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# The justice and policy implications of clean energy transition in Africa

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Despite the low local energy access rates, Africa is considered a key player in the global energy transition due to its large supply of fossil fuels and a large reserve of critical minerals essential for manufacturing renewable energy components in the energy sector and storage devices in the transportation and electronics sectors. But building a sustainable society at all levels across nations would only come when there exists a just and inclusive energy transition based on the idea of "leave no one behind". While many African countries have embarked on ambitious and transformative transition strategies, and many energy projects classified as "clean" have economic, environmental, and social implications that jeopardize the wellbeing of those already vulnerable to the impacts of climate change. This paper explores the policy implications of the just transition to ensure that efforts to steer Africa towards a lower carbon future are supported by fair, equity, and justice considerations. Our analyses provide valuable evidence for considering a just transition in Africa that will not exacerbate the current socio-economic challenges the region is facing but will support sustained poverty reduction and the achievement of faster economic growth. Our findings show that the African continent's multiple challenges of energy security, economic growth, and affordable access must feature in its clean energy transition. We draw conclusions that an incremental transition emphasizing low-carbon development is the most feasible and pragmatic approach to transform the region's economy and address climate change challenges.

KEYWORDS

**clean energy, just transition, energy justice, policy implications, economic development**

## 1 Introduction

The Global North, notably the European Union (EU), has been at the forefront of developing technologies and implementing policies to generate energy from renewable sources and mitigate climate change (Okpanachi et al., 102934), even though this transition has been progressing at varying rates among EU member states (Müller et al., 2021). But when we see the Global South, the actions on clean energy transitions vary highly from country to country, especially in Asia and Africa. Looking at Africa, although there is less information on "clean" energy transitions as well as actions than there is in the EU, the interest in this subject is developing both in academic and policy circles (Castán Broto et al., 2018), (International Renewable Energy Agency, 2019a). Initiatives for renewable energy policy have gotten a boost from pressure to promote technological innovation, competitiveness, and economic growth in

Africa concerns over greenhouse gas emissions, idealistic expectations of a post-fossil fuel future, and growing economic unpredictability in a post-COVID era. Similar to the EU, growth in Africa has been uneven, with different nations taking different political pathways and certain regions of the continent receiving less research attention than others. Although Africa's share of global investments in renewable energy development and installed capacity remains relatively small, the continent's recent robust economic growth and rapid population growth will require more energy resources to drive future development. In contrast to a projected 10% growth in worldwide energy consumption, it is predicted that by 2040, energy demand in Africa might be almost 30% more than it is today (Johnston, 2020).

During the COVID-19 pandemic lockdowns, energy demand in most African countries declined because of significantly reduced commercial and industrial electricity use (Johnston, 2020). However, while the economic impact of the pandemic was severe, the experience offers an opportunity for countries in Africa to make transformational changes and structural adjustments in how energy is generated and stored. The exacerbating impacts of climate change across the continent emphasize the need to transition from a fossil fuel-based, regional economy to one powered by clean energy. Africa is extremely vulnerable to the impacts of climate change because of its low adaptive capacity. Moreover, the continent is highly dependent on shrinking natural resources. Therefore, investing in clean energy will help African economies address the immediate consequences and long-term socio-economic impacts of the COVID-19 pandemic and the ongoing climate crisis.

Despite a historical and present contribution to carbon emissions below 3%, the continent's commitment to cutting emissions is admirable. However, Africa still confronts a unique challenge in gaining access to modern energy to meet its development objectives, including enhancing climate resilience (Renewable Energy Agency et al., 2021). Despite the fact that Africa is highly endowed with energy resources to supply both present and future demand, approximately 600 million people live without access to power on the continent. While several nations, notably Burundi and Chad, still only have access rates of 10% or less, South Africa and the nations that makeup Northern Africa have almost universal access to electricity (African Development Bank, 2022), (Carley and Konisky, 2020). This unequivocally underscores the need to focus on and customize initiatives to raise access rates in Africa. Additionally, the availability of power should not be seen as a stand-alone, binary signal because a poor, constrained, or expensive electrical supply may restrict its value. In order to meet its climate pledges, Africa must significantly increase its contemporary power generation and consumption in light of the continent's population, urbanization, and economic growth patterns.

Socio-cultural specificity that may undermine efforts regarding energy transition in Africa is the lack of awareness and understanding about the benefits of renewable energy sources. This is because many Africans still use traditional energy sources like wood, charcoal, and kerosene since they are both affordable and easily available (Simelane and Abdel-Rahman, 1243). As a result, people might not be willing to pay more for renewable energy options that are better for the environment. Furthermore, the lack of political will and leadership to promote and invest in renewable energy is another culturally distinctive aspect of this society. Meeting the short-term energy demands of their populations, many African governments care less about long-term sustainability (Simelane and Abdel-Rahman, 1243). Without strong leadership, getting financial and political backing for renewable energy initiatives can be challenging. Additionally, some African cultures may prioritize traditional energy production and consumption forms, such as using wood as a primary cooking fuel (Simelane and Abdel-Rahman, 1243). These cultural practices may be difficult to change, especially if they are deeply ingrained in the community.

Transforming Africa's energy sector will require technological advancements to reconcile economic growth with the conservation of natural resources. However, technical progress alone will not be sufficient to transition away from a conventional energy system; a strong political will, strategic planning, and a comprehensive policy fully utilizing renewable energy are also needed. Although the specific paths to a clean energy transition may differ, depending on the particular requirements of various nations and regions, all paths must be equitable and inclusive to help achieve the United Nations Sustainable Development Goals (SDGs) (S&P Global), (Hafner and Tagliapietra, 2020). A just and inclusive energy transition based on the idea of "leave no one behind" would improve individuals' wellbeing and health, boost resilience, and inspire innovation to achieve a sustainable society at all levels while spurring massive investment (Ceres Roadmap, 2030). This argument is based on the premise that proactively identifying and confronting obstacles can result in far better outcomes than those that can be resulted from doing nothing or waiting too long to act. Changing behaviors and a fair and just energy transition will require a negotiated vision and process centered on discussion and backed by a set of guiding principles (Eskom, 2022). The main objective of this work is to inform policymakers on the impacts of strategic decision-making in clean energy development. In this work, we analyze the just and policy implications of the clean energy transition in Africa, emphasizing the challenges hindering this transition, policy recommendations, and finally, the linkage between SDG and energy transition in Africa. Our analysis provides valuable evidence for considering a variety of policy interventions for a just energy transition in Africa.

