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# Renewable Energy for Sustainable Development in Developing Countries: Benefits to the Environment

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

The primary objective of this study is to investigate economic freedom of access to energy, energy utilization and consumption, improve energy security, mitigate climate change and ignite interest in various renewable energy sources in developing countries. Sustainable development is the benefit that meet the needs of the people without compromising access to affordability, reliability, sustainability and modern quality of human satisfaction of its citizens within the limitation of the environment. It has become widely recognized that the rising environmental hazards, depletion threatened the unreliable supply of electricity with huge economic cost associated with fossil fuel has made renewable energy issue a significant sustainability resource as the basic requirements for development in developing countries. This paper aims to present review and promote access to harnessing, harvesting, storage, conversion and technology of renewable energy sources for generating electricity in developing nations by 2050. In this review, we have identified the various renewable energy sources, challenges and benefits. The recommendation on this investigation shows greatly our contributions to the aspiration of citizens in developing countries for alleviating struggles to overcome the epileptic power supply that has harassed the economy of the nation in jeopardy for long time.

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## 1. INTRODUCTION

"Renewable energy resources is a numerate and quantitative property of proven technical and economic importance worldwide. Energy supplies from renewable (such as solar, wind, tidal, biomass, hydroelectric power, ocean, geothermal, hydrogen power, carbon neutral fuel, and MHD power generation) are essential components of every nation's energy strategy. In this section, we review the relevant literature to discuss how issues such as renewable energy, energy security, energy planning and sustainable development resilience should deserve more attention. Today, renewable energy resources have become increasingly more important due to the fact that they have fewer negative impacts on the environment than other sources of energies and the growing limitations of fossil fuels. Its consumption contributed to about 22% of the world's final energy consumption by 2015" [1]. "The comprehensive benefits of using renewable energy, the global demand for renewable energy is predicted to rise to 31% by 2035" [2]. On the same side, developed and developing countries are in advances to increase renewable energy generation.

This paper presents a global call for energy generation in all the developing countries of the world especially Africa for the next decade. This should also be regarded as a way to secure energy supply leading to significant technical, economic development and improvement in people's lives that is consistent with advancing environmental and social well being. With increasing use of renewable energy, there has been an extensive number of literature that examined the causal relationship between renewable energy consumption and economic growth in developed and developing countries. However, large gaps in the literature remain. There is a very limited awareness on these alternative energy vision irrespective of there being a device to intercept and harness this power [3-5]. Such energy may also be called green energy or sustainable energy. Furthermore, the economic switch from the energy obtained from static stores of energy that remain underground unless released by human interaction (such are oil and natural gas, nuclear fuel, fossil fuels of coal) may avoid using ungainly word 'non-renewable', such energy supplies are called brown energy switch to renewable energy is an intriguing way to achieve the 2030 sustainable development goals [6]. Similarly, Usman and Makhdum [7] argued that "renewable energy consumption could not underestimate to achieve sustainable development goals". Recently, Olabi et al. [8] focus on "the investigation of the relationship between renewable energy consumption, economic growth and sustainable development". Razmi et al. [9] highlighted that "economic growth rate significantly affects hydroelectric power, wind, solar and biomass energies in developing countries". On the other hand, the transition from non-renewable energy to renewable energy is challenging. Many developing countries have not made the transition from brown energy to green energy because of 'market failure' such as lack of financial availability, technical experts, environmental externalities, stress on importing dirty technologies and the public social behaviour [10].

## 2. ENERGY AND SUSTAINABLE DEVELOPMENT

"Energy is necessary for a number of reasons; the most basic and obvious involve the preparation of food and the provision of heat in order to make life comfortable, or at least, bearable. Adeosun et al. [11] explained that the easiest way to acquire useful energy is to simply find it in nature as wood or as a hydrocarbon fossil fuel and its advantageous to simply convert what is available in nature into more useful forms". "Energy is the quantitative property that must be transferred to an object in order to perform work or to heat the object" [12]. "Common forms of energy include the Kinetic energy of a moving object, the potential energy stored by an object's position in a force field (gravitational, electric or magnetic), the elastic energy stored by stretching solid objects, the chemical energy released when fuel burns, the radiant energy carried by light, internal energy gained by the object through friction is the sum of all microscopic forms of energy of a system and thermal energy due to an object's temperature" [13]. "The total energy of a system can be classified into potential energy, kinetic energy or combinations of the two. Mechanical energy is the sum of translational and rotational kinetic and potential energy in a system" [14]. "Energy resources are referred to as one of the natural resources and that are useful raw materials for living organisms, human consumption and utilization, manufacturing, production of goods. They occur naturally, meaning that man cannot make them but instead use and modify the resources for the benefit of the people and the environment. These energy resources include petroleum, natural gas, coal, water, solar, wind, tidal, ocean, biomass, geothermal, nuclear, hydrogen fuel, and carbon-neutral fuel" [15-17].

The word "Sustainable'' means able to be maintained and nourished. Sustainability is defined as the process applied to benefit the quality of Human life within the limitations of the environment. Oyedapo, [18] defined "sustainable development as that meets the need of the present without compromising the ability of future generations to satisfy the need of the people". However, "sustainable development implies a dynamic equilibrium between maintenance/ conservation sustainability and development" [19,20]. Avinash et al. [16] define sustainability as meeting the environmental, societal, economical and human needs. The word "Benefit'' means an aid from source, advantages or assistance derived from natural resources such as energy resources [13]. Every human endeavour requires energy which means there is no kind of activity that does not require energy and another energy resources of these types would not only help meet the growing energy demand but also preserve our environment from the devastating effect of this energy sources [21]. The benefits of these energy resources in our environment can be attributed to electricity generation that provide energy for our cars, pumping of boreholes, water supply, improving the quality of life, making power transformation sustainable, heating water for home uses, and solar power for devices [22].

"Sustainable development and benefits to the environment require the maintenance, advantages, rational use and enhancement of energy resources, as well as balanced consideration of environment and societal justice. More so, it involves solution for improving human welfare that does not result in degrading the environment on impinging in well-being of the people" [22-24]. Developed countries have to transfer their advanced technologies to developing countries in other to avoid undesirable development in the energy sectors (industry) and the benefits of energy resources in those regions. Adeosun et al. [11] explained that people who studied energy resources and management, energy systems engineering, energy storage and conversion seek to know the types of energy sources that are available for a particular environment and where they are more pronounced, and to create new technologies for harvesting, exploiting and harnessing the resources. McNicoll [23] pointed out that the discovery of new energy sources and usage of more energy resources is one way to derive more benefits.

## 2.1 Energy, Exergy and Anergy

Yumruta et al. [25] gave the concept of energy, "exergy and anergy constitute the potential of a system to do work with reference to its dead state as the energy of that system. The dead state emerges when equilibrium occurs between the systems and the environment. The energy which has no work potential and is rejected in the environment is referred to as anergy". "Equation (1) and Fig. 1 shows that the exergy of a system is the maximum useful energy possible during a process that brings the system into equilibrium with a heat reservoir reaching maximum entropy" [15]. Exergy is the potential of a system to cause a change as it achieves equilibrium with its environment. Exergy is the energy that is available to be used. After the system and surrounding reach equilibrium, the exergy is zero. The destroyed exergy is called anergy. Therefore exergy is that part of energy which cannot be converted into any other form of energy; the remainder is anergy. In general.

## 2.2 Energy and Environment

"The usage of energy resources in industry leads to environmental damages by polluting the atmosphere" [11]. "Few examples of air pollution are sulphur dioxide (($SO_2$), nitrous oxide ($NO_X$) and carbon monoxide ($CO$) emission from boilers finances, Chlorofluro carbons ($CFC$) emissions from refrigerants use, etc. In chemical and fertilizers industries, toxic gases are released. Cement plants and power plants spew out particulate matter. A variety of air pollutants have suspected harmful effects on human health and the environment" [14]. "These air pollutants are basically the products of combustion from fossil fuel. Air pollutants from these sources may not only create problems near to these sources but also can cause problems far away. Air pollutants can travel long distances, chemically react in the atmosphere to produce secondary pollutants such as acid rain or ozone" [17].

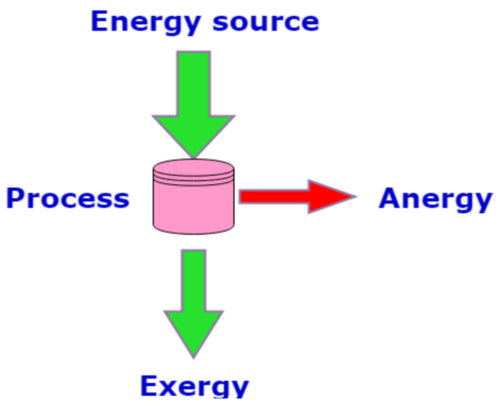


**Fig. 1. Schematic Diagram of Energy, Exergy and Anergy Process**

*Energy = Exergy + Anergy* *(1)*

"In both developed and developing countries, major threat to clean air is now posed by traffic emissions. Petrol and diesel engine motor vehicles emit a wide variety of pollutants, principally carbon monoxide $(CO)$, oxide of nitrogen $(NO_X)$, volatile organic compounds $(VOC_S)$ and particulates" [26]. However, "traffic pollution problems are worsening world-wide and may be particularly severe in developing countries with increasing vehicle population, infrastructural limitations, poor engine/ emission control technologies and limited provision for maintenance or vehicle regulation" [27].

