Energy, Environment and Storage (2021) 01-01-26-41

Energy, Environment and Storage

Journal Homepage: www.enenstrg.com

Green Technology Solution to Global Climate Change Mitigation

SA Olaleru[1*], JK Kirui[1], FI Elegbeleye[1*], TE Aniyikaiye[2]

[1]Physics Department, University of Venda, Thohoyandou, Limpopo 0950, South Africa
[2]School of Environmental Sciences, University of Venda, Thohoyandou, Limpopo 0950, South Africa

ABSTRACT. Climate change is probably the most substantial issue ever to have faced human political, social and financial frameworks. The risks are enormous, with serious vulnerabilities and dangers, the economic matters questionable, the science assaulted, the governmental issues severe and muddled, the psychology perplexing, the effects annihilating, the relations with non-environmental and environmental issues occurring in several directions. Appropriate public health and policy need to be put in place to face the present and impending pollution and climate change difficulties. The question is whether our responses should focus on a mitigation of its rate and magnitude by minimizing carbon emissions of economic activity and adaptation to its unavoidable consequences. In this review, we discuss on climate change, the risk and hazard emanating from GHGs emission and its climatic effects, global actions, meetings and approach to mitigate climate change effects, policies such as economic, regulatory, forest/land use, technological approach. We suggest that the preventative actions including both mitigation and adaptation measures are good options. However, prevention of environmental problems is a key issue to sustainability. The most ideal approach to deal with environmental problem is to prevent it from being created in the first place. Therefore, green technology proffer the solution to climate change and take the lead in preventing environmental problems resulting to a sustainable environment.

Keywords: Green technology, climate change, environmental remediation, sustainability, decarbonized economy.
Article History: Received:13.10.2020; Revised: 20.04.2021; Accepted:22.04.2021 Available online: 28.04.2021

Doi: XXXXXXXXXX

1. INTRODUCTION

Industrialization and urban development across the globe continue to result in emission of toxic and harmful material to the environment, also, the continuous combustion of fossil fuel resources to meet energy demand results in release of GHGs emission. Energy demand worldwide continues to increase at an alarming rate. The future projected increase in demand of energy from year 2020 to year 2050 is 250 quadrillion (see Figure 1)

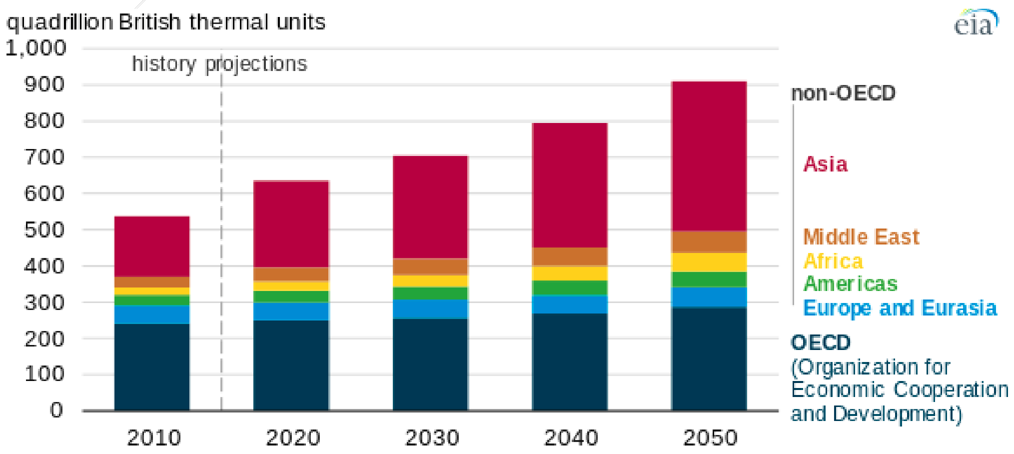

Figure 1: Future projected energy demand [1]

Statistical data reveals that fossil fuel energy resources is been utilized in meeting these enormous demand of energy (See Figure 2). Fossil fuels (coal, oil, gas) have, and will continue to demonstrate a major role in meeting global

*Corresponding authors: akinolaleru@gmail.com & ifelove778@gmail.com

energy demands However, fossil fuels have a great adverse effects, It is the leading source of environmental air pollution and cause of carbon dioxide ($CO2$) and other greenhouse gases emissions. There must be a balance in energy role in economic and social development in order to decarbonize across the globe, dependance on fossil fuel resources must be reduced to transit towards lower-carbon energy sources. The major driver of the industrial revolution is fossil fuel and social, economic, technological advancement which followed. Energy has demonstrated a major positive role in global climate change [2].

