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Engineering Technology in Adapting Climate Change and Global Warming for Environmental Sustainability

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Abstract

Environment is naturally endowed with all the wealth and also all that is needed for satisfactory living. Over utilization of the environment through human activities (HA) for rapid economic development or growth and more so unrestrained use of its natural resources causes substantial environmental problems and consequently disrupt future sustainability. Environmental problems globally need urgent attention owing to threat to safety on the earth which impact environmental sustainability. Climate change and global warming are current and topical issues in the debate and discourse among scholars and experts owing to the fact that they constitute emerging global challenges. Climate change and global warming will spell doom to the earth if no urgent adaptive or mitigating measures are taken. This means that the sustainability of the earth's ecosystem is under a threat as well as the future of human kind and the stability of the global economy. To alleviate this, Engineering Technology should be placed at the base line of climate change and global warming that are set to derail environmental sustainability. Through engineering technology, reduction of greenhouse gases (GHGs) to acceptable

limit, recyclability of wastes, pollution control and tolerable level of land use, land use change and forestry (LULUCF) can be achieved and thus adapting climate change and global warming.

Keywords: Climate Change, Engineering Technology, Environmental Sustainability, Global Warming and Greenhouse Gases.

Introduction

Climate change and global warming are among the most pressing global challenges of the 21st century, with profound implications for environmental sustainability. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as long-term alterations in temperature, precipitation, and other atmospheric conditions, often driven by human activities such as fossil fuel combustion, deforestation, and industrialization (IPCC, 2021). Global warming, a subset of climate change, refers specifically to the increase in Earth's average surface temperature due to greenhouse gas (GHG) emissions like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). In addition the following GHGs are responsible for global warming Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6) (UNFCCC 2007).

The consequences of these phenomena are far-reaching, including rising sea levels, extreme weather events, biodiversity loss, and ecosystem degradation (NASA, 2023). These changes threaten environmental sustainability, defined as the ability to maintain ecological balance while meeting human needs without compromising future generations' ability to do the same (WCED, 1987). Adaptation strategies are critical to mitigating these impacts, and engineering technology plays a pivotal role in creating resilient systems and reducing vulnerability.

Climate change poses complex challenges to environmental sustainability, impacting agriculture, water resources, infrastructure, and energy systems. For example, increased frequency and severity of droughts and

floods disrupt food production, while rising temperatures accelerate infrastructure deterioration (UNEP, 2022). Traditional methods of addressing these issues often fall short, as they rely on finite resources and fail to address the root causes of climate change.

Furthermore, global warming exacerbates socio-economic disparities by disproportionately affecting vulnerable populations, particularly in developing countries. Without innovative solutions, the world risks further environmental degradation, economic instability, and social inequities (IPCC, 2021).

Technological advancements, including renewable energy systems, climate-resilient infrastructure, and smart resource management tools, are essential to bridging the gap between environmental challenges and sustainability goals. However, there is a need for systematic integration, upscaling, and adoption of these solutions to create lasting impact.

Engineering technologies are instrumental in achieving environmental sustainability by providing practical, scalable, and cost-effective solutions to climate challenges. For instance, renewable energy technologies such as solar, wind, and geothermal power reduce dependence on fossil fuels, significantly lowering GHG emissions (IRENA, 2022). Similarly, advancements in building materials, such as green concrete and energy-efficient designs, enhance infrastructure resilience while minimizing environmental impact (Ashraf et al., 2021).

Beyond environmental benefits, these technologies promote economic growth and social equity. For example, decentralized energy systems powered by renewable resources can improve access to electricity in rural areas, fostering development and reducing poverty (World Bank, 2022). Additionally, smart water management systems, including precision agriculture and desalination technologies, ensure sustainable resource utilization in water-scarce regions.

The integration of engineering technology into climate strategies is crucial for balancing ecological preservation with human development. By fostering innovation, capacity-building, and cross-sector collaboration, engineering solutions can pave the way for a sustainable and climate-resilient future.