## 3. CLIMATIC CHANGE

"Human activities, particularly the combustion of fossil fuels, have made the blanket of green-house gases (water vapour, carbon dioxide, methane, ozone e.t.c.) around the earth thicker" [28]. The resulting increase in global temperature is altering the complex web of systems that allow life to thrive on earth such as rainfall, wind patterns, ocean current and distribution of plant and animals species. US EPA, [29] stated that "life on earth is made possible by energy from the sun, which arrives mainly in the form of visible light". "About 30 percent of the sunlight is scattered back into space by outer atmosphere and the balance 70 percent reaches the earth surface, which reflects in form of infrared radiation. The escape of slow moving infrared radiation is delayed by the greenhouse gases" [30]. A thicker blanket of greenhouse gases traps more infrared radiation and increase the earth's temperature as shown in Fig. 2.

### 3.1 Evidence from the Climate Change

Craig, [31] explained that "tornado (tropical cyclones), severe storms, hurricanes,landslides, volcanic eruptions,are occurring more frequently and tsunamis, earthquakes, floods, and droughts are more intense than before. This increase in extreme weather events cannot be explained far from random events. This tends towards more powerful storms, hotter and longer dry periods are predicted by computer models. Warmer temperatures mean greater evaporation is able to hold more moisture and hence there is more water aloft that can fall as precipitation".

### 3.2 Future Effects

"Even the minimum predicted shifts in climate for the 21st century are likely to be significant and disruptive" [30]. "Predictions of future climatic changes are wide-ranging. The global temperature may climb from 1.5 to 5.9 degrees C; the sea level may rise from 9 to 88 cm. Thus, uncertainty reflects the complexity, interrelatedness, and sensitivity of the natural systems that make up the climate" [28]. The risks that climate change poses to disaster may be to avoid the worst impact of climate change, emissions need to be reduced by almost half by 2030 and reach net-zero by 2050 (Christain Aall, 2022).

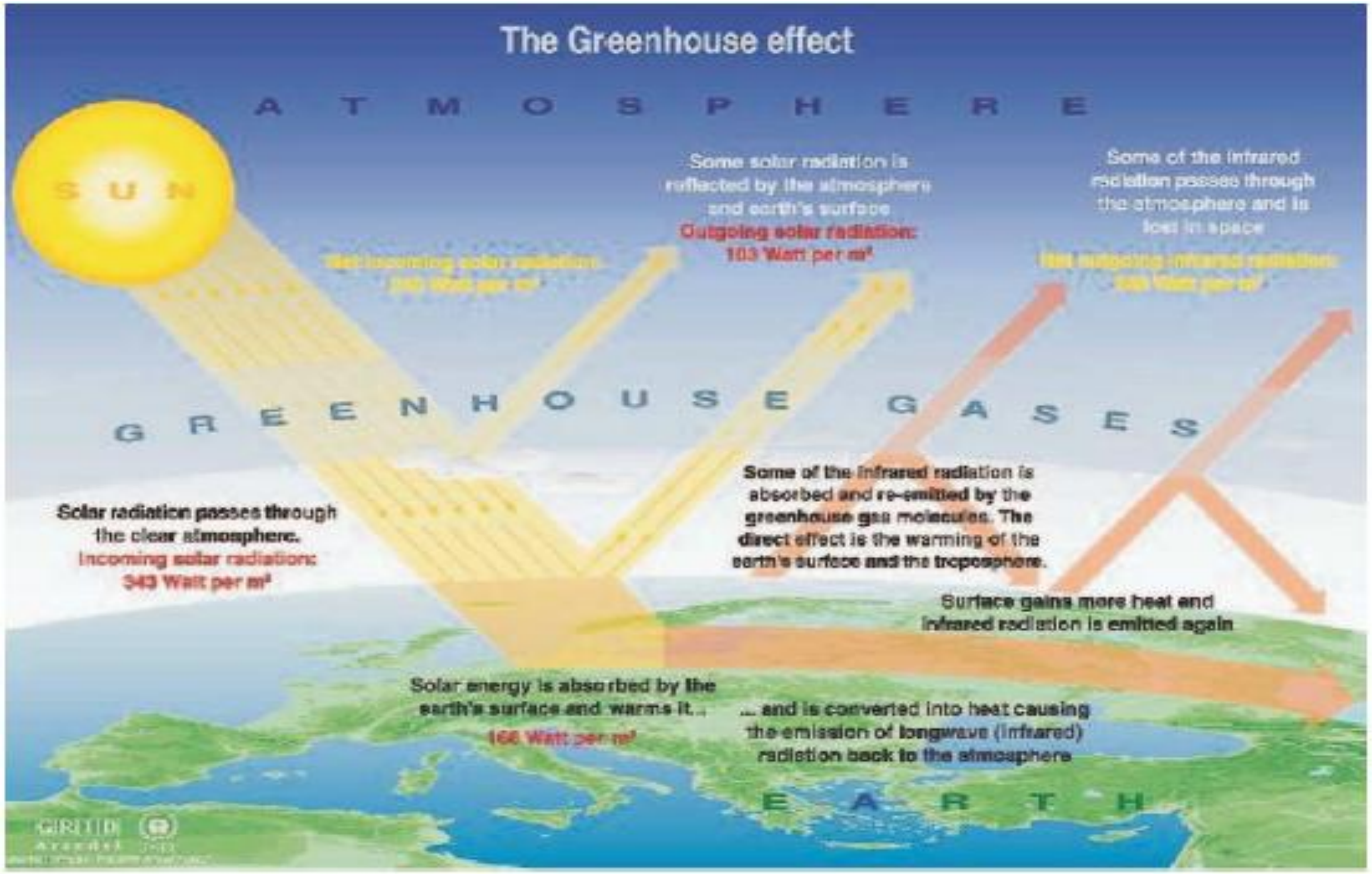


**Fig. 2. The greenhouse effects [29]**

## 4. OVERVIEW OF ENERGY RESOURCES CLASSIFICATIONS

Energy is one of the major inputs for economic and sustainable development of any country. In the case of developing countries, Lawrence, [32] explained that "the energy sector assumes a critical importance in view of the increasing energy needs requiring huge investment to meet them. Energy can the classified into several types based on the flowing".

### 4.1 Primary and Secondary Energy Sources

"Primary energy sources are those that are either found or stored in nature. Common primary energy sources are oil, natural gas, coal and biomass (such as wood), other primary sources available include nuclear energy from radioactive substance, thermal energy stored in earth's interior, and potential energy due to earth gravity" [11].

Primary energy sources are costly converted in industrial utilize into secondary energy sources for example coal, oil, or gas converted into steam and electricity. The major primary and secondary sources are shown in Fig. 3.

### 4.2 Commercial and Non-Commercial Energy Sources

"Commercial energy sources are those that are available in the market for a definite price. By far the most important forms of commercial energy are electricity, coal, lignite, and refined petroleum products" [24]. "Commercial energy forms the basis of industrial, agricultural, transport and commercial development in the modern world. In developed countries, commercialized fuels are predominant sources not only for economic production, but also for many household tasks of general population" [33]. Whereas the energy sources that are not available in the commercial market for a price are classified as non-commercial energy and this include fuels such as firewood, cattle dung, agro waste in rural areas, animal power for transport, threshing, crushing sugarcane, drying grains, lifting water for irrigation and drainage which are traditionally gathered, and not bought at a price used especially in rural households [24]. These are called traditional fuels as these are ignored in energy accounting.

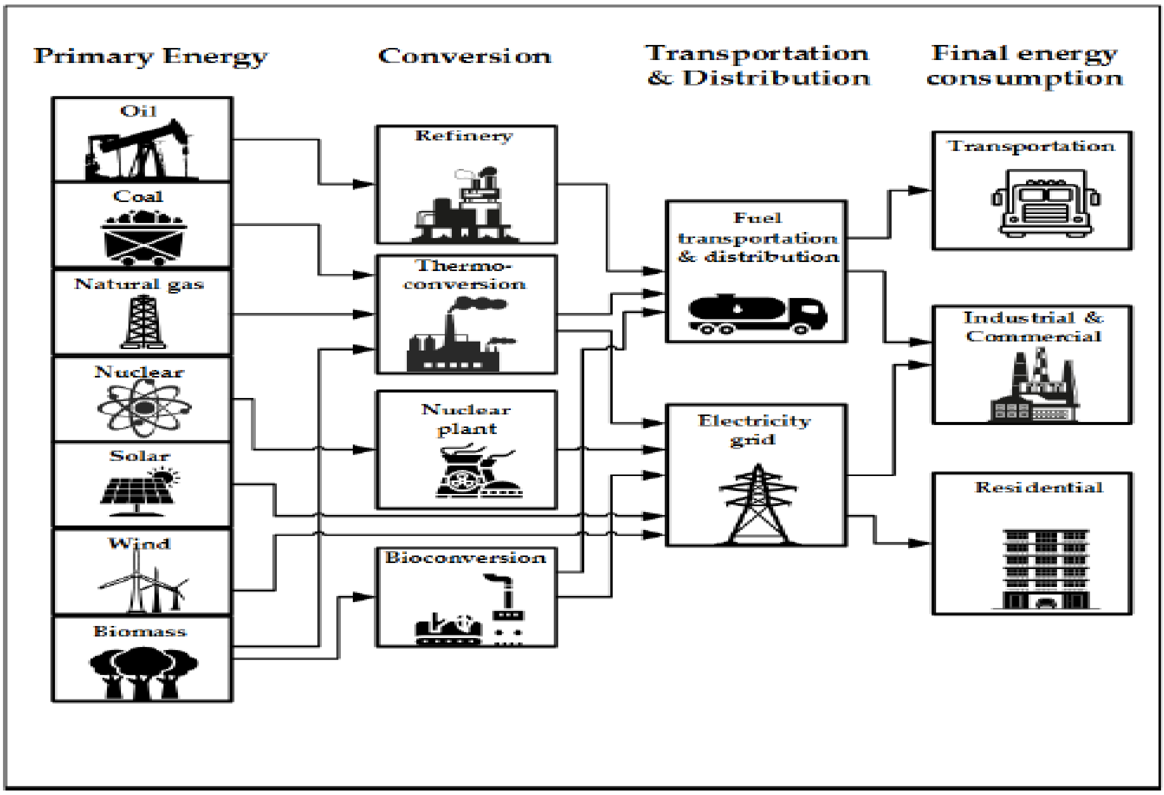


**Fig. 3. Flow of energy from primary energy to final energy consumption [32]**

### 4.3 Conventional and Non-Conventional Energy Sources

“Conventional energy sources which are being traditionally used for many decades and were in common use around oil crisis of 1973 are fossil fuels, coal, nuclear and hydro resources. Whereas non-conventional energy sources which are for large scale use after oil crisis of 1973 are solar, wind, biomass geothermal, and hydrogen power” [34].