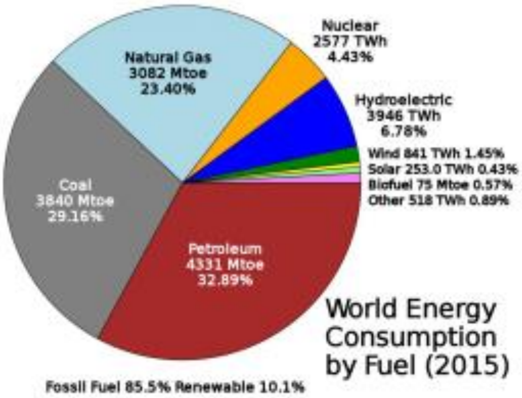

Figure 2: World energy consumption at 2015 [3].

The continuous combustion of fossil fuel has led to the release of toxic substances to the environment thereby leading to pollution and the release of greenhouse gas emissions (GHGS) such as CO2, N2O O3 to the atmosphere; these have resulted in global warming, pollution, climate change, ozone depletion, deforestation and lots more. If appropriate measures are not taken to embrace renewable, green energy resources in order to minimize the utilization of fossil fuel energy resources, we might run out of resources in the future and the environment might become uninhabitable to mankind. Hence the use of green technologies that are environmentally friendly and are not accompanied by the release of toxic GHG to the atmosphere is very pertinent

With the rise of GHGs in the air, long wavelength infrared (IR) radiant heat is reflected and enclosed in the atmosphere, bringing about the heating of the ground surface [4,5] This is further worsened by the diminishing function of the depleting ozone layer, thus allowing the penetration of more UVB radiation onto the earth surface and aggravating the global warming and climate change [4]. Climate change owing to GHG emissions has become a global environmental issue [4] The global temperature has an exceptionally close correlation with the atmospheric CO2 level [4]. There has been a progressive increase in GHG emissions since the industrial revolution [5], owing to the gradual build up and the long retention time of CO2 in the atmosphere [5].

The accumulation of GHGs in the air had resulted in the spontaneous rise in CO2 concentration from 280 ppm to 400 ppm in 2014 [6], accounting for a global temperature rise of 0.5°C, in the previous few decades [4]. About 90% of the heat from global warming is absorbed by the sea, resulting in the rise in ocean surface temperature [5]. Nonetheless, temperatures at the ground surface have increased equally, with each of the most recent thirty years being progressively hotter than the former since 1850 [5]. Ref. 5 reported the general global average land and sea temperature rise of about 0·85°C, between 1880 and 2012.

1.1 Causes of Climate Change

Climate change is considered to be caused by human activity, primarily the burning of traditional fuels, resulting in a build-up of GHGs [4]. CO2 is the major GHGs generated from human activities, especially fossil fuel combustion, resulting in 6-fold increase between 1950 and today [6]. The progressive rise in man-made emissions of CO2 and other greenhouse gases after the industrial age is drastically shifting the climate, both at the global and local level [7]. Conventional fuel CO2 emissions for the last 10 years have been at the climax of Intergovernmental Panel on Climate Change (IPCC) scheme due to economic advancement in less-industrialized nations [8].

The annual international GHG emissions organised in 2010 were projected at 49 gigatonnes of equivalent carbon-dioxide (GtCO2e) with the majority (about 70%) of total GHG emissions being attributable to the burning of traditional fuel for the generation of energy services, goods or energy extraction [5]. In the United States, CO2 accounted for 82% of greenhouse gas emissions, with 90% originating from combustion of fossil fuels (coal, oil, and natural gas)

and cement making, 9% and 6% attributable to CH4 and N2O, respectively, in 2012 [6]. Furthermore, the climate system shows substantial inertia, and temperatures will probably keep on rising for ages following the stabilization of greenhouse gas levels [8]. Man influences climate mainly through conventional fuel, industrial, agrarian, and other land use emissions that change atmospheric composition [8].