## 2 Just and policy implications of clean energy transition

The transition to clean energy in Africa has important justice and policy implications that should be carefully considered to ensure that this transition's benefits and burdens are distributed fairly. Environmental justice is a key aspect of this transition, as it involves ensuring that all people, regardless of their socioeconomic status, race, or ethnicity, have the right to live in a healthy and safe environment (U.S. Environmental Protection Agency, 2021). Africa requires a just and equitable energy transition that enhances inclusion and synergies while reducing inequality and empowering people through modern energy access. A cost-effective, dependable, and sustainable energy system is crucial not only for lifting millions of Africans out of poverty; the transition must create new opportunities and strengthen the rights of the poor but also for enhancing climate resilience, enhancing climate preparedness, and minimizing climate vulnerability (African Development Bank, 2022), (García-García et al., 2020). The equity ramifications and difficulties brought on by energy poverty, low consumption, and the unmet energy demand for economic growth and transformation in Africa must be carefully considered for a just energy transition. In the context of the transition to clean energy in Africa, this means ensuring that marginalized

groups and vulnerable individuals are not disproportionately impacted by the transition and that their needs and perspectives are taken into account in the planning and implementation of clean energy projects.

There are a number of marginalized groups and vulnerable individuals in Africa who may be disproportionately impacted by the transition to clean energy. These groups include but are not limited to, indigenous communities, rural communities, and low-income households (United nations development). These groups may be particularly vulnerable to the impacts of climate change, as they often rely on natural resources for their livelihoods and may have limited capacity to adapt to changing conditions (World Bank Group, 2021). Additionally, these groups may face barriers to accessing clean energy technologies and may be less able to afford the upfront costs of transitioning to clean energy. As more countries in Africa formulate and implement clean energy policies, failing to integrate justice into the process often leads to inequalities, uneven cost-sharing, and negative impacts associated with clean energy projects (Carley and Konisky, 2020). Recent debates have focused on the adverse impact of the energy transition on individuals, communities, and countries across Africa. The impacts often take the form of an excessive burden or a lack of access to possibilities for the energy transition in terms of affordability and access and inequalities that arise despite the benefits of clean energy projects. This section provides a comprehensive overview of the status of the clean energy transition in Africa, indicating the challenges which hinder a just energy transition and, in addition, a plea for striking a balance between Africa's energy needs and international climate obligations and gives practical strategy and policy suggestions.

## 2.1 Russia–Ukraine war and energy security: A lesson for Africa

What is seen as just in one situation might be considered unfair in another? According to Hirsch et al. (Hirsch et al., 2017), it is more challenging to implement a just transition in countries that have weak social support systems and heavy reliance on fossil fuel production than it is in countries that have robust social support systems and diverse industrial bases (Zinecker et al., 2018). African clean energy transition should not only entail replacing fossil fuels with renewables but also developing new, efficient, and flexible power systems fed by renewable energy sources and decentralized (including off-grid) facilities to minimize conditions wherein high demand must be satisfied by fossil fuels. While Africa's energy investment needs are significant, the additional demands connected with a shift to low-carbon energy may be viewed as realistic and pragmatic. The Russia–Ukraine conflict has caused energy prices to skyrocket in the European Union (EU), which is heavily reliant on Russian oil, gas, and coal (Besson, 2022). Despite decarbonization regulations, fossil fuels still account for a significant portion of the EU's energy mix. Leaders in the clean energy transition now face a dilemma; for example, Germany relies on Russia for roughly half of its natural gas and coal and more than one-third of its oil. Germany's near-term action is to increase the use of coal-fired power plants. This shows that in Africa, which faces problems of economic development and growth, energy security and affordable access must feature in its clean energy transition. The most feasible and pragmatic solution for Africa will be an incremental transition emphasizing low-carbon development rather than net-zero pathways.

## 2.2 Oil and gas *versus* economic development

Africa's energy transition must be predicated on leveraging the enormous prospects for energy access, employment, and industrialization based on the continent's tremendous renewable energy resources (Songwe et al., 2022). With appropriate technological and financial assistance, Africa can revolutionize its economies and become a global leader in inclusive green energy growth using its abundant energy resources. Figure 1 compares Africa with the rest of the world in terms of fossil fuel consumption and the GDP of the world. This shows that higher fossil fuel use is associated with a higher GDP, implying that countries require greater energy use to industrialize. Hence, for a country to attain a certain level of industrial growth, some amount of dependence on oil and gas is currently required. However, the societal and economic damages caused by climate change mean that dependence on greenhouse gas-emitting energy sources must be strongly discouraged globally. North America and Europe, having attained the highest level of industrialization, must work to significantly reduce their dependence on fossil fuels. The clean energy revolution cannot be restricted to small, incremental changes; to create a livable future, these efforts must be transformational, involving a system redesign based on the swift upscaling and use of all available clean and carbon-reducing technologies (United Nation Organization, 2021).

For continents with lower rates of economic development, less energy security, less affordable access, and poorer environmental sustainability, a different approach is needed. For Africa, a step-by-step transition must involve adjustments to an energy system that will not disrupt how established social, political, and economic systems coexist.

## 2.3 Evidence-based decision-making

While many African countries have embarked on ambitious and transformative transition strategies targeting underserved communities, many energy projects classified as "clean" have economic, environmental, and social implications that jeopardize the wellbeing of groups most vulnerable to the impacts of climate change.

### 2.3.1 Gender-inclusive policies

Gender inequality in many communities in Africa limits opportunities for women to participate in policy- and decision-making, affecting clean energy development. The 2019 Africa Gender Index Report (Gender, 2020) says that senior decision-makers in African firms are primarily male, with an Africa Gender Index score of just 22.9 percent. Women are underrepresented in parliament (25.3 percent). Very few managers, professionals, and technicians in Africa are women (41.4 percent) (Gender, 2020). A just transition should address the inequalities between men and women, as well as indigenous and minority groups, in decision-making processes. Marginalized or minority groups should be included in different stages of clean energy transition projects by including them in decision-making bodies.

### 2.3.2 Human rights in the mining industry

Critical materials used in manufacturing batteries and solar energy technology, such as cobalt and copper, are mined in Africa.