LITERATURE REVIEW

CLIMATE CHANGE AND GLOBAL WARMING IN NIGERIA

Climate change has become a major challenge globally. Human activities have several direct and indirect impacts on health. In Nigeria, the impacts of climate

change are more devastating due to their vulnerability and low coping capability. Recent studies highlight Nigeria's increasing vulnerability to the impacts of climate change, particularly due to its heavy reliance on agriculture, which is highly sensitive to changing weather patterns. The World Bank (2021) emphasizes that Nigeria's climate vulnerability is exacerbated by a high dependence on natural resources and low adaptive capacity, making it one of the most at-risk countries in Africa. Similarly, the World Resources Institute (2022) highlights that climate change-related shocks, such as droughts and floods, are disproportionately affecting Nigeria's rural agricultural communities, where poverty levels are higher, increasing the risk of food and water insecurity. The country's oil production further complicates its position in the fight against climate change. As one of the world's major oil producers, Nigeria faces significant challenges in balancing global energy demands with its urgent need for environmental sustainability. This dual dependency on oil and agriculture makes Nigeria particularly sensitive to both the environmental and economic effects of climate change (UNEP, 2019).

A stark manifestation of climate change in Nigeria is the drastic shrinking of Lake Chad. Once covering over 40,000 km², the lake now spans just 1,300 km², reflecting a significant loss of water resources due to rising temperatures and unsustainable water management practices. This shrinking of Lake Chad, which is a critical water source for millions of people in Nigeria and other neighboring countries, has led to the expansion of desertification in the region, displacing local populations in search of fertile land (World Bank, 2021).

These issues underscore the urgent need for technological innovations and sustainable policies to mitigate and adapt to climate change in Nigeria, with a focus on improving resilience in vulnerable communities and transitioning to greener energy sources to combat both environmental and economic challenges.

GLOBAL MEASURES FOR CURBING AND MANAGEMENT OF CLIMATE CHANGE AND GLOBAL WARMING

Recent global developments in measures to curb climate change and global warming emphasize the urgent need for faster, more comprehensive action across multiple sectors. Key measures include:

Paris Agreement

The Paris Agreement remains the central framework for global climate action, with countries committing to limit global temperature rise to well below 2°C, and ideally to 1.5°C, compared to pre-industrial levels. However, recent assessments, such as the United Nations Framework Convention on Climate Change (UNFCCC) report, indicate that current national climate plans (Nationally Determined Contributions or NDCs) are not on track to achieve these temperature goals. Under current trajectories, global emissions are expected to rise by 9% by 2030, far above the required 45% reduction from 2010 levels (World Resources Institute, 2023) and (UN Press, 2023).

Technological Innovations and Energy Transitions

There has been a notable acceleration in renewable energy, particularly in solar and wind power, though the rate needs to increase substantially to meet the 2030 targets. Innovations in carbon capture technologies and carbon removal are also being emphasized as essential tools in achieving global net-zero emissions by 2050 (World Resources Institute, 2023).

Carbon Pricing and Fossil Fuel Phase-out

A significant challenge remains the global reliance on fossil fuels. The world needs to drastically phase out coal and other fossil fuels, with OECD countries aiming to complete this by 2030, and the rest of the world by 2040. Carbon pricing mechanisms, such as emissions trading systems and carbon taxes, are also being expanded to incentivize emission reductions (UN Press, 2023)

Deforestation and Land Use

Addressing land use, including reducing deforestation, is another priority. In 2022, deforestation rates slightly increased, highlighting the need for stronger action. The restoration of ecosystems and sustainable agriculture practices are key areas of focus to mitigate climate change impacts (World Resources Institute, 2023)

OVERVIEW OF CLIMATE CHANGE CHALLENGES

Climate change, driven by anthropogenic activities such as fossil fuel combustion, deforestation, and industrial emissions, has significantly altered global environmental patterns. Its impacts are diverse and far-reaching, including:

Rising Temperatures

The global average temperature has increased by approximately 1.1°C since the pre-industrial era, with projections suggesting further increases if emissions continue unabated (IPCC, 2021). This rise affects ecosystems, human health, and agricultural productivity.

Extreme Weather Events

Increased frequency and intensity of hurricanes, droughts, floods, and heatwaves disrupt natural and human systems (NASA, 2023). For instance, severe floods damage infrastructure and displace communities, while prolonged droughts lead to water scarcity and crop failures.

Rising Sea Levels

Thermal expansion and ice sheet melting have led to sea-level rise, threatening coastal ecosystems and human settlements (UNEP, 2022).

Biodiversity Loss

Changes in temperature and habitat conditions have led to species extinction and ecosystem disruption. Coral reefs, for example, are experiencing bleaching events due to warmer oceans (WWF, 2023).

