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The Challenges and Opportunities of Energy Transition across Africa

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Authors' contributions

This work was carried out in collaboration among all authors. Author NSC designed the study, performed the analysis, wrote the protocol and wrote the first draft of the manuscript of this work. Authors APU and OBU verified the research methods. Authors ENI and EKC contributed to the to the interpretation of the results. Authors NSC and OPC supervised the findings. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The provision of energy infrastructure is essential for economic growth, social cohesion, and environmental sustainability. This paper served to evaluate the challenges associated with energy development and transition across the African continent and proffer opportunities for sustainable transition. Extensive use of documents, official data and statistics on different aspects of the African

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society was employed for this study. Exploratory documentary research materials, extant literature, publications, journals and articles on the current status of energy generation and delivery in Africa, the concept of renewable energy pathways, the need for energy transitions and the major strategies in place in Africa and around the world were important study areas for this work. Exploratory research method and systematic review approach were used to study the energy transition techniques, challenges and opportunities across Africa. Important research points were the concept of renewable energy pathways, the need for energy transitions, the major strategies in place in Africa and around the world to meet with the zero-carbon emission strategies of 2050, the future directions in energy provision—renewable energy development, economic diversification and energy-efficiency in Africa and the effects of energy transition on the social, political, economic and cultural spheres across Africa. Results obtained showed that energy transition in Africa is rapidly growing, though differently across the region, following huge investments made into the renewable energy sector, legislations and policies on the fossil fuel usage and carbon emission and introduction of better and more efficient systems. Nevertheless, the challenges reported in this studying plaguing the African energy transition come in five spheres: social, political, economic, technological and cultural. These challenges seem to be ancient, ubiquitous and multidimensional. Harnessing the opportunities in renewable energy will surely boost the economy of the different case study countries. A willing socio-political disposition towards renewable energy sources, increased investment plan for cleaner energy, reduced emphasis on fossil fuels and private-public sector collaboration will surely be giant steps to tapping into the numerous benefits of renewable energy sources. Energy transition in African countries can only be achieved under the auspices of a strong political will, social drive, cultural motivation and technological inclination towards a sustainable transition to cleaner renewable energy sources and less focus on fossil fuels.

Keywords: Sustainability; energy transition; renewable energy; energy security; energy access; fossil fuels; petroleum industry; Africa.

1. INTRODUCTION

1.1 Background of Study

The economic development of any country is dependent on the availability of energy. Energy is integral to every activity, whether domestic, industrial or large scale uses [1]. Despite the need for energy, about 1.2 billion persons around the world have no access to modern energy sources of energy such as electricity and further 3 billion people still rely on old-style energy sources of wood and charcoal (traditional biomass) for their domestic energy requirement [2]. Despite the heavy energy endowment, including conventional and unconventional resources, present in Africa, a lot have not been tapped. Due to the untapped energy resources, the continent is faced with numerous energy challenges ranging from low rates of electrification and the weighty dependence on conventional but outdated and inefficient energy sources [3].

Energy transition, therefore requires the movement or reduced dependence on conventional fossil fuel sources of energy to meet energy requirements [4]. Globally, a large percentage of our energy demands are met by fossil fuels sources of coal, crude oil and natural gas. Why then the need for energy transition? Cherp, Jewell and Goldthau [5] pointed out the limited reserves of these fossil fuels and their contribution to environmental degradation. How then do we drive this transition? The uniqueness in the energy transition is that it is policy-driven. Markets cannot provide platforms for these transitions as they are fossil-fuel driven themselves which is less costly, hence adding to greenhouse gas emissions. Therefore, the need to understand how policies, policy makers and implementations play the biggest roles in energy transitions in political economies is important [6].

At present, the climate concerns have influenced a lot of political leaders of different economies to tilt towards the zero-carbon emission campaign of 2050 and reduce dependence on fossil fuel energy sources. According to the International Renewable Energy Agency (IRENA), energy transition is defined as *"… a pathway toward a transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century (2050)*" [7]. Therefore, IRENA prioritizes the need to tackle the challenges of climate changes. This will be achieved through strategies and systems to reduce CO_2 emissions from fossil fuel energy sources, improve interests and investments in renewable energy sources as well as measures that are energy-efficient to help reduce the need for the reliance on the energy from fossil fuels.

The definition by IRENA is widely accepted by scholars and international bodies. The big question is whether the need for renewable energy transition by global economies will render Africa’s huge deposit of fossil fuel energy sources useless? To bridge the divide, Bridge et al. [8] asserted that such discussions on energy transitions will have to take into consideration the availability of these resources, their affordability of these resources, the reliability, efficiency, sustainability, and the costs of obtaining energy carriers. Furthermore, Bridge et al. [8] opined that social, cultural and economies lines/discrepancies as it relates to energy transition should also be considered very carefully as different countries face different energy challenges.

The pursuit of sustainable energy is strongly associated with political will and the necessary socio-economic structure, which differs across the regions of the world. Advancement of energy transition is central to development in Africa, but the pursuit has been very slow. This is based on weak political will, poor legislative framework and socioeconomic support towards the development. This study aims to provide an overview into the challenges and opportunities of energy transition across Africa, regardless of the differing political terrains. This paper is divided in two sections; section one probes into the current status of energy provision, access and delivery, the huge deposit of fuel resources and the need for cleaner energy transition in Africa. Section two discusses the challenges associated with cleaner energy provision whilst proffering opportunities and directions for the future—renewable energy development, economic diversification and energy efficiency policy formulation.

1.2 Energy Resources and Challenges of Energy Provision, Access and Delivery in Africa

Africa contributes the least to global greenhouse gas emissions from electricity production, accounting for only 3.6% of global fossil fuel (carbon dioxide, CO_2) emissions, even though it represents 17% of the world's population [9]. This figure drops to 1% if four countries with the highest absolute emissions (South Africa, Egypt, Algeria, and Nigeria) are excluded [9].

In 2018, approximately 548 million Africans, representing half of the continent's population, lacked access to electricity [10]. Furthermore, as of 2020, traditional biomass sources like wood and charcoal were the sole energy options for 900 million Africans, primarily in Sub-Saharan Africa [10]. This lack of reliable, affordable energy has hindered the growth of businesses, including microenterprises, agriculture, and industry in Africa. Without effective interventions, these problems are expected to worsen, potentially affecting up to 1 billion people in Sub-Saharan Africa and 100 million in North Africa by 2050 [11].

Despite Africa's relatively low contribution to global greenhouse gas emissions, the continent is highly vulnerable to the effects of climate change (Nalule, 2019; 2020). It is therefore crucial for African countries to invest in modern, efficient power generation systems to avoid dependency on fossil fuels. Transitioning to renewable energy sources is essential to meet the continent's growing energy needs while reducing carbon emissions. This transition does not entail completely replacing fossil fuel infrastructure but involves implementing more efficient, flexible, and decentralized (including off-grid) energy infrastructure.

The African continent is endowed with massive but untapped energy resources, including both conventional and unconventional resources. As Fig. 1. that follows shows, the African region, for instance, has a natural gas potential of approximately 558Trillion Cubic Feet [12]. This makes Africa the fourth-largest gas reserves holder in the world after North America [12]. Natural gas supplies come from established players like Nigeria and Egypt and nascent players like Tanzania, Mozambique, Senegal, and Mauritania as shown in Fig. 2. [13]. The region also has an estimated 65 billion barrels of proven oil reserves, equivalent to about five per cent of the world total [14].

Despite the above resources, however, the region faces various energy challenges, including low electrification rates (Fig. 3. and 5) and heavy reliance on inefficient energy sources such as traditional biomass (Fig. 4.) [3]. Globally, it is estimated that approximately 1.2 billion people have no access to modern energy such as electricity, and nearly 3 billion people rely on traditional biomass (such as wood and charcoal) for cooking and heating (United Nations Foundation, 2019; 2021). Unfortunately, most of this population live in Africa, with estimates indicating that nearly 600 million or 46 per cent of Africa's 1.3 billion population in 2019 still lack access to electricity [15]. Another 730 million people, or 56 per cent of the continent's population, lack access to clean fuels [12]. Specific country data on the access deficit shows that most of these people live mainly in Sub-Saharan Africa – for example, in Nigeria and the DRC, representing 85 and 68 million persons not connected to the grid as depicted in Fig. 5. Other countries in the region where electricity access efforts are needed to reach universal access include Ethiopia, Tanzania, Niger, Sudan, Kenya, Uganda, Mozambique and Angola – all countries with significant natural resource endowments.

