Energy and Emissions: Opportunities and Challenges for The Energy Transition

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Abstract

The purpose of this study is to review the role of energy in sustainable development by ensuring sustainability in electricity generation, supply, and consumption. Global electricity generation remains dominated by fossil fuels with renewable energy sources contributing a smaller proportion. Sustainable development needs sustainable energy which should be reliable, stable, good quality, affordable non-polluting and socially acceptable. Various measures can be put in place to limit emissions from various sectors. New technology should be developed and exploited for to maximize use of abundant but intermittent renewable sources a sustainable mix with limited non-renewable sources optimized to minimize cost and environmental impact but maintained quality, stability, and flexibility of an electricity supply system. Other measures that can limit emissions include electrification of transport and industrial activities with electricity coming from renewable and low carbon sources. This review recommends the use of the three main strategies to minimize carbon emissions in the energy transition. These are conventional mitigation, negative emissions technologies which capture and sequester carbon emissions and finally technologies which alter the global atmospheric radiative energy budget to stabilize and reduce global average temperature.

Key Words: Energy security; energy transition; energy and electricity sustainability; greenhouse gas emissions; sustainable electricity; renewable energy.

1.Introduction

Energy is a critical requirement for sustainable development and therefore optimum selection of low carbon and green energy sources remains a serious challenge for all developing and developed countries(Bhowmik et al. 2020). To realize green power generation, environmental, technical social, institutional, and economic dimensions should be used as a selection and development criterion for sustainable energy and grid electricity planning. Electricity and other energy resources are very important inputs from the economical aspect and human well-being to develop a good framework of sustainability for cleaner and stable global environment and economies. While choosing or selecting energy sources for development or exploitation, technology and cost play a crucial role in modern economies and societies (Bhowmik et al. 2020; Kabeyi & O. A. Olanrewaju 2020). With continuous increase in global population and socio-economic activities leading to increased urbanization, and industrialization around the world, demand for natural resources and energy is gradually increasing(Ebrahimi & Rahman 2019). It is notable that the world's population has grown 2.5 times since 1950, while energy demand for energy has grown 7 times(Şengül et al. 2015). These increasing energy demand is mostly met by fossil fuel combustion and nuclear power(Tunc et al. 2012).Apart from rapid growth increase in the global energy demand, other challenges are depletion of fossil fuel reserves, their price volatility , and global climate change have attracted much attention to renewable energy sources. As a result, many countries have adopted policies to support the growth of renewable energy sources and other sustainable energy measures in the energy transition (Ebrahimi & Rahman 2019).

Climate change is real and is here with us hence the need to pay serious attention to mitigation measures. In the year 2018, the world encountered 315 incidents of climate change related disasters that affected 68,500,000 million people , causing an economic loss of US$ 131.7 billion (Fawzy et al. 2020). The climate related disasters are mainly in form of drought, floods, wildfires, and storms. These disasters are a threat to humanity as they affect critical sectors like health, agriculture, water, energy, and human settlements(Fawzy et al., 2020; United Nations Climate Change (UNFCC 2019). Electricity as a form of energy is extremely important for socioeconomic development. Global electricity generation stood at 4114 GW in 2005 and increased to 5699.3 GW in 2014 and it continues to grow annually. Fossil fuel-based electricity accounted for over 60% of this generation in 2014 and 42% of CO_2. There is need to develop evaluation index system and models for sustainable electricity generation(Li et al. 2016). According to the emissions gap report prepared by The United Nations Environment Programme (UNEP) in its 2019 report noted that the total greenhouse gas emissions in 2018 was about 55.3 GtCO2e, Further analysis of this emissions showed that 37.5 GtCO2 came from fossil fuels combustion in the energy generation and industrial activities(United Nations Environmental Program(UNEP 2019).

Energy transitions refers to the fundamental processes in charge of evolution of human societies that drive and are driven by technical, economic, and social changes(Smil, 2010) Electric power plays an important role in human life, as it supports vital activities, infrastructures, utilities and operations in industry, services and households (Bayram & Ustun 2017; Beaudin & Zareipour 2015). Most of electricity globally is generated from fossil fuels which are expensive, scarce, exhaustible, polluting, and insecure since not all nations are endowed with these resources. The combustion of fossil fuels releases significant quantities of large amounts of greenhouse gases mainly in form of carbon dioxide (CO_2), Sulphur dioxide (SO_2), Nitrous oxides (NOx). These gases cause global warming and climate change which threaten the very existence of life on planet earth. This concern is the main motivation behind sustainable energy development by use of renewable and low carbon clean energy sources especially solar, wind, biomass, and hydro. These renewable and low carbon sources improve and widen power supply, enhance long term access and utility in energy production, decrease dependence on fossil fuel, and reduce carbon emissions(Nguyen et al. 2020; Rathor & Saxena 2020).

The world anthropogenic activities have so far resulted to a 1^oC rise in average global temperature above prehistoric level and may reach 1.5^oC between the year 2030 and 2052 if current emission rates are maintained(Fawzy et al. 2020). The current global electricity generation and supply system is largely based on fossil fuels and nuclear energy. This is not compatible with sustainable development energy objectives since at global level, power production contributes about twenty-six percent (26%) of total greenhouse gas emissions. This makes power generation the principal cause of global climate change(Kabeyi & Oludolapo 2020b). As a solution, there should be massive expansion in power generation capacity using renewable energy sources so as to achieve to achieve the two-degree (2^o) target limitation on global warming above the preindustrial level. (Burger et al. 2012).

There is need for everyone to have sufficient access to energy resources and services since energy is a pillar for human survival, wellbeing, economic progress, and alleviation of poverty in society. The challenge is that energy systems are associated with environmental impacts which vary in magnitude from one source to another and one use and process to another. Fossil fuels continue to dominate current systems and therefore significantly contribute to the global to global carbon dioxide (CO_2) and other greenhouse gases emissions to the atmosphere. To realize the global climate targets and avoid destructive climate change, there is need for a global transition in electricity generation, transmission and distribution and consumption. Humanity must strike a balance between developmental needs and the environmental conservation and protection(Ritchie & Roser 2020).

This study is a review and examines energy sustainability for sustainable development and the challenges and opportunities of sustainability in grid electricity generation, transmission and distribution and prescribe the road to sustainable electricity generation. The study examines sustainability issues in grid electricity generation and supply as well as consumption and development effort and makes recommendations on how to realize sustainability in energy resource use in a mixed supply and consumption of renewable and non-renewable energy sources in electricity generation for sustainable social economic development. This study explores the need for sustainability and sustainable use of energy resources particularly grid electricity as a function of sustainable development.