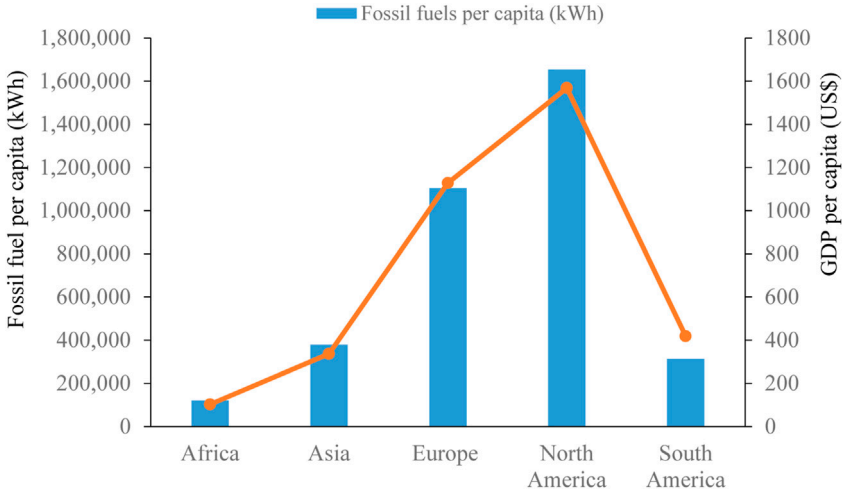


FIGURE 1
Fossil fuels *per capita* against GDP of the world (World Bank, 2022a), (Our World in Data, 2020).

More than 70 percent of the world's cobalt is produced in the Democratic Republic of the Congo (DRC), and 15–30 percent of Congolese cobalt is produced by artisanal and small-scale mining operations (Baumann-Pauly, 2022). A 2016 report from Amnesty International (Amnesty International, 2016) states that thousands of children mine cobalt in the DRC under hazardous conditions, and the DRC government and mining companies fail to protect mine workers from human rights abuses. A just energy transition requires a sustainable supply of critical materials produced in such a way that it respects the fundamental rights of miners and other workers.

### 2.3.3 Women, farmland, and energy transition

Women laborers are of vital importance to rural economies in Africa, providing 60–80 percent of the labor that supports African agriculture (Palacios-Lopez et al., 2017), (The World Bank, 2022). African women are known to live in poverty. According to (UN Women Data Hub, 2022), roughly 63 percent of the world's extremely poor women live in sub-Saharan Africa. While rural women play a critical role in Africa's economy, there have been multiple claims of women losing agricultural land to energy projects. For example, in Tanzania, there are claims that farmland was taken from a farmer in the coastal region to be used for a biofuel project (Makoye, 2013). If not managed well, these actions may increase the risk of food insecurity on the continent. Therefore, a just transition to clean energy must recognize the critical role rural women play and minimize their risk of losing access to agricultural land.

## 2.4 Strategies and policy Approaches for inclusive benefits

The transition to clean energy has the potential to bring numerous benefits to Africa, including improved access to electricity, increased economic opportunities, and reduced greenhouse gas emissions (International Renewable Energy Agency, 2019a). However, it is important to ensure that these benefits are distributed fairly, and that marginalized groups and vulnerable individuals are not left behind. In order to achieve this, a just and inclusive policy approach is needed. There are several key strategies that can be pursued to transition to clean energy in Africa.

- One of these is increasing the deployment of renewable energy technologies, such as solar panels and wind turbines, which can provide a source of electricity to communities that are not connected to the grid (International Renewable Energy Agency, 2019b). Renewable energy technologies can also create jobs and economic opportunities, particularly in rural areas, which can help to improve the livelihoods of marginalized communities.
- Promoting energy efficiency: Energy efficiency measures can help to reduce the overall demand for energy, which can in turn, reduce the need for fossil fuel generation. This can be achieved through a variety of means, such as implementing building codes and standards that require the use of energy-efficient appliances and equipment, providing incentives for the use of energy-efficient technologies, and promoting the adoption of energy-efficient behaviors.
- In addition to these strategies, it is also important to promote the use of clean cooking solutions in Africa. Traditional cooking methods, such as open fires and inefficient stoves, are a major source of air pollution and greenhouse gas emissions on the continent. Promoting the use of clean cooking solutions, such as improved stoves and clean fuels, can help to reduce these emissions and improve public health.
- Finally, it is important to support capacity building and technology transfer in Africa in order to fully transition to clean energy. Many countries on the continent lack the technical expertise and infrastructure needed to embrace clean energy technologies fully. Supporting capacity building and technology transfer can help build the necessary skills and infrastructure needed to support the clean energy sector's growth.

In order to effectively transition to clean energy and ensure that the benefits are distributed fairly, it is essential to adopt a just and

inclusive policy approach. This may involve implementing policies that support the deployment of clean energy technologies, such as feed-in tariffs or renewable energy targets, and implementing policies that support the needs of marginalized groups and vulnerable individuals, such as targeted support for low-income households to access clean energy technologies or training programs to help indigenous communities develop the skills needed to participate in the clean energy sector. By pursuing these strategies and adopting a just and inclusive policy approach, Africa can transition to clean energy and reap its numerous benefits.

## 3 Synergies between clean energy and sustainable development goals

The United Nations 2030 Agenda for Sustainable Development, also known as the Sustainable Development Goals (SDGs), is a global framework for achieving a better and more sustainable future for all. It aims to end poverty, protect the planet, and ensure peace and prosperity for all people, particularly those in developing countries (International Institute for Applied Systems Analysis, 2018). While the SDGs have the potential to address some of Africa's needs, they also have some limitations and challenges when it comes to fulfilling Africa's needs. One of the main criticisms of the SDGs is that they have an ethnocentric approach, projected by western countries, and do not adequately consider the specific needs and context of different regions and cultures (Cheever and Dernbach, 2015), (Matikainen, 2019). The goals and targets are often based on the values and priorities of the global north, rather than the realities and priorities of the global south. This can lead to a one-size-fits-all approach that does not adequately address the complex and diverse challenges facing Africa.

For example, the goal of universal access to electricity and modern energy sources is important for Africa, where many people still live without access to electricity. However, the goal does not adequately consider the specific energy needs and contexts of different countries in Africa (Matikainen, 2019). It does not consider the fact that some countries may have abundant renewable energy resources, such as solar or wind power, while others may rely more on fossil fuels or other non-renewable sources. The goal also does not consider the fact that some countries may have more developed infrastructure and capacity to implement renewable energy projects, while others may lack the necessary resources and capacity. Another example is the goal of achieving gender equality and empowering all women and girls. While this goal is important for Africa, where women and girls face numerous barriers to equality and empowerment, it does not adequately consider the specific cultural and social context of different countries in Africa (Security and Human Rights, 2017). It does not consider the fact that some cultures may have more traditional gender roles and expectations, which can be a barrier to women's empowerment. It also does not consider the fact that some countries may have more developed infrastructure and capacity to implement gender equality initiatives, while others may lack the necessary resources and capacity.