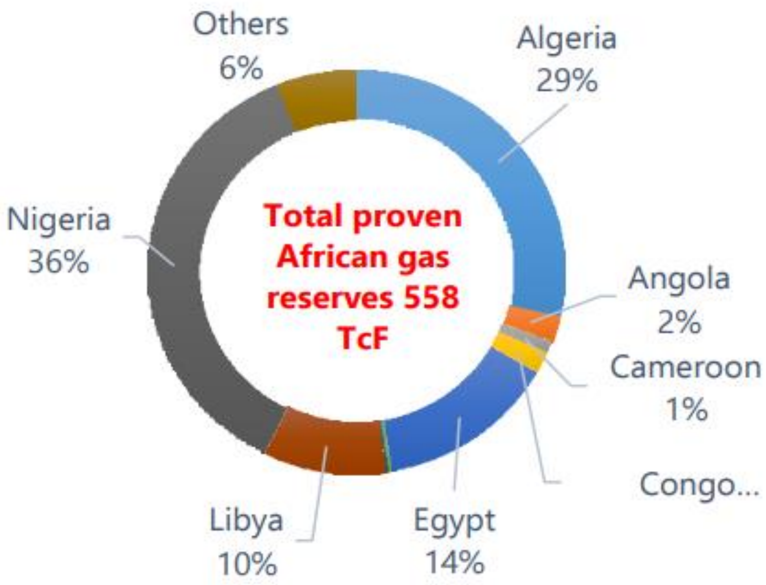

Fig. 1. Africa proven gas reserves distribution by percentage
(source: OPEC, 2019)

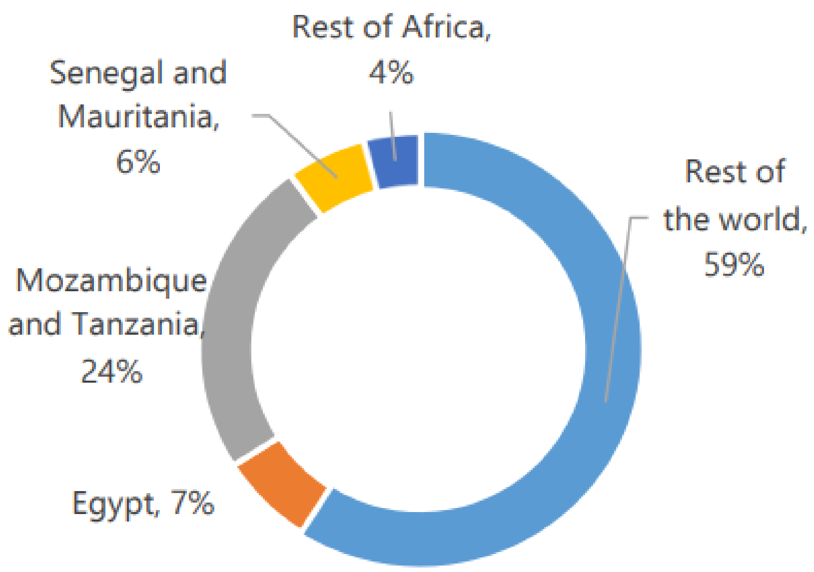

Fig. 2. Share of global gas discoveries, 2011-2018
(source: EIA, 2019)

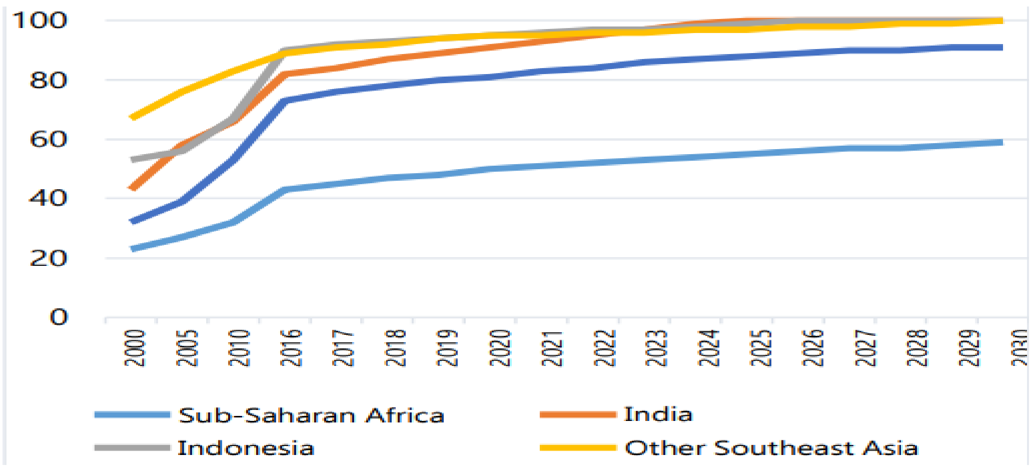

Fig. 3. Electrification rates in selected countries and regions (2000-2030)
(source: IEA, 2020)

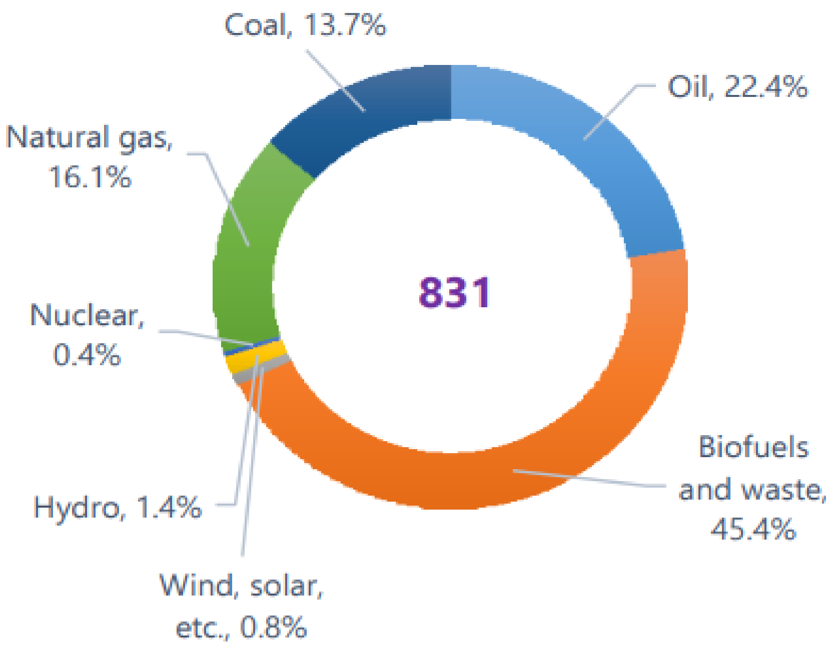

Fig. 4. Africa's primary energy supply mix
(source: IEA, 2020)

The coronavirus (COVID-19) pandemic reiterated the emphasis on the crucial role energy access plays in global development. While energy secure countries were primarily focused on vaccination and tackling the COVID-19 related illness, energy-insecure-developing countries worried heavily about unreliable electricity needed to, for example, run critical hospital systems and store vaccines. For instance, in the 2020 study carried out in Malawi, it was revealed that unreliable connectivity to energy sources in Malawi adversely affected the quality of health service delivery. The study showed that most health care facilities are connected to the electricity grid but experience weekly power interruptions averaging 10hours [16]. Other developing countries in Africa do experience the same energy access challenges. This situation clearly illustrates the importance of achieving the United Nations Sustainable Development Goal (SDG 7) on Energy Access, which is connected to other SDGs, including Goal 3 on good health and wellbeing (United Nations Sustainable Development Goals,).

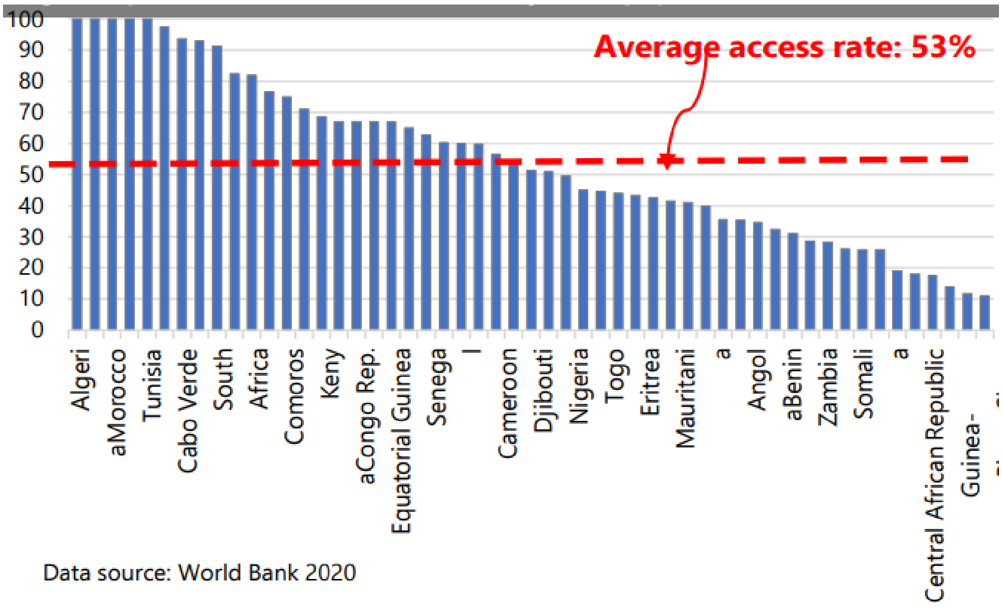

Fig. 5. Population with access to electricity (percentage of population)
(source: world bank, 2020)

Whereas the importance of the energy sector is emphasized internationally, it is worth noting that energy investments are awfully expensive ventures requiring the participation of different international energy investors [17]. This, therefore, implies that tackling energy access challenges on the African continent requires national, regional, and international cooperation [18]. Nevertheless, recent developments in the energy sector, such as the 2014-17 commodities price slump and the COVID-19 pandemic, have led to a global decrease in fossil fuel investments. These investments are forecasted to decline further with the energy transition. For example, capital expenditure cuts of between US$85-US$120 billion were announced globally following the collapse in oil prices in 2020 occasioned by the pandemic [19,20]. One could argue that fossil fuels are a significant source of global emissions, as such, meeting the 2015 Paris Agreement of limiting the increase in global average temperatures to well below 2°C above pre-industrial levels by 2050 requires different countries to significantly cut their emissions, which ultimately means curtailing some forms of energy sources [21]. However, Africa emits the least global carbon dioxide (CO_2) emissions (Fig. 6), although it stands to bear the most significant negative externalities of climate change: water resources, food production, environment, and health.

A question that arises in the context of the climate change agenda is: would African countries by 2050 have adequately tackled the challenge of energy access? Whereas there are various ongoing efforts to embrace natural gas, renewable energy (RE) and other energy efficiency technologies in multiple countries on the continent, one cannot help but wonder if it is practical (in terms of addressing both energy access and climate change) to advocate more for other clean technologies such as Carbon Capture Utilisation and Storage (CCUS) on the continent. This is because most developing countries in Africa are undergoing urbanisation and industrialisation. As such, these countries will require all the energy resources to tackle the existing energy access challenges and cope with the anticipated boom in industrialisation, urbanisation, and population growth [22]. Suppose the world is to embrace the rewon energy justice and just transition principles [23]. In that case, it becomes essential that developing countries are not made more impoverished because of the global move to transition to a low carbon economy [22].