The overall objective of the Intergovernmental Panel on Climate Change (IPCC) is to stabilize the atmospheric air carbon concentration. The target to facilitate this is a concentration of 350 parts per million (ppm) for CO_2 while maintaining temperature rise of 2^oC temperature change above the preindustrial level. This was adopted by the G8 and G20 group of nations and it implies having atmospheric level of 400-450 ppm of CO_2 as the limit. This can only be realized by minimizing the consumption of fossil fuels particularly in electricity generation and transport industries through substitution with renewable energy sources and electrification of transport among other measures. Renewable sources of energy like solar and wind power continue to have minimum contribution to the grid electricity and when they do, they have a challenge of unstable, unpredictable, and unreliable electric power supply (Chakravorty et al. 2010). The main challenges facing renewable energy sources is resource availability, resource access, resource location, security of supply, sustainability, and affordability (Samaras et al. 2019). The growing demand for electricity has led to increased demand and consumption of fossil fuels and growing level of economic activities have contributed to growth of the greenhouse gas emissions and consequently, global warming(Wang 2019). Therefore, the main challenge in energy resources exploitation is developing an optimized mix of energy sources in the light of the key challenges of energy security, affordability, security, and sustainability on real time basis. Technologies and strategies like smart grid, optimization techniques and other measures are needed to increase the share of variable renewable energy sources in both the total energy and electricity sources mix with very minimum use of fossil fuels and other high carbon energy sources of energy with increased investment in energy conservation, efficiency and saving at consumption level.

The sun warms land and ocean surfaces continuously which then continuously radiate thermal infrared heat energy. Greenhouse gases absorb heat and release it gradually. It is this greenhouse effect that warms the earth and keeps its average annual temperature above the freezing point of about 60°F(Lindsey 2020). However continuous increases in greenhouse gases have tipped the Earth's energy out of balance, with trapping of additional heat energy causing raise in Earth's average temperature. As a greenhouse gas, carbon dioxide absorbs less heat per molecule than many other greenhouse gases like methane or nitrous oxide, but because it is more abundant and stays longer in the atmosphere much longer, its effect is significant. it also absorbs thermal energy of wavelengths that cannot be absorbed by water vapour meaning it adds to the overall or total greenhouse effect in a different way. Increases in atmospheric carbon dioxide are responsible for about two-thirds of the total energy imbalance that is causing Earth's temperature to rise. Carbon dioxide also dissolves into the ocean and reacts with water molecules to produce carbonic acid which lowers the ocean's ph., The pH of the ocean's surface waters has dropped from 8.21 to 8.10 since the beginning of the Industrial Revolution. A drop of 0.1 may not seem like a lot, but the pH scale is logarithmic; a 1-unit drop in pH means a tenfold increase in acidity. A change of 0.1 causes about 30% increase in acidity of the ocean. The biological effect of ocean acidification is interference with marine life's' ability to extract calcium from the water to build their shells and skeletons (Lindsey 2020).

The global Carbon dioxide concentrations have been rising mainly due to fossil combustion. Fossil fuels took many millions of years to form through photosynthesis, but through combustion, the same carbon dioxide is returned to the atmosphere in just a few hundred years of use. The last time the atmospheric CO_2 amounts were relatively higher was about 3 million years ago, when temperature was 2°–3°C (3.6°–5.4°F) above the pre-industrial era, and while the sea level was 15–25 meters (50–80 feet) higher than it is today(Lindsey, 2020). Figure 1 below shows the changes in atmospheric composition of carbon dioxide between 1970 and 220.

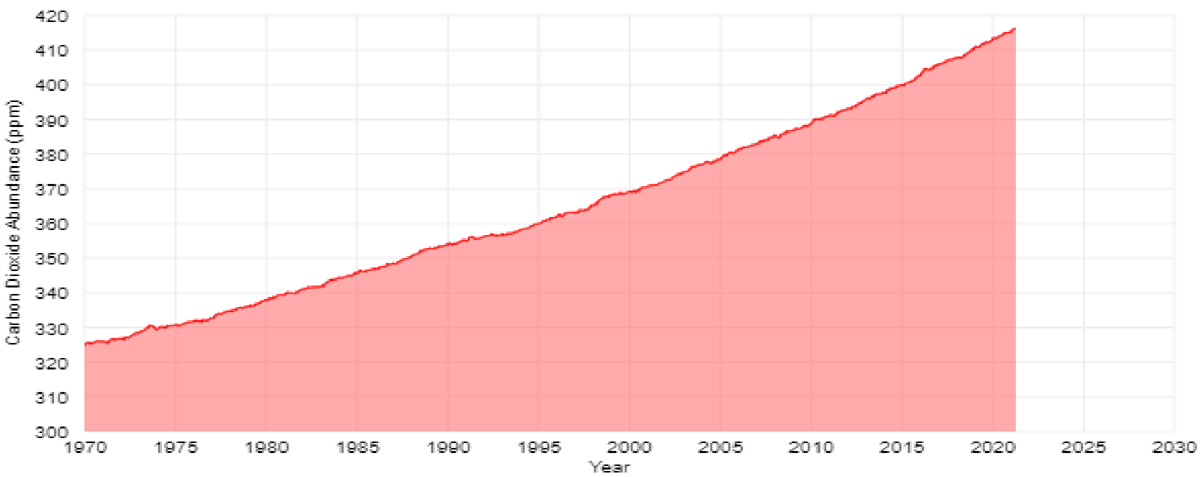

Figure 1. Changes in carbon Dioxide concentration between 1970and 2020 (Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022e; Lindsey 2020)

From figure 1, it is noted that emissions concentration increased from about 325 ppm in 1970 to about 415 ppm in the year 2020. Human activities have led to increased concentration of atmospheric hence increased greenhouse effect. The global average amount of carbon dioxide reached 409.8 ppm in 2019. The annual rate of increase in CO_2 in the atmosphere is about 100 times faster than previous natural increases over the past 60 years e.g. last ice age 11,000-17,000 years ago. Additionally , the ocean has absorbed enough carbon dioxide to lower its PH by 0.1 units causing a 30% increase in ocean acidity (Lindsey, 2020).

1.Global Energy and Electricity Mix

Various energy sources in varying proportions are used to meet the global energy demand. Different countries and regions are endowed differently with energy resources.

2.1. Global Primary Energy Supply Mix

The world has witnessed a massive energy transition from reliance on almost entirely renewable sources in form of biomass energy to an energy mix dominated by fossil fuels between 1800s and 2000s (Moriarty, 2019). According to (Smil, 2010) global primary energy use in the year 1800 was about 20.35 EJ (exajoule = 1,018 joule), of which about 20 EJ was in the form of fuel wood and the rest came from coal. In Figure 1 below, it is shown how primary energy use has grown since 1800, with significant contribution from fossil fuels more so between 1950 in 2016 where consumption grew from about 120 EJ to 576 EJ (International Energy Agency, 2018). Despite bioenergy falling to around 10% of global primary energy today, its use has also grown from 20.35 EJ in 1800 to around 50 EJ in 2019. The global reliance on fossil fuels has led to the release of over 1100 $GtCO_2$ into the atmosphere since the mid-19th century. Today, energy-related GHG emissions, mainly from fossil fuel combustion for heat supply, electricity generation and transport, account for close to 70% of total global emissions in form of CO_2, CH4 and NOx.(Bazmi & Zahedi, 2011).

