) 2(5) Nature Climate Change 328-333, 328.

7 Rose S Dimitrov, 'The Paris Agreement on Climate Change: Behind Closed Doors' (2016) 16(3) Global Environmental Politics, 1-1; Oluwaseye Oluwayomi Ikubanni and others, 'Protecting the One Earth: An Examination of the Legal and Institutional Frameworks on Environmental Protection in Nigeria' (2023) 14(1) Nnamdi Azikiwe University Journal of International Law and Jurisprudence 137-147.

8 Patrick Plotz, 'Unlikely to Play a Major Role in Sustainable Road Transport' (2022) 5 Nature Electronics 8-10.

9 Alex O Acheampong and others, 'The Political Economy of Energy Transition: The Role of Globalisation and Governance in the Adoption of Clean Cooking Fuels and Technologies' (2023) 186 (b) Technological Forecasting and Social Change 45. https://doi.org/10.1016/j.techfore.2022.122156

10 International Energy Agency, "Net Zero by 2050-Road Map for Global Energy Sector" (2021). Available at <https://www.iea.org/reports/net-zero-by-2050> Accessed 21st May 2024.

11 Sandro Nizetic and others, 'Smart and Sustainable Technologies in Energy Transition' (2023) 389 Journal of Cleaner Production https://doi.org/10.1016/j.jclepro.2023.135944

that technology is integral to the shift from conventional fossil fuels usage which impacts negatively on the sustainability of the environment to clean energy[12] through the adoption of alternative means of fuel such as hydrogen, electricity, and biofuels[13]. Globally, there is an upsurge in acceleration in the transition to a clean energy system.[14]

This study examines the relevance of scientific and digital technology towards te transition from fossil fuel usage to clean energy considering the accelerating damage of carbon dioxide (CO_2) and greenhouse gas emissions to the environment.[15] Furthermore, the study will analyse both international and regional laws to assess how effectively the current legal framework accommodates or restricts the transition to clean energy. Understanding these legal mechanisms is integral to identifying the legal challenges and restrictions to the effective realization of a clean energy transition.

2. METHODOLOGY

The study focuses on the role of digital and scientific technology in complementing the global legal framework towards clean energy transition. Concerning this the study adopts a doctrinal method, in this regard, primary sources of research material such as global international laws, policies, and agreements concerning clean energy transition were relied on. Furthermore, the study also places reliance on secondary sources of material such as journal articles by learned authors, monographs, online articles, textbooks, and other relevant researchable material. Concerning this, the data obtained from the primary and secondary sources were analyzed through a descriptive and analytical approach.

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[12] Bo Wang and others, 'How Does Artificial Intelligence Affect High-Quality Energy Development' (2024) 186 Energy Policy 1-12, 2.

[13] Noel Melton and others, 'Moving Beyond Alternative Fuel Hype to Decarbonise Transportation' (2016) 1(3) Nature Energy 1-10.

[14] Dazok Donald Jambol and others, 'Transforming Equipment Management in Oil and Gas with AI-Driven Predictive Maintenance' (2024) 5(5) Computer Science & IT Research Journal, 1090-1112; Dazok Donald Jambol and others, 'Enhancing Oil and Gas Production through Advanced Instrumentation and Control Systems' (2024) 19(3) GSC Advanced Research and Reviews 043-056.

[15] Adeola Ona-Olapo Esho and others, 'Electrical Propulsion Systems For Satellites: A Review Of Current Technologies And Future Prospects' (2024) 6(2) International Journal of Frontiers in Engineering and Technology Research 035–044.

The essence of adopting a doctrinal method of study is aimed at conceptualizing and examining existing global laws in ascertaining how these laws and agreements have over time provided for the regulation and enforcement of clean energy transition. Furthermore, it is also aimed at conceptualizing the various digital and scientific technologies concerning how they enhance clean energy transition in mitigating climate change and global warming.

3. CONCEPTUAL ISSUES CONCERNING HARMFUL ENERGY SOURCES AND CLEAN ENERGY TRANSITION

The world is gradually becoming a global village with technological development and scientific innovation which requires the generation of energy to meet the essential needs of humans such as; health, lighting, communication, mobility, cooking, and other industrial activities. Fossil fuel being the traditional source of energy has led to a lot of environmental, health, and economic challenges. Fossil fuels such as coal, oil, and gas appear as the major source of energy generation especially in developing countries because it is economical. Nevertheless, it has led to a lot of issues such as; high fossil fuel subsidies, high emission of carbon, and an increase in energy demand.[16]

The need for welfare development, technological innovations, and expansion of the economy, with a steady increase in population has increased energy consumption thereby causing high dependence on fossil fuel. The over-reliance on these harmful energy sources has caused a lot of negative effects and conceptual issues against humanity such as greenhouse gas emissions which are gradually depleting the ozone layer with negative implications on agriculture, forestry, fishing, and other resources needed for human survival.[17] However, without these essential resources, potential risks loom on human existence. Thus, it becomes imperative to shift to clean energy

[16] Clara Caiafa, and others, 'International Technology Innovation to Accelerate Energy Transitions: The Case of the International Energy Agency Technology Collaboration Programmes' (2023) Environmental Innovation and Societal Transitions 48 1-19.

[17] Darkwah Williams Kweku and others, 'Greenhouse Effect: Greenhouse Gases and Their Impact on Global Warming' (2017) Journal of Scientific Research & Reports 17 (6): 1-9.

transition such as solar, wind, biomass, and hydro which are renewable with lesser harmful effects on humanity and the environment. Hence, the contemporary issues generated by harmful energy sources are not limited to the following.

Environmental sustainability is one of the concerning issues that require urgent attention when addressing harmful sources of energy. The combustion of fossil fuel has led to a lot of negative impacts such as environmental degradation, over-exploitation of resources like land, and water, deforestation, and air pollution which kills millions of people every year.[18] Over-dependence on natural resources has led to various types of pollution which are hazardous to both humans and animals and failure to avoid this will continually affect the sustainability of mankind. The exploitation of harmful energy is one of the major causes of the emission of powerful green gas which is over 300 times more effective than carbon dioxide. Many of the coal miners are vulnerable to black lung diseases due to exposure to silica and other chemical substances dangerous to their health.[19]

One of the factors that determine human livelihoods is agriculture however, the emission of these natural gases has affected the sustainability of food production globally.[20] Over-dependence on fossil fuel has caused an increase in the cost of extraction and production of fossil fuel which has resulted in environmental damage and economic loss. Thus, there is a need to reduce reliance on fossil fuels to avoid scarcity, deforestation, loss of biodiversity, the collapse of the ecosystem depletion of the ozone layer to promote environmental sustainability. High levels of industrialization in developed nations such as China, the United States, and India are part of the threat to environmental sustainability under the concept of harmful energy. For instance, In 2021 in the sixth report assessment of the Intergovernmental Panel on Climate Change (IPCC) they stated that China contributes 28.1 %, the United States contributes 15.5% and India contributes 7.2% of CO_2 into

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[18] R Max, 'Data review: how many people die from air pollution?' (2021) WorldInData.Org. <https://ourworldindata.org/data-review-air-pollution-deaths'> Accessed on 20 July 2024.

[19] Jiannan Wang and Waseem Azam, 'Natural resource scarcity, fossil fuel energy consumption, and total greenhouse gas emissions in top emitting countries' (2024) Geoscience Frontiers 15 1.