Given the preceding, it is imperative to ensure that discussions about the energy transition take into consideration

a. the availability of energy resources,
b. the affordability of these resources,
c. the reliability, efficiency, sustainability, and
d. the costs of obtaining modern energy. Furthermore, it is also essential to consider the social and economic discrepancies

between different countries and the different energy challenges [22].

While trying to understand what energy transition means from an African perspective, we must be aware of the progressive character of energy transitions, which has inspired some scholars to advocate for 'Energy Progression' in developing countries [22]. From a historical perspective, we should appreciate that energy transition generally happens gradually and in different stages- all of which are influenced by various factors, including economic, social and technological development (Nakhle and Acheampong, [19] Nalule, [22]. Europe is an excellent example of the progressive character of the energy transition, for instance, initially, in the 19th century, the focus for European countries was to shift from wood and water power to coal; in the 20th century, the focus was to shift from coal to oil; in the 21st century, the focus is to shift from fossil fuels to renewable energy [18].

Whereas the current focus in the developed world is to shift from fossil fuels to renewables, we should be aware of developing countries' economic and social realities. For instance, the focus for most African countries now is to shift from biomass to electricity grids (even if these are powered by high-carbon intensity energy resources such as coal) [24]. Therefore, the economic and social differences between developed and developing countries necessitate applying energy transition principles differently in these countries [24].

1.3 Energy-Related Emissions in Africa

Between 2008 and 2017, the average greenhouse gas emissions increased by nearly 20% though from a very low initial level, despite the fact that during these years, Africa contributed the least as compared to other developed and developing economies as shown in Fig.7. Energy demands in Africa is expected to rise almost as double as it is now by 2040, even if efficient measures are put in place. This growth is related to population growth and improved standard of living (IRENA, 2019) despite Africa contributing the least in global CO_2 emission as shown in Fig. 8. and 9.

Therefore, to achieve the zero-carbon emission target of 2050 in Africa, the system requires reducing the emission rates from emission-producing sources even as demands increases. This emphasizes the need to focus more on renewables and other low-carbon energy sources and reduce the investments on fossil fuels. This is hugely dependent on the electricity sector – as this sector accounts for the largest share (42% of the total) energy-related CO_2 emissions in Africa as at 2018 (IEA, 2021).[21] Other high emission sectors such as transport and industry account for 31% and 20% of total energy-related emissions respectively and decarbonization pathways for these three high emission sectors will include building robust, green electricity sectors across the African continent.

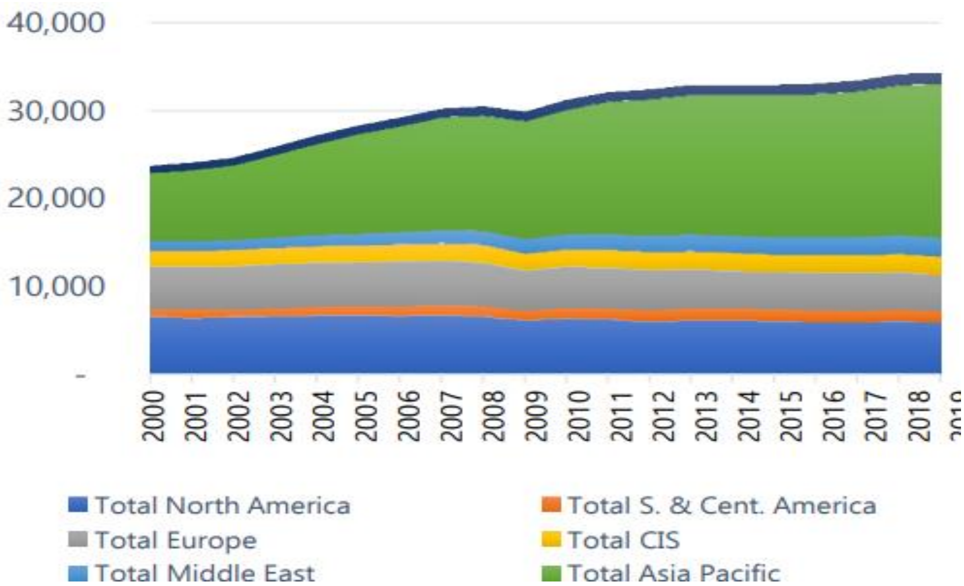

Fig. 6. Global CO_2 emissions (Million tonnes of carbon) (BP energy statistics, 2020)

Fig. 7. Cumulative CO_2 emissions globally
(source: IEA, 2021)

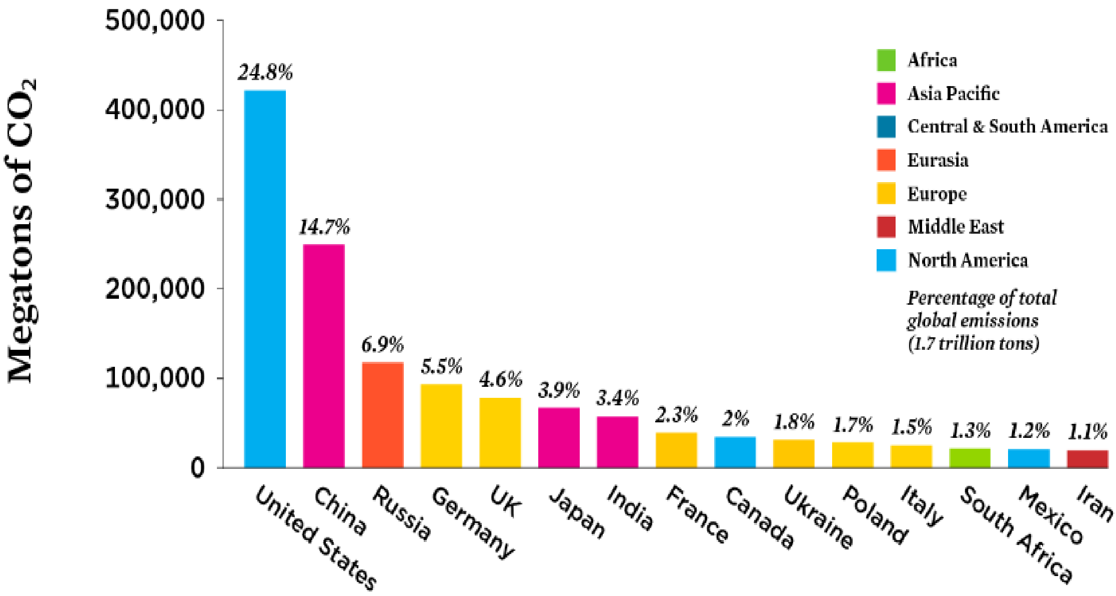

Fig. 8. Global CO_2 emissions (from fossil fuels and cement) by countries and regions
(source: IEA, 2021)

1.4 Need for Energy Transition in Africa

The World Resource Institute [11]. reported that 73 per cent of global greenhouse gas emissions were products of energy-related activities in 2016. Such energy related activities include emissions due to electricity production (through fossil fuel combustions), transport, manufacturing and domestic sectors. The foundation of global decarbonization economy and efforts to meet with the Paris Agreement targets is efforts to decouple the energy demands from emissions.

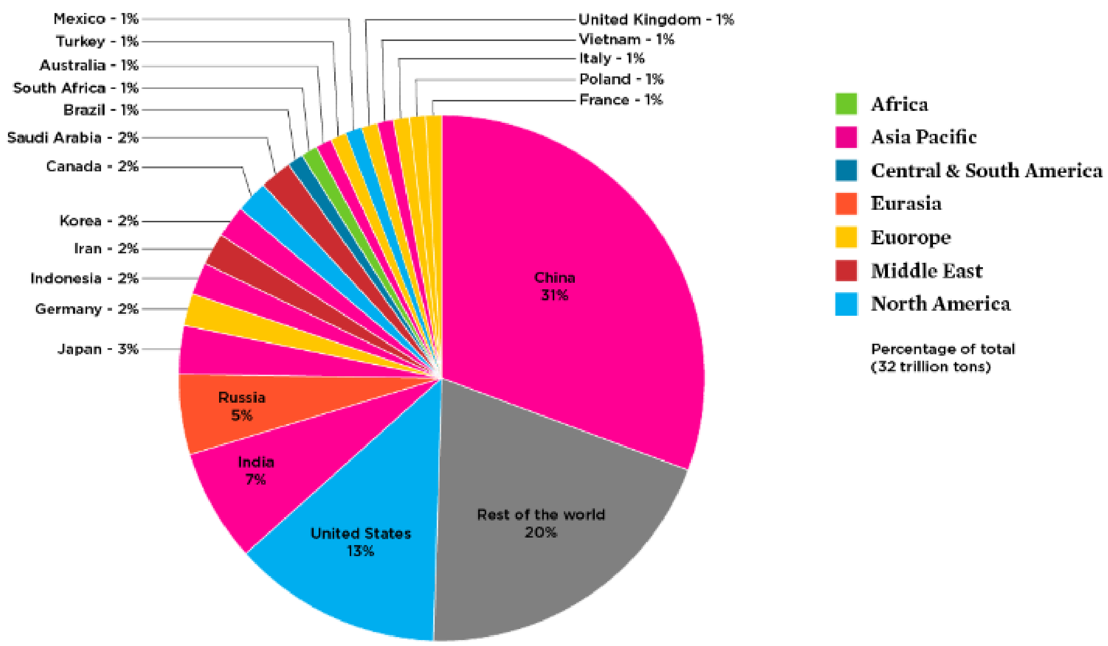

Fig. 9. Top annual CO_2 emitting countries from fossil fuels, 2020
(source: World Bank, 2020)

Where economies are developed or highly developing, economic growth and energy-related emissions seem to have an indirect relationship; this causal relationship means that as economies grow and develop, energy-related emissions seem to drop. This is evident in the report by the IEA [21] where average annual rate of energy-related emissions dropped by 0.9% for the Organization for Economic Co-operation and Development (OECD) countries while average annual economic growth of these countries grew by 1.3% for year 2008 – 2017 under review.