## 5. RENEWABLE ENERGY RESOURCES

Renewable energy resources is natural and persistent flows of energy occuring in the immediate environment and can also be considered as any energy resources that is available naturally on a continuous basis or can be continuously regenerated over a short period of time, which may be on a daily basis or over several days or years (Amoah et al. 2020). This energy sources are replaced through natural processes at a rate that is equal to or greater than the rate at which they are exploited and depletion is usually not a threat. Bugaje, [35] stated that renewable energy sources are derived directly from the sun (such as solar, thermal, photochemical, photoelectric), indirectly from the sun (such as wind, hydroelectric, photosynthesis energy stored in biomass), and from their natural phenomena of the environment such as geothermal, ocean waves, tidal, hydrogen fuel cells and carbon neutral fuel [36].

### 5.1 Solar Energy

“Solar energy is the energy that refers to direct use of the sun ray’s to supply energy for the needs of people in the form of electromagnetic radiation emitted from the sun and harnessed using sophisticated technologies such solar heating, solar thermal, solar photovoltaic panels of different architecture and artificial photosynthesis” [37,38]. “Solar energy is inexhaustible and cheaper and is now use to power homes, stores, and restaurants. It is one of the most important sources of renewable energy and its techniques are either passive solar or active solar depending on the way they are capture, distribute or convert it into solar electricity” [39,40]. “Active solar methods include the use of photovoltaic panels, concentrated solar power and solar water heating to tap the energy. Passive solar methods include orienting a building to the sun, selecting materials with advantages thermal mass or high dispensing properties and designing spaces that naturally circulate air. Solar photovoltaic and concentrating solar power method are also being used by developers and utilises to produce electricity to power houses both residential and commercial” [24].

**Fig. 4. Solar cells power plant [33]**

Although, solar energy is free, as depicted in Fig. 4 that the necessary equipment and its installation are not free. The initial cost of setting up a solar energy system, including a supplemental heating unit can be substantial, but over a long period, solar energy systems focus on radiation emitted by the sun ray's for at least along a single photovoltaic axis to generate temperatures of about $350^oC$ for which to a lager extent will only complement non-renewable energy [37,41]. "The US Energy information Administration has classified the solar energy as low, medium and high temperature collectors. Low temperature collectors are flat plates generally used to heat swimming pools. Medium temperature collectors are also flat plates and are used for creating hot water for residential and commercial use, while high temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production" [42,33]. However, business and industry also use solar energy to complement and diversify their energy sources, improve efficiency and save cost but the future of this technology is uncertain [14]. In addition to being relatively inefficient, solar cells are presently very expensive to produce and are easily damage by the elements while finding solution to environmental issues [15]. Nigeria can benefit largely from solar energy for being located within a high sunshine belt in Africa with enormous sunlight potentials. The benefits of solar energy as renewable source are abundant sunshine, sustainable, available at reduced electricity cost and low maintenance cost, environmental friendly and the technology is ever improving.

## 5.2 Wind Energy

Wind is air in motion and it has been used for centuries as almost free and non-polluting source of energy. Wind energy is affordable, efficient and abundant sources of electric power. Sailing ships and wind power grist will represent two of the early ways that this renewable energy was harnessed [38]. Wind power works by harnessing energy from the wind through spinning turbines. The wind drives the turbine which in turn drives an electric generator. Wind power can generate electricity efficiently if it is based on turbine power, the average annual wind speed, weibull function as shown in Equ.3.

"Wind turbines create energy though the process of converting wind to energy. This creates a sustainable and affordable source of energy. To ensure that energy from a home wind turbine is sufficient and reliable, one must determine how much energy your small turbine will produce. A wind turbine is a device for converting the kinetic energy in wind into the mechanical energy of a rotating shaft usually that rotating mechanical energy is converted immediately by a generator through the streaming air to electric power" [13]. Investigation has revealed that power is produced in the wind speed of 4 – 25m/s range.

Weibull function prediction is usually from a mathematical formula that is very good at fitting a wide range of empirical data set. Such as symmetric and asymmetric unimodal curves, sigmoid – shaped curves and many other non-linear functions. In the wind industry, the version of the Weibull function commonly used is:

$$\Gamma(v) = \left(0.89\frac{k}{v}\right)\left(0.89\frac{v}{\bar{v}}\right)^{k-1} exp\left(-\left(0.89\frac{v}{\bar{v}}\right)^{k}\right) \qquad (3)$$

$\Gamma(v)$ is the probability that wind speed will be $v$ over one year period, $k$ is the Weibull constant, $\bar{v}$ is the average annual velocity. The inherent problems with wind are power availability, since the wind neither blows constantly or the speed depends on area.

## 5.3 Turbine Efficiency Varied with Wind Speed

If the turbine could convert all the wind power to mechanical power, we would say it was 100% efficiency. But as we probably know, the real world is never so generous, to even achieve 50% is uncertain and would be a very efficient machine. A 50% efficient turbine would convert half of the power in the wind to mechanical power. This can be seen from the turbine power curve that is based on field experimental observation [43]. "A given wind turbine has a design point that generally defines its peak efficiency at the wind speed for which the system is designed. At wind speed above and below the design speed, the efficiency is the same or less, maybe much lesser. If a turbine best efficiency is 40% at a wind velocity of 1.4m/s, it will be 40% only at that wind speed. At all other wind speeds, it will be something worse" [43]. "The turbine will generally operate at lower than its best efficiency because wind speeds are never constant. The electric power actually produced will still be lower because the generator efficiencies are also less than 100%" [44].

Economically, this is not feasible in developing countries like Nigeria to have large dense and automatic weather observational network [24]. Although, the future for wind power appears promising, it is not without difficulties. There are many technical problems to overcome in building large, efficient turbines. In addition, noise pollution and cost of large tracts of land (wind farm) in populated area present other significant obstacles for development [41]. The benefits of wind energy are more than its adverse effects. It is clean, cheap to run, no pollutant, cost effective, sustainable, abundant supply, completely free as renewable source.

## 5.4 Hydroelectric Power

People have used falling water as an energy sources for centuries and the mechanical energy produced by water wheels was also used to mills and other machineries. Today the power generated by falling water is used to derive turbines and produced electricity in Kanji Dam as shown in Fig. 4 [27]. Hydroelectric power plant contributed about 19% of the country's needs at present and most of this energy is produced at large dams which allow for a controlled flow of water [38]. Energy from moving water is capable to conceive the largest sources of electricity in Nigeria through the water turbine in Kanji Dam in Fig. 5 [31]. However, hydroelectric power makes use of the kinetic energy water gains when it drops on elevations. It is a renewable source. The water impounded in a reservoir is a form of stored energy that can be released through turbines generators at time to produce electricity [38].

Hydroelectric power has been the essential supply of electricity since the beginning of the electric age. Nigeria for example is fairly endowed with small and large rivers, and some few waterfalls and streams, within the present split of the country into eleven river basin authorities which have been dammed to produce hydroelectricity [41]. The hydroelectric power has the potentials to supply uninterrupted electric power in the country. The total hydroelectric power (small and large) energy generation capacity in Nigeria is round 14,750 MW and even at that, only 2,065 MW which is about 14% of the total capacity is being generated at Kanji, Shiroro and Jebba which represent 30% of the gross installed grid-connected electricity generation capacity in the country [45]. Despite the fact that large hydroelectric power has high capacity, it is still under-utilized due to unexploited off-grid coupled with the advantages associated with small hydroelectric power (SHP) such as small power generating alongside irrigation, navigation, flood prevention, fisheries, lesser civil work provided the country with SHP supplemental consideration in Nigeria [41]. Though, SHP site exist virtually in all parts of the country with an estimated total capacity of 3, 500 MW that is about 23% of the entire hydropower potentials in twelve states and four rivers basins were over 278.3 MW of electricity [46]. With numerous rivers systems, a total of 70 micro dam, 126 mini dam and 86 small sites were identified as source of hydroelectric power (Aliyu and Elegba, 1990). In addition to a total of 30 MW of SHP installed capacity in 3 states, 21 MW of hydroelectric power energy is being generated by Nigerian electricity supply company (NESCO), and that Nigerian rivers have estimated 11, 000 MW exploitable hydroelectric power potentials in the country. Yet, only 19% that is 2,090 MW is being tapped [41].