[20] William Adzawla and others, 'Greenhouse Gasses Emission and Economic Growth Nexus of Sub-Saharan Africa' (2019) Scientific African 3 1-9.

the atmosphere respectively[21]. This is due to the rapid economic growth and over-dependency on fossil fuels to meet the needs of these looming populations.[22]

Furthermore, it suffices to state that, recently, an increase in demand for energy has brought a lot of global issues. The record of the first mining of coal can be traced to Richmond Virginia in the year 1,750 and since then many nations have relied heavily on the use of fossil fuel as their source of energy.[23] Incidentally, coal has been the major source of generating energy, especially in rural areas. Record has it that more than 1.4 billion people do not have access to electricity while 85% of them live in rural areas and depend on coal as their source of energy.[24] This figure was projected to reach 2.7 billion by the year 2030. Inaccessibility to electricity has pushed many people in rural areas to place much reliance on the traditional use of biomass such as firewood and charcoal as their sources of energy because it is relatively cheaper and easier to get.

The harmful energy sources such as coal, gas, and oil have affected the source of livelihood of many, destroyed the ecosystem as a result of exploitation, and at the same time threatened the resilience power of the climate. Burning of fuel is perceived to be the main source of air pollution, greenhouse gasses, and global warming. For instance, it was recorded in 2017 that global carbon emission increased to 1.4% reaching 32.5Gt which was the highest ever recorded in history at that time due to an increase in the population and continual reliance on fossil fuel for energy generation.[25] In addition, overreliance on fossil fuels can make subsidy to be burdensome. For instance,

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21 IPCC (2021) 'Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change', Cambridge University Press. Available at: <https://www.ipcc. ch/report/ar6/wg1/> (Accessed: 23 August 2024).

22 Wang and Azam (n4) 4.

23 Phebe Asantewaa Owusu and Samuel Asumadu-Sarkodie, 'A Review of Renewable Energy Sources, Sustainability Issues and Climate Change Mitigation', (2016) Cogent Engineering, 31.

24 World Bank Group Press Release Report on Universal Access to Sustainable Energy Will Remain Elusive Without Addressing Inequalities, 2021 <https://www. worldbank.org/en/news/press-release/2021/06/07/report-universal-access-to-sustainable-energy-will-remain-elusive-without-addressing-inequalities>accessed> on 20 July, 2024.

25 Lv Yongjun, 'Transitioning to Sustainable Energy: Opportunities, Challenges, and the Potential of Blockchain Technology' [2023] Front. Energy Res. 1-20.

in the year 2016, it was estimated by the International Energy Agency (IEA) that over US $ 260 billion was used for global fossil fuel consumption subsidies.[26]

In addition, in 2023, the Nigerian government paid a sum of 3.6 trillion naira as a subsidy for fossil fuel and projected that it will reach 5.4 trillion naira by the end of 2024. This has been affecting the economic power of the country and it was for this reason that the Nigerian government removed fuel subsidies to prevent over-reliance on harmful energy sources. Despite the huge amount paid on fossil fuel subsidies, the majority of the masses do not benefit from them for instance, the International Monetary Fund reported that out of the subsidies paid in Sudan in the year 2014, only 3% went to the poor while above 50% went to the rich.[27] In 2015, a study revealed that the post-tax subsidies in Egypt, Mexico, and Indonesia on fossil fuel went from US $ 4.9 trillion to US $ 5.3 trillion.[28] This could be far more in countries like the USA, Russia, China, the European Union, and India which are considered the top five subsidizers globally.[29] Whereas, this huge amount of money could have been diverted to other needs of the countries such as health care, defence, education, agriculture, and other investment.

It must also be noted that the process of generating energy from fossil fuel requires burning which in turn produces large amounts of carbon dioxide, a greenhouse gas which is being released into the air thereby causing global warming.[30] For instance, the Middle East and North Africa region witnessed more than 65% increase in C_{O2} emissions from the year 2010 to 2020 due to harmful energy sources such as fossil fuel and other related dirty energy generation[31].Climate change can aggravate erosion and decline in organic matter, destruction of biodiversity, desertification, flooding, and high concentrations of Co_2 emission. The burning of fossil fuels releases a lot of

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26 ibid

27 Tarek Safwat Kabel and Mohga Bassim, 'Reasons for Shifting and Barriers to Renewable Energy: A Literature Review', (2020) 10 (2) International Journal of Energy Economics and Policy 89-94.

28 ibid

29 Xiang Wang and others 'Hydroxymethylation of unsaturated hydrocarbons with CO_2: An overview' (2021) 50 Journal of CO2 Utilizatio, 56.

30 ibid

31 IEA (2022) 'Global Energy Review 2022', International Energy Agency. Available at: <https://www.iea.org/reports/global-energy-review-2022> (Accessed: 23 August 2024)

Co_2 emission which traps the sun's heat in the form of a blanket thereby leading to global warming and climate change.[32]

Industrialized countries such as China and India have been alleged to generate more greenhouse gas than other developed nations.[33] The need to prevent the negative effects of climate change is mandatory since it has become a global issue because the future of human existence would be at risk if there is no shift from fossil fuel to renewable energy. A shift in climate change due to dirty energy generation can jeopardize the production of food which can cause an unexpected negative impact on the survival of mankind. The concern issues surrounding climate change arising from dirty energy sources propelled the Paris Agreement, a concerted international effort aimed at a particular objective to limit the rise of global temperatures below 1.5 degrees Celsius above pre-industrial level.[34] The need to avoid the effect of climate change necessitated the introduction of clean energy which at present contributes to about 15% of global energy Bioenergy has 10%, hydropower generates 3%, and solar 2% respectively with the target of generating 90% of global energy consumed through renewable and clean energy by 2050 to drastically reduce Co_2 emission against mankind.[35]

Concerning the above, it suffices to state that the consumption of energy is increasing daily due to rapid growth in population and industrialization, hence it becomes imperative to source alternative means of energy such as renewable and clean energy.[36] Continuous reliance on fossil fuels will increase the hazardous level of poisonous gas emissions which is inimical to health. Coal generates the largest percentage of electricity globally with about 36% but it can lead to the death of an average of 25 people in a year because it produces 970 tonnes of greenhouse gas emissions. Oil produces about 3% of global electricity with an average death of 18 people in a year as it produces 720 tonnes of greenhouse gas emissions. Natural Gas produces 22% of global

[32] Santosh Kumar and others, 'Utilization of Zeolites as CO_2 Capturing Agents: Advances and Future Perspectives' (2020) 41 Journal of CO2 Utilization 62.

[33] Ziheng Jiao and others, 'Comparing Decoupling and Driving Forces of CO_2 Emissions in China and India' (2022) 10 Front. Environ. Sci, 23-46.

[34] Clara Caiafa, and others, 'International technology innovation to accelerate energy transitions: The case of the international energy agency technology collaboration programmes' (2023) Environmental Innovation and Societal Transitions 48 1-19.