Despite these limitations, the SDGs can still be a useful framework for addressing Africa's needs, if they are implemented in a way that is sensitive to the specific context and needs of different countries in Africa. For example, the SDGs can be used as a roadmap for prioritizing and investing in key areas such as education, health, agriculture, and infrastructure (International Renewable Energy Agency, 2019a). These sectors are critical for Africa's development and have the potential to make a significant impact on people's lives and wellbeing. One way to ensure that the SDGs are more effective in addressing Africa's needs is to involve African stakeholders in the implementation process (International Renewable Energy Agency, 2019a), (International Institute for Applied Systems Analysis, 2018). This includes local communities, civil society organizations, governments, and the private sector. By involving these stakeholders in the planning and implementation of the SDGs, it is more likely that the goals and targets will be relevant and achievable in the African context. Another way to make the SDGs more effective in addressing Africa's needs is to ensure that they are aligned with other regional and national development frameworks and initiatives. For example, the African Union's Agenda 2063 (African Union Commission, 2022), which is a vision for Africa's development over the next 50 years, can be used to complement and support the implementation of the SDGs in Africa. By aligning the SDGs with Agenda 2063 and other regional and national development frameworks, it is more likely that the goals and targets will be relevant and achievable in the African context. We discuss eight of them in the context of a just transition to clean energy in Africa.

### 3.1 SDG #1: End poverty in all its forms everywhere

Increased power generation capacity can help eliminate poverty through many channels, and it is important to distinguish its macro- and micro-impacts (Lockwood and Pueyo, 20132013). Increased electric power capacity can indirectly reduce poverty at a macro level by promoting economic growth, as shown in Figure 2. The energy industry boosts economic growth in two ways. First, energy is a vital economic sector that provides jobs and creates value by producing, transmitting, and distributing energy across an economy (Alam et al., 2018). Second, the energy industry's effects spread throughout the economy. Energy is a necessary component in producing almost all goods and services in an economy and supports economic activity in all sectors. Electricity alone cannot provide all the conditions needed for economic growth; however, it is vital to meeting households' basic demands and supporting economic activity (Oda and Tsujita, 2011). Several factors, such as employment and productivity, health, and education, can explain the relationship between access to electricity and poverty alleviation. The most recent research on energy and poverty emphasizes the connection between the two (Khandker et al., 2012). Poverty limits access to power and energy consumption, restricting opportunities for education and economic growth; for example, often-prohibitive connection fees can prevent homes from connecting to the electricity grid (Golumbeanu and Barnes, 2013).

Of the approximately 39 percent of Cameroon's population living below the poverty line of $1.90 per day (Food and Agriculture Organization, 2019), most do not have access to clean, affordable energy; thus, people are forced to spend many hours covering big distances to gather firewood for cooking. Although access to electricity has gradually increased over the years, in 2016 only 60 percent of Cameroon's population had access to electricity, comprising only 21.3 percent in rural areas when compared with 92.0 percent in urban areas (The World Bank, 2020a). Reliability issues in

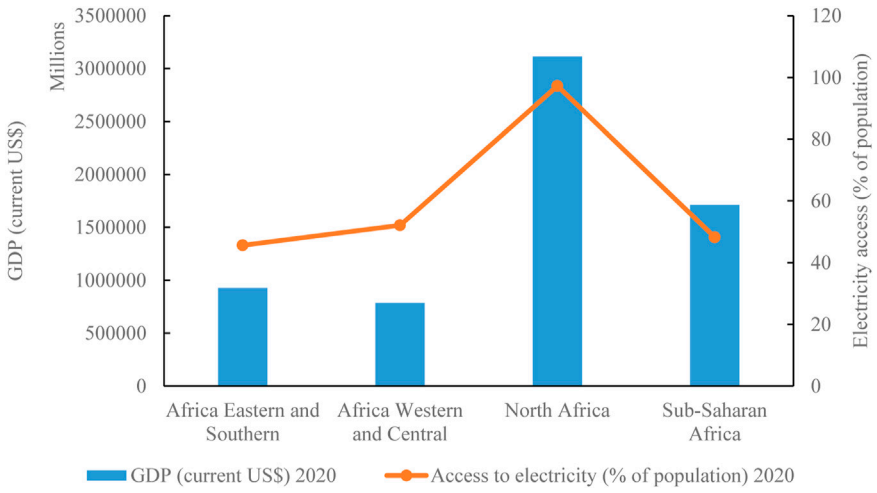


FIGURE 2
Access to Energy and GDP, Africa's context (The World Bank, 2021a), (The World Bank, 2021b).

Cameroon's electricity sector are severe. Thus, businesses and homes are without electricity for several hours each day and occasionally for several days. Access to electricity is essential for basic services, such as hospitals and schools, and the growth of small businesses at the household level (Alam et al., 2018).

Improving Cameroon's energy infrastructure will require proportionate expenditures as energy demand rises. Investments in the energy sector will increasingly need to focus on renewable energy so that the country can avoid being locked into unsustainable energy systems in the face of climate change and realize the potential benefits clean energy offers. According to Qudrat-Ullah et al. (Qudrat-Ullah and Nevo, 2021), a 1 percent increase in renewable energy consumption is predicted to result in short-term growth of 0.7 percent and strong long-term growth of 1.9 percent in Africa (Qudrat-Ullah and Nevo, 2021). Cameroon has abundant renewable energy resources, and deploying renewable energy systems through microgrids could significantly increase household incomes *via* job creation. According to (Wei et al., 2010), expanding a renewable energy infrastructure can create many jobs, including construction, installation, and operations, and supports other economic activities that produce job opportunities. For example, during the construction phase of the Memve'ele and Nachtigal hydropower plants, 10,000 and 1,500 jobs were created, respectively (Nachtigal Hydro Power Company, 2017), (Wikipedia, 2022). This increased the wealth of households in those communities. In addition, people may increase their working hours, diversify their sources of income, and even switch to jobs that are more productive. This is because of the increased amount of time they can spend with the lights on. Furthermore (Dinkelman, 2011), discovered many benefits of electricity availability on women's employment, likely because of a reduction in time spent performing housekeeping chores, freeing women to pursue paying jobs. Energy is a crucial input in producing goods and services across the agricultural, industrial, and service sectors. It is needed to improve irrigation systems and mechanize farms, which increases agricultural output, which, in turn, provides more income and food security for millions of households and increases agricultural exports, thereby reducing poverty. Growth in these industries requires a greater supply of energy, which can be achieved through the deployment of renewable technologies.