Hydroelectric power capacity to a greater extent depends on the seasonal amount of rainfall, its distribution to river systems are subject to periodic drought. The total annual rainfall increases from about 500 mm or nm depth in the northern part with precipitation lasting for over 4 months in a year as compared to 3,400 mm depth at the southern part of the country with precipitation that could be less than 8 months [47,40]. The under exploited hydroelectric power could be well developed by putting an end to the advantages of small rivers in the rural communities to set up SHP plants. The dams built to provide hydroelectricity have finite lifetimes.

## 5.5 Biomass Energy

Biomass is considered as one of the most important alternative source of energy that can be used to reduce the drastic effects of the instability, inaccessible option in the generation of electricity [48,36]. Biomass energy is the energy derivable from organic materials such as plants and animals, wood, grasses, agricultural crops, crop residues, forestry and plantation, animal dung, garbage, municipal wastes, manure, bead trees and household trashes to mention but few. Being an energy sources, biomass could be used either as solid fuel or technologically converted to liquid or gaseous forms for the generation of fuel energy, heat or electric power [49].

**Fig. 5. Kanji-dam. (Source: www.nigeria alternativeenergy.org)**

Available biomass sources in Nigeria includes agricultural and forestry if considered as a single system offers a lot of potentials for renewable energy in form of biomass. Woods have been known for years to provide energy for cooking, space heating, metal-ore refining and crop processing. With advances in biotechnology, bioengineering, household trashes, garbage, animal waste and waste arising from municipal and industrial activities as well as marine aquatic were the most promising feed stock for biofuel energy production [48,50]. All these materials, especially of organic origin are called biomass and plant can be utilized as fuel and could also be fermented by anaerobic bacteria to produce a cheap fuel gas (biogas). Biogas production from agricultural residues, industrial and municipal wastes and animal dung does compete for land, water and fertilizers with food crops like is the case with bioethanol and biodiesel production [48,51].

Conversion of biomass to either thermochemical is a process that could lead to the production of solid, liquid or gaseous fuel [51,40]. The potential of biomass to help meet the world energy demand has been widely recognized. When burnt, the chemical energy in biomass is released as heat, which is used to produce steam that can in turn be used to either drive a turbine for the production of electricity [13]. Another utility of biomass in the production of electric power is the gathering together all forms of biomass, brought to power plant where the biomass is dumped into huge hoppers from where it is fed into a furnace to burn. The resulting heat is then used to boil water in a boiler, and the energy in the steam is used to turn turbine and generators [46].

Another option is to tap biomass resource at the landfills with burning waste products. When garbage decomposes, it gives off Methane. The Methane produced is then piped into the power plants to make electricity [40]. This type of biomass is called landfill gas. Similar landfill gas may be obtained with manure produced by animals and when decomposes, it also gives off Methane gas similar to garbage. The gas may be burnt right at the farm to make electricity. Biofuel maybe produced when wood is heated to $500^oC$ in the absence of oxygen to produce pyrolysis oil – a flammable liquid that can be used to make liquid fuel. Wood may also be heated to $700^oC$ with small amount of oxygen and steam to produced synthetic gas or syngas which can run a combustion engine and generate electricity [41].

Combustion is a direct conversion of biomass to heat energy. It is initially accompanied by drying the biomass followed by dissolution at about $250^oC$ and above to solid residue. The process on small-scale is always used for thermal application while a large –scale combustion plant produce steam for running steam engine and is essential for electricity power generation [48,35]. The benefits of biomass energy are more apparent than its adverse effects. It is carbon neutral, cheap raw materials, and does not contribute to global warming; it is clean, cost effective, and abundant in large quantities.

### 5.6 Geothermal Energy

Geothermal energy is defined as the heat from the earth. It comes from the natural heat of the earth primarily due to the decay of the naturally radioactive isotopes of Uranium, Thorium and Potassium [53]. Original heat formation of the earth and radioactive heat production (alpha, beta and gamma) are from radioactive decay of minerals within the earth's core. Geothermal energy is clean and sustainable and it provides continuous energy 24 hours a day [54]. Geothermal energy is the most versatile and exploited renewable energy, in developed nations where hot springs have also been used for heating, washing, bathing, cooking and health related issues. Geothermal energy brings potential energy and economic benefits as well as reducing ecological and health problems. Mohamon Omar, [55] gives an overview of what geothermal energy really is study and creates awareness of possible explanation and exploitation for harnessing this clean energy, no fuel is burnt, and no air pollution, it will serve as a cheap fuel, for heating and electricity generation in Nigeria.

Geothermal energy is heat inside the earth and the deeper inside of the earth is very hot and sometimes this heat comes near the surfaces as volcanoes and earthquake eruptions [46]. It has three layers namely: Fig. 6 shows the core, the mantle, and the crust. At the centre is the solid core made of outer core iron and melted hot rocks called the magma. The middle layer is a mixture of rock and magma called the mantle. Finally we have the crust of the earth with oceans and mountains which is the outer shell which we live on. In some places, magma comes close to the earth's surface and heats the water underground. This heated water resulted in hot water and steam that are stored underground in a reservoir called geothermal reservoirs [53].

Geothermal anomalies are linked to geophysical anomalies for delineation, assess to the properties, identify areas with potential thermal heat, and locate the best site for suitable drilling targets [56]. These are necessary because changes in temperature and geothermal gradient can change subsurface physical properties that influence measurement at the surface [57]. Geophysical exploration is usually the first step in geothermal energy exploitation.

### 5.7 Geothermal Reservoirs

"Geothermal system requires heat, permeability and water. The heat from the earth 'core continuously flow in the form of energy and geothermal energy is the heat contained within the earth. Sometimes the heats, as magma, reach the surface as lava, but usually remain below the earth crust, heat nearly rock and water and sometimes to level as hot as 700°F. When water is heated by the earth's heat, hot water or steam can be trapped in permeable and porous rock under layers of impermeable rock and a geothermal reservoir can form. This hot water can manifest itself on the surface as hot springs, geysers and fumaroles" [58]. Geothermal system is made up of three major components, the heat source, reservoir and water. The heat source is a very high temperature magmatic intrusion that has reached relatively shallow depth and increases with depth.

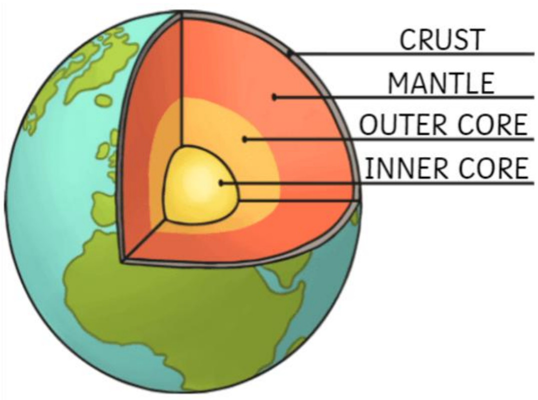


**Fig. 6. Schematic diagram of the Earth Crust**

### 5.8 Utilization of Geothermal Energy

"Geothermal power generation is to produce electricity by rotating a turbine directly with the steam taken out of the deep underground that requires heat from temperature ranging from 212°F $to$ 482°F. The power plants route the steam or hot water from the geothermal reservoir through turbine/generator units either directly or through heat exchangers. The heated fluid is used to drive turbine to produce electricity" [47]. Electricity generation is the most important form of utilization of geothermal resources. To generate electricity from this resource, wells are drilled into a geothermal reservoir. The wells bring the hot water or steam to the surface, where its heat energy is converted into electricity at a geothermal power plant.

"The types of geothermal power plants are flash power plant, binary power plant and dry steam power plant and combined power plant. Geothermal energy is derived from the hot interior of the earth. The earth is a reservoir of heat energy, most of which is buried and is observed during episodes of volcanic eruption at the surfaces. Geothermal is one of the most promising renewable source of energy which is plentiful, eco-friendly, reliable and a clean source of energy available in the earth's crust" [53].The benefits of geothermal energy is generally considered environmental friendly, no pollution, naturally replenished with no exhaust, it is potential with heating and cooling and provide stable electricity, available underground at less cost.

### 5.9 Ocean Energy (Tidal and Waves)

Ocean energy is currently in its developing stage and will soon come to limelight in the energy industry. Three distinct types of ocean energy resources are commonly mentioned as possible energy source; tides, current, waves and ocean temperature differential (ocean thermal energy conversion, OTEC) (Mohammed et al. 2015).

"Tidal energy scheme capture water at high tides and releases it at low tides. Tide is the periodic change of a sea level. The level of water in the large oceans of the earth rises and falls according to predictable patterns. The main periods $\tau$ of these tides are diurnal at about $24\ hrs$ and semidiurnal at about $12hrs\ 25\ mins$ , while the change in height between successive high and low tides is the range $R$. This varies between $0.5\ m$ in general and about $10\ m$ at particular sites near continental land masses and the movement of the water produces tidal currents, which may reach speeds of $\sim 5\ ms^{-1}$ in coastal and inter-island channels" [59].