[35] Elisa Papadis and George Tsatsaronis, 'Challenges In The Decarbonization of the Energy Sector, (2020) 205 Energy 1-15

[36] Dolf Gielen and others, 'The Role of Renewable Energy in the Global Energy Transformation', (2019) Energy Strategy Reviews 38-50

electricity with an average death of 3 people in a year as it produces 440 tonnes of green gas emissions. Biomass produces 2% of global electricity with an average death of 5 people in a year as it produces 78-230 tonnes of greenhouse gas emissions.[37] Nuclear energy produces 10% of global electricity with an average death rate of 0.03 per terawatt-hour which means that every 33 years, a single person would die as it produces 6 tonnes of greenhouse gas emissions. Solar produces 4% of global electricity with an average death rate of 0.02 per terawatt-hour which means that every 50 years, a single person would die as it produces an average of 53 to 83 tonnes depending on technology and location of green gas emissions.[38]

Global energy consumption has been predicted to rise by 28% from 2015-2030 with an estimated increase from 575 quadrillion British thermal units (Btu) in 2015 to 663 quadrillion Btu by 2030 and reaching 736 quadrillion Btu by 2040 due to rapid population and fast economic growth.[39] In developing countries, it is anticipated that energy consumption would increase by 90% in 2040 and China is predicted to consume twice the energy as that of the United States because of technological advancement.[40] It becomes imperative that if the same level of energy is generated from fossil fuel it will not be enough for consumption and at the same time when more energy is generated it will lead to more harmful effects and scarcity in a few years to come. For instance, it was reported that Egypt had an issue in generating electricity from coal due to scarcity and placed more reliance on oil and natural gas which make up its 95% of total energy generated in Egypt.[41] Thus, there is a need for clean and renewable energy transition through technology innovation and scientific discovery, to increase energy generation for distribution and consumption in years to come.

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[37] Hannah Ritchie 'What are the safest and cleanest sources of energy?' <https://ourworldindata.org/safest-sources-of-energy>accessed> on 22 July 2024.

[38] ibid.

[39] Lv Yongjun, 'Transitioning to Sustainable Energy: Opportunities, Challenges, and the Potential of Blockchain Technology' [2023] Front. Energy Res. 1-20.

[40] ibid

[41] Doaa Akl Ahmed and Amira Akl Ahme, 'The Impact of Energy Prices on Electricity Production in Egypt', (2019), 9 (5), International Journal of Energy Economics and Policy, 194-206.

4. GLOBAL LEGAL FRAMEWORK ON CLEAN ENERGY TRANSITION FOR ENVIRONMENTAL SUSTAINABILITY

Legislation encourages and promotes the transition from fossil fuels to clean energy.[42] Much legislation that focuses on climate change centres around the reduction of greenhouse gas emissions and the sustainability of the environment within a projected and specified timeframe.[43]

In international fora, several conventions or treaties are put in place as measures to regulate human activities that may have adverse environmental effects. These treaties emphasises the collective necessity of countries to respond to climate change and to facilitate the sustainability of the environment. In International law, there is no specific law that regulates clean energy or clean energy transition. However, these treaties are recognised internationally as the foundation for the discussions and agitations for clean energy and clean energy transition in combating the danger of human activity on the environment and climate change. These treaties are briefly examined thus:

i. The United Nations Framework Convention on Climate Change (UNFCCC)

The rise in global warming in the twentieth century due to the increase in greenhouse gas emission concentrations caused by human activities became of scientific concern around the mid-1980s that the ongoing global warming was more artificial than natural and in effect endangers the human race. The United Nations considered the necessity for the establishment of the Intergovernmental Negotiating Committee (INC) in 1990 to negotiate a convention that would legally respond to the rapid rise in the temperature and greenhouse emissions that were impacting human health[44]. Consequently, the United Nations Framework Convention on Climate

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[42] Guptar Mutezo and Jonnes Mulopo, 'A Review of Africa's Transition from Fossil Fuels to Renewable Energy Using Circular Economy Principles' (2021) Renewable and Sustainable Energy Reviews, 137.

[43] Hans Kros and others, 'Region Oriented and Integrated Approach to Reduce Emissions of Nutrients and Greenhouse Gases from Agriculture in the Netherlands' (2024) 909 Science of the Total Environment 1-14.

[44] Daniel Bodansky, 'The United Nations Framework Convention on Climate Change: The Commentary' (1993) 18(451) Yale Journal of International Law 451-558, 453.

Change (UNFCCC) otherwise referred to as the Convention was signed at the Earth Summit in Rio De Janeiro, Brazil in 1992 and came into force on the 21st of March 1994[45]. The Convention represents the global acknowledgment that the activities of humans are responsible for the increase in the atmospheric concentrations of greenhouse gases and that developed countries produce the largest share of global greenhouse emissions[46]. It remains the bedrock of global reaction to climate change birthing two other international agreements as Kyoto Protocol and the Paris Agreement.[47] The Convention contains 26 Articles but Articles 2, 3, and 4 remain crucial to this research.

Similar to its preamble, while Article 2 of the Convention sets out the objective of the Convention which is the stabilization of the greenhouse gas emission in the atmosphere to maintain such a level that a change in the climate will not threaten human existence, Article 3 set out the principles that parties to the Convention must imbibe to achieve the ultimate objective of the Convention. This principle includes the protection of the Climate system for the present and future generations, the needs of the developing state parties that are vulnerable to the negative impact of climate change must be of utmost importance, parties must take precautionary measures to reduce the causative agents of climate change and ensure that policies and measures that will enhance sustainable development are put in place. Article 3 demonstrates the necessity for state parties to encourage sustainable adaptation to climate

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45 Emma L. Tompkins and Helene Amundsen, 'Perceptions of the Effectiveness of the United Nations Framework Convention on Climate Change in Advancing National Action on Climate Change' (2008) 11(1) Environment Science and Policy 1-13.

46 Preamble to the United Nations Framework Convention on Climate Change. Available at <https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf> Accessed 13th July 2024

47 S Jolly and GD Naik, 'Sega of Indo-US Climate Contestation and Cooperation: A Legal Analysis' in Dhaliwal Shveta (eds) Indo-Us Relations: In The Changing World Order (Routledge India, 2021) 60-80.

change[48] while recognising the fragility and susceptibility of various states especially those developing to climate change.[49]

An in-depth analysis of Articles 2 and 3 of the Convention indicates that the Convention promotes the transition to clean energy. The Convention emphasises that state parties must be committed to putting policies and measures that will reduce the causes of climate change and enhance sustainable development. This research so far has shown that greenhouse gas emissions through the use of fossil fuels are one of the major factors responsible for climate change[50]. The adoption of technology to transition to clean energy is integral to the objectives and principles set out by the Convention. Conversely, the Convention has been considered by many as a disappointment[51] by failing to recognise expressly and incorporate the adoption of technology in combating the challenge of climate change.[52] This inadequacy is a barrier to transitioning to low-carbon energy.[53] This Convention came into force many decades ago when technology was quite nascent, especially in developing countries. Though it implies the use of technology and scientific discovery to achieve the reduction of greenhouse gas emissions, it does not expressly address the adoption of technology to transition to clean energy.[54]

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48 Sifuni Nikombolwe Lusiru, 'The Beneficial Opportunities of Climate Change for Enhanced Socio-Economic Development: a review' (2023) 13(1) International Journal of Environment and Climate Change 75-80. https://doi.org/10.9734/ijecc/2023/v13i11628

49 Shantanu Kumar Patra and others, 'Corporation' Sliability on Illegal Dumping's Impact on Climate Change According to the UFCCC and Its Implementation in Indonesia' (2022) 2(1) Jassp 57-64. https://doi.org/10.23960/jassp.v2i1.46

50 Portia Oduro and others, 'Renewable Energy Expansion: Legal Strategies for Overcoming Regulatory Barriers and Promoting Innovation' (2024) 12(1) World Journal of Advanced Engineering Technology and Sciences 168-186.

51 Raeker K Pachauri, The Climate Change Convention: What It May Mean for the Poor, NETWORK '92 (Centre for Our Common Future, Geneva), 1992, 14.

52 Daniel Badansky (n 19) 454.

53 Oduna V Akagha and others, 'Company Secretarial and Administrative Services in Modern Irish Corporations: A Review of the Strategies and Best Practices Adopted in Company Secretarial and Administrative Services' (2023) 5(10) International Journal of Management & Entrepreneurship Research, 793-813.