1.2 Impacts of Climate Change

Today, climate change is gaining growing attention globally, due to its increasing diversified and multi-pronged detrimental effects [9]. The effects of climate change on meteorological processes and environmental events are well reported [10]. Climate change is known to alter climate patterns, resulting in outrageous weather occurrences and increases in the frequency and intensity of the events [10, 11]. Severe weather events include heat waves, rising ocean levels, fluctuations in precipitation patterns [9], global temperature increase, cold waves, floods, drought, storms, tropical typhoons, heavy precipitation, snowstorms [10], mounting ocean level, elevated sea stratum, reduced ocean-ice level, and varying trend of sea movement, and freshwater in-flow [8].

The extreme climate events present diverse horrible and interrelated effects, which are progressively intense, prompting deaths, injuries and fatal communicable maladies [5,10]. Effects of climate change can be immediate such as heatwaves and severe weather occurences or indirectly caused by the impacts of climate change on ecological systems such as reduced crop and animal productivity, food instability and undernourishment, air contamination as well as the spread and varying patterns of disease [5,9], socioeconomic structure such as migration, dislodging, mental sickness and conflict [5]. Other impacts of climate change are increasing ocean temperatures and acidity [8], air and water pollution and forest fires [10].

The resulting effects on health can be classified as vector-borne diseases, rodent-transmitted diseases, malnutrition, and respiratory diseases [10]. Another result of harsh weather phenomena is diarrheal or gastrointestinal diseases, which are usually the result of increased precipitation over a short period of time [10]. Globally, over 530 000 people are victims of direct consequence of about 15 000 extreme climate occasions within 20-year (1993 to 2012), resulting in loss of over US$2.5 trillion [10]. Changing climate will affect the basic requirements for sustainable, such as, clean air and water, sufficient food, and adequate shelter [10].

The impacts of climate change are unevenly appropriated, with more serious dangers in the less evolved nations [5]. This current imbalance in danger of being influenced by environmental change is roughly 80 times higher in low income nations than in industralised nations, with females being around 14 more susceptible to death through natural disasters than men [9]. Other populations at risk of climate change include pregnant women, children, older people, people with medical issues or incapacities, poor and marginalised communities, outdoor workers, and people within coastal and low-lying riverine zones [5,10].

1.2.1 Global Warming Leading to Heat Waves

Globally, the average surface temperature has been consistently ascending [9,12] since the late nineteenth century, accounting for an increase of 1.1 °C [12]. The global warming potential (GWP) compares how much heat a greenhouse gas traps compared to a similar mass of CO2 [6]. Major bye-products of burning activities such as carbon monoxide (CO) , non-methane volatile organic compounds (VOCs), nitrogen oxides, sulphur dioxide, black carbon and organic carbon aerosols with some secondary contaminants (such as ozone) can possibly raise the global temperature alteration directly or implicitly [7]. CO, non-methane VOCs and nitrogen oxides are responsible for decrease in the oxidant intensity of the atmosphere prolonging the lifespan of methane [7].

Extensive, heat-capturing greenhouse gases (CO2, CH4, N2O, tropospheric ozone, and chlorofluorocarbons) warm the planet's surface around the world, while relatively short-lived particulate matters can either warm or cool the territory [8]. CH4 has a shorter atmospheric lifespan relative to the CO2, however, the former has a stronger heat trapping capacity [6]. In 2013, the Intergovernmental Panel on Climate reported that CH4 has 34 times stronger heat-trapping gas than CO2 over a 100-year time scale [6]. Direct radiative heating is intensified through a sequence of favourable climate feedback [8]; best estimates of anticipated international average temperature upsurge over the 21st century ranges from about 1.8° C to 4.0° C, based on emission condition [8]. The global temperature increase is more pronounced in the tropical zone, with an increase of about 4.0° C [12].