"The power of tidal currents may be harnessed in a manner similar to wind power; this is also called *tidal stream power.* In practice, tidal current is likely to be attractive for power generation only where it is enhanced in speed by water movement in straights between island and mainland. Therefore the opportunities for viable commercial sites are unusual. Where it is possible however, much of the discussion concerning the use of the power is in common with tidal range power. The harnessing of tidal range power has been used for small mechanical power devices. For optimum electrical power generation from tides, the turbines should be operated in a regular and repeatable manner. The mode of operation will depend on the scale of the power plant, the demand and the availability of other sources" as stated below [60].

a. If the tidal-generated electricity is for local use, then other assured power supplies must exist when tidal power is unavailable. However, the tidal basin provides energy storage, so extending power generation times and being available for storage from other power sources.
b. If the generated electricity can feed into a large grid and so form a proportionately minor source within a national system, then the predictable tidal power variations can be submerged into the national demand.
c. If the immediate demand is not fixed to the human (solar) period of $24hr$, then the tidal power can be used whenever available. For example, if the electrical power is for transport by charging batteries or by electrolysing water for hydrogen, then such a decoupling of supply and use can occur.

The technology that is used to produce electricity using the difference between the low and high tides is very similar to the one used on the generation of electricity on the traditional hydroelectric power plant.

### 5.10 Ocean Currents and Waves

"Ocean currents are driven by solar heating and wind in the water near the equator, also by tides, salinity and density of the water. Current can be divided into two types: marine currents and tidal currents; Marine currents are relatively constant and flow in one direction. Tidal currents occurred closed to the shore due to gravitational forces. The interaction of the sun-moon-earth system causes one of the strongest phenomena, tides. Tides rise and fall is the product of the gravitational force and centrifugal forces, of primarily the moon with the earth" [59]. The gravitational forces maintain the moon on its position with respect to the earth, forcing to pull the earth and the moon together. The centrifugal force acts on the opposite direction pulling the moon away from the earth. The two forces act together to maintain the equilibrium between these two forces.

"Ocean waves can be formed through the presence of many forces that acts on the ocean surface. The gravitational force like the one that acts between the earth, moon and the sun and the geological forces that produces sub-sea earthquakes that can generate tsunamis are source of the forces that acts on the formation of ocean waves" [61]. When the sun heats the earth surface, it generates zones with different pressure that produce wind. As those wind blows over the ocean surface, the friction that is created between the wind and the water forms the waves. The size of the waves will depend on strength of the wind, amount of time the wind blows, the distance over which it blows. Very large energy fluxes can occur in deep water sea waves. The power in the wave is proportional to the square of the amplitude and to the period of the motion. Motion wave energy devices are designed to extract energy from deep water waves. "Tide energy system trapped high tides in a reservoir. When the tide drops, the water behind the reservoir flows through a power turbine, generating electricity. Ocean thermal energy conversion uses the difference in temperature between warm surface and cold deep ocean water to make electricity" (Muhammad et al. 2015).

## 5.11 Ocean Thermal Energy Conversion (OTEC)

"The term ocean thermal energy conversion refers to the conversion of some of this thermal energy into useful work for electricity generation. Given sufficient scale of different equipment, electrical power generation could be sustained day and night at $200\ KW,$ from access to about 1 k$m^2$ of tropical sea" [59]. "The attractiveness of OTEC is the seemingly limitless energy of the hotter surface water in relation to the colder deeper water and its potential for constant, base load, extraction. However, the temperature difference is very small and so the efficiency of any device for transforming this thermal energy to mechanical power will also be very small. Even for heating, warm seawater cannot be split on land due to its high salt content. Moreover, large volume of seawater needs to be pumped, so reducing the net energy generated and requiring large pipes and heat exchangers" [60].

## 5.12 Hydrogen Power Energy

"A prominent renewable energy is the hydrogen fuel cell power that may take the world by storm if properly harnessed. One of the reasons proposed in support of the argument is based on the occurrence of this energy source, water and other phenomenon. Hydrogen is the simplest element and an energy carrier. An atom of hydrogen consists of one proton and one electron" [62]. "It is also the most plentiful element in the universe. Despite its simplicity and abundance, hydrogen does not occur naturally as a gas on the Earth – it is always in combination with other elements. Water, for example, is a combination of hydrogen and oxygen $(H_2O)$. Hydrogen is also found in many organic compounds, notably the hydrocarbon that makes up many of our fuels, such as gasoline, natural gas, methanol and propane" [43].

Hydrogen can be separated from hydrocarbon through the application of heat-a process known as reforming. In modern refinery, hydrogen production is essential for various processing units. e.g. Catalytic hydrogen aided processes, desulphurisation, denitrogeneration, demetallation, hydrogenation, hydrocracking and currently most hydrogen is made through this way from natural gas. Hence a separate hydrogen plant is essential to produce hydrogen of the required quantity and purity. Equation 4 shows the electrolysis of water produces purest hydrogen but at an enormous cost, hence commercial hydrogen is obtained from coal or petroleum. Hydrogen can be produce commercially by carbon monoxide formed in the secondary reforming which converted to additional hydrogen when reacting with steam [63].

$$CO + H_2O \rightarrow CO_2 + H_2 \quad (4)$$

"This is an exothermic reaction and in order to dissipate the heat, this reaction is carried out at two temperature ranges, one at high temperature (HT) between $400^oC$ and $450^oC$ and the other at low temperature (LT) between $200^oC$ and $300^oC$. Gas mixture from the (LT) shift reactor contains much steam, Carbon monoxide, Carbon dioxide, unconverted hydrocarbon, nitrogen and hydrogen. Cooling of the gas mixture separate the steam as water and the dehydrated gas mixture is then passed through a series of absorbers cyclically operated to absorb the gases except hydrogen in a pressured swing absorption unit" [64]. Hydrogen purified by this method produces 99.9% pure hydrogen that could be stored and transported to large fuel cells devices that convert hydrogen to electricity.

The other method is the electrolysis of water. Hydrogen fuel cells combine hydrogen and oxygen in fuel cells to produce electricity, heat and water. It is possible to churn out hydrogen wherever you need it by splitting water using electrical current from sources such as solar cell, and wind turbines [65]. This will allow urban settlement or town to create and store their own energy instead of relying on a huge infrastructure to distribute electricity. Nevertheless, production of hydrogen power fuel cells car with its own based power station which creates electrical current to drive its motor engine. However, if hydrogen power is exploited, vehicles and cars may soon run on water. The fuel cell converts chemical energy directly to electrical energy and heat. The process uses both electrochemical process between hydrogen and oxygen to generate a DC current. This device usually separated by electrolysis [63].

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O \qquad (5)$$

Hydrogen is high in energy, yet an engine that burns pure hydrogen produces almost no pollution. Liquid hydrogen has been used since 1970s to propel the space shuttle and other rockets into orbit. Hydrogen fuel cells power the shuttle's electrical systems, producing clean by-product pure water, which the crew drinks.

## 5.13 Hydrogen Fuel Cells

A fuel cell combines hydrogen and oxygen to produce electricity, heat and water. However, the fuel cell will produce electricity as long as hydrogen is supplied, never losing its charges. Fuel cells are a promising technology for use as a source of heat and electricity for lighting, and an electrical power sources for electrical motors propelling vehicles.

Fuel cells operate best on pure hydrogen. Fuels like natural gas, methanol or even gasoline can be reformed to produce the hydrogen required for fuel cells [62]. In future, hydrogen could also join or use as a supplementary to hydroelectricity. Hydrogen is an energy carrier that moves and delivers energy in a usable form to consumers. This renewable energy source can produce energy at all time. However, hydrogen can be stored until it is needed. It can also be transported to a location where it is needed. Renewable energies such as solar, wind, biomass, geothermal, hydroelectric power, carbon dioxide neutral fuel and ocean energy have potentials to limit our dependency on hydrocarbon fuels, but one issue remains prominent – storing energy (*or energy storage*) [43]. While the sun provides radiation for solar and generates wind, when its cloudy or dark we are unable to produce energy. One must provide a means to store that energy for use when needed. This is where fuel cells enable energy conversion and storage to play a reliable role.

Fuel cells provide the enabling technology that allows hydrogen to serve as the storage and transport agent. The solar energy that is produced during the daylight is used in an electrolyser to produce hydrogen that is in turn, is then used to operate the fuel cell producing electricity at night when it is needed [62]. This process is called the solar-hydrogen energy cycle.

Fuel cells are devices that convert chemical to electrical energy. It is an electrochemical energy conversion device. In the chemical process of a fuel cell, hydrogen and oxygen are combined into water, and in the process, the chemical conversion produces electricity. In the electrolyser, an electrical current is passed through water (electrolysis) and is the reverse of the electricity-generating process occurring in the fuel cell [62]. Hydrogen fuel cells in Fig. 7 offer tremendous opportunity for storing and transporting energy, enabling broad applications for home, business, motor vehicle and large-scale energy projects. Factors to consider in using hydrogen fuel cells include operating temperature ranges, operating efficiency and material used for the electrolyte (Catalyst that separates hydrogen) and fuel oxidant (that transfers the oxygen atoms).