Most industrialized countries continue to use fossil fuels for their huge energy and electricity and the world generally views fossil energy as a very large energy store, so that, so far, there has been no geological limits on annual withdrawals (Moriarty, 2019). Figure 2 demonstrates the, global energy consumption since 1800.

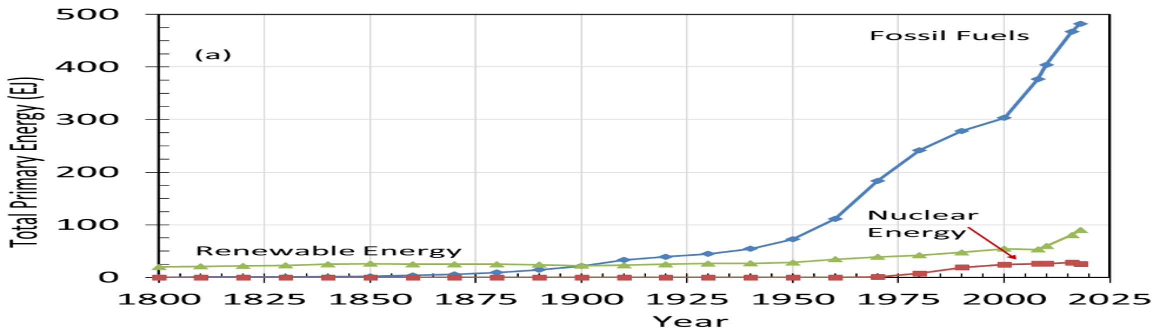

Figure 2. Total global energy use by energy type between 1800–2018 (Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022e; Moriarty, 2019)

Figure 2 shows the energy consumption trends for renewable energy, nuclear and fossil fuels between 1800 and 2020. It shows moderate increase in the use of fossil fuel from the year 1850 to 1950 followed by rapid growth particularly after World War II due to increased industrial activity. The consumption of renewable energy was almost static between 1800 to around 1950 where it started realizing relatively faster growth. Nuclear energy started realizing positive contribution to the energy mix in 1960s and continued to play an important though limited contribution. In the 1970s, nuclear energy started to play an important contribution in the energy mix. Today, fossil fuels continue to meet most of the global energy needs but the contribution is decreasing, just like nuclear energy whose contribution is also falling, while renewable energy contribution is currently low but growing at relatively faster rates(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022e; Moriarty 2019).

Figure 3 below shows the changing contribution of various energy sources to the global primary energy mix.

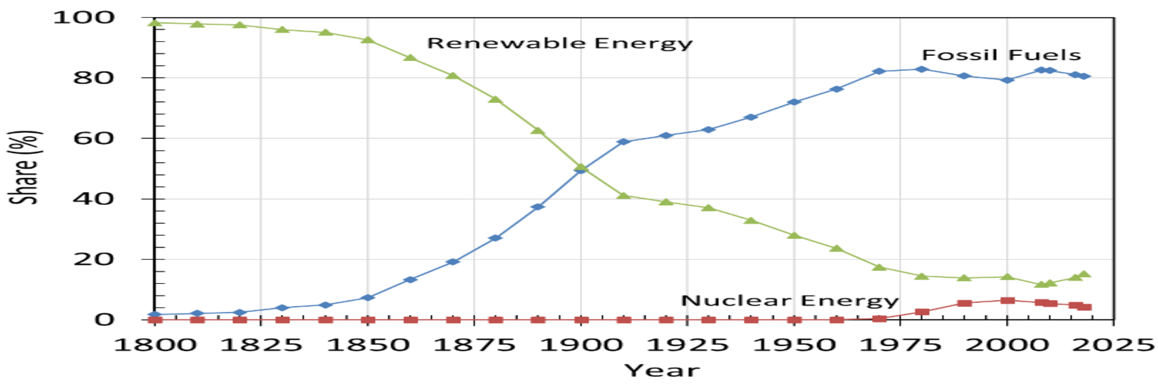

Figure 3. Global primary energy use contribution, 1800–2018 in EJ (Moriarty, 2019)

Figure 3 above shows that at around the year 1800, renewable energy contributed almost all energy needs with fossil fuels contributing a small fraction of the balance. In 1900, both renewable and fossil fuels contributed about 50% of the energy needs with fossil fuels taking a growing trend and renewable energy a reducing trend.

2.2 Global Electricity Supply Mix by Sources

Historically, the global energy demand and supply has been growing as shown by supply increase of about 60% between 1990 and 2016 when supply it hit 568 EJ. In the mix, the international bunkers realized 16.3 EJ in 2016 accounting for 3% of global total energy supply and this was a double growth since 1990, an indication of growing activity and hence energy consumption internationally(United Nations(UN), 2019). The global electricity generation more than doubled between 1990 and 2016, to reach about 25,000 TWhrs. Between 1990 and 2016, the largest absolute growth in terms of energy sources came from coal with about 5,300 TWh representing +116% followed by natural gas at 3,500 TWh growth represented +213% growth. While renewables mainly solar, wind grew by +2,224% or 1,370 TWh which was the fastest growth recorded for renewable sources of energy. However, over 75% of electricity in 2016 was generated from non-renewable sources, mainly from thermal energy accounting for 65% or 16,186 TWh and nuclear 10% or 2,608 TWh. On the positive note, between 2000 and 2016, 50% of new electricity generating capacity came from renewable energy sources(United Nations(UN), 2019; Wanga et al., 2020). Figure 4 below shows the changes in total energy supply between the year 1990 and 2016.