In reality, the vast majority of the documented global warming has happened in the previous forty years, with 2016 and 2017 being confirmed as the hottest years on record [12]. Extreme average global temperature was also documented in the first half of 2010, with heat extremes experienced in many continents [9]. Under a medium to high emission situation, the number of hot days could increase by factors of 2.1, 3.6, and 5.1 compared with 1961–1990, by 2020, 2050 and 2080, respectively [9]. Warming causes direct health risks through exposure to elevated level of heat beyond human tolerance [9]. In numerous urban populaces, an average rise of 2 °C in temperature would raise the yearly mortality rate by an projected factor of at least 2, as a result of hotter heatwaves. Developing nations, are the ones mostly affected by global warming [9].

Heatwaves are becoming more common and more severe than in previous years and consequently more death toll [9]. Heat wave associated with dehydration cause heat stroke, which may result in increased hospital admission cases and or mortality rate [10]. The 2003 European heatwave accounted for over 60,000 unexpected deaths [9] and France being most affected with excess mortality estimate of about 14 800 [10]. In 2009, temperatures in the outer suburbs of Melbourne (Australia) reached 48 °C [9]. The extremely hot heatwaves experienced in the Canada, United States, Asia, Europe, and Russia in 2010 were responsible for instability in power, interfering with transport, cooling, and high death cases. A heatwave with temperature reaching 53.5°C (128°F) was experienced in India and Pakistan in June 2010 [9].

Cardiovascular issues heighten risk as outrageous warmth puts extra burden on the heart [9]. Psychological disability, diabetes, malignant growth, and corpulence likewise raise vulnerability to hyperthermia. Chronic heat exposure incurs significant damage where laborers are incessantly dried out, and the result is emaciating health ,capability, and psychological capacity, which further devastates the workers [9]. Global warming also threatens the ecological frameworks which supply the food, air, and water we depend on for survival [9].

Global warming causes the migration of animal species towards the poles [6] and reduced oxygen level of water bodies' subsurface [8]. World-wide temperature increase thus presents both monetary and health risks [9].

1.2.2 Drought Leading to Food Shortage

Drought occurs as a result of water scarcity owing to a range of climatic origins and a marked decrease in precipitation. A notable example is the water scarcity crisis in Cape Town, in early 2018 [12]. Sub-Saharan Africa has demonstrated a notable drop in precipitation prompting an average decrease in discharge of 40-60% of certain watercourses since the early 1970s. Long-term outrageous drought patterns are seen across Africa, North and South America, the Middle East, China, and other parts of Asia. [9]. At present, approximately 1 billion individuals across the globe live in arid lands, with 20% of them residing in Africa. Arid and dry semi-arid zones in Africa are anticipated to escalate by approximately 11 per cent [9], partly attributable to depleted water resources (Collier et al., 2008), with the likelihood of being unsuitable for crop farming [9].

Climate change will worsen aridity, and cause increasingly outrageous downpour and progressively furious storms, which will interfere with food and water supplies. An average 2 °C increase in world-wide temperature could result in 5 to 20 per cent reduction in cereal grain production across South Asia and Sub-Saharan Africa by [9]. Currently, Nigeria is experiencing declining agrarian productivity due to decreasing precipitation in desert inclined regions in the north prompting expanding desertification, diminishing food productivity [11]. For many individuals these essential requirements for man wellbeing, food, water, and safe house are now being disrupted by outrageous climatic events [9].

Climate change impacts on food security will be most noticeably terrible in nations previously enduring elevated levels of hunger and will aggravate with time [13]. Over 70 per cent of current global populace, equivalent to 4.2 billion individuals reside in the 80 poor food scarcity nations, and in 2010, over 1.2 billion individuals, above 16.7% of the world populace, are hungry and undernourished [9]. In addition, increased population and food scarcity may drive more individuals to look for sustenance from the oceans, resulting in the overdependence on marine food systems. Fish stocks might be stressed as climate variations mounts additional tension on marine food systems [9]. The consequences for global undernutrition and malnutrition resulting from doing nothing in response to climate change are potentially large and will increase over time [13].

1.2.3 Air Pollution, Wild Fire and Human Health

Climate change and air pollution are intrinsically connected since greenhouse gases and air pollutants originate from the same source, fossil fuel combustion [7]. Combustion processes emit both greenhouse gases, like carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), and other air pollutants, like particulate matter (PM), sulphur dioxide (SO2), nitrogen dioxide (NO2) and carbon monoxide (CO) [7]. It is widely recognized that the release of air pollutants, even at low concentrations have significant impacts on human health, with a pronounced influence on respiratory sicknesses [7].