54 Chidiogo Uzoamaka Akpuokwe and others, 'Legal Challenges of Artificial Intelligence and Robotics: A Comprehensive Review' (2024) 5(3) Computer Science & IT Research Journal, 544-561.

Conclusively, the UNFCCC with its 198 state parties is an international convention with wide acceptance and participation as a response to climate change[55] and uniting efforts over legal frameworks such as the United Nations Sustainable Development Goals, Sendai Framework for Disaster Risk Reduction, the Paris Agreement, Kyoto Protocol, and so on.[56] While state parties demonstrate the commitment to applying the UNFCCC through the Kyoto Protocol and the Paris Agreement, the lack of legal avenues to enforce the UNFCCC in the case of loss or damage to fragile states because of the rise in climate change remains a major challenge of UNFCCC.[57]

ii. The Paris Agreement

The Paris Agreement is an offshoot of the United Nations Framework Convention on Climate Change (UNFCCC).[58] It was adopted on the 15th of December 2015 but came into force on the 4th of November 2016.[59] It is a collective agreement of the parties to UNFCCC to address climate change through the adoption of appropriate measures to hold the increase of global warming below 2 degrees Celsius and working to achieve 1.5 degrees Celsius above the pre-industrial levels[60] by which each country identified a target for combating greenhouse gas emissions under the Nationally Determined

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55 Bina Desai, 'The Climate Change Conundrum: A Case for Course Correction in the Global Regulatory Approach' (2024) 54(1) Environmental Policy and Law 3-14. https://doi.org/10.3233/epl-239028

56 D Cubie and T Natoli, "Coherence, Alignment, and Integration: Understanding the Legal Relationship Between Sustainable Development, Climate Change Adaptation, and Disaster Risk Reduction" in Stephen Flood, Yairen Jerez Columbie, Martin Le Tissier , and Barry O'Dwyer (eds) 'Creating Resilient Futures: Integrating Disaster Risk Reduction , Sustainable Development Goals and Climate Change Adaptation Agendas' (Palmgrave Mcmillan, 2021) 45-65.

57 Pieter Toussaint, 'Loss and Damage and Climate Litigation: The Case for Greater Interlinkage' (2020) 30(1) Review of European Comparative and International Environmental Law, 16-33. https://doi.org/10.1111/reel.12335

58 D Freestone, 'The United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Kyoto Mechanisms', in David Freestone and Charlotte Streck (eds), Legal Aspects of Implementing the Kyoto Protoco lMechanisms: Making Kyoto Work (Oxford University Press, 2008) 4.

59 Antto Vihma, 'Climate of Consensus: Managing Decision Making in the UN Climate Change Negotiation' (2015) 24 (1) Review of European Community and International Environmental Law 57, 60.

60 Felix Ekardt and others, 'Energy Charter Treaty: Towards a New Interpretation in the Light of Paris Agreement and Human Rights' (2023) 15(6) Sustainability 5006. https://doi.org/10.3390/su15065006

Contribution (NDC) climate policy.[61] Furthermore, it demonstrates the collective efforts of the countries of the world to contribute their quota at the national level to ensure the reduction of greenhouse gas emissions.[62] The Paris Agreement is a global agreement under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) that demonstrates the collective efforts of the countries of the world to contribute their quota at the national level to ensure the reduction of greenhouse gas emissions.[63] Signed by 195 countries[64], the Paris Agreement is reached to actualize the objectives and principles of the UNFCCC as contained in Article 2 of the Agreement. The provision of Article 1 paragraphs a, b, and c demonstrates the commitment of state parties to not only combat and adapt to the impacts of climate change but also facilitate the reduction of greenhouse gas emissions.

Article 3 requires that all parties to the Agreement undertake ambitious efforts to achieve the goals of the Agreement as stated in Article 3 through their nationally determined contributions. Articles 4, 7, 9, 10, 11, and 13 impose obligations on all state parties, developed and developing to prepare, communicate, and undertake planned actions to combat greenhouse gas emissions with the ridar that developing countries shall receive support to achieve this purpose. One of the major challenges to the Paris Agreement is its enforceability, particularly against state parties that fail to comply with the objective of reduction of greenhouse gas emissions in their country. This has been a subject that has generated concerns over the decades.[65] Though the Paris Agreement creates legal obligations on state parties, it contains no express provision for punitive consequences for non-compliance[66]. This has

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61 Mario Larch and Joschka Wanner, 'The Consequences of Non-participation in the Paris Agreement' (2024) 163 European Economic Review 1-18, 2.

62 Chidiogo Uzoamaka Akpuokwe and others, 'Legislative Responses to Climate Change: A Global Review Policies and the Effectiveness' (2024) 6(3) International Journal of Applied Research in Social Sciences 225-239, 227.

63 Ibid.

64 Florian Humpenoder and others, 'Food matters: Dietary Shifts Increase the Feasibility of 1.5°C Pathways in line with the Paris Agreement' (2024)10(13) Science Advances 1103-1104. https://www.science.org/doi/full/10.1126/sciadv.adj3832

65 Daniel Bodansky, 'The Legal Character of the Paris Agreement' (2016) 2 Review of European Community and International Environmental Law 142, 143.

66 Ngozi Chinwa Ole and Onyekachi Eni, 'Towards the implementation of the Paris Climate Change Agreement 2015: Opportunities and Challenges for the Network

generated debates and unending discussions on the bindingness of the obligations it imposes on state parties and the necessity for carbon budgets for alignment with human rights and environmental imperatives.[67] Hautereau-Boutonne and Stranadko, therefore, argue that to realise the objectives of the treaty in the face of its present enforcement mechanism, there must be progressive analysis and adaptations to ensure its potency for combating climate change[68].

The Paris Agreement may not contain express provisions on the use of scientific and digital means or discoveries to transition to clean energy. However, it remains one of the most vital international instruments promoting the reduction of greenhouse gas emissions and combating climate change. This is concerning the fact that it imposes obligations on state parties to focus on a target at the national level to reduce greenhouse gas emissions. In essence, the Paris Agreement supports any policies and measures that will address the increase in greenhouse gas emissions globally of which recent scientific and digital technology discovery remains one of the global measures for the reduction of greenhouse gas emissions through the transition to clean energy.

iii. Kyoto Protocol

The Kyoto Protocol is the first multilateral international agreement under the auspices of the United Nations to combat the increasing global effect of greenhouse gas emissions and climate change[69]especially the industrialised countries and the ones in transition. It is complementary to the UNFCCC and binding. The Kyoto Protocol, though adopted in December 1997, was

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of Universities Legal Aid Institutions (NULAI) Nigeria' (2020) 27(3) International Journal of Legal Education 146-175, 149.