For the same years under review (2008 – 2017) by the IEA [21] the average annual economic growth as well as average annual rate of energy-related emissions did not grow for non-OECD countries as it did for the OECD countries, but still improved significantly over the same period. In 2017, OECD countries had per capita emissions from electricity emissions that exceeded the global emissions by 230%.

The IEA [21] has reported that in Africa, developmental models that are highly dependent on hydrocarbon revenues are no longer sustainable, at least in the long run. These models are based on the fact that Africa has abundant natural resources and these revenues accrued from them are the drivers for economic development in the regions of their abundance (Fig. 10.) [9].

Nevertheless, the changing global energy dynamics have caused a review of these models, stressing that abundance of oil reserves does not translate to sustainable and reliable future revenues. This is also aided by the technological advancements that fast-tracks the production of shale oil in the United States, which have become strong competitors for the lighter crudes produced in Africa. To that effect, shifts and transitions from fossil energy sources will lower their demands and prices, which in turn will affect the revenues in future. Therefore, there is a pressing need to develop more pragmatic and strategies models that will be centered on future investments, transparent resource revenue management and efforts to reform and diversify economies (IEA, [21] IRENA, [10].

In recent times, more pragmatic and strategies economic models are being developed in many African countries, putting into consideration other mineral resources that are not hydrocarbon-based. The many mineral resources in Africa can be the driving force of global energy transitions if utilized. For example, South Africa provides the world with about 70% of the global platinum demands while the Democratic Republic of Congo provides two-thirds of the global cobalt demands [6]. A rise in the demands of these minerals offers opportunities of economic growth and energy transitions for these mineral-rich countries and can be fully developed under a responsible and forward-thinking government. There are increasing scrutiny mechanisms for the supply of these minerals, and these requires adequate oversight to ensure that the revenue accrued are used to produce results that are both visible and sustainable for local communities while reducing negative environmental impacts to the barest minimum [21].

1.5 The Relevance and Necessity of Modern Energy Services for Sustainable Development

In the UN's Sustainable Development Goal (SDG) 7, there are three main aims which are targets for 2030 (Fig. 11). The UN targets that by 2030:

i. access to modern energy systems and services are universal, affordable and reliable;
ii. the share of renewable energy infrastructure in the global energy mix has increased considerably;
iii. the rate of global improvement in the efficiency of energy systems and services has doubled

Beyond just access to better energy sources, UN opines that these three targets of UN's Sustainable Development Goal (SDG) 7 will directly improve the global livelihood especially for girls and women who are primarily regarded as the energy managers of the household. Furthermore, access to better and modern energy sources and systems will act as the foundation for the actualization of other SDGs.

In developing countries, gross domestic product (GDP) is reported to grow as the demand and access to electricity increases. This is documented in macro-economic studies according to Stern et al. [25]. Reliable and sufficient electricity supply creates a lot of free time for other economic activities, reduces the burden of time on household activities and enables the creation of values and the economic growth through productive use.

Modern economies that are built upon digital infrastructure and telecommunications relies heavily on electricity as a gateway. Aside that, it provides the platform for improved efficiency and leverage for players (both existing and potential) in the traditional space and enable them participate in local and global markets. Inadequate electricity generation capacity, poorly designed and drafted transmission and distribution networks are the burdens on many African countries. The effects of these are unreliable, and yet expensive electricity supply and these have negative ripple effects on critical social and economic activities. Modern off-grid systems based on renewable energy can provide a range of energy services that conventional energy systems fail to provide. The energy requirements for productive economics generally requires voltage levels that only a centralised electricity grid or a robust mini-grid can provide, modern systems can provide better ranges of power supply that improve standards of living and livelihoods.

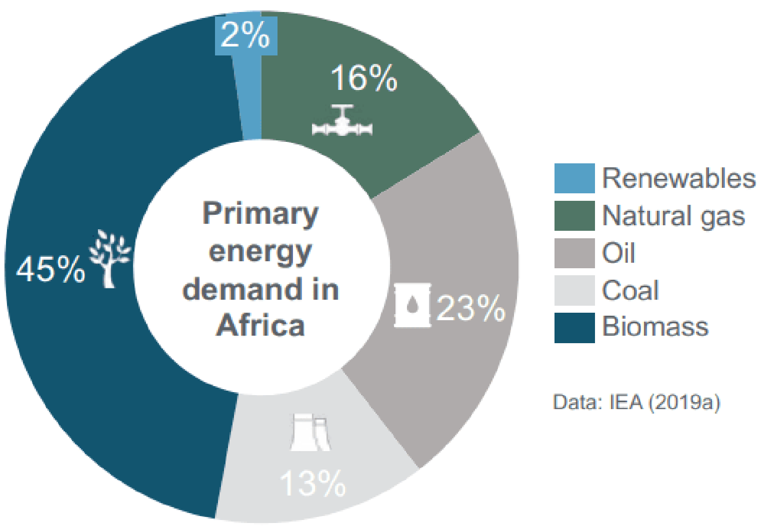

Fig. 10. Primary energy demand in africa
(source: IEA, 2019)

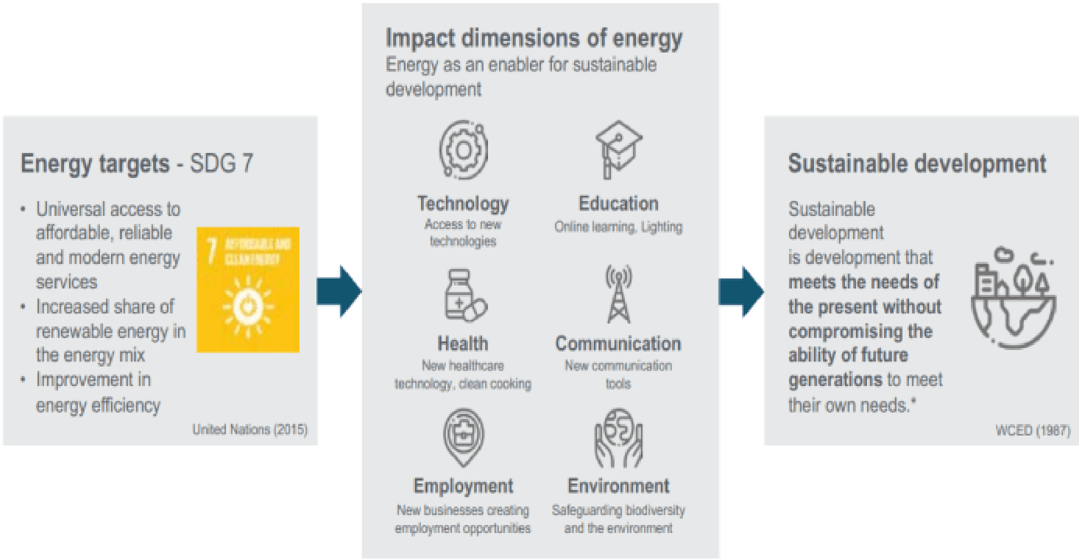

Fig. 11. Impacts of access to modern energy services on sustainable development
(source: Stern, Burke and Bruns, 2019)

Reliance on traditional biomass (wood and charcoal) for energy production was peaked at 45% of the primary energy demand in Africa in 2018 [21]. This reliance comes with serious adverse effects in that 490, 000 premature deaths are recorded in Sub-Saharan Africa yearly due to exposure to indoor air pollution [26]. These deaths are recorded mostly amongst women and children due to their prolonged exposure to hearths and fireplaces. Moreover, the need for wood leads may lead to deforestation if left unchecked- and ultimately environmental degradation.

1.6 Opportunities in the Energy Provision, Access and Delivery in Africa

1.6.1 Renewable and alternative energy sources

Renewable energy, also called flow energy (source) refers to energy sources that are naturally replenished and do not deplete over time. These sources are considered sustainable because they have a minimal impact on the environment compared to fossil fuels, which release greenhouse gases and contribute to climate change (Fig. 12.) [27].

Renewable energy technologies harness energy from natural resources like sunlight, wind, rain, tides, and geothermal heat Renewable energy plays a crucial role in reducing greenhouse gas emissions, combating climate change, and promoting energy security. As technology advances and becomes more cost-effective, renewable energy sources are becoming increasingly competitive with fossil fuels in terms of both efficiency and affordability [28]. Governments, businesses, and individuals worldwide are increasingly adopting renewable energy solutions to transition towards a more sustainable and eco-friendly energy future [21].

Zero carbon or low carbon energy refers to sources of energy that have minimal or no net emissions of carbon dioxide (CO_2) and other greenhouse gases during their generation and use. These energy sources are essential in the fight against climate change, as they help to reduce the overall greenhouse gas emissions that contribute to global warming.

- **Renewable Energy:** Renewable energy sources like solar, wind, hydroelectric, geothermal, and biomass are generally considered low carbon or even zero carbon, as they do not produce direct emissions of CO_2 during their operation. While there may be some emissions associated with the manufacturing and installation of renewable energy infrastructure, these are typically offset by the emissions avoided during their operational lifespan.
- **Nuclear Power:** Nuclear power is a low carbon energy source because it does not

produce CO2 during electricity generation. Instead, it generates electricity through nuclear fission, which involves splitting atoms to release energy. However, it's important to note that nuclear power does produce radioactive waste, and its use raises concerns about safety and long-term waste disposal.