## 3.2 SDG #2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture

Climate change and expanding populations may significantly affect agricultural output and the agriculture sector's environmental impact, particularly concerning irrigated agriculture, which produces nearly 40 percent of the world's food on just 18 percent of its cropland. Because of changes in rainfall patterns, hydrological regimes, and weather patterns, as well as an increased reliance on land and water resources, rain-fed food production systems will also experience significant strain, further degrading available resources and reducing productivity. According to (Schwerhoff and Sy, 2017), food production is most vulnerable in Africa. One reason is that much of Africa's crop production depends on rain, and changes in climate and precipitation have a direct impact on crop output. Long-lasting droughts and intense rainstorms can drastically alter water supplies and exacerbate risks already present in agriculture. Crop production relies on energy inputs to provide even the most basic food output. Depending on a country's degree of development, on-farm food production consumes two to five percent of commercial energy (Khan and Hanjra, 2009). Similarly, a good deal of energy is used to transport raw materials to processing facilities where they are frozen, canned, dried, ground, baked, and undergo other processes. The dependence of the world's food systems on energy is further highlighted by the food processing and agricultural support businesses probably already requiring more energy than farming itself.

According to (Food and Agriculture Organization, 2013), total food losses in sub-Saharan Africa are estimated at $4 billion annually, an amount that could feed 48 million people. Hunger is predicted to increase due to adverse effects of climate change, such as drought, high temperatures, and increased pest attacks, on crops. This is likely to reduce agricultural productivity, increase food prices, and severely

increase famine among vulnerable groups, especially in rural areas. According to Morel et al. (Morel, Mungai), the agriculture sector employs approximately 28 percent of Gambia's working population, and approximately 80 percent of the country's rural households are, in one way or another, employed in the agricultural sector. Unfortunately, Gambia's agriculture is threatened by climate change, the agriculture sector has been underperforming compared to the rest of the economy, and its contribution to the country's GDP has been decreasing. Specifically, the agricultural sector's share of GDP decreased from 29% in 2010% to 16.9% in 2017. This will, in turn, increase the country's undernourished population.

Increased usage of renewable energy technology and customized energy systems reduces the percentage of the population that is undernourished by improving agricultural production, helping to ensure food security and end hunger (The World Bank, 2020b). Most farmers in sub-Saharan Africa still water their gardens and farms using labor-intensive bucket-lifting techniques, which is particularly hard for women, who do most of the labor (Morel, Mungai). Solar-powered irrigation systems and water pumps would help farmers maintain and increase their yields in areas affected by drought. Some irrigation and water pumping technologies have significant potential to ensure food supplies throughout the year and generate additional household income (Karekezi et al., 2005). An increase in household income helps ensure regular access to food. In addition, solar-powered meteorological stations could be built in rural areas to provide data that can guide farmers on planting and irrigation dates.

Customized energy systems can also help combat hunger by reducing post-harvest losses, Gambia wastes a lot of food due to a lack of transport and storage facilities. According to (Jallow et al., 2020), more than 45 percent of composted waste in Gambia comes from food waste. Losses of cereals due to poor handling are high and are likely greater for perishable products. The impact of high post-harvest losses on the poor is twofold. First, it implies that available food is less nutritious than the perishables that are wasted, leaving the poor undernourished. Second, post-harvest losses equate to lost potential income. Therefore, developing solar-powered grain silos and ovens to store excess food produced during farming seasons could reduce food waste and increase food security. Furthermore, the need for energy to process food would add value and thus increase household incomes.

## 3.3 U.N. SDG #3: Ensure healthy lives and promote wellbeing for all

Living without stable energy reduces options for education and employment, compromising health and overall wellbeing. The lack of energy impacts the ability of healthcare facilities to serve patients, affecting lighting, heating, ventilation, and cooling systems, blood banking, storage of vaccines and other medications, and information and communication technology (ICT) services, limiting the availability of life-saving care. Businesses cannot operate, transportation networks cannot run, and homes and workplaces cannot be heated and cooled to comfortable temperatures without reliable electricity. Around 2.4 billion people, the majority of whom reside in low- and middle-income countries, still cook over open fires and inefficient stoves that burn solid fuels (including wood, crop wastes, charcoal, coal, and dung) and kerosene (World Health Organization, 1748). These inefficient cooking methods contribute significantly to indoor air pollution, including tiny soot particles that can get deep into the lungs. Indoor smoke in poorly ventilated homes can produce levels of fine particles that can be 100 times greater than what is considered safe. Women and young children spend the most time close to a domestic stove or fireplace and are therefore at the greatest risk for exposure. Each year, respiratory illnesses, such as pneumonia, linked to exposure to indoor and outdoor air pollution kill almost 600,000 children under the age of five (World Health Organization, 2016). Most of these households' energy services are purchased and utilized by women and girls, who suffer the brunt of the health hazards and other costs associated with the usage of unclean and inefficient home energy systems.

Nigeria's industrial sector is still growing, and ambient air pollution has not yet reached harmful levels; however, household air pollution (HAP) is the highest contributor to ambient air pollution. According to Ifegbesan et al. (Ifegbesan et al., 2016), nearly 81 percent of homes in rural regions rely on solid fuel—primarily firewood—kerosene, and liquefied petroleum gas (LPG) for cooking. Biomass fuel (BMF) used for cooking and space heating is one of Nigeria's biggest sources of ambient air pollution and has contributed to an estimated 114,100 early deaths in the country [1]. Several studies (Ifegbesan et al., 2016) show that people who use biomass fuels are more likely to develop respiratory morbidity and chronic obstructive pulmonary disorders.