67 Andreas Geiges and others, 'Incremental Improvements of 2030 Targets Insufficient to Achieve the Paris Agreement Goals' (2023) 11(3) Earth System Dynamics, 697-708. https://doi.org/10.5194/esd-11-697-2020

68 Mathilde Hautereau-Boutonnet, 'Combining Tools and Actors for a Better Enforcement: A Case of the 2015 Paris Agreement on Climate Change' (2024) 53(5-6) Environmental Policy and Law, 415-424. https://doi.org/10.3233/epl-239011.; Nataliya Stranadko, 'Global Climate Governance: Rising Trend of Translateral Cooperation' (2022) 22(4) International Environmental Agreements Politics Law and Economics 639-657. https://doi.org/10.1007/s10784-022-09575-6

69 Rachel Aichele and Gabriel Felbermayr, 'Kyoto and the Carbon Footprint of Nations' (2012) 63(3) Journal of Environmental Economics and Management 336-354; Michael Cary, 'Molecules of Inefficiency: How Tariffs Impact Carbon Intensities, Carbon Dioxide Emissions, and the Environment' (2020) 713 Science of Total Environment 186-187.

entered into force in February 2005.[70] It was a laudable achievement for developing and developed (industrialised) countries to come together to combat the increasing effect of greenhouse gas emissions and climate change globally. To achieve its objectives, the Clean Development Mechanism (CDM) was introduced to enhance the reduction of greenhouse emissions.[71] The Protocol has been lauded by early researchers that it reduced carbon dioxide emissions by 7%-10%.[72]

However, Ziyu Peng argued that the Kyoto Protocol though a beacon of hope for the fight against the rise in greenhouse gas emissions and global climate change, collapsed and failed to achieve its potential for global environmental change thereby becoming ineffective.[73] The failure has been attributed to several reasons including the fact that some major carbon emitters such as the United States of America which is arguably the second largest carbon dioxide emitter refused to ratify while a country such as Canada also withdrew.[74] Furthermore, China and India, though developed and developing countries respectively, are one of the largest emitters of greenhouse gas emissions globally yet non-inclusive in the Kyoto Agreement. It is therefore imperative to state that the limited signatories and lack of punitive measures against violators are chief of the contributing factors to the failure of the Protocol.

Perhaps, the ineffectiveness of the Kyoto Protocol was the drive for a shift to a more flexible and non-binding approach noticeable in the Paris Agreement.[75] Kang et al posit that the Kyoto Protocol was instrumental to the trade dynamism that is evident in the shift in the manufacturing of non-

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70 Rachel Aichele (n 44) 336.

71 Yoomi Kim, 'Technological Innovation, the Kyoto Protocol, and Open Innovation' (2021) 7(3) Journal of Open Innovation Technology Market and Complexity 198.

72 Michael Cary and Heather M. Stephens, 'Economic, Environmental, and Technical Gains from Kyoto Protocol: Evidence from Cement Manufacturing' (2024) 91 Resources Policy 104.

73 Z Peng, 'The collapse of Kyoto Protocol: An analysis based on Game Theory' being a Paper Presented at the International Conference of Development of Digital Economy held at Holiday Inn Tbilisi in Tbilisi, Georgia on 27-28 June 2024, 1. Available at <https://www.shs-conferences.org/articles/shsconf/pdf/2024/08/shsconf_icdde2024_03018.pdf> (accessed 16th July, 2024)

74 Ibid.

75 Sado Thakur, 'From Kyoto to Paris and Beyond: the Emerging Politics of Climate Change' (2021) 77(3) India Quarterly Journal of International Affairs, 366-383. https://doi.org/10.1177/09749284211027252

carbon-intensive products to countries that are not signatories to the Protocol.[76] Though failed to achieve its targets, the Kyoto Protocol was a step in the right direction of combating greenhouse gas emissions from industrialised countries.

Concerning the above, it suffices to state that there several frameworks concerning the need for the use of clean and sustainable energy sources. However, there seems to be a high demand and use of harmful energy sources that are deleterious to the global environment and human health. Hence the need to examine and harness some digital technology and scientific discoveries such as the metaverse concept, biotechnology, and nanotechnology on how they could enhance the global legal framework towards clean energy transition.

5. THE ROLE OF DIGITAL AND SCIENTIFIC TECHNOLOGY TOWARDS CLEAN ENERGY TRANSITION

It suffices to state that virtually most countries within the global environment rely and depend on energy such as fossil fuels, nuclear energy, and biomass fuel products such as firewood and charcoal for cooking and heating. Despite the dangers posed by these harmful energy sources to the global environment and serious health risks, the demand continues to surge high[77]. Furthermore, several industries within the global environment place reliance on fossil fuels (considered harmful to the environment and pose a severe health risk) in executing their industrial activities[78]. However, the reason for the high demand for energy sources is as a result of the inability of most developing

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[76] Sing Kang and others, 'Impacts of Environmental Agreements on Bilateral Trade of Climate Industry' (2021) 14(21) Energies, 7277. https://doi.org/10.3390/en14217277

[77] Aidonojie Paul Atagamen and others, 'A Facile Review on the Legal Issues and Challenges Concerning the Conservation and Preservation of Biodiversity', (2023) 2(2), Global Sustainability Research, 34-46; Aidonojie Paul Atagamen and others, 'The Environmental Conservation, and Ethical Issues concerning Herbal Products in Nigeria', (2022) 1(3), Journal of Environmental Science and Economics, 26-32. https://doi.org/10.56556/jescae.v1i3.124

[78] Andrews-Speed Paul, 'Applying institutional theory to the low-carbon energy transition', (2016) 13, Energy Research and Social Science, 216–225. https://doi.org/ 10.1016/j.erss.2015.12.011

countries to have access to alternative energy that is sustainable, cost-effective, and environmentally friendly.

Concerning this, several scientists and technologists have postulated that the continuous use of fossil fuel and biomass products could further result in more deleterious and catastrophic environmental and health hazards. This is concerning the fact that biomass, fossil fuel, and other harmful energy products could result in the release of pollutants such as nitrogen oxides (N2O), sulfur hexafluoride (SF6), carbon dioxide (CO2), methane (CH4), and hydrofluorocarbons (HFCs)[79] These substances are considered pollutants that could result in climate change and global warming as a result of the release of greenhouse gases and other harmful pollutants. Hence in a bid to find a lasting solution of clean energy transition to ameliorate the danger posed to the global environment and human health. Several scientists and technologists have sought to through inventions and discovery of technological and digital solutions towards a drive of clean energy transition. Some of these scientific, technological, and digital technologies are discussed below to the extent they have resulted in enhancing the clean energy transition,

The metaverse concept is a trending digital technology that operates as a virtual reality. It involves a combination of the virtual world, augmented or amplified realities, and internet connectivity. It is a virtual world where user or individual appear in avatar form to interact and carried activities through technological simulation[80]. Virtually every activity carried out in the physical world can be executed in this virtual world, hence the metaverse concept operates side by side with the physical world. It presents an avenue for all sectors to operate seamlessly without any distance severing as a barrier. Concerning this, it suffices to state that in leveraging virtual reality and augmented reality, the metaverse could aid in enhancing a transition from the use of harmful industrial energy sources to sustainable clean energy sources. This is made possible through digital technology simulation that can model

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79 Abdisa L. Tana, 'Power outages, economic cost, and firm performance: Evidence from Ethiopia', (20218) 53, Utilities Policy, 111–120. https://doi.org/10.1016/j.jup.2018.06.009

80 Aidonojie Paul Atagamen and others, 'The Prospect and Legal Issues of Income Tax in the Nigerian Metaverse', (2024) 6(1), Trunojoyo Law Review (TLR), 17-50. https://doi.org/10.21107/tlr.v6i1.23874

and optimize clean or renewable energy systems[81]. It could also aid in enhancing the design and execution of wind turbines, smart grids, and solar farms. Furthermore, the concept of the metaverse, could aid in enhancing and driving collaboration towards knowledge sharing, hosting of workshops, conferences, and training of experts concerning innovative issues such as clean energy transition within the global environment[82]. For example, the World Economic Forum has been able to use the virtual reality platforms in hosting the need for a clean and sustainable energy transition within the global environment[83].