Primary and secondary pollutants have been linked to a various respiratory health impacts, including aggravation of ailments in patients already suffering from chronic respiratory sicknesses, such as, asthma and incessant obstructive pneumonic infection (COPD), resulting in frequent hospitalisations and emergency room visits for the underlying sickness, malfunctioning of the lung, asthma attacks, untimely death and, perhaps, the event of new respiratory issues, like, new-onset asthma [7]. Respiratory health is generally affected by air pollution as well as by climate conditions, particularly in individuals above 75 years of age [7]. Low income nations are progressively influenced by metropolitan air contamination because of accelerated economic and population surge [7]. It has been estimated that current ambient concentrations of particulate matter led to the loss of about 40 months from the average life expectancy in China, but that this loss could be reduced by half by 2050 if climate mitigation strategies are implemented [5].

Climate change related increase in wild fire occurrences will likewise influence particulate concentrations with increased fire risk in Mediterranean nations, particularly in territories with timberland [7]. The 2003 heatwave in Europe is significant since it was linked to records of wildfire and high particulate matter (PM) levels, particularly, the fine particles with aerodynamic diameter 2.5μm, which have longer atmospheric retention time (of the order of days) and may be conveyed by wind over long distances away from the source.

Respiratory diseases are on the rise globally [7]. In summer, each degree Celsius rise in maximum observable temperature over a city specific threshold limit (between 23 and 29°C) is linked to 7% expansion in daily respiratory mortalities [7]. Highly reduced temperatures also negatively impact the respiratory health, with a 3 to 4% rise in daily death and hospitalisations from respiratory illnesses in the populace above 75 years of age for each degree Celsius decline in minimal temperature or minimal observable temperature. . Ozone effect on respiratory admissions is more pronounced in summer [7]. Jamal et al [10] argue that urban air pollution over the globe accounts for 800, 000 deaths annually, with the worst consequences of climate change occurring in developing countries [7]. Changes in climate are anticipated to further exacerbate the impact of air pollution on these infections [7].

1.2.4 Changing Pattern of Disease

Another effect of an unnatural climate change is rise in mortality rate which could be partly attributable to increase in infection transmitting insects. Varying trends of infection are springing up as result of varying environmental scenarios [7]. For instance, the topographical distribution and the paces of development of mosquitoes are exceptionally affected by temperature, precipitation, and stickiness. There have been resurgences of malaria in the highlands of East Africa as of late. The temperature in the highlands of East Africa has ascended by 0.5oC since 1980, much faster than the global mean temperature and this is associated with a sharp increment in mosquito population.

1.2.5 Glacial Ice Melting

Upper-sea heat content has increased significantly since the 1950s, with average universal sea-surface temperature (SST) rising about 0.4°C during this interval [8]. Warming is not evenly distributed in space due to sea movement, space-related variable fluctuations in winds, and relationship with natural modes of climate changes such as El Nino/Southern Oscillation (ENSO) and the North Atlantic Oscillation. Ocean ice level has declined drastically in the Arctic and along the western Antarctic Peninsula (WAP), especially during summer [8].

Arctic ocean ice is diminishing at a rate of about 50 000 km^2 annually, the Antarctic ice sheet is presently losing 159 billion tons of ice yearly, and ocean levels are rising unavoidably [5]. 80% volume reduction in Arctic sea ice during late summer, and more than five-fold rise in the Greenland ice sheet melt rate was observed, between 1979 and 2012 [6]. Due to thermal increase and melting of land fast ice (glaciers and ice caps and sheets), warming has resulted in increased ocean level, with a prevailing rate of about 3 mm per year [8]. The ceaseless shrinkage of rise ice sheets, glacial retreat and declining Arctic ocean ice all add up to the ocean level rise in numerous locations on the globe [12].

1.2.6 Sea Level Rise- Flooding

As already mentioned global warming, to a large extent also influences the seas, which retain a significant portion of the heat [6,12]. Such atmospheric changes have brought about an increase in temperature of both the top layer (up to 700 m) and in the deeper waters [12]. The aftermaths of the elevation of the height of the sea is flooding and displacements of neighbouring communities [11]. The gradual disappearance of land due to ocean level rise has influenced human settlements for quite a while [12]. An example is the displacement of the Carteret community, a small island which is 1000 miles North East of Australia [11].