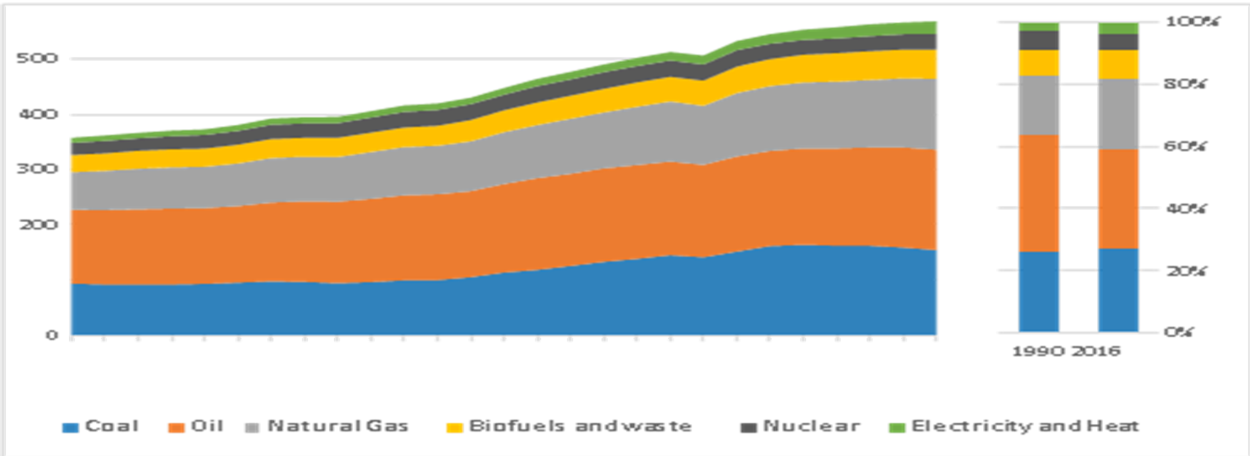

Figure 4. World Total Energy Supply between 1990 and 2016(United Nations 2019)

From figure 4 above, it is noted that between 1990 and 2016, the contribution of coal to global electricity generation increased slightly, oil reduced, natural gas and biofuels increased marginally, nuclear energy shrunk slightly while combined heat and power increased slightly. Overall, the combined contribution of fossil fuel sources remained the highest with over 80% contribution to electricity mix.

3. Global Greenhouse Gas Emissions and Greenhouse Effect

Greenhouse effect refers to a natural process that has taken place over millions of years but was first discovered by Jean Baptiste-Joseph de Fourier in 1827(Wallington et al., 2004; Wang, 2019). The discovery was demonstrated experimentally by John Tyndall in 1861 and quantified in 1896 by Svande Arrhenius. In the work of Svante Arrhenius, it was observed that the release of large amounts of CO_2 from fossil fuel combustion and doubling of atmospheric CO_2 concentration would warm the earth by 5-6ºC, as compared to current climate models which predict a 1.5 – 4.5 ºC rise by doubling the concentration of CO_2 (Kabeyi & Oludolapo, 2020a, 2020b). The study further established that greenhouse gas effect is a result of the interaction between solar energy with greenhouse gases in the atmosphere._ In 1957, Roger Revelle and Hans Suess observed that the build-up of carbon dioxide in the atmosphere constituted a large-scale geophysical experiment whose consequences were unknown and so should be monitored and controlled. As a result, the year 1958 was designated as the International Geophysical Year. This marked the origin of ongoing program of continuous measurements of atmospheric CO_2 levels at Mauna Loa, Hawaii, in the USA by Charles Keeling. This measurement demonstrated that the levels of carbon dioxide were rising steadily from 315 parts per million (ppm) in 1958 to 370 ppm in 2001 (Wallington et al. 2004).

3.1 Carbon Emissions from Fossil Fuels

Fossil fuels are the main sources of global carbon emissions which have been growing steadily between 1900 and 1950 as a result of increased consumption of fossil fuels particularly in power generation. world carbon emissions from fossil fuels have grown consistently since 1900. Industrial processes and fossil fuel combustion contributed about 78% of the total greenhouse house gases between 1970 and 2011. This is followed by contribution from deforestation, and other land-use changes(M. J. B. Kabeyi & A. O. Olanrewaju, 2021; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022b, 2022c, 2022d, 2022f).

3.1. Non-Carbon Dioxide Emissions

Besides carbon dioxide emissions, non-CO_2 greenhouse gases have continued to record positive growth trends since 1900[33]. The energy sector is the second largest contributor in aggregate terms, at 22% to global emissions of non-CO2 emissions In 1990, the energy sector accounted for 1,931 MtCO2 equivalent of non-CO_2 GHG emissions [47]. Therefore, the agricultural sector and energy sector are leading polluters of non-carbon emissions.

3.2. Background of Global Warming and Greenhouse Gas Emissions

Greenhouse gases are normally molecules made up of more than two constituent atoms loosely held together in a way that enables them to absorb heat and vibrate because of this heat absorption. These gases include Carbon dioxide, methane, nitrous oxide and fluorinated or halogenated compounds like CFCs and SF6 gases(Bishoge et al., 2019). Greenhouse gas effect is a result of the ability of these gases to capture heat that causes greenhouse effect by absorbing infrared radiations and heat in the atmosphere (Darkwah et al. 2018).

The global average CO_2 concentration in 2018 was about 407.4 parts per million (ppm) with uncertainty of + and - 0.1 ppm. Today, carbon dioxide levels are the highest over the past 800,000 years (Lindsey 2020). Over 400 billion metric tons of carbon dioxide has been released to the atmosphere from fossil fuels combustion and cement production since 1751, with about 200 billion metric tons coming from fossil fuel combustion. Since the late 1980s. Between 2013 and 2014, about 9855 million metric tons of fossil-fuel based carbon dioxide emissions were emitted representing an increase of 0.8%. Liquid and solid fuels accounted for 75.1% of the global carbon emissions from fossil-fuel burning and cement production in 2014. Gaseous fuel accounted for 18.5% of the emissions which is about 1,823 million metric tons of carbon emissions from fossil fuels in 2014. This depicts a gradual increase in global utilization of natural gas. Which is encouraging transition. In 2014, emissions from cement production were 568 million metric tons of carbon indicating a more than double increase in the last decade to represent 5.8% of global CO_2 emissions from fossil-fuel burning and cement production. Emissions from gas flaring, which accounted for about 2% of global emissions during the 1970s, reduced to less than 1% of global carbon emissions from fossil-fuel(Boden et al. 2017). This shows that fossil fuel combustion which mainly comes from power generation and cement production in the manufacturing industry are leading polluters of the atmosphere in terms of carbon emissions.

In 2014, the global carbon emissions to the atmosphere were about 36 billion tons, which is approximately 1.6 times the 1990s rates, an increase which has been associated with average global temperature rises(Gamil et al., 2020). Figure 5 below shows the variation and composition of greenhouse gases between 1990 and 2018.