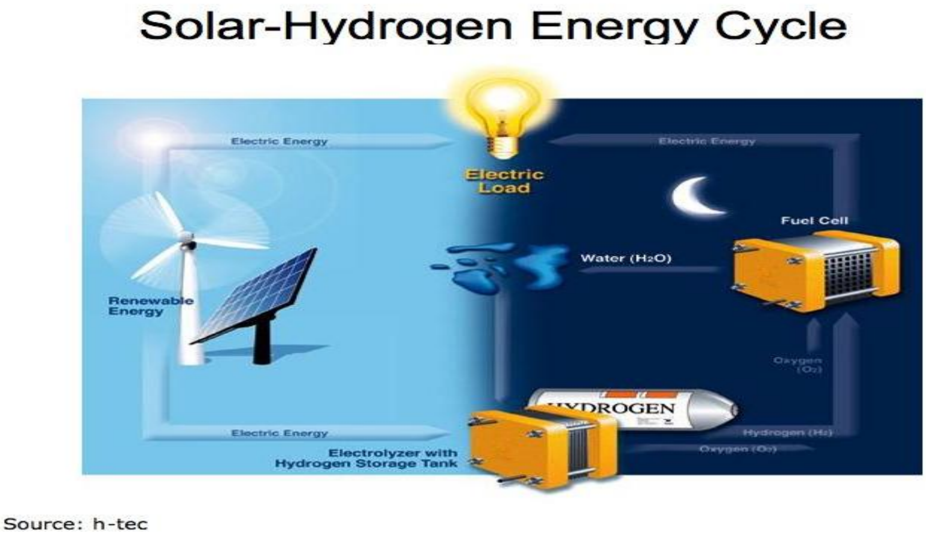


**Fig. 7. Solar-hydrogen energy cycle [62]**

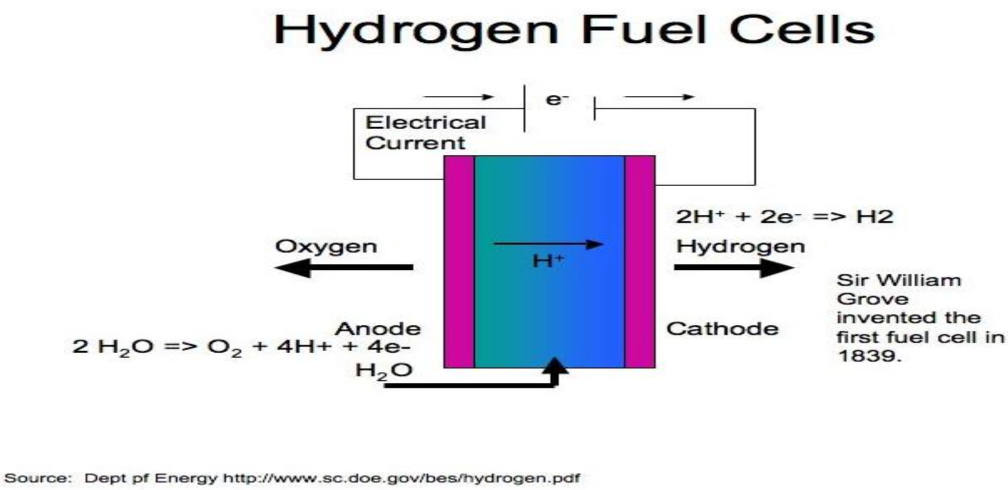


**Fig. 8. Hydrogen Fuel Cell Technologies [63]**

"One of the most practical fuel cell technology used for motor vehicle include Proton Exchange Membrane (PEM) because it operates at normal ambient temperature and offer high electrical efficiency as seen in Fig. 8. We are also seeing progress on fuel cell vehicles that could ultimately ameliorate our demand for oil. Further research into hydrogen fuel cells could significantly reduce our dependency on oil" [63]. This research study is to inform the developing countries populace on all beneficiary aspects of the renewable energies and economic wealth of a nation through these innovative, clean energy technologies. Below are the source of resources on fuel cell systems and hydrogen energy.

### 5.14 Fuel Cell Basics

"A fuel cell is composed of an anode, a cathode, and an electrolyte membrane. A fuel cell works by passing hydrogen through the anode of a fuel cell and oxygen through the cathode. At the anode site, the hydrogen molecules are split into electrons and protons. The protons pass through the electrolyte membrane, while the electrons are forced through a circuit, generating an electric current and excess heat" [26]. At the cathode, the proton, electrons, and oxygen combine to produce water molecules.

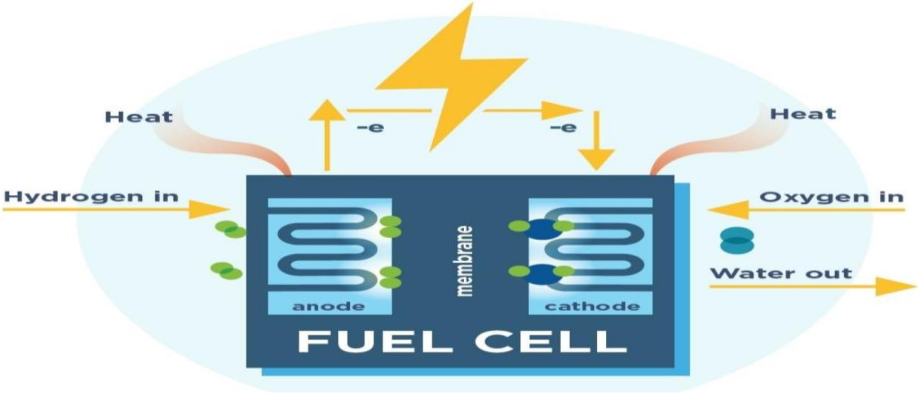


**Fig. 9. Fuel cell system configuration [59]**

## 5.15 Hydrogen Energy Basics

Hydrogen when used as a fuel is an energy carrier for fuel cell rather than energy resources. Both electricity and hydrogen can be produced from all energy resources available (renewable and non-renewable). Fig. 9 shows how hydrogen and electricity can be generated from greenhouse gas-neutral sources, addressing climate change and urban air quality problems. As with electricity, hydrogen can also be produced from sustainable domestic and renewable energy resources, such wind or solar powered electrolysis which enhances our long term energy security. A team of scientists and engineers have also developed a ceramic membrane that generates compressed hydrogen derived from natural gas for electricity [64].

## 5.16 Carbon-Neutral Fuel Energy

Carbon-neutral fuels are synthetic hydrocarbons. They can be produced in chemical reactions between carbon dioxide, which can be captured from atmosphere or air or power plants and hydrogen, which is created by the electrolysis of water. Carbon dioxide ($CO_2$) is a gas that is found naturally in the atmosphere and is being augmented by fuel combustion [14]. This importance of carbon dioxide lies in the fact that it is transparent to in-coming short-wavelength solar radiation, but it is not transparent to some of the long-wavelength [17]. Fig. 10 shows the portion of the energy leaving the ground is absorbed by $CO_2$ and subsequently re-emitted part of it toward the surface, thereby keeping the atmosphere near the ground warmed than it would be without $CO_2$. Carbon dioxide is one of the gases responsible for warming the lower atmosphere [14]. The process is called greenhouse effect. $CO_2$ absorbs heat and any change in the air content could alter temperature in the lower atmosphere. When there is an increase of more than $25\%$ in $CO_2$ content of the atmosphere, the enhancement of greenhouse effect would be much more dramatic and measurable than in the past.

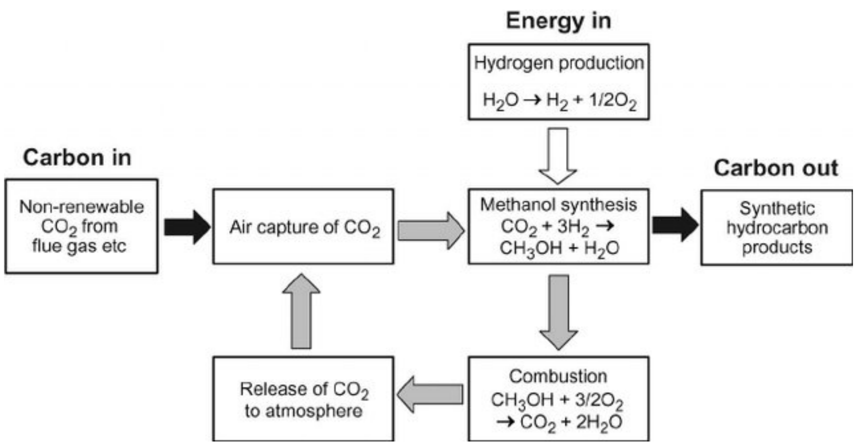


**Fig. 10. Schematic diagram of Carbon Neutral Fuel**

"Carbon-Neutral Fuel is the energy fuel which has no net greenhouse gas emissions. It is evident that carbon-neutral fuel displaces fossil fuel or if they are produced from waste carbon or seawater carbonic acid and their combustion is subject to carbon capture at the flue of exhaust pipe, they result in negative $CO_2$ emissions and the net $CO_2$ removed from the atmosphere constitute a form of greenhouse gas remediation" [17]. Such power to gas carbon-neutral and carbon-negative fuels can be produced by the electrolysis of water to make hydrogen. Other carbon-negative fuel includes synthetic fuels made from $CO_2$ extracted from the atmosphere can be seen in Fig. 10.

**Carbon-neutral:** Carbon dioxide ($CO_2$) could be the future fuel. The process is by capturingcarbon dioxide form atmosphere into a big cooling large tower usually connected with large fan. The fan draw $CO_2$ in the atmosphere into the large tower and chemical reaction takes place with uniformly distributed reactions [14]. This is a new concept of energy recycle; it is a technology that recycles fuel. The carbon in the atmosphere combined with hydrogen and water. This is chemically the same as gas or jet fuel with no pollutant; no smoke and burning are completely clean. This is the fuel that makes very high performance fuel than its stuff. It is a carbon-neutral fuel that is compatible with any vehicle in the world, particularly transportation generate about $20\%\ CO_2$ emission similar to carbon-neutral gas. It is a renewable energy. Similarly, carbon-negative fuels only remain carbon-negative as long as the fuel is not combusted. Upon combustion, the carbon they contain is release into the atmosphere. The time between fuel production and combustion of the fuel (carbon storage) can thus be quite short [63]. "The renewable fuels could alleviate the cost and dependency issues of fossil fuels without requiring either electrification of the vehicle fleet or conversion to hydrogen or other fuels, enabling continued compatible and affordable" [66].