Another case is the severe land erosion of the Sundarbans community in the India Ocean region, attributable to global warming [11]. Currently, Nigeria is experiencing increasing occurrence of flooding, and annihilation of means of subsistence due to rising waters in coastal region [11]. Since the late 18th century, the sea level has being rising at rate of 0.3 cm/year [6]. Impacts associated with sea level rise include:thermal expansion, fluctuations in groundwater storage, glacier ice loss, Greenland ice loss, Antarctic ice loss, flooding and warm water fuel hurricanes [6] and increased frequency and intensity of tropical cyclones on coastal communities [12].

1.2.7 Storms/Cyclone/Tonados

Cyclone is another extreme weather event caused by climate change that leads to sea level rise, owing to global warming [12]. The communities residing at the regions nearest to the seas as well as those living in low-lying zones are at risk; this is where a considerable percentage of the world population reside [11]. A typical example is the 1991 cyclone which occurred in Bangladesh, a low-land of which two-thirds is less than five meters above sea level, murdered 138,000 and affected more than 13 million, with a flood 7.2 meters high [11]. Another example is the 29 August 2005 Hurricane Katrina, where winds with speed of about 200 kilometers per hour was lashed out at population residing on the Gulf Coast of the United States, resulting in about 1300 deaths [11]. Changing climate could possibly increase the frequency and intensity of this extreme weather event.

1.2.8 Ocean Acidification

Climate warming influences local wind trends and hence sea movements in multiple dimensions [8]. Warmer SSTs may affect the frequency and strength of tropical storms, increasing the vulnerability of coastal habitats. In the open ocean, rising atmospheric CO2 and the resulting increased oceanic CO2 uptake are the predominant factors of driving ocean [8]. Ocean acidification reflects a series of chemical changes such as elevated aqueous CO2 and total inorganic carbon as well as reduced pH, carbonate ion, and calcium carbonate saturation states [8]. Sea-surface pH is projected to have fall by 0.1 pH units since the pre-industrial generation, a 26% rise in acidity during the last 150 years. Future projections suggest further declines of 0.2 to 0.3 pH units over the century [8].

Sea acidification makes it more complicated for corals to discharge and keep their skeletons [8]. Besides, changing area use and waterway stream can modify stream alkalinity and, in turn, impact coastal inorganic carbon balance. Changing climate may be physiologically tolerable, allowing acclimatization or adaptation, or may be intolerable, promoting migration, change in phenology, or death and local extinction if adaptation is not possible [8]. Some basic habitat-forming marine benthic species, such as oysters or corals, seem susceptible to CO2 and climate variations both directly and through pathogens [8].

1.2.9 Impacts On Ocean Chemistry And The İnhabitants

Direct impacts of variations in sea temperature and chemistry may modify the normal behaviour and demographic qualities (e.g., efficiency) of organisms, prompting alterations in the size, space-related range, and periodic profusion of demography [8]. These transition, in turn, result in modified species communication and trophic routes as change falls from main producers to upper-trophic-level fish, seabirds, and aquatic vertebrates [8]. The impact of rising CO2 on ocean ecosystems include: coastal and benthic habitat degradation, over exploitation of fish stocks, rising aquaculture production, and invasive species [8]. Coastal hypoxia is increasing and expanding globally [8]. Ecosystem deterioration is intense and increasing, especially for waterfront frameworks, with half of salt marshes, 35% of mangroves, 30% of coral reefs, and 29% of seagrasses already either lost or degraded globally [8].

1.3 Global Meeting on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) is a global agreement on the environment sanctioned by all of world's leading countries, established at the June 1992 Rio Earth Summit [6]. By 2014, the convention comprised of 196 nations or parties with a goal of stabilizing greenhouse gas levels in the atmosphere to a less harmful state [6]. But no limit was set for emissions by 1992 [6]. This resulted in the structuring of target and timetable for emissions of the developed countries, while exempting the United States, in the Kyoto, Japan COP, in 1997. In the conference no binding targets and compliance mechanism for GHGs emissions was given, but it did set up a legally nonbinding target that called for the developed countries to bring their emissions of GHGs back to 1990 levels, while a target of at least 5% reduction relative to 1990 levels within the time frame 2008-2012 was set for the developing nations. Each nation was saddled with the responsibility of reducing GHGs emissions, however, much emphasis was laid on the developed nations, whose parties were enjoined to take the leading role in combating climate change and the attributed adverse effects, since the largest share of historical and current global emissions of greenhouse gases has originated from them [6]. At these summits innovative financing measure called Clean Development Mechanism (CDM), to lower the cost of emissions reductions while assisting the low-income nations to finance their clean energy projects was also established [14].

