





Research Article

The Role of Blockchain Technology in Addressing Climate Change: A Review

Chidi Ukamaka Betrand* , **Chinwe Gilean Onukwugha** ,
Christopher Ifeanyi Ofoegbu , **Douglas Allswell Kelechi** 

Department of Computer Science, School of Information and Communication Technology, Federal University of Technology, Owerri, Nigeria

Abstract

Climate Change is one of the biggest concerns of the 21st century due to its worldwide economic, social, and environmental causes and consequences which primarily impact poor countries. Climate models indicate that if present emissions trends continue, temperatures might rise by more than 2°C, which is alarming. As a result, over the next 40 years, yearly emissions per person must be gradually reduced from about seven tons to two tons. Blockchain technology, which provides a decentralized, transparent, and unchangeable system that can encourage sustainable practices, has become a game-changing instrument in the worldwide struggle to combat climate change. This study investigates how blockchain can be used to improve environmental programs' efficiency, accountability, and transparency in the fight against climate change. Better carbon tracking, renewable energy certificate verification, and assistance for sustainable supply chains are all made possible by blockchain's special features. Blockchain technology has a lot of promise to combat climate change and promote sustainable development, but its uptake needs to be balanced with factors like scalability and energy efficiency. It can offer long-term answers to climate issues by advancing low-energy consensus methods and enabling legislation, fostering a more transparent and sustainable global economy. This review offers important insights for the different stakeholders looking to use technology for environmental improvement by highlighting the benefits and difficulties of incorporating blockchain into climate action plans. In the end, this research emphasizes that although blockchain is not a magic bullet for climate change problems, it has great potential as a component of a larger set of solutions required to successfully lessen its effects.

Keywords

Climate Change, Fossil, Fuel, Blockchain, Energy, Technology, Green House Gas, CO₂

1. Introduction

One of the biggest issues facing the globe now is climate change. Governments employ a variety of tactics and methods in their efforts to combat climate change. Numerous studies have demonstrated that human activity is to blame for the rise in carbon dioxide levels, which raise Earth's atmos-

phere's temperature and cause major climatic changes. A group of 1300 independent scientific experts from various countries about the world working under the auspices of the United Nations concluded in its Fifth Assessment Report that there is a greater than 95 percent chance that human activi-

*Corresponding author: chidi.betrand@futo.edu.ng (Chidi Ukamaka Betrand)

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ties over the past 50 years have warmed our planet [1]. Without a doubt, natural catastrophes like floods and tsunamis. Long-term changes in regional or worldwide climatic patterns are referred to as climate change. The main causes of which are human activities that produce greenhouse gases into the atmosphere, such burning fossil fuels, deforestation, and industrial operations. Because these gases trap heat, the earth's temperature rises, ice caps melt, intense weather occurs, and ecosystems are disrupted [2].

Greenhouse gases, including carbon dioxide (CO₂), are released into the atmosphere during the burning of fossil fuels including coal, oil, and natural gas. Climate change and global warming are caused by these gases' ability to trap heat. Fossil fuel burning has contributed significantly to the rise in CO₂ levels since the Industrial Revolution, intensifying the greenhouse effect and altering global climate patterns [3]. The combustion of fossil fuels and biomass, which is linked to deforestation, releases emissions into the atmosphere that may cause a climate shift. While particles generated from released SO₂ promote cooling by raising cloud albedos through modification of droplet size distributions, emitted trace gases heat the atmosphere through their greenhouse effect [4]. The primary source of greenhouse gas (GHG) emissions into the atmosphere is energy production and consumption, especially the burning of fossil fuels. Carbon dioxide is the GHG with the largest concentration fluctuations. This study looked at the current global and regional production and consumption forecasts for fossil fuels (coal, oil, and natural gas) and examined the relationship between the use of these fuels and global carbon dioxide emissions from 1990 to 2019 [4]. Deforestation, contribute to climate change by taking up carbon dioxide from the atmosphere during photosynthesis, trees function as carbon sinks. This stored carbon is released back into the atmosphere as carbon dioxide during the clearing or burning of forests, which increases greenhouse gas emissions [5]. Trees contribute to the regulation of local and regional climates by releasing moisture into the atmosphere through transpiration; unfortunately, this process is hampered by deforestation, which results in variations in temperature and precipitation patterns. Furthermore, the destruction of trees worsens ecosystems and decreases biodiversity, which exacerbates the effects of climate change [6].