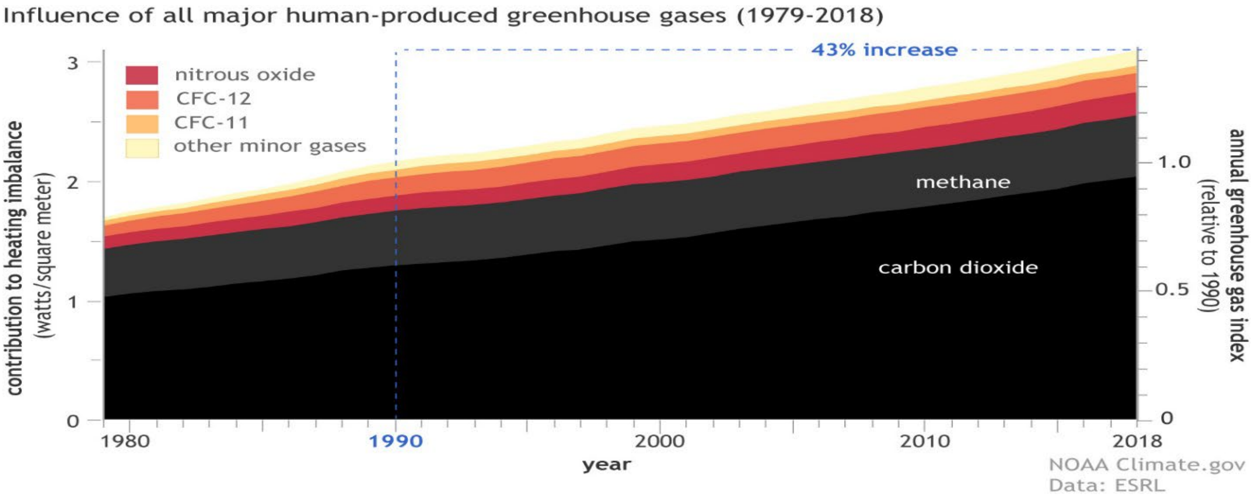

Figure 5. Concentration and Composition of Greenhouse Gases (Lidsey, 2020; Lindsey, 2019)

Figure 5 shows that the main element in greenhouse gases is carbon dioxide, followed by methane, nitrous oxides, CFC -11 and CFC- 12 and other minor gases.

Historically, the natural increases in CO_2 concentrations have been warming the earth during ice age cycles for millions of years in episodes that started with slight increase in solar radiations reaching the earth due to a slight wobble in Earth's axis and path of rotation around the Sun that caused some little warming. This phenomenon caused the warming of oceans and increased emission of CO_2 from the ocean causing an increase in rate of global warming. Carbon dioxide concentration did not exceed 300 ppm during these periods of about a million years ago. Before the industrial revolution that started in of mid-1700s, the global average amount of carbon dioxide was about 280 ppm (Lindsey, 2020). Figure 6 below shows the historical growth of CO_2 emissions and concentration between 1750 and 2020.

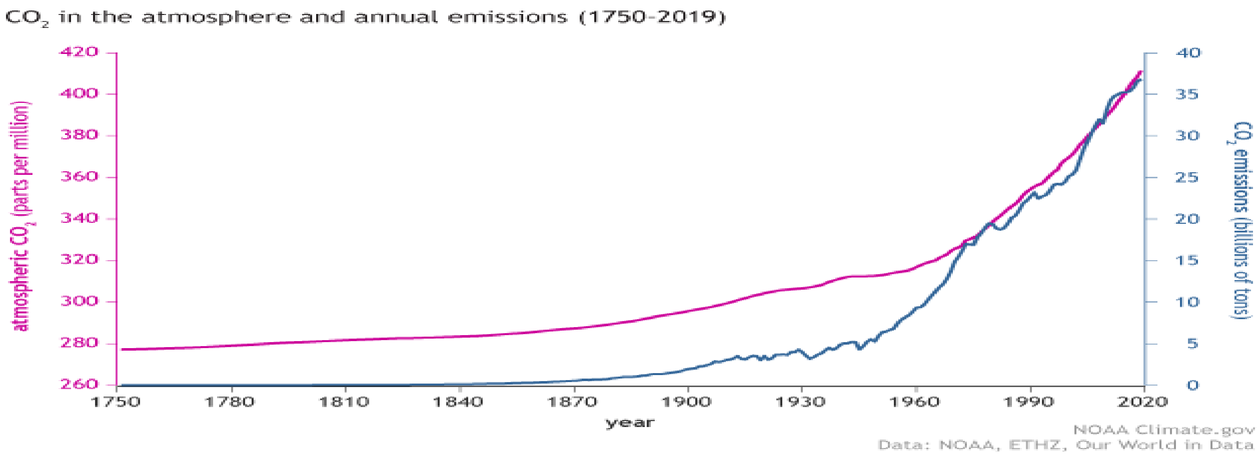

Figure 6. Concentration of Carbon Dioxide Emissions between the year 1750 and 2020 (Lidsey, 2020; Lindsey, 2019)

Figure 6 shows that the global CO_2 emissions remained constant between 1750 and about 1840 where it started increasing. The atmospheric concentration increased slightly between 1750 and 1960 where the rate increased significantly to the year 2020 mainly due to increased use of fossil fuels and industrial activity.

3.3. Types of Greenhouse Gases

At the global scale, the key greenhouse gases emitted by human activities are:

Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is a greenhouse gas with ability to absorb and radiate thermal energy. The Natural increases in CO_2 concentrations have been warming the earth over time with increase in temperature during ice age cycles over millions of years. These warm episodes or interglacial started with a small increase in sunlight when the earth had a tiny wobble in its axis of rotation around the Sun. This event led to some warming of the earth's surface and oceans causing increased release of carbon dioxide. The extra CO_2 in the atmosphere magnified the initial warming. Among the anthropogenic greenhouse gases, CO_2 is responsible for about 60% of the greenhouse gas effect(Tunc et al. 2006).

The use of fossil fuels in like coal, natural gas, and petroleum (diesel and petrol) is the primary source of CO_2 emissions especially in power generation. Other leading sources are direct human-induced operations and activities like deforestation for land preparations, charcoal burning and human settlements. According to carbon dioxide enters the atmosphere from combustion of fossil, solid waste, vegetative matter, and other biological materials(Lindsey, 2020). Other leading sources are industrial chemical reactions like cement production. Carbon dioxide is mainly removed from the atmosphere or sequestered through photosynthesis (United States Environmental Protection Agency (EPA), 2017). Carbon dioxide absorbs and radiates heat and so when warmed by sunlight, it continuously radiates heat in form of thermal infrared energy. Without this radiation, the earth's average annual temperature would be just close to 60°F. With the rapid increase in greenhouse gas emission, additional heat has been trapped leading to raising Earth's average temperature above the pre-industrial level(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022e; Kabeyi & Olanweraju, 2022).