These challenges underscore the urgent need for technological interventions to mitigate risks and enhance resilience.

METHODOLOGY

The methodology used to gather information for the study on "Engineering Technology in Adapting Climate Change and Global Warming for Environmental Sustainability" primarily involves a combination of qualitative review, case studies, and data analysis. These approaches are typically structured to provide a comprehensive understanding of the role of engineering technologies in addressing climate change challenges.

Qualitative Review

A thorough review of the existing literature is essential to establish a broad understanding of climate change impacts and the engineering technologies being

developed or implemented for adaptation. This includes reviewing peer-reviewed journal articles, conference papers, reports from governmental and non-governmental organizations, and technical documents on innovations in renewable energy, water management technologies, and resilient infrastructure. This review helps to identify trends, common themes, and the effectiveness of various technologies in different regions. Recent studies by authors such as Verbruggen et al. (2018) and Amadou et al. (2022) explore the advancements in sustainable engineering solutions.

Case Studies

Case studies of specific engineering technologies applied to climate change adaptation are integral to understanding their real-world applications and challenges. These case studies typically involve detailed examinations of pilot projects or large-scale implementations, such as renewable energy systems, water purification technologies, or green building practices. For example, research on solar energy deployment in rural Africa (Akinmoladun et al., 2021) and flood resilience infrastructure in coastal regions (Parker et al., 2020) provides insights into the practical challenges and successes of such technologies in mitigating the effects of climate change.

Data Analysis

Data-driven approaches are employed to analyze the effectiveness of engineering technologies in terms of energy efficiency, cost, and environmental impact. This may involve the collection and analysis of empirical data from monitoring projects, such as the use of data from smart grids or water resource management systems (Boccaletti et al., 2020). These data points can be used to measure key performance indicators like energy savings, greenhouse gas reduction, or improvements in water usage efficiency.

Analytical framework

Literature Survey

The most fundamental method for data collection in this field is conducting a systematic literature review. This involves gathering existing research from

academic journals, books, technical reports, and conference papers. Studies on climate change adaptation and engineering technologies, such as renewable energy systems, water management technologies, and resilient infrastructure, are reviewed. Sources like the *Journal of Cleaner Production* and *Renewable and Sustainable Energy Reviews* regularly publish research on sustainable engineering solutions (Verbruggen et al., 2018; Akinmoladun et al., 2021). This survey helps to understand the advancements, challenges, and gaps in the application of engineering technologies to climate change adaptation.

Expert Interviews

Interviews with engineers, climate scientists, policymakers, and stakeholders in relevant sectors provide valuable primary data. These experts can share insights on the real-world applications of engineering technologies, technological challenges, policy implications, and regional adaptation strategies. For instance, engaging with experts working in renewable energy (solar, wind, etc.), water resource management, or green building technologies can yield rich qualitative data. Studies by authors like Amadou et al. (2022) have utilized expert interviews to assess the implementation of climate adaptation strategies in different regions.

Field Studies

Field studies are crucial for gathering empirical data on the performance of engineering technologies in the context of climate change adaptation. This may involve visits to pilot projects, such as solar microgrids, water filtration systems, or flood defenses, to assess their real-world impact. These studies allow for firsthand data collection, such as energy consumption, cost-effectiveness, and environmental outcomes. For example, case studies on solar energy deployment in rural African communities (Akinmoladun et al., 2021) or urban water management technologies (Boccaletti et al., 2020) provide valuable insights into their effectiveness.

Data from Monitoring Systems

Many projects, particularly in renewable energy and smart infrastructure, collect data through monitoring systems that track key performance metrics, such as

energy generation, efficiency, and sustainability outcomes. Analyzing this data can provide quantitative insights into the success of engineering technologies in adapting to climate change. For example, smart grids, IoT-enabled water management systems, and environmental sensors provide real-time data for evaluating technology performance (Parker et al., 2020).

Surveys and Questionnaires

Collecting data from stakeholders through structured surveys and questionnaires helps gather broader opinions and experiences. These can be distributed to communities affected by climate change, local government officials, or industry players involved in sustainable infrastructure development. Surveys can be used to understand challenges, barriers, and support needed for scaling up climate adaptation technologies.

Economic and Engineeering Technology Practices for Mitigating and Adapting Climate Change and Global Warming in Nigeria

In Nigeria, both economic and engineering technology practices play significant roles in addressing climate change challenges.