Industralization also is one of the major causes of climate change by releasing greenhouse gases and other pollutants into the atmosphere. Large volumes of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases are released during manufacturing, energy generation, and other industrial processes. These gases trap heat and are a contributing factor to global warming [7]. Other pollutants including sulfur dioxide (SO₂), nitrogen oxides (NO_x), and particulate matter can also be released as a result of industrial activities, and these pollutants can affect the climate system directly or indirectly. For instance, emissions of sulfur dioxide can result in the production of sulfate aerosols, which reflect sunlight back into space and temporarily lower the

planet's temperature. Environmental concerns are further exacerbated by the use of ozone-depleting substances (ODS) in some industrial processes, such as hydrochlorofluorocarbons (HCFCs) and chlorofluorocarbons (CFCs), which damage the ozone layer in addition to contributing to climate change [7, 8].

2. Related Works

Technological advances are being made on a daily basis to bridge gaps in the economic as well as environmentally green systems. The work by [13] analyzed the current advances, limitations and the possible application of blockchain within the regional energy context, using the diffusion of innovation theory. A suggestion is being made of platform like Iota for deployment in the case of lack of requisite network infrastructure and hiccups in finance. However, the emphasis on innovative and disruptive business models for harnessing renewable energy sources towards improved energy efficiency and overall socio-economic development, remains. Ebekozen et al [14] in their studies show that the fourth industrial revolution (4IR) technologies can be used to transform the built environment sector in the 21st century. Blockchain technology having been identified as a driving force for 4IR. The impact of the blockchain technology and ways of promoting its application in the Nigerian built environmental professionals(BEP) were major part of their work.. Lv, 2023 [19] gives an overview of integrating blockchain technology for sustainable energy solutions, the need for renewable energy investments notwithstanding the limitations Because of their advantages for the environment and the economy emphasizes is made on how crucial it is to switch to sustainable energy sources. The results provided provide insightful information to help guide future research initiatives in this area and inform policy decisions. This study helps to create a more sustainable global economy by encouraging the development of sustainable energy technology.

Hawashin et al, 2024 [20] focusing on the blockchain technology to capacity to address some of the challenges faced by UAV systems examine its relevance and application. The relevance of this technology in data security within supply chain processes to facilitate efficient and efficient flight operations management of the UAV system gives significance Blockchain's potential applications and future prospects in the UAV sector, including as decentralized verification systems and real-time data management were also dealt on. Vincent et al, 2025 [21] investigated the influence of women's empowerment and social networks on adopting the use of clean cooking fuels and technologies (CCF&Ts) among households in Uganda. Focusing on about 9388 households and analyzing data spanning for two years while employing a double hurdle model, the result shows that at a significance level of $p < 0.05$, the findings indicate that social network effects (coefficient = 0.24) and women's empowerment (co-

efficient = 0.045) together predict roughly 22.4% of households' adoption of CCF&Ts and 15% of their sustained use. Additionally, the study reveals that a number of characteristics have a "significant positive impact" on the adoption and continued usage of CCF&Ts, including the sex of the family head, household income, size, roof type, home material, and urban residence. In order to improve household capacity to adopt and maintain the usage of CCF&Ts, the study suggests giving priority to policies that empower women and encourage the exchange of energy-related information among social groupings. The study also suggests that for a more thorough knowledge of the factors impacting the adoption of CCF&Ts, future research should use qualitative, primary, and panel research methodologies. It should concentrate on adopters who would not use these fuels and technology sustainably and target metropolitan downtown districts, slums, and town fringes.