Methane (CH_4)

Agricultural activities, waste management, energy use, and biomass burning all contribute to Methane emissions. Methane generated from various natural and artificial processes like anaerobic digestion and during the production and transport of fossil fuels like coal, natural gas, and oil. (United States Environmental Protection Agency (EPA), 2017). Therefore, methane is added to the atmosphere through natural and anthropogenic sources. 30% of the methane flux originates from natural sources while about 70% is contributed by anthropogenic sources. Natural sources contribute approximately 160 Tg (CH_4) yr^{-1} (1Tg= 10^{12} g, 1000 Tg = 1Gt). Wetlands, termites, and oceans are the largest natural sources contributing about 115, 20, and 10 Tg (CH_4) per $year^{-}$, respectively (Wallington et al., 2004). Controlled biodegradation through anaerobic digestion and use of clean fuels is the best strategy to limit methane emissions.

Nitrous oxide (N_2O)

Food production particularly the use of fertilizers is the primary source of N_2O emissions. As well as fossil fuel combustion in power generation, industry, and transportation as a product of combustion and wastewater treatment process (EPA, 2017). Nitrous oxide (N_2O) is the third most abundant well mixed greenhouse gas after CO_2 and CH_4 a life span of about 130 years. The natural sources of N_2O come from soils and the oceans and are estimated to deliver 10.2 TgN yr^{-1} to the atmosphere. Anthropogenic emissions originate from biomass combustion, fossil fuel combustion, and industrial production of adipic and nitric acids, and nitrogen fertilizer use inn agriculture(Wallington et al., 2004). Measures to limit Nitrous oxide (N_2O) emissions include use of cleaner and renewable fuels, controlled combustion of fuels and exhaust gas cleaning measures among others.

F Gases

The F gases result from industrial processes, refrigeration systems, and the use of some consumer products associated with emissions of F-gases. These gases include hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Hydro fluorocarbons, perfluorocarbons, sulphur hexafluoride, and nitrogen trifluoride are synthetic, and come from industrial processes. These Fluorinated gases are occasionally used a substitute for ozone-depleting substances e.g., chlorofluorocarbons, hydro chlorofluorocarbons, and halons. These gases have high global warming potential gases even though they are released in small quantities(United States Environmental Protection Agency (EPA) 2017). The main negative impact of Sulphur hexafluoride (SF_6) is that is highly potent and has intense absorption at 10.3 μm (969 cm^{-1}) in the atmospheric window region and while it has atmospheric lifetime of 3200 years. SF_6 is present in small amounts in fluorites which provides a small natural source that results in a natural background concentration of 0.01 ppt. The gas is a useful industrial chemical used as an insulating gas in electrical switching equipment. Anthropogenic emissions have increased the level of SF_6 in the atmosphere to approximately 400 times more than natural background levels and the concentration increases at about 0.2 ppt yr^{-1}. Another related gas SF_5CF_3. Its level in the atmosphere increased from zero in 1960 to 0.12 ppt in 1999. Although the concentration of SF_5CF_3 is very low and with insignificant role in global warming, it is of major concern since it is the most potent greenhouse gas yet identified on a per molecule basis in the atmosphere(Wallington et al., 2004).

3.4. Composition of Greenhouse Gases

The composition of greenhouse gases globally is summarized in figure 7 below

Figure 7 below shows the global composition of greenhouse gases by composition.

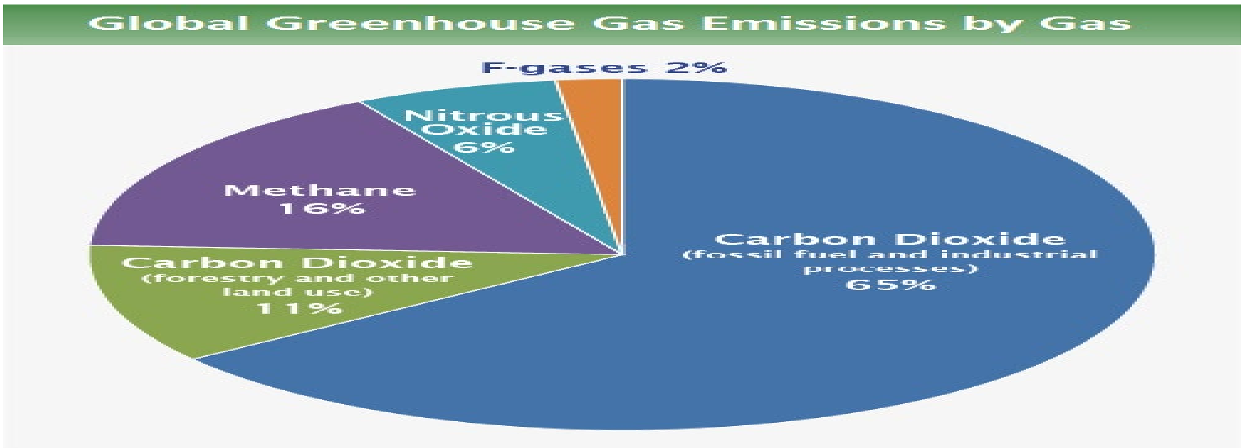

Figure 7. Global greenhouse gas emissions by gas(Boden et al., 2017).

From figure 7, it is noted that carbon dioxide remains the dominant greenhouse gas with most of it coming from fossil fuel combustion in industry, heat, and power generation. Other sources of carbo dioxide are agriculture and forestry related activities.

4. Global Greenhouse Gases by Economic Sectors

The global greenhouse gas emissions can also be broken down by the economic activities that lead to their production or emission. These economic activities contributing greenhouse gases include other energy sector, related sources, and industry, transportation, buildings then agriculture and forestry activities(Kabeyi 2012; Kabeyi 2018; Marcus 1992).

4.1. Emissions By Sector

The various economic sector have varying degree of environmental impact in terms of emissions as well as mitigation strategies as follows;

Electricity and Heat Production

About 25% of 2010 global greenhouse gas emissions came from electricity and heat production which include coal combustion, natural gas, and oil combustion for electricity and heat application. This constitute the highest single source of global greenhouse gas emissions (Boden et al., 2017).This percentage can be reduced through options like cogeneration for own power generation, shift to renewal energy sources and energy generation and conservation efficiency(Moses Jeremiah Barasa Kabeyi & Oludolapo A. Olanrewaju, 2021; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022; Moses Jeremiah Barasa Kabeyi & O A Olanrewaju, 2022).

Industry
About 21% global greenhouse gas emissions came from industrial operations with onsite facilities for energy production mostly involving fossil fuels like coal, gas, and petroleum products like diesel. These sources include industrial chemical processes, metallurgical processes, and mineral refining and transformation processes(Boden et al., 2017). The industrial sector is also characterized huge and diversified consumption of energy resources. The industrial sector also has the most diversified application of energy(United States Department of Energy, 2015). This makes the industrial sector a candidate of wide-ranging energy saving energy options. Methods that can be applied include process efficiency improvement, cogeneration and use of renewable and alternative sources can significantly reduce greenhouse gas emissions from industrial processes. Therefore, industry has a very important role to play in the energy transition to green and low carbon energy sources.