Economic Practices

Economically, Nigeria has adopted market-based mechanisms like carbon pricing and emissions trading to incentivize lower emissions, particularly in industries such as oil and gas (World Bank, 2021). Investments in renewable energy sources like solar and wind power have been prioritized to diversify the energy sector and reduce reliance on fossil fuels. Programs supporting green job creation in areas like sustainable agriculture and forestry further contribute to economic resilience against climate impacts.

Involvement in Emission Trading (Carbon Market)

Nigeria is actively engaging in the carbon market as part of its strategy to mitigate climate change and promote sustainable economic growth. Key developments include:

Policy Framework

Nigeria has implemented the Nigeria Carbon Market Activation Policy (NCMAP), which aims to create a structured carbon market by 2030. This policy is expected to unlock carbon market potential worth between $736 million and $2.5 billion and create millions of green jobs. It also focuses on enhancing Nigeria's Nationally Determined Contributions (NDCs) under the Paris Agreement by incentivizing emission reductions and attracting both local and international investments (Nairametrics, 2024) and (PM News, 2024).

Institutional Support

The Federal Government has established committees and collaborations, including partnerships with the Africa Carbon Market Initiative and international bodies like the UNFCCC. These initiatives are designed to position Nigeria as a leader in carbon market development and facilitate projects aligned with global emissions trading standards (Nairametrics, 2024) and (Mondaq, 2024).

Regulatory Advances

Nigeria's climate strategies include mechanisms under Article 6 of the Paris Agreement, particularly Internationally Transferred Mitigation Outcomes (ITMOs). These frameworks are being integrated into Nigeria's governance, enabling the trading of carbon credits while aligning with national climate priorities (Mondaq, 2024) and (PM news, 2024).

Economic Goals

By fostering a transparent and efficient carbon market system, Nigeria aims to stimulate sustainable development, enhance industrial growth, and integrate private sector participation. The country's approach includes creating financial incentives for renewable energy projects, forestry initiatives, and other climate-friendly interventions (Nairametrics, 2024) and (Mondaq, 2024).

How Emission Trading is done

In an emissions trading system, participants may either receive an initial allocation of carbon credits free of charge or purchase them through auctions. These carbon

credits represent the right to emit a specific amount of carbon dioxide (CO_2). Companies that successfully reduce their emissions below their allocated credits can sell their surplus credits to other participants whose emissions exceed their allowances, effectively commoditizing carbon and creating a marketplace for emissions (UNFCCC, 2008). This trading mechanism provides flexibility for businesses to meet regulatory targets, with financial incentives for those that invest in cleaner practices and technologies (Schmalensee & Stavins, 2017).

Technological Adaptations

Engineering technologies offer innovative solutions to adapt to climate change and promote environmental sustainability. Key areas of development are provided as follows:

Innovations in Energy-efficient Infrastructure

Innovations in energy-efficient infrastructure, such as green building designs and smart grid technologies, help reduce the country's carbon footprint while conserving resources (IRENA, 2020). Additionally, the development of waste-to-energy plants allows Nigeria to turn urban and agricultural waste into renewable energy, decreasing landfill emissions and providing electricity. Water management technologies, such as improved irrigation systems and rainwater harvesting, also help Nigeria adapt to shifting rainfall patterns and manage water resources more sustainably (FAO, 2020). These combined approaches support Nigeria's ability to mitigate and adapt to climate change while fostering a more sustainable, climate-resilient economy.

Control of Exhausts and Fumes from Vehicles, Industrial Plants and Machines

Exhaust and fumes from vehicles, industrial plants and machines contribute substantial amount of carbon dioxide into the atmosphere especially vehicles that are not new (those not capable of exhibiting complete stoichiometric combustion). Only few Nigerians could afford to buy brand new vehicles and use for a short time. Nigeria has become a dumping ground of old vehicles and machines. Bearing in mind that the end product of the combustion is CO_2 which is the major gas responsible for greenhouse effects leading to depletion of the Ozone layer.

Engineering technology is going a long way in solving this problem of CO_2 production in the near future. Nigerians can as well take this gigantic stride.