Also, it suffices to state that the metaverse concept has been attributed to play some formidable role as it concerns sensitization and awareness campaigns towards a change in behavior and dangers of utilising fossil fuels, eliciting the support towards the focus and acceptance of the transition towards clean and sustainable energy source. It must also be noted that the metaverse concept as a potential drive towards clean and sustainable energy sources has gained momentum of success towards sustainable and clean energy sources in most developed countries. For example, a German company known as Siemens was able to develop a virtual simulation and digital twin technology to enhance the efficiency of energy sources, management of energy projects, and smart grids. Also, the United States National Renewable Energy Laboratory utilizes a virtual simulation in the designing and development of clean and sustainable energy technologies[84]. Furthermore, companies in Japan such as Toshiba and Hitachi have been able to develop virtual reality models to improve and enhance the reliability and efficiency of their renewable energy source[85]. Other developed countries that have been able to utilize the

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[81] Kingsley Eghonghon Ukhurebor and others, 'Environmental Influence of Gas Flaring: Perspective from the Niger Delta Region of Nigeria', (2024) Geofluids, 17, 2024. https://doi.org/10.1155/2024/1321022; Aidonojie Paul Atagamen and others, 'Breaking Legal and Socio-economic Challenges to Plastic Waste Regulation in Nigeria: Lessons learned from Singapore', (2024) 13(1), Yustisia, 64-88.

[82] Aidonojie Paul Atagamen and others, 'Potential and Legal Challenges of Metaverse for Environmental Awareness and Sustainable Practice in Nigeria: A Comparative Study with Singapore', (2024) 5(1), Administrative and Environmental Law Review, 37-64. https://doi.org/10.25041/aelr.v5i1.3230.

[83] Ibid

[84] Aidonojie Paul Atagamen and others, 'The Prospect, Legal, and Socio-economic Implication of Metaverse Operation in Nigeria' (2024) 19(4), YURISDIKSI, 455. https://doi.org/10.55173/yurisdiksi.v19i4.201

[85] Ibid.

metaverse technology toward clean energy transition include China, South Korea, and the United Kingdom[86].

It must be noted that the concept of biotechnology is scientific and technological discoveries that involve the utilisation of organism and biological processes for the development of various products in agriculture, medicine, and industrial activities. It involves various use of techniques such as synthetic biology, genetic engineering, cell culture, and fermentation, that could enable the biological objects or entities manipulation within a cellular and molecular level[87]. In this regard, it suffices to state that the concept of biotechnology is aimed at providing or proffering innovative ideals in resolving food insecurity, medical treatment, and conservation of the global environment. Concerning this it suffices to state that biotechnology could result in environmental conservation and preservation[88]. This is because through biotechnology bioproducts and biofuel products could be developed to enhance a clean energy transition, thereby avoiding the use of fossil fuels. Furthermore, through biotechnology, enzymes, microorganisms, and plants can be harnessed to generate renewable energy products that could result in mitigating greenhouse gas releases or emissions. Furthermore, it suffices to opine that bioethanol and biodiesel are also derived from the fermentation process of sugar in plants like sugarcane and corn, fat and oil respectively, are derived through biotechnology. In this regard, these biofuel products can replace diesel and gasoline which are considered not friendly to the global environment[89]. Furthermore, there are several other methods through which biotechnology can be harnessed in enhancing clean energy transition and they include the following:

i. Converting organic matter through bacterial generates electricity
ii. Conversion of wastewater treatment plant into electricity

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[86] PwC (2022) 'The Metaverse and Climate Change: How the Metaverse Can Help Drive the Transition to Net Zero', PricewaterhouseCoopers. Available at: <https://www.pwc.com/gx/en/industries/technology/metaverse/metaverse-climate-change.html> (Accessed: 23 August 2024).

[87] Rapini Rose and Marrazza Gaza, 'Electrochemical aptasensors for contaminants detection in food and environment: recent advances', (2017) 118, Bioelectro chemistry 47–61.

[88] Riget Foss and others, 'Twenty years of monitoring of persistent organic pollutants in Greenland biota' (2016), 217, A review. Environ Pollut, 114–123.

[89] Aidonojie Paul Atagamen and others, 'Bioenergy revamping and complimenting the global environmental legal framework on the reduction of waste materials: A facile review', (2023), 9(1), Heliyon https://doi.org/10.1016/j.heliyon.2023.e12860

iii. Also, the replacement of petrochemicals through the development and advancement of bio-based chemicals. A good example is the use of bio-based solvents and biopolymers that is derived or generated from a biomass plant and it is capable of being used in industrial manufacturing activities and is eco-friendly

Concerning the above, it suffices to state that biotechnology could complement the global legal framework concerning clean and sustainable energy transition. It proffers a better alternative towards eradicating or curtailing the incessant use of harmful energy sources that are detrimental to the global environment and human health.

Furthermore, another notable scientific discovery that could also complement global energy law towards a clean energy transition is nanotechnology[90]. This technology utilizes a synthesis, design, and application of devices and materials at the nanoscale of 1 to 100 nanometers. Material placed at a scale of 1 to 100 nanometres is capable of displaying unique physical, biological, and chemical properties that could accelerate and enhance or improve reactivities, surface area, and quantum effects[91]. Concerning this, these properties can be utilized in the development of advanced technologies toward achieving clean energy sources. For example, it is considered that silicon-based solar cells have potential and could be effective. However, it has the limitation of high cost and less efficiency, in this regard, scientists have discovered that nanotechnology possesses the potency to address this shortcoming through the use of nanomaterials such as nanowires, perovskite, and quantum dots[92]. This nanomaterial has been proven to be capable of creating or initiating a flexible and efficient photovoltaic cell. Furthermore, it also suffices to state that utilize the unique properties through the nanoscale, does not only aid in clean energy generation but also be utilized in clean energy storage[93]. This is concerning

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[90] Onyancha B. Robert and others, 'Facile synthesis and applications of carbon nanotubes in heavy-metal remediation and biomedical fields: a comprehensive review', (2921), J Mol Struct 1238:130462.

[91] Pandit Sadau and others, 'Nanotechnology based biosensors and its application' (2016) 5(6), Pharma Innov J, 18–25.

[92] P A Aidonojie and others, 'Legal Implications of Nanobiosensors Concerning Environmental Monitoring. In: Singh, R.P., Ukhurebor, K.E., Singh, J., Adetunji, C.O., Singh, K.R. (eds) Nanobiosensors for Environmental Monitoring.(2022), Springer, Cham. https://doi.org/10.1007/978-3-031-16106-3_21

[93] Salouti Maoulu and Derakhshan F. Kran, 'Biosensors and nanobiosensors in environmental applications'. In: Ghorbanpour M, Bhargava P, Varma A,

the fact that it has been discovered that the energy density and charging capacity of lithium-ion batteries can be enhanced and increased through nanostructured materials. Furthermore, given the potential of carbon nanotubes and graphene which are nanomaterials, that have been used to reform and transform supercapacitors, providing sporadic storage necessary for grid stability and electricity vehicles[94].

Concerning the above, it suffices to opine that digital and scientific technology (such as biotechnology, nanotechnology, and the metaverse concept) over time has proven to be very viable in curtailing the use of harmful energy sources by providing an eco-friendly alternative means. Hence, they are also capable of complementing the global energy laws towards a clean energy transition. In this regard, it suffices to state that there is a need for international collaboration toward enhancing the development and investment in the metaverse concept, biotechnology, and nanotechnology that could ensure an effective transition toward a clean energy source.