Agriculture, Forestry, and Other Land Use
Emissions from agriculture, forestry, and other land applications accounted for about 24% of 2010 global greenhouse gases were emitted from agricultural activities like crop cultivation, livestock farming activities and agricultural related deforestation. However, on the positive note, the value does not include carbon dioxide removed from the atmosphere by sequestering carbon in biomass through the natural process of photosynthesis. These process from agriculture and forestry activities offsets about 20% of carbon dioxide emissions from the atmosphere(Boden et al., 2017). This shows the positive side of agricultural activities which can be enhanced through agroforestry, and energy crops farming which help reduce atmospheric CO_2 concentrations. This implies that the use of energy crops and biomass sources for power generation has a very significant role in the transition of energy and grid power generation to low carbon and green electricity.

Transportation
The transport sector is one of the leading polluters contributing 14% of 2010 global greenhouse gas emissions. The main sources are transportation activities on road, rail, air, and marine transportation. About 95% of the 14% emissions from transportation energy came from petroleum-based fuels, inform of petrol, gasoline and diesel(Boden et al., 2017). Additionally, the transportation sector heavily relies on petroleum-based fuels with light duty vehicles being the dominant users of the fuel consumed in transportation(United States Department of Energy, 2015). Measures to limit these emissions include use of electricity from renewable sources in traction e.g., rail, increased use of biofuels and other renewable energy fuels and investment in fuel efficiency measures. Therefore, electrification of transport promise to have a huge impact on carbon emissions mitigation if grid electricity is derived from renewable and low carbon electricity sources like nuclear and renewable sources like wind, solar, geothermal(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022; Moses Jeremiah Barasa Kabeyi & O A Olanrewaju, 2022).

i.) **Buildings**
The building sector is another source of emissions accounting for 6% of 2010 global greenhouse gas emissions. Main building sector activities responsible include onsite power generation, burning fuels for heat in buildings, or cooking and other energy consuming activities(Boden et al., 2017). On the positive side buildings can significantly reduce this load by own generation from renewable sources, energy savings and decentralized grid generation for grid supply. Buildings are the largest consumer of electricity and additionally they are the largest consumer of primary energy(United States Department of Energy, 2015). Therefore, promotion of renewable energy sources is a solution to these emissions especially through decentralized generation from renewable sources aimed at reducing the load on electricity grids (United States Department of Energy, 2015).The contribute to energy transition to a green and a low carbon grid electricity by increased use of decentralized generation from renewable sources like geothermal wellhead, wind, solar and hydropower generation(Kabeyi, 2019, 2020; Moses Jeremiah Barasa Kabeyi & Oludolapo A. Olanrewaju, 2021). The use of smart grids can significantly enhance onsite grid connected power generation from intermittent renewables.

Other Energy
The remaining 10% of 2010 global coming from energy sector related sources other than heat and electricity production like fuel extraction, extraction and refining, processing, and stationary automotive engine applications(Boden et al., 2017). Energy economics and efficiency applications in consumption and use of renewable energy sources can reduce this type of emissions.

4.2.Summary of Emissions by Economic Sector

The economic sectors contributing to missions can be broadly divided energy, industry, building, transport, and agriculture, forestry and other land activities. The distribution of emissions by economic sector is presented in figure 8 below

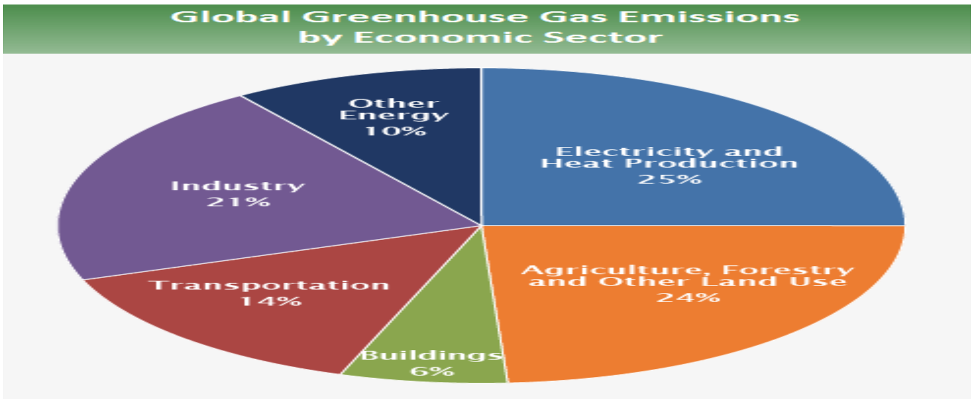

Figure 8. Greenhouse gas contribution by economic sector (Boden et al., 2017)

From figure 8, it is noted that electricity and heat generation is the leading source of greenhouse gas emissions by sector followed agriculture, forestry and land activities.

5. Results and Discussion

The future of humanity as defined by the Sustainable Development Goals in the face of climate change has made sustainability the concern for all major systems including energy or electricity systems(Vine 2019). There is significant distortion of competition among electricity sources in favour of fossil fuels due to subsidies and failure to account for the environmental cost of power generation from the conventional fossil fuels like coal, gas and diesel(Burger et al., 2012). The climate is very important to man and other living organisms on the planet, yet there is overwhelming evidence that the world is facing changing climatic conditions due to the greenhouse effect(Wallington et al., 2004). The global electricity generation grew by about 3% annually between 2000 and the year 2018, but slowed down in 2019 by 1%, which is an indicator of reduced demand due to relative milder weather conditions and slower growth of the world economy(Smil, 2010). Coal contributed 36% of the global electricity for 2019 which is a 3.5% reduction. Generation from natural gas increased by +3.2%, nuclear increased by 3.6%), wind grew significantly by +12% and while solar grew by 24% in generation capacity (Enadata 2020).

5.Dimensions of Energy and Electricity Sustainability

Energy sustainability assessment is divided into five major dimensions. The dimensions are economic, technical, social, institutional and environmental. Energy sustainability is important because it is a requirement for sustainable development which has three of the five dimensions of sustainability i.e. economic, social and environmental(M. J. B. Kabeyi & A. O. Olanrewaju, 2020; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022a; Kabeyi & Olanweraju, 2022). The dimensions of energy sustainability are demonstrated in figure 9 below.

Figure 9. Dimensions of energy sustainability (M. J. B. Kabeyi & A. O. Olanrewaju, 2020; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022e)

From figure 9, it is observed that sustainable energy and electricity has five dimensions of environment, economic, social, institutional.