**Carbon-Neutral Fuel Production:** are basically synthetic hydrocarbons. "The can be produced in chemical reaction between carbon dioxide which can be captured from the atmosphere or hydrogen or power plant, which is created by the electrolysis of water using renewable energy" [67] The fuel referred to as electro fuel, stores the energy that was used in the production of the hydrogen, but that would not a carbon-neutral source. $CO_2$ can be captured and buried making fossil fuels carbon-neutral, although not renewable.

"The stored energy can be recovered by burning the methanol in a combustion engine, releasing $CO_2$, water and heat. Methane can be produce in a similar reaction. Special precaution against methane leaks is important since methane is nearly $100$ times as potent as $CO_2$" [27].The synthetic fuels produced are both carbon-neutral and function as a storage for surplus renewable energy [68].

## 5.17 Steps to Fuel Production

The first step of technology sees that the plant captures Carbon dioxide from the atmosphere or at ambient air in a cyclic process. The direct air capture (DAC) technology clime-work uses a specifically treated material for this purpose.

Air then passes across the filters which absorb the $CO_2$ molecules. Under vacuum and at $95^oC$, the captured carbon dioxide releases from the surface and is pumped out.

The second step is the electrolytic splitting of $CO_2$ and water vapour that takes place simultaneously. The mixture can be applied as synthesis gas for a number of processes in chemical industry. Co-electrolysis has a high efficiency and theoretically binds in the synthesis gas with $80\%$ of the green energy used in chemical form.

The third step, the Fischer-Tropsch synthesis is used to convert the synthesis gas into long-chain hydrocarbon molecules. For this, ineratec, a spin-off of KIT, contributes a micro-structured reactor.

The final step, hydrocracking takes place – a process in which the quality of the fuel yield are optimised under a hydrogen atmosphere, the long hydrocarbon chains are partly cracked in the presence of a platinum-zeolite catalyst and shift the product spectrum towards more directly usable fuels.

**Magnetohydrodynamics (MHD) Power generation:** Magnetohydrodynamics (MHD) or Hydromagnetics is an applied mathematics concepts which studies the dynamics of electrically conducting fluids moving through powerful magnetic fields. These fluids include plasma (ionized gas), liquid metals, and salt water [69]. A Magnetohydrodynamic Generator is a device which converts heat energy of a fuel directly into electrical energy without a conventional electric generator.The generator used in this process is called MHD generator. “MHD power generation is a method for converting heat directly into electrical energy without the use of a rotating electrical power generation. MHD power generation is also the process of using powerful magnets involving MHD generator to convert thermal energy into electrical energy without passing through a mechanical energy. The conversion of potential energy into mechanical energy is considerably high (70 to 80%) but conversion of thermal energy to mechanical energy is considerably low (40 to 45%)” [70]. In addition to this mechanical components required for converting heat energy into mechanical energy are large in number and considerably costly. MHD conversion process was first described by Michael Faraday in 1831 when he discovered the relationship between electricity and magnetism which can be seen in Figs. 11 and 12; he later confirmed that MHD electrical power generation is feasible.

MHD power generation has been studied as a novel power plant due to its advantage of high-efficiency with high-working temperature [71]. In an MHD generator, thermal plasma is moving across a magnetic field generating electric power (Salvatore and Alessandra, 2014). Open-cycle and Closed-cycle MHD generators are the two of MHD systems under consideration in Fig.11 and 12, classified on the basis of the working fluid and the heat source [72]. MHD generator is classified in three different designs which are Faraday generator, Hall generator and Disk generator. The main practical issue with Faraday generator is differential voltage and currents in the fluid short through the electrodes on the side of the tube.

**MHD System model:** MHD generator requires an applied magnetic field and a moving conductive fluid to generate an electrical current that is extracted by electrodes. The electrodes are placed according to the direction of the applied magnetic field Band the velocity of the conductive fluid v, since the electric current generated (known as the Faraday current, *J*) is in the direction v × B. Bilal et al. [71] consider a high velocity MHD generator, which is advantageous to the MHD equations from conservation laws that characterized the conservation theorem and shocks. MHD power generation process is governed Maxwell and Faradays law of electromagnetic induction and as such the flow of conducting plasma through a magnetic field at high velocity causes a voltage to be generated across the electrodes, perpendicular to both the plasma flow and the magnetic field according to Flemings Right Hand Rule.

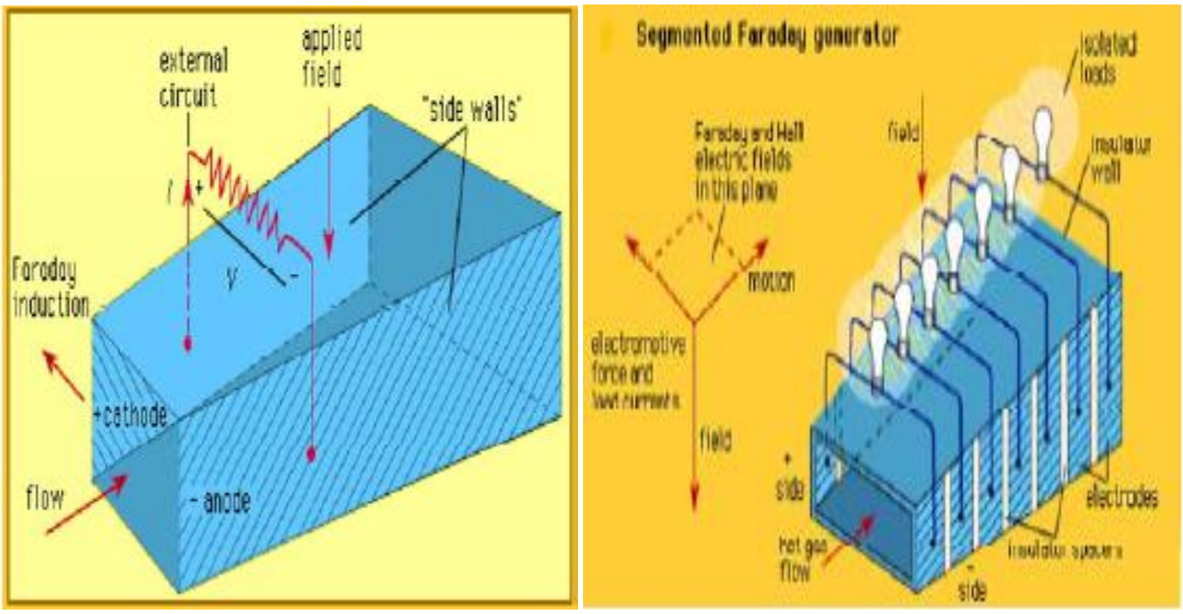


**Fig. 11. Segmented Faraday Generator [71]**

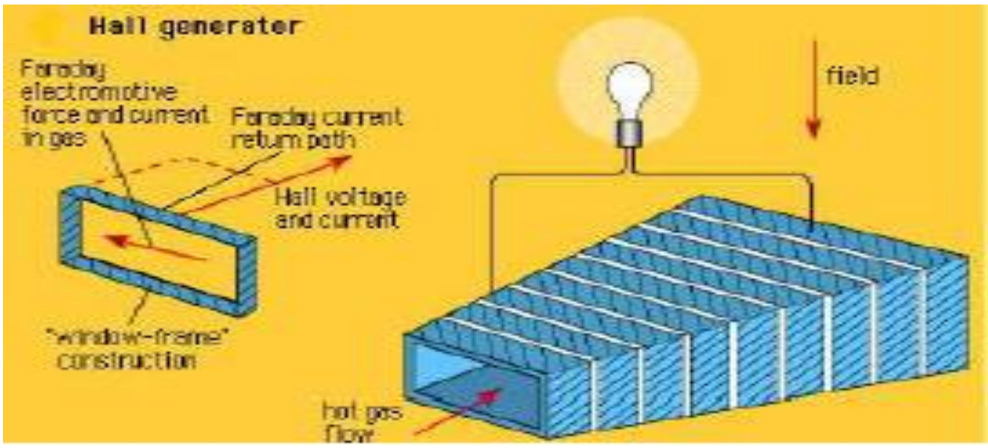


**Fig. 12. Hall Generator [71]**

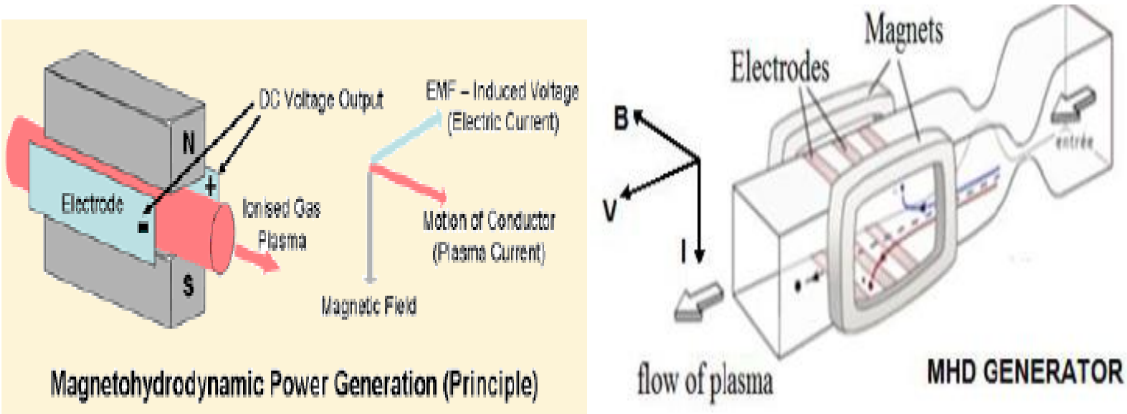


**Fig. 13. MHD power generation principle [73]**

Fig.13 is a typical MHD flow of plasma that obey Lorentz Force Law describes the effects of a particle moving in a constant magnetic field. The simplest form of this law is given by the vector equation.

$$F = Q \cdot (V \times B) \tag{6}$$

- $F$ is the force acting on the particle,
- Q is the charge of the particle,
- $V$ is the velocity of the particle, and
- $B$ is the magnetic field.