Abdelhameed et al, 2024 [22] improved community microgrid integrated community energy management system (CEMS). It is intended to maximize energy use in households and make energy sharing across smart homes easier. In order to solve important issues with current energy management strategies, such as load scheduling and effective peer-to-peer energy trading, the suggested solution combines the constrained mixed-integer programming (CMIP) approach with sophisticated optimization techniques and a cooperative game theory-based pricing mechanism. Grid-connected community power systems that integrate local energy sources like solar and battery storage systems use the CEMS technique. This system is put into practice using a feed-in tariff for energy transfer from the community peers to the main grid, a modified mid-market pricing mechanism for the P2P energy exchange, and a time-of-use dynamic pricing model for energy transfer from the main grid to the community peers. Additionally, the scheduling problem is submitted to a rounding procedure to get the best feasible solution, and the CMIP problem is relaxed using the seagull optimization technique to obtain the optimal rational solution. The results show a significant decrease in electricity expenses, with daily savings of 72.21% and a 41.95% reduction in grid dependency. In addition, 82.2% of the community's energy needs were satisfied by locally produced resources, and the overall CMG self-consumption ratio increased by 18.39% when compared to the reference operating scenario. The study concludes by showing how well the management system works to enhance load profiles, optimize the usage of nearby renewable energy sources, and lower power costs—all of which contribute to the creation of a sustainable and financially feasible paradigm for smart grids of the future.

3. Blockchain Technology in Addressing Climate Change

The Blockchain technology, a distributed ledger system

that operates decentralized and securely, The potential of blockchain technology to offer decentralized, transparent, and safe systems for a variety of uses makes it relevant. It provides answers to a number of problems, including as data security, problems with trust, and inefficiencies in conventional centralized systems. Its potential extends to several areas, including banking, healthcare, supply chain, and voting. It provides improved security, efficiency, and transparency in data management and transaction processes [9].

3.1. Opportunities with Blockchain Technology

Several opportunities abide in which the blockchain technology may be used to combat climate change and advance sustainability. One important area is the trade of renewable energy, where blockchain technology can enable peer-to-peer energy transactions. This allows people and companies to directly buy and sell excess renewable energy, therefore lowering their dependency on fossil fuels. Blockchain may also be used to track and validate carbon offsets and emissions, bringing accountability and transparency to the carbon markets. Additionally, it may improve supply chain transparency by tracking the origins and environmental effect of items, empowering customers to choose sustainable products with knowledge [10, 11]. All things considered, blockchain technology has the power to completely transform the way we deal with climate change by boosting efficiency, trust, and openness in environmental projects. Peer-to-peer trading of renewable energy can be facilitated via blockchain-enabled platforms, allowing communities and individuals to purchase and sell excess energy produced by renewable sources like wind turbines or solar panels [14]. This can lessen reliance on fossil fuels and encourage the usage of renewable energy. In presenting new opportunities to improve the management and operation of modern electrical networks, often known as smart grids, Through using the inherent qualities of blockchain technology, intelligent platforms may be strengthened, maintained, and enhanced in efficacy [15]. Blockchain technology has potential to significantly impact climate change efforts by enhancing transparency, accountability, and efficiency in various environmental initiatives. The tracking of goods from point of origin to final consumer, guaranteeing ethical sourcing methods is made possible as customers get to see how their purchases affect the environment, which can help stop unlawful deforestation, overfishing, and unsustainable mining [15, 16]. Businesses that use blockchain technology can offer validated data on their carbon footprint, which helps consumers who care about the environment select low-impact goods.