5.Sustainability Measures

Various sectors have different opportunities to exploit to ensure sustainability in resource applications. They are listed as follows;

i.) Energy sector: Transition from fossil fuels, nuclear, energy, renewable energy, smart grids, energy efficiency measures
ii.) Agriculture: Use of bio wastes for energy, bio fertilizers, and other green practices like use of green manure from biogas digesters.
iii.) Buildings: Use biogas/biomethane and consumers to be converted to prosumers with grid modernization, as well as energy conservation measures.
iv.) Transportation: Electrification of transport, use of biofuels, energy efficiency, use of hydrogen energy(M. J. B. Kabeyi & A. O. Olanrewaju, 2020; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022e).

5.1. Characteristics of sustainable Energy

The following are the characteristic features of sustainable energy

i.) For energy sources and systems to contribute to sustainable development, they should possess the following characteristics.
ii.) Energy resources and systems are sustainable if they are renewable or perpetual in nature.
iii.) Sustainable energy system should not be wasteful but efficiently produced and used with minimum resource wastage.
iv.) Sustainable energy and energy systems should be economically and financially viable.
v.) Energy is sustainable if the source is secure and diverse.
vi.) Sustainable energy and energy systems should be equitable or readily accessible, available, and affordable.
vii.) Sustainable energy development should bring positive social impacts.
viii.) Sustainable energy should be associated with minimal environmental impacts(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2021a; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2021; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2021b).

5.2. Greenhouse gases

The composition of global atmospheric greenhouse sources and their sources is summarised in table 1 below.

Table 1. Global greenhouse gases, sources and effects

% Comp.	greenhouse gas	description	effect and control measures
76	Carbon dioxide (CO_2)	Carbon dioxide (CO_2) is a greenhouse gas with ability to absorb and radiate thermal energy whose main source is fossil combustion. Increases in atmospheric carbon dioxide are responsible for about two-thirds of the total energy imbalance that is causing Earth's temperature to rise.	This can only be realized by minimizing the consumption of fossil fuels particularly in electricity generation and transport industries through substitution with renewable energy sources and electrification of transport among other measures.
16	Methane (CH_4)	Emitted by natural and artificial processes like anaerobic digestion and during the production and transport of fossil fuels like coal, natural gas, and oil. Therefore, methane is added to the atmosphere through natural and anthropogenic sources. 30% of the methane flux originates from natural sources while about 70% is contributed by anthropogenic source	Controlled biodegradation through anaerobic digestion and use of clean fuels is the best strategy to limit methane emissions.
6	Nitrous oxide (N_2O)	Food production particularly the use of fertilizers is the primary source of N_2O emissions. As well as fossil fuel combustion in power generation, industry, and transportation as a product of combustion and wastewater treatment process.	Measures to limit Nitrous oxide (N_2O) emissions include use of cleaner and renewable fuels, controlled combustion of fuels and exhaust gas cleaning measures among others
2	F Gases	The F gases result from industrial processes, refrigeration systems, and the use of some consumer products associated with emissions of	The main negative impact of Sulfur hexafluoride (SF_6) is that is highly potent and has intense absorption at 10.3

		F-gases. These gases include hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6	μm (969 cm^{-1}) in the atmospheric window region and while it has atmospheric lifetime of 3200 years

From table 1, it is observed that the main greenhouse gas emissions from anthropogenic sources are F Gases, with about 2% atmospheric composition, Nitrous oxide (N_2O) with about 6% concentration, Methane (CH_4) with about 16% concentration and Carbon dioxide (CO_2) which has got the highest atmospheric composition of about 76%.

5.3. Emissions by Sector and Mitigation Measures

Various economic sectors have different contributions to the global greenhouse gas emissions as summarised in table 2 below.

Table 2. Contribution of greenhouse gas emissions by sector

	Economic sector	% Share of emissions	Description
1	Electricity and heat production	25	greenhouse gas emissions came from electricity and heat production which include coal combustion, natural gas, and oil combustion for electricity and heat application. This constitute the highest single source of global greenhouse gas emission. This percentage can be reduced through options like cogeneration for own power generation, shift to renewal energy sources and energy generation and conservation efficiency
2	Industry	21	Emissions came from industrial operations with onsite facilities for energy production mostly involving fossil fuels like coal, gas, and petroleum products like diesel
3	Agriculture, Forestry, and Other Land Use	24	Greenhouse gases are emitted from agricultural activities like crop cultivation, livestock farming activities and agricultural related deforestation. However, on the positive note, carbon dioxide is removed from the atmosphere by sequestering carbon in biomass through photosynthesis
4	Transportation	14	The main sources are transportation activities on road, rail, air, and marine transportation. About 95% of the 14% emissions from transportation energy came from petroleum-based fuels, inform of petrol, gasoline and diesel. Measures to limit these emissions include use of electricity from renewable sources in traction e.g., rail, increased use of biofuels and other renewable energy fuels and investment in fuel efficiency measures
5	Buildings	06	Main building sector activities responsible include onsite power generation, burning fuels for heat in buildings, or cooking and other energy consuming activities. On the positive side buildings can significantly reduce this load by own generation from renewable sources, energy savings and decentralized grid generation for grid supply
6	Others	10	About 10% global emissions come from energy sector related sources other than heat and electricity production like fuel extraction, extraction and refining, processing, and stationary automotive engine application. Energy economics and efficiency applications in consumption and use of renewable energy sources can reduce this type of emission

From table 2, it is noted that electricity and heat production has the highest contribution to global greenhouse gas emissions by economic sector. Others in the order of their contributions are agriculture, forestry, and other land use, industry, transportation and buildings.

Conclusions

This study showed that carbon dioxide has the highest atmospheric composition of greenhouse gases followed by methane, Nitrous oxide (N_2O) and F gases. Electricity and heat production and energy related upstream and downstream operations are the largest sources of greenhouse gas emissions followed by the agriculture, forest and land related activities. Other leading sources of greenhouse gas emissions are the industry, transportation and the buildings sector. Global electricity generation remains dominated by fossil fuels with renewable energy sources contributing a smaller proportion. Sustainable development needs sustainable energy which should be reliable, stable, good quality, affordable non-polluting and socially acceptable. Whereas sustainable development has social, economic, and environmental pillars, sustainability of energy and electricity generation systems are assessed by a five-dimensional approach consisting of environmental, economic, social, technical, and institutional sustainability as a strong measure of resource and system sustainability.

Various measures can be put in place to limit emissions from various sectors. New technology should be developed and exploited for to maximize use of abundant but intermittent renewable sources a sustainable mix with limited non-renewable sources optimized to minimize cost and environmental impact but maintained quality, stability, and flexibility of an electricity supply system. Other measures that can limit emissions include electrification of transport and industrial activities with electricity coming from renewable and low carbon sources.

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