6. ISSUES AND CHALLENGES OF TECHNOLOGY TOWARDS CLEAN ENERGY TRANSITION

Absolute dependence on harmful energy has brought a lot of challenges such as an increase in the emission of greenhouse gases leading to global warming[95], depletion of the ozone layer, deforestation, destruction of the ecosystem, pollution, poor environmental conditions, reduction of economic powers, the uncertainty of human sustainability and to mention a few.[96] As a result of this, there is a need to strike a balance between the generation of energy for human consumption and the negative effects it has on mankind[97]. Thus, to reduce the hazardous and perilous effect of reliance on fossil fuel as

Choudhary D (eds) Biogenic nano-particles and their use in agro-ecosystems. (2020), Springer, Singapore. https://doi.org/10.1007/978-981-15-2985-6_26

94 Anani O. Anthony and others, 'Application of Microorganisms as Biofactories to Produce Biogenic Nanoparticles for Environmental Cleanup: Currents Advances and Challenges', (2023) 19(6), Current Nanoscience, 770-782.

95 Aidonojie Paul Atagamen and others, 'The Legal Challenges and Effect concerning the Environmental Security in Nigeria: A Lesson from International Perspective', (2022) 9(1), Journal of Commercial and Property Law, 110-120.

96 Annamaria Buonomano and others, 'Latest Advancements and Challenges of Technologies and Methods for Accelerating the Sustainable Energy Transition', (2023) 9 Energy Reports 3343–3355.

97 Aidonojie Paul Atagamen, 'Environmental Hazard: The Legal Issues Concerning Environmental Justice in Nigeria', (2023) 3(1), Journal of Human Rights, Culture and Legal System, 17-32. https://doi.org/10.53955/jhcls.v3i1.60

a source of energy, there is a need to divert to a sustainable and low carbon emission energy that is human-friendly. As such, since the 21st century, technological advancement and scientific discovery have been given much attention as an area of focus for scientists and technologists to produce clean energy for the safety of mankind. Despite the advantages attributed to clean energy transition, there are some challenges attributed to technological and scientific advancement towards clean energy transition. Some of the notable challenges are:

i. **Limited storage capacity of energy:** Coal has a high net of energy and a unit of coal can generate more energy than other sources of energy, thus neglecting it. More than half of the electricity generated in developing countries is from coal because is cheaper with high utility despite the negative implications on humanity.[98] On the other hand, renewable and clean energy has a limited production capacity. For instance, hydropower has been said to have about 14, 576 TWh generation potential which was estimated at 3,721 GW.[99] However, the current global installation of hydropower is far less than its capacity with just four countries i.e. China, Brazil, Canada, and the United States of America taking over 50% according to the World Energy Council Report.[100] Furthermore, the World Energy Council has revealed that the energy from solar radiation is more than 7,500 times the world's total annual primary energy consumption but the challenge is the storage capacity. Thus, with technological advancements in producing clean energy transition, there is a need to work more on the storage capacity of the renewable and clean energy generated.
ii. **Poor market turnout and low patronage:** Technological advancement and scientific discovery toward clean energy sources can be subjected to mass rejection in the market especially in developing countries for many reasons such as high cost, poor utility measures, illiteracy, difficulty in

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98 Hanif Auwal Ibrahim and others, 'Sustainability of Power Generation for Developing Economies: A Systematic Review of Power Sources Mix' (2023) 47 Energy Strategy Reviews 1-22.

99 Lv Yongjun, 'Transitioning to Sustainable Energy: Opportunities, Challenges, and the Potential of Blockchain Technology' [2023] Front. Energy Res. 1-20.

100 Phebe Asantewaa Owusu and Samuel Asumadu-Sarkodie, 'A Review of Renewable Energy Sources, Sustainability Issues and Climate Change Mitigation', (2016) Cogent Engineering, 3 1-14.

adapting to a new system and so on.[101] Many people in the rural area are not educated and as a result, they do not understand the importance of clean energy over fossil fuels. Hence, clean energy sources may receive low patronage in the market. Another factor that can influence the low patronage is the fear of repair when it is damaged. As a new technology and scientific discovery recently introduced to developing countries, especially rural areas, there would be fear of failure to repair when such a device has a fault.[102]

Limited knowledge and awareness of clean energy systems due to socio-cultural barriers can further increase the chance of rejection of clean energy sources of energy in the market especially in Sub-Saharan Africa where a larger percentage of the people there are uneducated and uncivilized. Thus, the market barrier can prevent the advancement of technology and scientific discovery towards clean energy. Limitation of information can also be a contributing factor to the low patronage of newly advanced means of clean energy for consumption. The irregular and fluctuating price system of clean energy with the high cost of initiating processes such as procurement, installation, and subsequent operational costs can discourage people from patronizing, thereby reducing market acceptance.[103]

iii. **Limited raw materials and technical barriers:** There is a need for adequate materials to produce the desired clean energy generation. The generation of clean energy would depend on the level of technical know-how of the personnel involved. Limited resources can limit the potential and output of the investors or manufacturers of clean energy.[104] For instance, to generate hydropower, water is essential, hence it will be difficult to

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[101] Aidonojie Paul Atagamen and others, 'Environmental Law in Nigeria: A Review on its Antecedence, Application, Judicial Unfairness and Prospects' (2020) 1(2), Archive of Science & Technology, 211-221; Anani O. Anthony and others, 'Bio-Nano Filtration as an Abatement Technique Used in the Management and Treatment of Impurities in Industrial Wastewater' (2023), Bio-Nano Filtration in Industrial Effluent Treatment, 171-182.

[102] Ukhurebor E. Kingsley and Aidonojie Paul Atagamen, 'The Influence of Climate Change on Food Innovation Technology: Review on Topical Developments and Legal Framework', (2021) 10(1), Agriculture & Food Security, 1-14. https://doi.org/10.1186/s40066-021-00327-4

[103] Carol. Parrado, '2050 LCOE Improvement Using New Molten Salts for Thermal Energy Storage in CSP Plants' (2016) 57 Renewable and Sustainable Energy Reviews 505-514.

[104] Amadi Hana, 'Renewable Energy in Nigeria: Prospects and Challenges' 2024, 11(4) European Journal of Advances in Engineering and Technology 51-60.

achieve this in desert-related areas. Whereas, it might be possible to generate more solar power in such a place but with lower turnout in places with excessive rainfall. Regions with low educated people might encounter more challenges because of limited trained personnel for large output. For instance, in Nigeria, solar energy appears the most alternative source of energy relied on apart from fossil fuel. This could be as a result of limited trained personnel in other sources of renewable energy such as hydropower, or wind energy. Thus, limited experienced workers will necessitate a prolonged training period and additional cost and this can discourage the generation of renewable energy by some investors. Records also stated that in Saskatchewan Canada, technological powers limited their willingness to invest in wind energy.[105] The effect of poor technical can increase the fear of failure, transmission problems, and servicing and maintenance of the equipment without reliable assurance of its sustenance, such impending fear can discourage people from patronizing or adopting the technological and scientific clean energy source in place of traditional sources of energy.

The geographical and ecological status must also be considered while thinking of a shift in energy transition. One must consider the increase in the population of people and the topography of the geographical location which could prevent renewable energy manufacturers from having adequate resources needed. For instance, to get adequate solar power, a large expanse of land is needed for mounting the solar panel, thus overpopulation could lead to scanty or limited solar power generation due to poor geographical.

iv. **Financial and infrastructural problems:** Most countries would be reluctant to shift from fossil fuel energy generation to clean energy because of the financial implications. The cost of infrastructural development to generate and transfer renewable energy is very high. For instance, the International Energy Agency stated that about US $600 billion is needed to invest in electricity grids annually until 2030 to achieve clean energy.[106] Many of the developing countries with low economic powers would prefer to opt for economical sources of energy

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[105] Garrett Richards and others, 'Barriers to renewable energy development: A case study of large-scale wind energy in Saskatchewan, Canada' (2012) 42 Energy Policy 691-698; Garrett Richards and others, 'Barriers to renewable energy development: A case study of large-scale wind energy in Saskatchewan, Canada'(2012) 42(1) Energy Policy 691-698.