Wastes Management through Environmental Engineering

Human activities, driven by the need for survival, have caused significant harm to both the environment and public health (Goodland, 1995). A major concern is wastewater, which arises from domestic, industrial, hospital, and agricultural sources (Tchobanoglous et al., 2004). Composed of 99% water and 1% solids, including fats, carbohydrates, and proteins, untreated wastewater fosters pathogenic microorganisms that pose health risks when consumed (Spellman, 2013). Unfortunately, centralized wastewater treatment plants are scarce in Nigeria, especially in rural areas, exacerbating hygiene challenges (Adewumi et al., 2010). While urban areas manage better, untreated wastewater remains a significant issue (Ogedengbe & Akinbile, 2004). Waste stabilization ponds, relying on natural processes, present a viable treatment solution in favorable climates (Mara, 2004). Additionally, wastewater sludge offers opportunities for resource recovery, including water, compost, fertilizers, and corrosion-resistant materials (Zurita et al., 2009).

Solid and hazardous waste management is another growing challenge, intensified by urbanization, industrialization, and population growth (UNEP, 2009). Unmanaged waste accumulates in urban centers, creating unsanitary conditions, where people often share space with animals at waste sites (Kaza et al., 2018). Open waste incineration worsens air pollution and visibility, leading to accidents (World Bank, 2022). However, transforming biodegradable waste into briquettes offers a sustainable alternative to firewood, reducing forest depletion and promoting a circular economy (Suleiman et al., 2020). Hygienic waste conversion not only mitigates environmental risks but also provides energy for other sectors, contributing to sustainable development (Hoornweg & Bhada-Tata, 2012)

New Innovations in Agricultural Practices

The agricultural sector is witnessing rapid advancements driven by technology, aimed at improving efficiency, sustainability, and resilience. Precision agriculture, which uses GPS, IoT sensors, and data analytics, enables farmers to monitor crop

health, soil conditions, and water levels in real-time, leading to increased yields and optimized resource use (Shamshiri et al., 2018). Vertical farming is another breakthrough, allowing crops to be grown in stacked layers indoors under controlled conditions, making it possible to grow food in urban areas with limited land (Benke & Tomkins, 2017). Furthermore, biotechnology innovations, including gene editing with CRISPR, are enabling the development of crops that are more resistant to pests, diseases, and climate extremes (Zhang et al., 2018).

In addition, regenerative agriculture, which focuses on soil health, biodiversity, and water cycles, is gaining attention as a sustainable alternative to traditional methods. Practices such as crop rotation, cover cropping, and minimal tillage help sequester carbon in the soil, promoting long-term agricultural productivity and environmental health (LaCanne & Lundgren, 2018). Drones are also being used for tasks like planting seeds, applying fertilizers, and monitoring crops, reducing labor costs and improving precision (Tsouros et al., 2019). Together, these innovations are transforming modern agriculture and contributing to food security.

Fossil Fuels Extraction, Processing and Delivery

The extraction, processing, and delivery of fossil fuels significantly contribute to environmental degradation. For instance, fossil fuel spillage during transport can contaminate water sources, causing substantial harm to aquatic and terrestrial life and contributing to the decline of certain species (Vaughan et al., 2014). This contamination is one of several factors leading to biodiversity loss as some animal and plant species face extinction due to polluted habitats and other environmental stresses (Pimm et al., 2014).

Additionally, fossil fuel production and combustion are major sources of pollution, including greenhouse gas (GHG) emissions, which contribute substantially to the greenhouse effect and global warming (IPCC, 2014). To address these adverse impacts, engineering technology plays a critical role. By implementing advanced technologies to control GHG formation in fossil fuel activities, the engineering field can help mitigate climate change. This includes innovations in carbon capture and storage (CCS) and other methods to reduce emissions, supporting efforts to adapt to global warming and its effects (Haszeldine, 2009).

Conclusion

These frameworks and tools are essential for evaluating engineering technologies aimed at adapting to climate change and global warming. They offer a comprehensive and systematic way of assessing not only the environmental impact but also the economic and social feasibility of these technologies. The integration of these frameworks enables decision-makers to choose the most suitable technologies for climate adaptation that are sustainable in the long term.

RECOMMENDATIONS

Scientists, engineers and technologists have an increasing challenge due to increasing population and human activities and they need to double up efforts in order to combat climate change and ensure environmental sustainability practices. Government should as well provide the necessary and needed support and funding in Research and Development (R and D). Any nation that disregards research or pursue of R and D is a dying nation.

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