The vector $F$ is perpendicular to both $v$ and $B$ according to the right hand rule. The fundamental laws that guide MHD power generation are the Maxwell's 8 equations with 8 unknowns.

$$\frac{\partial B}{\partial t} = -\nabla \times E \qquad Maxwell\ equations \tag{7}$$

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho V) = 0 \qquad Mass\ conservation \tag{8}$$

$$\rho \frac{dV}{dt} = -\nabla p + j \times B \qquad F = ma\ for\ fluids \tag{9}$$

$$\nabla \times B = \mu_O J \qquad Low\ frequency\ Maxwell \tag{10}$$

$$\frac{d}{dt}\left(\frac{p}{\rho^{\gamma}}\right) = 0 \qquad Adiabatic\ equation\ for\ fluids \tag{11}$$

$$E + V \times B = 0 \qquad Ideal\ Ohm's\ Law\ for\ fluids \tag{12}$$

### 5.17.3 Benefits of MHD power generation

MHD power generation has more benefits and offers many advantages as compared to other non-conventional electric generation. It is simple and compact, can stand very high temperature environment, very silence due to no-moving part, more reliable with high efficiency, short transient time and high power density and above all, easier fabrication at micro-scale. Developing countries are currently in darkness due to energy crisis. To overcome the world energy crisis, MHD power generation would be a good approach; it has low running cost and minimizing the need of new plants. MHD power generator does not have any mechanical moving part therefore, reduction in the energy losses is quite visible, and efficiency is enhanced [61]. Use of liquid metal for MHD conversion enables low temperature application in compression to ionized gas MHD generator.

The heat capacity of the liquid MHD generator is greater than ionized gas MHD generator. The cost can be predicted accurately and the capital cost of MHD plant is competitive with most conventional energy. It has better fuel utilization and clean fuel with high efficiency and thermal pollution of water is eliminated. MHD generation is elegantly simple technology than the conventional ones and easing of legal environmental condition. In near future, MHD power generation system can improve the efficiency of other conventional energy resources [61].

## 6. NON-RENEWABLE ENERGY RESOURCES

Non-renewable energy resources suggest that they are natural resources that are not replaceable or re-growth naturally. These resources are exhaustible and are extracted faster than the rate at which they are formed. Common examples are oil, natural gas, coal and nuclear. Energy resources are replaced through natural processes at a rate that is equal to or greater than the rate at which they are exploited, and depletion is usually not a threat. The problem the whole world is envisaging about the conventional energy is that fossil fuels cannot be replaced and that one day, the earth's reserve of these fuels will run out. This is not true. Scientists also think that gases released when fossil fuel burns are causing climate change and pollution. It is clear that a heavy reliance on coal, oil, and gas cannot continue indefinitely, thus we must look for alternative source of energy to fuel the world ever increasing needs [71].

### 6.1 Petroleum and Natural Gas

Petroleum and natural gas are found in similar environment and typically occur together. Petroleum is a single chemical compounds (carbon and hydrogen) and may contain small quantities of other elements such as sulphur, nitrogen and oxygen [26]. There is also gaseous hydrocarbon (natural gas) of which the compound methane ($CH_4$) is the most common. Petroleum and natural gas are biological products derived from the remains of organisms. Petroleum formulation is complex and we know that it began with the accumulations must occur where biological activity is high. With increasing burial over millions of years, chemical reactions gradually transform source of the original organic matter into liquid and gaseous hydrocarbon [11]. The use and benefits of crude oil are numerous and these energy sources are useful and sustainable. It takes a lot of engineering, and a substantial amount of processing to get the petrol from the oil reservoir into your car (transportation) or electricity from natural gas power plants to light switch in various household. Crude oil generates heat and heating this material and other petroleum products can warm homes in colder weather. Many petroleum products are useful jelly [74,75]. Some examples include fertilizer, perfume, insecticides, soap, and vitamin capsules e.t.c. Another school of thought believed that one day, It is clear that a heavy reliance on oil, and gas cannot continue indefinitely, thus we must look for alternative source of energy to fuel the world ever increasing energy demanding world [38].

### 6.2 Coal Fuel Technology

Coal is the most abundant specimen among fossil fuel (i.e the coals, oil shales, oil, and gas deposits of the earth). Coal is quite different from other sedimentary rocks. Nevertheless, it is often grouped with biochemical sedimentary rocks. However, "unlike other rocks in this category, which are calcites or silica-rich" Gordana et al. [14]. "Coal is made of organic matter, wood that have been chemically altered and still identifiable. This supports the conclusion that coal is the end product of the burial of large amount of plants materials over extended periods". Banerjee et al. (2016) explanation on "partial decomposition of plants remains in an oxygen-poor swamp creates a layer of peats, a soft brown material in which plants structure are still easily recognized. With shallow burial, peat is changed to lignite, a soft brown coal. Burial increases the temperature of sediments as well as the pressure on them. The higher temperature brings about chemical reactions within the plants materials and yield water and organic gases". As load increases, the water and volatile are pressed out and the proportion of fixed carbon increases [76]. The greater the carbon content, the higher the coal will rank as a fuel. During burial, the coal becomes increasingly compact, for example, deeper burial transforms lignite into a harder, more compacted black coals called bituminous. Lignite and bituminous coals are sedimentary rocks [77]. Coal has been an important fuel for centuries until the mid-twentieth century. Coal is an important domestic heating fuel as well as power source for industry. However, its direct use and benefits in households is being largely replaced by oil and gas and electricity. These fuels were preferred because they were more readily available for use as cleaner fuel [14)].

## 6. 3 Nuclear Energy

Nuclear energy comes from splitting of atoms in a reactor to heat water into steam, turn a turbine and generate electricity. It is without carbon emissions because reactors use Uranium, not fossil fuel. Nuclear energy offer many advantages as the emissions free-workhorse of our energy grid. The fuel for these facilities comes from radioactive material that reduces energy by the process of nuclear fission (Chen et al.2022; [78]. The benefit of nuclear energy extends far beyond carbon free electricity. “Nuclear energy is the energy in the nucleus of an atom. There is enormous energy in the bonds that hold atoms together. Nuclear energy can be used to make electricity. But first, the energy must be released from atoms in two ways: Nuclear fusion and nuclear fission. In nuclear fusion, energy is released when atoms are combined or fused together to form a large atom. This is how the sun produces energy. In nuclear fission, atoms are split apart to form smaller atoms, releasing energy. Nuclear power plants use nuclear fission to produce electricity” [79]. “Nuclear reactors involve changes in an atom nucleus and thus cause a change in the atom itself. Nuclear power plants convert the energy released from the nucleus of an atom via nuclear fission that takes place in a nuclear reactor. When a neutron hits the nucleus of a Uranium-235 or plutonium atom, it can split the nucleus into two smaller nuclei and the reaction is called nuclear fission. Nuclear energy damage is explained as any injury to or the death, sickness or disease of a person or damage to the environment including loss of property which arises from ionising radiation associated with nuclear installation of radioactive materials” (Chen et al. 2022). Bamidele et al. [80] provided major benefits of nuclear energy to the extent that it is far beyond carbon-neutral electricity. It usually used for nuclear powers space exploration, sterilizes medical equipment, provides potable water through desalination, and supplies radioisotopes for cancer treatment. Some other benefits include nuclear fights, nuclear ensures leadership in technology, nuclear produces electricity that is sustainable, reliable, and nuclear generate jobs; nuclear protects our air (climate change), nuclear power electric vehicles, base load energy, low pollution, high energy density and nuclear boost international development [81,82].

“There are also challenges when producing nuclear energy, these include expenses and waste. It is estimated that there have been as many as 10,000 deaths from long term effects of radiations in a particular region” (Chen et al. 2022). Nuclear power presents a unique threat to our national security because it is powered by nuclear energy. Terrorists might target nuclear power plants with intention of creating a disasters. These are the negative effects of nuclear energy as it also reduces our carbon emissions.

## 7. CONCLUSION

The study examined the review of renewable energy to the well being of the people and the benefits to the environment and dis-aggregated measures of economic freedom as drivers of the share of renewable in total energy consumption in developing countries. Renewable energy issues is a significant resources requirements for development in Africa. We have harnessed and reviewed each energy resource with their technology and also presented varieties of renewable energy resources that are available based on their generation, storage, cost and durability.

Conclusively, we have make known all the energy resources and their benefits to the environment for sustainability. We have no doubt that this green energy if properly harnessed will alleviate the suffering of the epileptic power supply and greatly enhanced the economy of most developing Countries. The benefits of these energy resources in our environment was attributed to electricity generation and improving the quality of life and property. In a nutshell, given that improvement in human development and strong sustainable development are key drivers of the share of renewable in total energy consumption in Africa, governments is encourage to promote these drivers in line with the sustainable development goals.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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