Providing access to high-quality healthcare and fulfilling the SDGs requires consistent access to reliable electricity. In most African countries, more than half of all healthcare institutions lack access to reliable electricity or do not have any electricity at all. Reliable energy is essential for healthcare institutions to operate at night, pump water, store vaccines and other medicines, and manage hazardous waste. The health of hundreds of millions of people, particularly women and children who frequently suffer from inadequate primary healthcare, is at risk due to the lack of sufficient and dependable power. More than 289,000 women worldwide die each year due to difficulties associated with pregnancy and childbirth; many of these deaths could be avoided with improved lighting and other electricity-dependent medical services (Porcaro, 2019). Therefore, access to dependable electricity can greatly impact people's health and wellbeing, especially in terms of reproductive and children's health. Increasing access to reliable electric power through renewable energy technologies could increase access to safe drinking water, provide clean power for heating and cooking that would reduce indoor pollution, and provide a variety of communication tools (such as radio, television, and the Internet) that can significantly impact efforts to provide healthcare and combat diseases. Without a reliable source of light and power, doctors are unable to perform medical procedures or assess patients at night. Access to reliable power would improve the ability to provide labor and delivery services—thereby reducing deaths associated with childbirth—make vaccines more widely available through refrigeration; and support critical medical equipment in health clinics.

1 "2019_nigeria". State of Global air 2019. Health Effects Institute.

## 3.4 SDG #4: Ensure inclusive and equitable quality education and promote lifelong learning for all

Energy poverty is a challenge faced by both students and teachers across sub-Saharan Africa, at home and in school. According to (United Nations Educational Scientific and Cultural Organization, 2022), more than 25 percent of schools in rural areas have access to electricity in India, while approximately 90 percent of pupils in sub-Saharan Africa attend educational institutions that lack electricity. Approximately 190 million students in Cameroon, Nigeria, Liberia, South Sudan, Central African Republic, Chad, Sierra Leone, and Malawi (Lindeman, 2022) combined attend schools that do not have electricity. The inability to access reliable electricity severely limits teachers' and students' ability to access and use instructional supplies and classroom materials, directly contributing to significant barriers that prevent people from achieving escape velocity from the clutches of poverty.

Access to electricity supports education by improving household incomes, which directly affects a family's ability to afford tuition. In 2010, 11.4 million pupils repeated a primary grade in sub-Saharan Africa, representing more than one-third of the global total (United Nations Educational Scientific and Cultural Organization, 2022). In Rwanda, for example, a lack of reliable electricity has been a major barrier to education. Many schools in rural areas do not have access to electricity, which limits the ability of teachers to use instructional materials and technology. This has led to lower enrollment and retention rates, as students may be unable to afford tuition or may be discouraged from attending school due to a lack of resources. In addition, the lack of electricity can make it difficult for schools to offer vocational training and other specialized classes that require lab equipment or other resources. The government of Rwanda has enforced regulatory and legal reforms to attract private investors and operators into isolated or standalone grid facilities like isolated grids operated by Virunga SARL, which was founded by the Virunga National park's Virunga Foundation, and received donor funding to build and operate mini-grids Mutwanga powered by two HPPs of 0.38 and 1.35 MW respectively, and a 13.1 MW HPP at Matebe serving 5,520 customers (World Bank Group, 2022). This has greatly increased access to electricity in various regions and has also encouraged school enrollment for youngsters as ICT and other lab equipment are being introduced in education. The benefits of increasing access to electricity in schools also include the ability to use a variety of ICT technologies, such as computers and the Internet, which are critical to fully participating in modern society. It also provides better staff retention and teacher training and generally increases school performance as students are more motivated to learn, which reduces truancy and absenteeism.

## 3.5 SDG #6: Access to clean water and sustainable sanitation practices

Access to clean water and sustainable sanitation practices is a critical development challenge in many African countries, as a lack of access to these basic services can have serious consequences for public health, economic development, and food security. Coupled with the impact of climate change, this means that roughly 771 million people in the world lack access to clean water (Project World Impact, 2022). Particularly in sub-Saharan Africa, access to clean water requires financing, transportation, and even physical labor. The inability to efficiently meet the growing water demand can lead to food insecurity (Mehta et al., 2015). Mitigating the global challenge of providing access to clean water requires a sustainable energy approach, particularly in rural areas of the country where most households lack access to clean water. According to (Food and Agriculture Organization, 2017), agricultural production will increase by 60 percent, causing the demand for water for irrigation to increase to about 11 percent. In this context, it is important to consider the role of renewable energy technologies and sustainable sanitation practices in addressing these challenges and in improving access to clean water and sanitation for all. One example of a country in Africa that is addressing the challenge of water access and management through the use of renewable energy technologies is Senegal. According to the African Ministers' Council on Water (AMCOW), approximately 84% of the Senegalese population has access to improved drinking water sources, but access is still limited in some rural areas (Weltbank, 2011). To address this challenge, the Senegalese government has implemented a number of initiatives to increase access to clean water, including the deployment of solar-powered water pumping systems in rural areas (International Renewable Energy Agency, 2019b). These systems can help to increase the availability of water for agricultural and domestic use and can help to reduce the reliance on fossil fuels, which can be expensive and environmentally damaging.

Another example can be seen in Tanzania, where the Tanzanian government has implemented water conservation and management strategies to conserve and manage water resources more effectively, including through the use of rainwater harvesting and efficient irrigation systems (Bank, 2017). These systems can help to increase the availability of water for agricultural and domestic use and can help to reduce the reliance on fossil fuels, which can be expensive and environmentally damaging. Addressing the challenge of providing access to clean water and sustainable sanitation practices in Africa requires a holistic and integrated approach that considers the role of clean energy, sustainable sanitation practices, and community engagement and education. By addressing these issues together, it is possible to improve water quality and availability and reduce food insecurity and other development challenges.

## 3.6 SDG #8: Promote inclusive and sustainable economic growth, employment, and decent work for all

Energy is an indispensable force driving all economic activity (Alam, 2006). Reliable energy could increase production capacity globally, fostering greater economic growth. Although there is no one way "when energy is scarce, it imposes a strong constraint on the growth of the economy, but when energy is abundant, its effect on economic growth is much reduced" (Stern, 2011). The lack of reliable electricity makes it impossible for many industries to reach production capacity. Almost 80 percent of industrial enterprises in Cameroon face output losses ranging from 16 to 50 percent due to power outages. It was reported in (Tei Mensah, 2016) that a 1-percent increase in power outage reduces production in Cameroon by 0.6–1.1 percent. According to the country's national electricity demand forecast (MINEE, 2030), electricity consumption in Cameroon will double by 2030, and the Ministry of Economy, Planning, and Regional

Development reports that power outages would reduce Cameroon's GDP by 5 percent. Therefore, responding to the urgent need for energy is a sustainable way to stimulate economic growth through industrial production. Since energy is needed across all sectors of an economy to support growth, its productive use is a critical facilitator of income-generating activities. While access to electricity is not the only factor affecting economic growth, studies suggest that power usage and GDP tend to be related, as shown in Figure 2, and access to electricity is expected to be a major facilitator of economic growth.