- **Carbon Capture Utilization and Storage (CCUS):** CCS is a technology that can be applied to certain high-carbon energy sources, such as fossil fuel power plants. It involves capturing CO2 emissions before they are released into the atmosphere, transporting the captured CO2, and then storing it in underground geological formations. By implementing CCS, fossil fuel-based power generation can become low carbon or even zero carbon, as the emissions are effectively sequestered.
- **Hydropower:** While large-scale hydropower projects can have environmental and social impacts, they generally do not produce direct carbon emissions during electricity generation. Smaller run-of-the-river or low-impact hydroelectric projects can be considered low carbon energy sources.
- **Advanced Bioenergy with Carbon Capture and Storage (BECCS):** BECCS is a technology that combines biomass energy with carbon capture and storage. Biomass, such as plant material or agricultural waste, is used to generate energy, and the resulting CO_2 emissions are captured and stored, effectively creating a negative emissions process.

Transitioning to zero carbon or low carbon energy sources is a crucial step in mitigating the impacts of climate change and achieving global sustainability goals. Governments, businesses, and individuals must work together to accelerate the adoption of these cleaner energy options and reduce our reliance on high carbon fossil fuels.

1.6.2 Types of renewable energy

The most popular renewable energy sources currently are energies harnessed from natural elements. They include energy from sources as sun, wind, water, tides, geothermal systems, biomass facilities [5,7,10,21].

Fig. 12. Renewable energy plans- from fossils to eco-friendly
(source: IRENA, 2018)

1.6.2.1 Solar energy

Solar energy refers to the energy harnessed from the sun's rays and converted into usable electricity or thermal energy. It is a renewable and sustainable source of power, as the sun is expected to continue emitting energy for billions of years. Solar energy can be utilized in various ways, including:

i. **Photovoltaic (PV) Solar Panels**: Photovoltaic cells, commonly known as solar panels, convert sunlight directly into electricity (Fig. 13). When sunlight strikes these panels, it creates a flow of electrons, generating direct current (DC) electricity. This electricity can be used to power homes, businesses, or even be fed back into the grid.
ii. **Solar Thermal Systems**: Solar thermal technology captures the sun's heat and uses it to heat water or other fluids. The heated fluid can be utilized for space heating, water heating, or even to generate electricity through steam turbines.
iii. **Concentrated Solar Power (CSP)**: Concentrated Solar Power systems use mirrors or lenses to focus a large area of sunlight onto a small area, typically a receiver. This concentrated heat is then used to drive a steam turbine and generate electricity.

1.6.2.2 Wind energy

Wind energy refers to the electricity generated by harnessing the kinetic energy of moving air (wind). Wind power is a renewable and clean energy source, and it has been used for centuries to pump water and grind grain. In modern times, wind energy is predominantly captured and converted into electricity through large wind turbines.

i. **Wind Turbines**: Wind turbines consist of large rotor blades mounted on a tall tower. The rotor blades capture the kinetic energy of the wind as it blows past them (Fig. 14).
ii. **Electricity Generation**: When the wind blows, it causes the rotor blades to rotate. The rotating motion drives a generator housed inside the turbine's nacelle (the structure atop the tower). The generator converts the mechanical energy from the turbine's rotation into electrical energy, typically producing alternating current (AC) electricity.
iii. **Power Distribution**: The electricity generated by wind turbines is then transmitted through power lines to homes, businesses, or the electricity grid for immediate use or storage.

1.6.2.3 Hydro energy

Hydro energy, also known as hydroelectric energy or hydropower, refers to the electricity generated from the energy of flowing or falling water. It is one of the oldest and most widely used sources of renewable energy, with water-driven mechanical power being used for various purposes for thousands of years. Hydropower systems typically involve the following components:

Fig. 13. Roof-mounted solar panels
(source: Stern, Burke and Bruns, 2019)

Fig. 14. Wind mills in Aberdeen, Scotland
(source: Journal of Renewable Energy, 2018)

i. **Dam or Reservoir**: In large-scale hydroelectric power plants, a dam is constructed to create a reservoir, which stores a large volume of water at an elevated level (Fig. 15). The height difference between the reservoir and the turbines allows for the potential energy of the water to be converted into mechanical energy.
ii. **Penstock**: A penstock is a large pipe or channel that directs water from the reservoir to the turbines. The water pressure in the penstock helps to rotate the turbines.
iii. **Turbines**: Turbines are machines with blades or buckets that are turned by the force of flowing water. As the turbines rotate, they convert the kinetic energy of the water into mechanical energy.
iv. **Generator**: The rotating turbines are connected to a generator, which is responsible for converting the mechanical energy into electrical energy. The generator contains coils and magnets that create an electromagnetic field, generating electricity through electromagnetic induction.
v. **Transmission**: The electricity produced by the generator is transmitted through power lines to homes, businesses, or the electricity grid for distribution and use

Fig. 15. Roselend Dam, Beaufort, France
(source: IRENA, 2018)

1.6.2.4 Tidal energy

Tidal energy, also known as tidal power (Fig. 16.), is a form of renewable energy that harnesses the kinetic energy from the regular and predictable movement of ocean tides. It is a subset of hydropower and is based on the gravitational forces between the Earth, Moon, and Sun, which cause the tides to rise and fall. Tidal energy can be harnessed through various technologies:

i. **Tidal Barrages**: Tidal barrages are large structures, usually constructed across estuaries or bays, that capture and store water during high tide. When the tide recedes, the water is released through turbines, generating electricity as it flows back to the sea. Tidal barrages are similar in concept to hydropower dams but are specifically designed to exploit the tidal cycles.
ii. **Tidal Stream Generators**: Tidal stream generators are underwater turbines or similar devices installed on the seabed or in areas with strong tidal currents. As the tides flow in and out, the movement of water drives the turbines, generating electricity.
iii. **Tidal Lagoons**: Tidal lagoons are artificial basins or enclosures built along coastlines with sluice gates. During high tide, water flows into the lagoon through the sluice gates. As the tide ebbs, the water is released through turbines, generating electricity.

1.6.2.5 Geothermal energy

Geothermal energy is a renewable and sustainable form of energy that harnesses the heat from the Earth's interior to generate electricity or provide heating and cooling for various applications. This energy originates from the heat retained within the Earth's core since its formation and from ongoing radioactive decay processes. There are two main types of geothermal energy applications:

1. **Geothermal Power Plants**: Geothermal power plants generate electricity by tapping into high temperature geothermal reservoirs. These reservoirs contain hot water or steam trapped in porous rock formations beneath the Earth's surface. The heat from the reservoirs is used to produce steam, which drives turbines connected to generators, generating electricity.

   a. ***Dry Steam Power Plants***: In locations where naturally occurring steam is available, dry steam power plants are used to direct the steam from underground reservoirs directly to the turbines (Fig. 17.).
   b. ***Flash Steam Power Plants***: In reservoirs where hot water is present but not in vapor form, flash steam power plants are used. The high-pressure hot water is released into a lower-pressure tank, causing it to flash into steam and drive the turbines.
   c. ***Binary Cycle Power Plants***: In areas with lower temperature geothermal resources, binary cycle power plants are used. Hot water from the reservoir is passed through a heat exchanger, heating a working fluid with a lower boiling point (such as isobutane). The vapor from the working fluid is then used to power the turbines and generate electricity.

2. **Direct Use Applications**: Geothermal energy can be used directly for heating and cooling purposes without the need for electricity generation. In direct use applications, geothermal energy is utilized for space heating in buildings, greenhouse heating, spa resorts, and industrial processes such as drying crops or aquaculture.

1.6.2.6 Biomass energy

Biomass energy is a renewable energy source that derives from organic materials, such as plant and animal matter, as well as their by-products and residues. It is one of the oldest sources of energy used by humans and continues to play a significant role in modern energy systems.

There are several ways biomass is utilized to produce energy:

a. **Combustion**: Biomass can be burned directly to produce heat or steam, which can then be used for space heating, water heating, or to generate electricity through steam turbines. This process is commonly used in biomass power plants and for heating in residential and industrial settings.
b. **Biogas**: Biomass, especially organic waste like food scraps, agricultural residues, and animal manure, can be anaerobically digested to produce biogas (Fig. 18).

Biogas is composed mainly of methane and can be used as a renewable fuel for electricity generation, heating, and as a transportation fuel.

c. **Biofuels**: Biomass can be processed into liquid or gaseous biofuels, such as biodiesel and bioethanol. Biodiesel is produced from vegetable oils or animal fats and can be used in diesel engines. Bioethanol is typically made from crops like corn, sugarcane, or wheat and is used as a biofuel additive to gasoline or as a standalone fuel for some vehicles.

2. MATERIALS AND METHODOLOGY

2.1 Materials

2.1.1 Research design/style

Extensive use of documents, official data and statistics on different aspects of the African society was employed for this study. A lot of exploratory documentary research materials, extant literature, publications, journals and articles on the current status of energy generation and delivery in Africa, the concept of renewable energy pathways, the need for energy transitions and the major strategies in place in Africa and around the world were important study areas for this work.

Further studies and analyses will be on current state of energy markets on the African continent. In general, the totality of the studies made for this research work will be to evaluate the current level of energy markets across the different regions of Africa, with attention to the peculiarities and differences as it relates to culture, technology and politics. The challenges, which are usually cultural, social, economic, political and demographic, that these transitions have faced and will face are the major talking points. Areas of interests will be on the consumption, economic and legal framework surrounding the provision of energy in these case study countries. This work will probe into the economic potentials of energy provision for the teeming youthful populations in these nations, the skill development and employment strategies that this transition will provide for national economies.

2.1.2 Data collection

Documents and archives from several sources were used in data collection and analysis to have a better understanding of on the current status of energy generation and delivery in Africa, the concept of renewable energy pathways, the need for energy transitions and the major strategies in place in Africa and around the world to meet with the zero-carbon emission strategies of 2050. Some of the documents and archived documents were locally sourced, providing very reliable information on Nigeria especially. While literature with very reliable information on countries as Cote d'Ivoire, Ghana, South Africa, Morocco and Rwanda were very scanty, other documentary sources from the International Energy Agency (IEA), Energy Information Administration (EIA), and the World Energy Council (WEC) provided some needed information.