Double counting and fraud are two issues in the carbon credit market that blockchain can help with. Businesses and individuals can safely purchase, sell, or retire carbon credits on an open ledger by utilizing blockchain technology, which increases transaction transparency and verifiability [16, 23]. Blockchain technology can be used to issue and track credits

for new projects, which will facilitate funding for small-scale environmental projects. Peer-to-peer energy trade and incentives for the production of renewable energy are made possible by blockchain technology, which can make energy networks more decentralized. For instance, without a central utility, households with solar panels can sell extra energy to nearby residents. By lowering the overall carbon footprint and increasing access to and incentives for renewable energy, this could lessen dependency on fossil fuels [17]. By providing transparent and traceable transactions, blockchain can simplify climate funding. Investors can increase accountability by tracking the use of funding for environmental projects using "green bonds" [18]. Blockchain-based fundraising initiatives are more transparent, which can draw in more investors and guarantee that money goes to the right companies. Programs that compensate people or businesses for adopting sustainable habits, such as recycling, taking public transit, or using less energy are developed *viz-a viz* [19]. Greener behavior can be financially incentivized by issuing tokens or credits as prizes for eco-friendly initiatives. The storing, sharing, and validation of climate-related data are impacts of blockchain technology. Better climate models and well-informed decision-making can result from scientists and researchers working together more accurately and securely to log environment [12].

3.2. Challenges Faced in the Implementation of Blockchain Technology

In as much as the shift towards sustainable energy sources poses opportunities, there are also imminent challenges with that. One of the most significant obstacles is the transition to sustainable energy sources. Given how strongly the current energy infrastructure depends on conventional energy sources, one of the biggest challenges is the need for investment in renewable energy technologies [24]. Significant investment in renewable energy technologies, such as hydro, wind, solar, and geothermal, is necessary to ensure their accessibility and affordability and enable their widespread implementation. This is necessary for the adoption of sustainable energy sources [25, 26]. Changing policies to encourage the use of sustainable energy is another major obstacle. By altering policies, governments may significantly contribute to the promotion of sustainable energy use. Because of these policies, renewable energy technology can flourish and become more widely available and reasonably priced for customers. However, putting these policies into practice can be difficult and calls for public support and political will [27, 28]. Many blockchain networks tend to struggle with getting large number of transactions processed without wasting time, as a limited number of transactions happen per time. This sometimes lead to the difficulty in communication experienced while trying to relate on the different blockchain platforms [29]. With the field of blockchain technology continuous evolvement, there arises the need for IT personalities with domain-specific skill sets as successful implementation

calls for collaboration among expertises [30].

4. Conclusion

Blockchain technology presents encouraging ways to help make a long-lasting difference in the battle against climate change. Blockchain can transform environmental projects in a variety of areas, from guaranteeing sustainable supply chains to simplifying carbon credit systems, by promoting openness, accountability, and efficiency. It lowers the global carbon footprint by empowering decentralized energy systems, attracting finance for green projects, and providing incentives for eco-friendly behavior. Even though issues like excessive energy usage still exist, developments in more environmentally friendly blockchain technology, such proof-of-stake, could make these solutions feasible on a large scale. Blockchain has the potential to be a key component in creating a more sustainable future with further development.

Although blockchain has promise for mitigating climate change, there are still issues, particularly with regard to energy usage for specific blockchain variants (such as proof-of-work). However, blockchain's use in environmental solutions is expected to grow as energy-efficient blockchain technologies like proof-of-stake and carbon-neutral protocols gain traction. Blockchain technology has the potential to be a potent weapon in the battle against climate change, promoting sustainable behaviors and strengthening international climate initiatives, provided these obstacles can be removed.

Abbreviations

GHS	Green House Gas
BIM	Building Information Model
ODS	Ozone Depletion Substance
4IR	Fourth Industrial Revolution
CFCs	Chlorofluorocarbons
UAV	Unmanned Aerial Vehicle
CEMS	Community Energy Management System
CMIP	Constrained Mixed-integer Programming

Author Contributions

Chidi Ukamaka Betrand: Conceptualization, Writing – original draft

Chinwe Gilean Onukwugha: Methodology, Writing – review & editing

Christopher Ifeanyi Ofoegbu: Validation

Conflicts of Interest

The authors declare no conflicts of interest.

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