Similarly, in Burundi, access to electricity has also been a major challenge for economic development. According to International Renewable Energy Agency (IRENA) ("ENERGY PROFILEa), only about 11.7% of the population had access to electricity in 2020. This has had a significant impact on the country's economic growth, as many businesses and industries are unable to operate at full capacity due to the lack of reliable power. The government of Burundi has made efforts to increase access to electricity through initiatives such as the Decentralized Rural Electrification Strategy (2015–2017) (The World Bank, 2019), which aims to optimize the social effect of distributed renewable energy while addressing issues at the individual, institutional, and policy levels. One major goal is to facilitate the transfer of knowledge, expertise, and techniques from academic and research institutions to businesses and community organizations, allowing their members to better serve the needs of rural youth and families. The energy value chain is a significant source of job opportunities. A just energy transition would use people with various skill sets, degrees of expertise, and backgrounds. Africa's economic development rate in 2013 was insufficient to guarantee sufficient job opportunities for its fast-growing population (International Labour Organization, 2013). However, the International Renewable Energy Agency (IRENA) shows that the renewable energy sector might provide up to 30 million jobs by 2030 (up from 11 million in 2018) and up to 42 million jobs by 2050.

## 3.7 SDG #9: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation

Over the past 2 decades, electricity has been crucial to industrial expansion, gaining priority for economic development among academic researchers and decision-makers (Abbasi et al., 2022). To prosper economically, a country needs a strong industrial base, and countries with a strong industrial sector have experienced relatively high economic growth in the past. Encouraging sustainable and effective use of natural assets can be greatly aided by creating new, greener facilities, retrofitting or reconfiguring existing infrastructure systems, and making good use of smart technologies.

Effective, sustainable industrial and innovation strategies must be accompanied by reliable energy policies and planning (United Nations Industrial Development Organization, 1984). Indeed, a country's industrialization is determined by its rational and efficient use of energy (Armel et al., 2015). In 2010, 43.5 percent of the electricity produced in Cameroon was consumed in the industrial sector when compared with 23 percent and 19 percent in the residential and public sectors, respectively (Modeste et al., 2015). This indicates that energy is a key input to industrialization. Furthermore, energy is needed to foster innovation as testing and scaling new technology requires energy. A system to regulate energy use is needed in order to allow technology start-ups to test concepts, models, and theories that help promote innovation. Energy's key role in industrialization is the basis for the highest projection of energy consumption in Africa, as shown in Figure 3.

An example of the importance of energy access in fostering industrialization in Africa can be seen in Ethiopia, which has made significant progress in expanding its electricity generation capacity in recent years. In 2015, the country launched its Growth and Transformation Plan (GTP), which included a goal of increasing electricity generation capacity from 2.8 to 4.9 GW by 2020 ("ENERGY PROFILEb). To achieve this goal, the government implemented a number of initiatives, including the construction of large hydroelectric dams, the expansion of solar and wind power generation, and the development of geothermal energy sources. The results of these efforts have been impressive. By 2019, Ethiopia had exceeded its GTP target, reaching a generation capacity of over 4.6 GW ("ENERGY PROFILEb). This expansion of electricity access has had a significant impact on the country's industrial sector, with a number of new factories and industrial parks being established in areas that previously had limited or no access to electricity. One such example is the Hawassa Industrial Park, which was established in 2016 with the support of the Ethiopian government and international investors (World Bank, 2022b). Located in the southern region of the country, the park has attracted a number of major international companies, including H&M, PVH, and the Chinese textile firm Zhongtai. These companies have been attracted to the park due to its low-cost labor, favorable investment climate, and access to reliable electricity. As a result, the park has become a major contributor to Ethiopia's economic growth and development, generating over $500 million in exports in its first 3 years of operation. Similarly, in Ghana, access to electricity has been a key factor in the country's industrialization efforts. The government has implemented a number of initiatives to increase access to electricity, including the construction 17 MW solar farm. Because of this initiative, more Ghanaians now have access to power, which has spawned the establishment of Meridian Industrial Park, which is home to around 68 businesses and directly supports the employment of 7,000 people in Ghana (BFT Online, 2021).

In conclusion, the relationship between energy access and industrialization in Africa is clear. Access to reliable, renewable energy is an important factor in enabling industrialization and fostering innovation in African countries. Through the implementation of initiatives to increase access to electricity and the promotion of renewable energy sources, African countries can create the conditions necessary for economic growth and prosperity. Countries that have made significant progress in expanding their electricity generation capacity often experience significant economic growth and development. Furthermore, access to reliable, renewable electricity helps to build a healthier, better-educated population that can support various industries and innovate. By promoting access to education and better healthcare, countries can build a more resilient infrastructure that is better equipped to support industrialization and innovation. Overall, it is important for African countries to prioritize the expansion of their energy generation capacity and the promotion of renewable energy sources in order to create the conditions necessary for economic growth and prosperity.