Fig. 16. Tidal waves
(source: IRENA, 2018)

Fig. 17. Geothermal Terminals at Tanzania
(source: IRENA, 2019)

Fig.18. Agricultural biomass-conversion center
(source: IRENA, 2018)

However, these international documentary sources only have useful evidence and records of African countries, especially Nigeria post-independence (1960 onwards). These agencies have, in their archives, records and data of the case study countries' energy resources, consumption, and production, covering as far as the 1980s to present day. While some of these documents may not provide a reliable means of getting a true historical picture of the case study countries, they however provide very insightful and hands-on data for substantial conclusions and recommendations.

2.2 Methods

For the purpose of this study, the manner and rate of energy transition across African countries were studied and analysed.

As a method of research, qualitative and descriptive analytical (quantitative) methods were the methods of data analyses. Exploratory documentary research methods were adopted for this study and this involved the exploration of documents, official data and statistics on the and publications on the African petroleum industry in connection with trade, traditional energy use, culture, and norms. In general, the totality of the studies made for this research work will be to evaluate the current level of energy markets in the African space, probing into the political, economic, social, technological, legal and environmental aspects of the petroleum industry.

3. RESULTS AND DISCUSSION

With the demands for energy across the globe on the increase, the energy demands in Africa have become subject of concern as the population of Africa is on an exponential rise and options, strategies and policies are being put in place to see that the energy demand gaps are bridged. In recent times, multinational companies in the energy industry (oil and gas) are gradually and heavily investing in renewable and cleaner energy sources as part of sustainable development goals.

3.1 Challenges in the Sustainable Transition of Energy in Nigeria and other African Countries

3.1.1 Policy framing and very poor synergy amongst policy makers

Working in isolation for energy policymakers poises a lot of risks as it relates efficient policy making. Isolative policies may not be synergistic, hence slowing the energy-access gains and decelerating economic growth. In worse cases, it may create conflicting results as it relates to political, social, cultural and technological impacts. Therefore, the need for a broad stakeholder agreement cannot be overemphasized. Private (multinationals) and public sector (multilateral and national development institutions) partnership play an important role in this decarbonization path. Private sector mobilization is a crucial role that public institutions need to play. The existing frameworks present today, for instance in the electricity sector, originally designed for large-scale and technically complex conventional power-generation and transmission systems, designed and built primarily by regulated entities has resulted to heightened costs and unfeasible project timelines. In a larger sense, these frameworks decelerate national development by hindering the transitions to more modern solutions. With consumers now switching into prosumers, the need for transformational change for economies and societies in the short-term while securing long-term sustainability is very important.

3.1.2 No or poor involvement of the private sector in the energy policy formulation and execution

Increasing and channelling the investments from private sector into the areas of most need is another challenge that policy makers will face. This is because in recent years, several high-profile investment funds from the private sector has flooded into greener (renewable) energy sources. At such, a lot of money are no longer being invested in fossil fuels. Therefore, the policymakers are charged with making sure these financial investments are judiciously put into cleaner energy sources, from production, transmission to distribution and end use. For example, as electricity demand grows, grid investments become very important and there is need for an accelerated move to variable sources of energy. A significant challenge is to ensure these investments are made in the right sequence and at the necessary scale.

3.1.3 Inflexible political, economic, social and cultural spheres

Renewable energy technologies are so dynamic; which means that ensuring supply meets with the demands will rely highly on the flexibility of the energy systems. There is an increase in power demands; from access demands to electrification of end-users (domestic, transport and manufacturing sectors) and these huge demands need a sufficiently robust transmission and distribution networks. The major challenge our energy planners and network operators face is the creation of adaptability of our energy systems to accommodate localized energy generation.

With the rapidly growing investment in clean energy production, the need for parallel spending on infrastructure is very important so as to modernize the insufficient energy systems of today and improve electricity access. As mentioned before, the essentiality of finances to meet up the demands of today and spread to entire energy system is important effort to meet with the policy requirements of today. At the same time, the increasing use of distributed generation, together with storage facilities and charging needs for e-mobility, will lead to challenges in network planning and operation that have their own costs. Prioritizing renewables, electrification, efficiency, and associated energy infrastructure is a sure way to ensure systems that are sustainable, environmentally-friendly and reliable in the future are put in place with the substantial investments that are being made. This will also require strategic planning to avoid lock-in effects of these investments which are not well-matched with the Paris Agreement.

Political, regulatory and operational spheres of the economy, even amongst neighbouring economies and sub-regions need a huge collaboration in the development of national infrastructure. It is expected under this collaborative and cooperative space, countries with less abundant renewable resources will benefit from the countries with more abundant renewable resources in the energy transitions through exportation of resources. Cross-border integration can also provide a unique opportunity to connect remote regions to power supplies. Since different energy sources across Africa are abundant, connectivity across regions, the provision and supply of reliable energy all year-round will lead to lowered tariff prices in the providing countries while also creating a space for revenue for them.

In recent years, the collaborations among states are on the rise, improving renewable energy integration and improving flexibility — these involve infrastructural investments in digital economies and better energy solutions to make for efficient supply of energy and meet the increasing demands. These can help in transport systems; sector coupling for example, in the provision of energy for emerging technologies as smart charging of electric vehicles (EVs). Long-lasting solutions which are crucial to the transition to flexible, integrated systems that are built on renewable energy sources can only be achieved not just through technological advancements, but also through pragmatic business models and regulatory frameworks.

3.1.4 Challenges of demand, energy efficiency and finance

The IEA [9] asserted that improvements in the demands of energy make up 40% of the total emission reduction needed to deliver the requirements and goals of the Paris Agreement—particularly in the short term; as well as present countries with economic, employment and social benefits. In reality, there has been a decline for three years in a row in the area of demand improvement. To meet up with SDG goal 7 for efficiency, then we need to reverse this trend and keep countries around the world on track to meeting the Paris Agreement Goals.

Additionally, aggressive efficiency strategies must follow an increasing share of renewables. As at the time of the establishment and announcement of the SDG 7, the global annual improvement rate of energy efficiency was targeted at 2.6%. One of the targets of the SDG was to double this efficiency by 2050. Referencing the IRENA and the IEA, the global annual improvement rate of energy efficiency was targeted at 2.7% and 3.2% respectively to meet with the net-zero target of 2050. The figures show that viewpoints of these agencies congregate at around 3% per annum.

Yet, only few countries have taken an in-depth look at the energy-efficiency opportunities available to reduce their future emissions. This is because improving energy efficiency will cut across all sectors regardless since all sectors are driven by power availability. Even at the presence of available and affordable technological systems, governmental policies such as via cross-cutting and action-oriented efforts will be needed to establish frameworks for new incentives that will accelerate scalability and market absorption and at same time deal with associated challenges as inadequacies in energy infrastructure, issues of regulation, behaviours and cultures, demands management and inadequate financial incentive systems.

3.2 Harnessing the Opportunities in Sustainable Energy Transition in Nigeria and other African Countries

3.2.1 Willing socio-political disposition towards promoting sustainable energy sector

While developing nations are faced with a lot of challenges with the energy transition, developed nation seem to find it almost seamless owing, not only to their superior financial strength, but to other factors as sustainable policy structure, constructive legislations, well established competitive yet regulated market environments that operate under the ambits of legality. Political motivations fundamentally drive sustainable energy transitions as well as the democratization of energy (Burke and Stephens, 2018). Due to need for decarbonization and issues of fossil fuels on climate have led to a reduced share of coal in the United States in the last few years.

However, the terms in the Paris Agreement recently do not favour the socio-political and economic values of the United States when compared to other strongly emerging technologies as Russia, China, Japan etc. Hence, the U.S. pulled out of the agreement and this is further supported by the fact that their energy plan is centered on policies favouring renewed gas utilization [29]. A step like this requires a very strong political will despite opinions that are differing globally. Remember, that the United States is a developed nation.

For developing nations like Nigeria, lessons can be learnt from the United States to take strong political decisions that will drive economies according to the social, political, culture, economic, legislative and technological conditions of the day. This reflects on the strong wills of the political elites at the executive, legislative and judiciary arms of government.

3.2.2 Increase investment plan for hydroelectric power technology

In Nigeria, only about 17% and 2% of our large hydro resources and small hydro-resources have been deployed. For returns on investment, operation, and maintenance, the economy of scales etc., hydropower remains one of the most reliable energy sources. Therefore, investing in hydropower will ne immensely beneficial to meeting the demands of energy and environmental sustainability in Nigeria. Another way of utilizing the abundant hydro resources in Nigeria is via the investment in pumped hydro energy storage system (PHESS). The pumped hydro energy system involves the storage of water to a high raised reservoir from ground level natural or artificial water dam, using energy from a reversible pump-turbine system. This is done when the cost of energy production from either the renewable or non-renewable energy system is low. When energy production cannot meet demands (peak load demand periods) or the other means of energy generation is too high, the stored water can be used to drive the pump-turbine systems, hence generating electricity [28]. However, both the pumped hydro energy storage system and the conventional hydroelectric generation systems are faced with issues of site suitability/availability and the initial cost of construction/investment. Credible sites and elevated topography for the establishment of pumped hydro energy storage system are available; but may require expert geographical, hydrological, geological, and topographical surveys and mappings of the suspected regions.

3.2.3 Energy resource management and energy supply conservation

The best use of the available energy resources forms the foundation of energy resource management. More than not, the available energy sources we have are highly mismanaged, left to waste and constitute to environmental degradation. A sustainable way to manage the energy resource is the gas-to-grid model systems. A lot of economies, like Italy have benefited from this energy resource management strategy. With the high level of reusable wastes such as agricultural and some non-toxic/organic biological wastes from domestic and industrial wastes available, it is imperative to consider the efficient waste-to-energy models.