[106] A Covatariu, 'European energy security requires stronger power grids' 2024, Atlantic Council <https://www.atlanticcouncil.org/blogs/energysource/european-energy-security-requires-stronger-power-grids/> accessed on 25 July, 2024.

to reduce costs and make more profit rather than generating clean or renewable energy. The infrastructural cost also includes the work and other materials needed for the generation of clean energy. Also, in 2017, installation of solar systems ranged between $2000-$3700 per kilowatt whereas, if the same energy is generated from natural gas plants it would cost about $1000/kW.[107] Poor physical facilities for transmission, connection to grid, and distribution is another major setback for renewable or clean energy transition especially in developing countries with low technical and educational knowledge.

v. **Regulatory and political related issues:** The adoption and acceptance of any new technology depends on the regulatory framework and political undertone of any nation. There is a need for clear legislation, policies, terms, and conditions before a product can be introduced into the market of any country. There are various bodies in place to approve any product brought into any country. For instance, the Standard Organization of Nigeria is in charge of determining the standard of any product imported into Nigeria. Thus, where there are no adequate regulatory measures on the importation and acceptance of clean energy sources in a nation, it would be difficult for the investors to make any meaningful impact and such can limit the technological transition of renewable energy across the globe.[108] Furthermore, the disparity in the regulatory framework amongst the countries within a region can also add more to the challenges of technological advancement in clean energy. These policies are essential for authorization of the private sector to produce and market their products and at the same time to reduce the act of dumping from developed to developing countries. Without the input of the political will, private sector investors would find it difficult to a larger scale market for their products.

vi. **Negative environmental effect:** Despite the technological advantage attributed to renewable or clean energy, continual usage has negative implications for the environment which is harmful to humankind. For instance, photovoltaics generated from solar power produce some toxic components such as cadmium and arsenic. Solar power can also increase

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[107] Tarek Safwat Kabel and Mohga Bassim, 'Reasons for Shifting and Barriers to Renewable Energy: A Literature Review', 2020, 10(2), International Journal of Energy Economics and Policy, 89-94.

[108] A O Anthony and others, 'Environmental Principles and Ethics: Current Challenges in the Field of Bioscience and Law, Ethics, Media, Theology and Development in Africa': A Festchrift in Honour of Msgr. Prof. Dr. Obiora Francis Ike, Global.net Co-Publication & Others, Geneva, Switzerland, (2022) 142-158.

the chance of blindness due to solar radiation, wind depletion, and a high rate of soil evaporation which affects agricultural produce.[109] There is a need to cool the effect of photovoltaic with water to reduce the destruction of plant, animal and soil organisms and this can reduce the energy force in the course of transmission. In addition, wind energy can also cause noise pollution and also subject birds and other flying to a great risk.

Hydropower also poses an environmental challenge in the sense that, where artificial water or lake is generated such can reduce the flow of water, cause poor accumulation of water nutrients, reduction of fresh water, reduction of aquatic habitats, increase water stagnation, displacement of human and animals, an increase of water-borne diseases can be experienced as a result of the renewable or clean technologically generated energy transition at the detriment of mankind.[110] Wind turbines can also distort the frequency and waves of the network and increase noise pollution in an area. The negative challenges can reduce the acceptance of clean energy with the help of technology and scientific discovery to replace traditional sources of energy.[111]

7. RECOMMENDATIONS

This research makes the following recommendations:

1. **Improvement of the Legal Framework:** The study revealed that the international Conventions and multilateral Agreements on Climate change lack any specific provision on the adoption of technology and recent scientific discoveries in the transition to clean energy. This is fundamental to transitioning to clean energy. Technology and recent scientific discoveries have its meaning advantages and disadvantages both for consumers and energy providers. The use of digital technology and scientific discoveries in clean energy transition in one country may also

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[109] Atalay Atasu, Serasu Duran, and Luk N. Van Wassenhove, 'The Dark Side of Solar Power' [2021] Harvard Business Review 24.

[110] Annamaria Buonomano and others, 'Latest Advancements and Challenges of Technologies and Methods for Accelerating the Sustainable Energy Transition', (2023) 9 Energy Reports 3343–3355.

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have a cross-border effect on another country. There is a need for a specific international Convention that addresses this concern especially as the use of digital technology and scientific discoveries in energy transition increases globally.

2. **Increased Cybersecurity Mechanism:** The use of digital technology in clean energy transition may occasion a cybersecurity threat. It is recommended that there should be solid protocols such as regular updates, consistent assessment of vulnerability, and the introduction of encryption technologies that are advanced to protect digital technology systems from cybersecurity threats. This recommendation is germane in the wake of advanced cybersecurity breaches that have dominated cyberspace globally.
3. **Advanced Technical Training and Expertise:** The transition to clean energy through the use of digital technology and scientific discoveries requires advanced technical training and expertise. Unfortunately, especially in Africa, this technical know-how is a fundamental clog to efficient transition. Clean energy professionals and stakeholders must possess sufficient digital technology and scientific discoveries operational knowledge and skills required to enable the smooth and efficient transition from the use of fossil fuels to clean energy. Therefore, there is a necessity to have a consistent program such as workshops to train and educate professionals on how digital technology and scientific discoveries may be used to transition and maintain clean energy.
4. **Adequate Funding/Provision of Financial Support:** The initial financial implication of utilizing Information Communication Technology for clean energy transition is highly capital intensive. Governments at the national level must be willing to provide subsidies, incentives, or assist in funding the project. More so, financial institutions must be willing to provide non-interest or low-interest loans to corporate bodies that are committed to this project. Furthermore, international organisations/bodies and governments of developed nations must be willing to offer support to small or developing countries especially in Africa to enable the transition to clean energy. This support may be either in the areas of the provision of financial assistance or deployment of their human resources (experts) to train professionals on the use of ICT.

8. CONCLUSION

The over-reliance on traditional fossil fuels remains a serious threat to human existence, especially considering the environmental havoc it is causing, the danger to human health, and climate change globally. Unfortunately, while there are international Conventions and Agreements by which countries around the world bound themselves to be committed to the reduction of greenhouse gas emissions at the national level and within the global space, it appears the unfolding development in recent times has shown that these conventions and agreements are ineffective. The ineffectiveness of these Conventions and multilateral agreements has been blamed on the non-inclusion of the major greenhouse gas emitters around the world, the lack of implementation and enforcement measures, and the vulnerability of the developing nations with little not no provision for assistance among others. These challenges make the necessity for transiting from the traditional use of fossil fuels to clean energy. The transition to lean energy guarantees both the safety of human health and the environment. This approach substantially aids the reduction of greenhouse gas emissions at both the global and national levels.

Furthermore, digital technology and scientific discoveries are very important in enhancing easy management and transition to clean energy. The emergence of smart meters, blockchains, and electric cars are good examples of clean energy transition that can ensure the reduction in greenhouse gas emissions to cleaner energy. The smart grid management is highly instrumental to this transition. While the energy system benefits immensely from the use of digital technology and scientific discoveries (such as the metaverse concept, biotechnology and nanotechnology) in its operational performance and proficiency, energy consumers can make decisions concerning the use of energy. Unfortunately, the deployment of ICT in the transition to clean energy has many challenges such as the initial cost of setup, cyber security threats, lack of sufficient technical expertise, and so on. However, notwithstanding these challenges, the advantages of ICT to transition to clean energy are enormous.