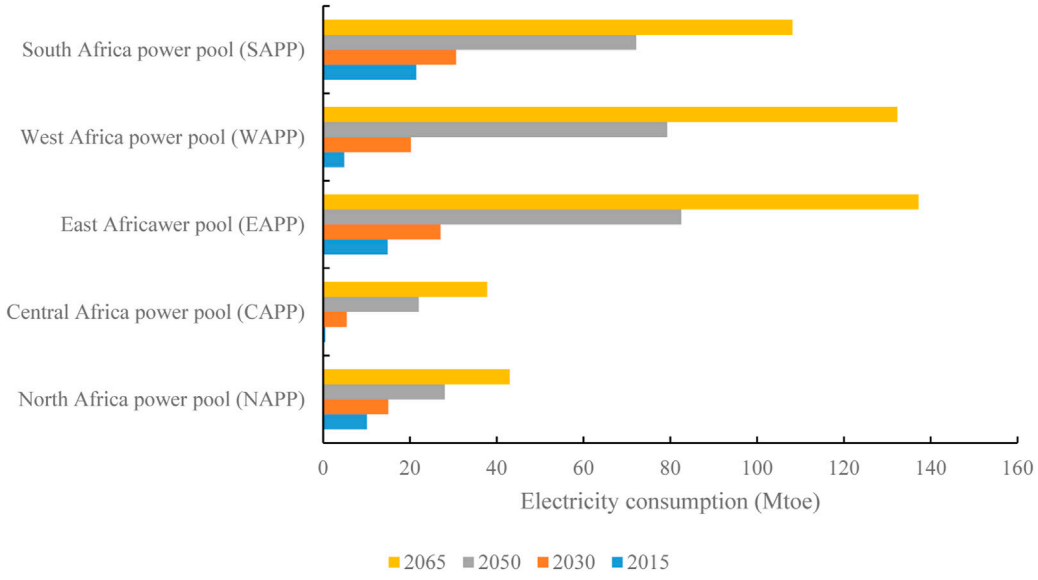


FIGURE 3
Projection of energy consumption in Africa—highest scenario (Pappis et al., 2019).

## 3.8 SDG #13: Take urgent action to combat climate change and its impacts

Rapid temperature increases in Europe, the United States, and other regions of the world are evidence that the consequences of climate change are being felt all across the globe. As a result, reducing emissions of greenhouse gases has become an urgent global concern. In order to reduce emissions, electrification is recommended by IRENA (Simelane and Abdel-Rahman, 1243); however, this strategy cannot stand alone and must be linked with renewable energy production. It is critical for African nations to translate RE policy into implementation change in light of the fact that many industrialized nations have set objectives for the total integration of renewable energy systems into their respective grid networks. Reducing greenhouse gas emissions is essential to decreasing the rate of global warming, which makes combating climate change and its effects an important worldwide concern. Many developed countries have set targets for fully incorporating renewable energy systems into their grid networks; for Africa to make a meaningful contribution to international efforts to mitigate climate change, it must do the same. Morocco is an example of an African country that is working to cut emissions and expand its usage of renewable energy. Morocco plans to generate 52% of its power from renewable sources by 2030 (Simelane and Abdel-Rahman, 1243), as stated by the International Renewable Energy Agency (IRENA). The government of Morocco has undertaken a variety of programs to this end, such as the construction of large-scale solar and wind projects and the installation of decentralized renewable energy systems in rural communities (Simelane and Abdel-Rahman, 1243). In addition to lowering its carbon footprint, Morocco is strengthening its energy independence and decreasing its dependence on fossil fuels by boosting the use of renewable energy sources.

Similarly, Nigeria relies on fossil fuels for its electricity needs. To a large extent, Nigeria did not begin tapping its renewable resource potentials until quite recently. As a result, Nigeria would have a more difficult time meeting its 2020 and 2030 renewable energy targets than will several other ECOWAS Member States. One-sixth of Nigeria's electricity supply is expected to come from renewables by 2030, under the country's National Renewable Energy and Energy Efficiency Policy 2015 (ICREEE, 2015). Although there has been a rise in the use of renewable energy in recent years, significant increases in deployment over the next decade will be necessary to reach the target. The Energy Commission of Nigeria (ECN) released a draft analysis and modeling in 2012 demonstrating how to achieve the 16% renewables aim by 2030 as part of the Nigerian Renewable Energy Roadmap (ICREEE, 2015). Insight into the document's meaning is provided by these findings. Small hydropower (7.07%), solar (5.90%), biomass (2.78%), and wind (0.25%) all make up less than 5% of total electricity consumption. Hence it is possible to meet the goal of delivering 16% renewable energy by 2030 with domestic activity. These percentages are not a limit on Nigeria's ambition but rather a depiction of how the country may achieve its 16% renewable energy goal. Changes in the energy industry and advances in technology mean that the relative importance of different industries may shift over time. Nigeria is committed to meeting its renewable energy goals, and the federal government is putting in place the framework and launching the necessary programs to make that happen.

Another example is Egypt as it plans to use renewable energy sources more extensively and lessen its dependency on fossil fuels. Hydropower accounted for 2.8 GW of the country's built renewable energy capacity in 2020, while solar and wind energy each accounted for around 0.9 GW (Renewable Energy Agency, 2018). The ISES to 2035 reports that Egypt's government has set lofty goals to expand the share of renewable energy in the country's electrical mix, with the objective of 20% by 2022% and 42% by 2035 (Renewable Energy Agency, 2018). The Egyptian government has established a feed-in tariff program, established a national renewable energy fund, and developed large-scale renewable energy projects like solar and wind farms in order to meet these objectives.

## 4 Conclusion

This study highlighted the importance of a just and inclusive transition in the move towards clean energy in Africa. Achieving a just energy transition in Africa requires a comprehensive policy framework that ensures that the most vulnerable and marginalized groups are not left behind. This includes considering the needs and perspectives of countries that currently rely heavily on fossil fuels, as a complete transformation from fossil-based energy production and consumption systems to renewable energy sources could create economic hardship. To overcome the multiple challenges faced by Africa and create economic, environmental, and social benefits for marginalized groups and vulnerable individuals, it is essential that the global and local challenges of energy security, economic growth, and affordable access are considered in the clean energy transition. This includes addressing the issue of climate change and formulating and implementing inclusive policies that do not jeopardize the wellbeing of groups most vulnerable to its impacts.

To ensure that efforts to transition to clean energy are effective and sustainable, it is important for policymakers to base their decisions on evidence and the experiences of individuals and communities. This requires a thorough understanding of the socio-economic conditions of the African continent and the specific needs and challenges faced by different countries and regions. In order to effectively address the global issue of climate change and the local environmental problems faced by Africa, a planned energy transition strategy must take into account the current socio-economic conditions of the continent and the specific needs and perspectives of countries that depend mainly on fossil fuels. This will ensure that the transition to clean energy is equitable and inclusive, and that it benefits all members of society. In summary, it is clear that the transition to clean energy in Africa requires a comprehensive and inclusive approach that considers the needs and perspectives of all stakeholders, including marginalized groups and vulnerable individuals. By ensuring that this transition is just and equitable, it is possible to create economic, environmental, and social benefits for all members of society.

## Author contributions

Conceptualization was by BK and data collection was done by NS, AY, DC, and NK. Writing of original draft was done by all the authors. Supervision and review was done by J-SH. All the authors have read the final version of the manuscript submitted to the journal.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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