In Nigeria, the University of Nigeria, Nsukka (UNN) have championed the use of waste-to-energy models by the construction of their refuse-derived fuel (RDF) gasification power plant capable of generating 100kVA electric power [30]. This is a credible achievement by all standards in developing economy like Nigeria; and should inspire other energy research institutes as the country seeks to create pathways to energy and sustainability. In relation, energy conservation deals with reducing the associated wastages with the use of an energy resource, whilst maximizing the benefits of the resource and the rational use of the transmitted energy [6]. Research centers as the NCEEC and the NCEE are saddled with the responsibilities of developing systems for conserving energy. They are also expected to provide sensitization and education programmes on the importance, the arts and the acts of energy conservation and management. Replicating this over Nigeria and the Sub-Shahram region will require the provision of cutting-edge technologies. Frameworks for advanced energy auditing, monitoring and metering are to be explored for better deployment of better energy. Doing so will include small and medium scale energy generators and providers through distributed generation (DG) approach, net-zero energy building design and demand-side management (DSM). Like in other parts of the world, systematic models can be employed to profile customer demands. The need for improved regional electricity grid such as the West African Power Pool (WAPP) is a sure way to create collaborative leverage of the strengths of the nations in the region for the deployment of accessible, quality and cheap, sustainable energy infrastructure.

3.2.4 Increased involvement of the private sector in the energy industry via public-private sector collaboration

Tackling the issues availability technologies for affordable energy transition relies on increasing the share of investment. Costs may have dropped significantly in many areas, though not witnessed in all countries. Particularly, there should be some assistance provided to the poorest and most vulnerable countries to enable them join in the energy transition trend through building of local capacities and access to modern technology for effective utilization of resources. The dynamics in the many technical, economic, and social aspects of energy transitions will require policies that balance these different aspects. While some renewables are falling in prices, speedy technological advancements and sharing of ideas have made this balance a lot easier and more straightforward now than in the past.

However, the issues of meeting long-term demands and impacts with short-term needs is still a challenge in a global economy filled with uncertain, which is still very much dependent on fossil fuels.

3.2.5 Decreased reliance on fossil fuels and emergence of cleaner energy sources

Developing countries such as those in Africa do face different energy challenges than those in developed countries. For instance, in most African countries, the focus is to transition from traditional energy to modern energy [1]. The focus is also on ensuring energy access, whereas, in the developed world, they have already transitioned to modern energy, and their focus is to ensure energy security and sustainability [1].

The need for flexible and sustainable energy systems is the foundation of sustainable development and energy transition in any nation. The drivers of the past and present electricity production systems in terms of fuel and technologies have evolved and will continue to evolve in the long run. Globally, there is a shift from the energy systems and supply chains that have been prevalent. The energy supply globally is changing, paving way for significant opportunities and trends as well as associated challenges and all. With the dynamics in the energy systems globally, economies and systems that rely on fossil fuels as drivers will have to face the uphill tasks of falling demands and increase pressure to reduce carbon emissions.

This is further aided by the fact that huge investments end-users are currently made in renewable power generation sources as the most economic option to meet decarbonization targets, the demands for fossil fuels will continue to decline. Which is why oil-rich nations are currently investing in cleaner energy sources, example green hydrogen and diversifying in economic approaches. The diversification may have a short-term negative effect on the economies of many oil-rich economies, it will also present long-term opportunities for all globally. Such opportunities as allowing for countries to harness the potentials in their native resources for greater independence in energy production and also providing a cooperative space for countries in different regions to establish linkage in trade and power generation.

Furthermore, strong collaboration between independent economies will create integrated markets which will bring about quick adjustments in the fate of changing demands. For many developing economies, these transitions will require international intervention; both technically and financially. International funds from multilateral and bilateral development finance institutions may be available to aid these transitions since suspension on the investment in coal has been announced and agreed upon. With these assistances available, transitional countries will need to overcome the challenge of ensuring supply frameworks and systems that meet their national demands.

With more than 10% of the world's population not having access to electricity according to UNP [31]. there is need to change that narrative. Even at areas where access to electricity is high, growing demands for electrification by sectors as transport, heating and cooling and industrial processes will rise significantly. Governments of different economies will be faced with the challenge of forecasting and planning for secure supplies following the growing demands for power and the dynamic nature of the global energy supply.

3.2.6 Reduced emphasis on fossil fuels via a pragmatic approach to cleaner energy sources

There are a lot of opportunities in the energy sector; as demands are growing, the need for technologies in the renewable energy space are also on the rise to meet these demands and creates promising markets for industries. The largest rewards will be received by those who have, through innovations, services and resources, positioned themselves as front bearers in energy transitions.

About 15% and 10% of the global power generation have come from hydropower and nuclear energy sources. These sources are faced with challenges of limited or no expansion capacities, according to many projections. Therefore, the decisions and policies of smaller economies will determine the trends in the future. The prevalence of low-carbon solutions in varied settings will be strongly hinged on factors as resilience and cost-competitiveness. Since development of nuclear power stations require a lot of time and expertise, their contributions to global power may not be significant until 2030. Therefore, the present decarbonization framework is based on utilizing the already existing technologies as efforts is made to develop better Research, Development and Diffusions (R, D and D) models such as steel and cement industries that are last-mile decarbonization strategies.

Actualizing the achievements of SDG 7 and Net-Zero emissions will also require more attention to be given to advanced biofuels, green hydrogen and ammonia which are produced via renewable energy methods and are becoming relevant in transport, shipping, and aviation, and other hard-to-abate sectors.

The Carbon Capture and Storage (CCS) methods, which use existing techniques and infrastructure for the production of natural gas-based hydrogen i.e. blue hydrogen is being considered so as to avoid the stranding of assets in the petrochemical industry. The production of blue hydrogen has been adopted by some countries as efforts to expand capacity to supply sufficient green hydrogen to the rapidly growing market. However, not all technologies are suitable for all countries. Therefore, policy makers should ensure that the technologies that meet their local needs are put in place to meet the demands of the dynamic markets and avoid the risks of stranded assets. Economic development, energy security and benefits from newer and cleaner energy sources (in terms of health and environment) will not be maximized if poorly formulated policies, poor attention to market signals, undue priorities short-term thinking and inordinate attraction to status quo are in place.

3.2.7 Proper financing and energy efficiency management

All sectors of the economy and all tiers of government—national, state, local or any other level—are needed to be involved in the energy efficiency. This is because energy efficiency is diverse and the need for regulation and incentivization is important. The following are viable and proven steps towards achieving this:

i. **Regulation,** such as building codes, minimum energy performance standards for equipment, and import restrictions on sub-standard products. These remove the poorest performing systems from the market.
ii. **Information**, such as endorsement labels or comparison labels, product databases, capacity building and training courses for a wide range of market actors, including policymakers, producers, workers, and end users. This information should also feature conservation and demand reduction, where options for changing behaviour are available.
iii. **Incentives**, such as tax schemes, subsidies, or rebates that increase the uptake of high efficiency products, or those with low global-warming-potential (GWP) refrigerants.
iv. **Aggregating demand**, through public procurement and private buyers' clubs, can accelerate the uptake of best available technologies and drive down the cost of energy-efficient and climate friendly equipment.

The necessity for actions to be based on a unified strategy with other goals is very necessary; this is common with other parts of the energy sector transformation. The unification of energy efficiency strategies, demand-reduction measures and supply expansions methods are needed to find the best grounds especially for affordability, accessibility and service delivery. Furthermore, the opportunities that new digital technologies offer need to be fully utilized. This is critical to enhance the efficient integration of the divergent energy systems in line with demand protocols.

Financing is a general issue with energy efficiency outside government policies and regulation. This may be attributed to the size of the activities of energy providers which are considered too small to attract the interest of commercial and development financial institutions. Other arguments are that there is the lack of the required proficiency and know-how some of the financial institutions in the evaluation and preparation of investment plans for energy efficiency. While there are many models to overcoming the above barrier, government and private sector partnership to address issues of market failure, risk management and sharing and participatory strategies to ensure the collaborative efforts of low-income groups.

3.2.8 Tackling energy access challenges in rural areas through renewable energy

The presence of renewable energy laws has made it possible to pursue projects to tackle Africa's energy access and poverty challenges, especially in rural areas. For instance, in 2016, Sierra Leone passed the Renewable Energy Policy. The Policy is posed as a climate change mitigation strategy [7]. It also emphasises the need to provide electricity to rural areas that cannot expect grid energy in the near to medium term via mini-grids. As an outcome of this Policy, the Rural Renewable Energy Project (RREP) was initiated. This project implemented by UNOPS (United Nations Office for Project Services) and funded by DFID (Department for International Development) installed mini-grids in 50 villages in Sierra Leone. These were handed over to private operators in 2019, a process that is expected to ensure economic sustainability [1].

Additionally, the Environment Protection Agency, in support of the Ministry of Energy, produced guidelines for Environmental Impact Assessment of Renewable Energy and Mini-Grid Projects (up to 1MW). These guidelines significantly reduce the cost, red tape and time required to acquire an environmental permit for renewable energy projects. The guidelines are scheduled to be converted to regulations in 2020 to promote rural electrification [7].

3.2.9 Harmonisation with regional renewable energy laws and policies

Total replacement of fossil fuels may not occur any time soon as fossil fuels are more abundant in some parts of Africa than in others. In the near future, the energy mix will consist of hydrocarbons and renewable energy [32]. Transforming the country's socioeconomic system is a necessity if the transition will be achieved. It is also critical to ameliorating the anticipated impact global energy transition will have on the country [33-36]. Energy transition cannot be approached separately from the socioeconomic system in which it is positioned. It should consist of all the social and economic composition and relationships present in a society. Diverse transition path can be followed, as well as different transition of the socioeconomic system [7]. Consequently, the transition is dependent on Nigeria's target and socioeconomic configuration.

There has been an increase in regional cooperation in tackling energy access challenges. This is also reflected in the deployment of renewable energy and energy efficiency technologies. In this respect, the relevant renewable energy laws and policies recognise the need to harmonise with regional laws. For instance, in Sierra Leone, the renewable energy policy expressly states the need to harmonise its rules with the renewable energy policy of ECOWAS/ECREEE (Economic Community of West African States/ Center for Renewable Energy and Energy Efficiency), which will be implemented through a National Renewable Energy Action Plan (NREAP) Sierra Leone [37-40].

3.2.10 Applying the concept of paradigm shift method (*"avoid-shift-improve"* method)

A necessary part of energy transition requires transformative strategies in the transport sector. To meet with the overall net-zero greenhouse gas emissions, the current high reliance on fossil fuels by the transport sector needs to be addressed and reduced. There is need for government to integrate the transport system in the overall energy transition strategy, engaging all sectors—national, state, local or any other level—the private sectors and all (Fig. 19).

From the onset, there should be processes that provide agreement to establish mid-and long-term targets that parallel with national sustainable development plans and the SDG 7 (2050 net-zero goals). These policies and processes should integrate a lot of approaches towards reaching the transition goals as well as identify the main prerequisites for success. Sustainable development policies and goals should include room for policy and institutional development, necessary labour skills enhancements, and financing and infrastructure needs.

There are calls to governments to adopt the integrated developmental strategies that reduces demands, improve energy efficiency while changing transport modes. This method is called the **"**Avoid-Shift-Improve**"** approach.

Governments should adopt the following strategies:

i. ***Avoid***—Managing travel demand can be done in many direct and indirect ways. Options include infrastructure design, for example, building higher-density cities and local integration of workspaces and domestic dwellings. Pricing in different forms is also important, including taxes on vehicles, fuels, and parking; road use levies; freight handling charges in harbours; and departure/arrival taxation in airports.
ii. ***Shift***—Stimulating use of the least energy-intensive modes of transport by, for example, creating favourable conditions for pedestrians, building bike lanes, and strengthening public transport and car-pooling choices through subsidies, and constructing fast track lanes in congested places. Integration of different transport modes benefits end users and enhances system efficiency. Electrification of both private and urban public transport, where possible, and creating fast electric train connections between major cities is another option.
iii. ***Improve***—Increasing energy efficiency of vehicles and motorized two-wheelers through design, engine improvements, efficient air conditioners, and the use of more efficient electrical motors. For land and sea freight and aviation, exploring and promoting the use of modern biofuels, hydrogen, or ammonia where electrification is not relevant will be critical.

Documentation of policy tools as vehicle efficiency norms and fuel standards are important so that the adoption of more sustainable transport technologies can be encouraged. Other efficient tools as vehicle and fuel pricing, if used in combination with a functional charging set-up for electrical vehicles can also be helpful to drive energy transition. For climate benefits to be maximized, emphasis must be placed on "green electricity" as well as "green hydrogen" (Fig. 20).

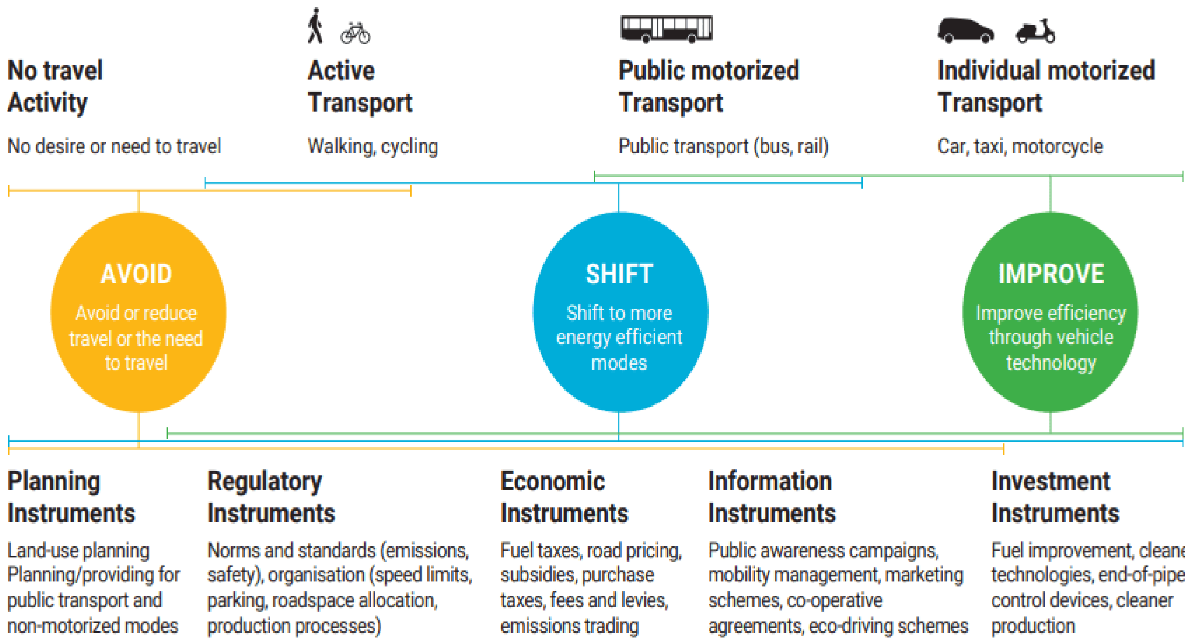

Fig. 19. The paradigm shift method of harnessing the potentials in energy transition
(Source: IEA, 2021)

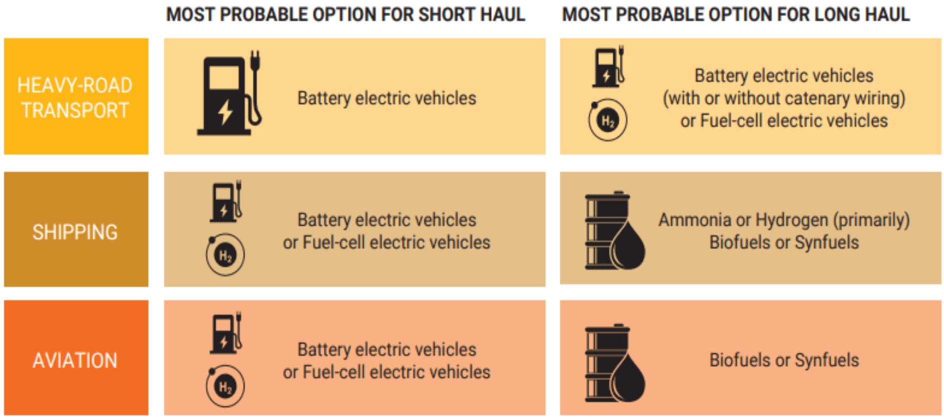

Fig. 20. Improvement in transport systems via the go-green campaign
(Source: IEA, 2021)

Developed and rapidly developing nations as China and India can leverage on the abundance of electrical vehicles in the market presently as all major manufacturers of automobiles and vehicles are opting for the electrical power systems and this has reduced the cost of batteries and drive systems rapidly. With that in place, electrification of both private and public sector transport systems looks to be the leading medium-term option. For global acceptance to take place, a lot of time is required as other slowly developing economies would require a lot of time to catch up considering the challenges of affordability and insufficient power supply and infrastructure. These countries will still make use of the current transport systems but improve on the efficiency as it relates to emission due to use of fossil fuels and improve on the use of use of sustainable biofuels. Current electrification in terms of technologies and cost is not currently feasible for sub-sectors in the transport industry as shipping, aviation and parts of heavy-duty land freight transport. For these subsectors, decarbonization strategies would hinge on demand management, fuel efficiency improvements and use of energy from biofuels, hydrogen, ammonia, and other synthetic low-carbon fuels.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

In terms of energy demands versus energy production in African countries, over 64% of the African population do not have access to electricity and other forms of energy. Despite the advancements in technology, most of African fuel production have come from fossil fuels, hydro-powered dams and most recently, the solar photovoltaic cells.

Energy transition in African countries has not been as quick as expected. In spite of the high level of education on the effects of fossil fuels as regards environmental degradation, much of the demands on domestic fuel in Africa rests on fossil fuels (charcoal). The uncanny bond Africa has with fossil fuel has been the major reason why transition into cleaner energy has not been fully achieved. Especially for the OPEC countries, crude oil and other fossils have been the economic mainstay of these countries and the political, social, economic and technological will to adjust into the cleaner, renewable energy sources is still absent.

The dwindling demands for fossil fuels on a global scale have been an opportunity for most countries to seek alternative means of meeting their populace's energy demands. Despite the slow transition into renewable energy, the private sector as well as multi-nationals are gradually but surely investing into renewable energy sources (solar energy and bio-energy sources). The challenge with this development to the average African is the high cost of obtaining and tapping into cleaner energy sources as these.

5. RECOMMENDATIONS

i. Addressing the challenges of energy transition in the study areas (countries) will require an all-inclusive process. It will need a drastic change in the political desires and more symbiotic relationship especially for those at the helm of affairs.

ii. At its best, this approach will bring about an enabling environment for the private sector to thrive as they play a prime role in the growth and provision of the cleaner renewable energy sources and ensuring that more funds are allocated to this sector and such funds are judiciously managed.
iii. Energy transition in African countries can only be achieved under the auspices of a strong political will, social drive, cultural motivation and technological inclination towards a sustainable transition to cleaner renewable energy sources and less focus on fossil fuels.
iv. Harnessing the opportunities in renewable energy will surely boost the economy of the different case study countries. A willing socio-political disposition towards renewable energy sources, increased investment plan for cleaner energy, reduced emphasis on fossil fuels and private-public sector collaboration will surely be giant steps to tapping into the numerous benefits of renewable energy sources.
v. No much will be achieved if left out the social and cultural aspects of these contextual challenges, especially in typical African community where strong attachment to fossil fuels are uncannily strong and rigidly practised. The policies and strategies towards energy transition in Africa must be critically reviewed so they fit into the existing socio-cultural norms prevalent in these areas.
vi. If all these are astutely considered, on a platform of discipline, honesty and transparency, in no distant time will the Africa join their Western counterparts to tap into the potentials of the renewable energy sources. These measures will accelerate the transformative role of natural gas in Africa's energy future.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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