After the pronouncement of the treaty, several strategies were put in place by many nations, especially the European Union, to cut the release of carbon emission [6]. The exception of United State coupled with the sporadic increase in the developing nations' emission, especially Chinas after year 2000 resulted in overall global emission growth [6]. The United Nations Intergovernmental Panel on Climate Change (IPCC) in 2007, identified elevated global atmospheric and oceanic temperatures, widespread melting of snow and ice, and increased global average sea level as consequence of climate change [6]. At the 2009 climate summit, held in Copenhagen, Denmark, many of the world's leading nations understood "the scientific view of the increase in global temperature should be below 2 degrees Celsius" and 2°C was agreed upon as the threshold at which dangerous interference began. In response, a consensus regarding this was reached with the aim of holding total global warming to below 2°C above pre-industrial levels and this was embraced at the December 2010 Conference of parties (COP) in Cancun [6].

Keeping the universal average temperature rise to less than 2°C to prevent the danger of conceivably calamitous climate change impacts requires cumulative anthropogenic carbon dioxide (CO2) emissions to be kept below 2900 billion tons (GtCO2) before the year 2100 [5]. As of 2011, total emissions since 1870 were about 50% of this, with current patterns expected to surpass 2900 GtCO2 in 15–30 years' time [5]. Most of the past emissions are retained in the air and will stimulate continued warming in the years to come [5]. Ref. 5 reported the progressive rise in GHG level at an irreconcilable rate with the intended limiting warming to 2°C by 2050, thus exceeding the IPCC's "worst case scenario". Hypothetically, the persistence of this scenario may result into a universal mean temperature increase greater than 4°C beyond pre-industrial temperatures by 2100, at which point universal temperature will continue to rise by about 0·7°C every 10 years [5]. To curtail the global GHGs emissions and the attendant effects, President Obama announced a new target to cut net greenhouse gas emissions 26-28% below 2005 levels by 2025 in the 2014 U.S.-China Joint Announcement on climate [6]. In 2015, all parties were committed to developing a follow-on agreement to Kyoto, one that includes commitments by the United States as well as major emitters in the developing world such as China [6].

1.4 Policy on Climate Change

Climate change is probably the most significant issue ever to have faced human social, political, and financial frameworks [15]. The stakes are gigantic, the dangers and vulnerabilities serious, the financial matters questionable, the science assaulted, the governmental issues severe and muddled, the psychology perplexing, the effects annihilating, the interactions with other environmental and non-environmental issues running in numerous directions [15]. To address both the existing and up-coming climate issues, appropriate policy and public health measures must be put in place [7]. Since climate change is a universal issue, with severe effects mostly felt in low income nations, international measures are imperative [7]. Strategies for reducing GHG emissions need to be determined, particularly in nations with the major emission burden [7]. A decarbonizing economy obviously need to include changes in consumption patterns, whether induced by government policy and price increases, or chosen by consumers [15].

1. The major strategies used by the constituted authorities to retard the growth in GHGs emissions of a country could be categorized into 4 groups namely [6]:
2. Economic policy
3. Regulatory policy
4. Technological policy
5. Forestry/land-use policy.

1.4.1 Economic

Economic policy involves the establishment of policies aimed at hiking the price of CO2 and other GHG emissions or subsidizing the cost of carbon-free energy sources such as nuclear power or renewable forms of energy (such as solar and wind) in order to discourage the use of high carbon energy while encouraging the uptake of new technologies. This is done so as to estimate the economic cost of hydrocarbon (HC) fuel (coal, oil, and natural gas) combustion and the impacts of their emissions on humans and the environment. This aim is achieved through a carbon tax or a cap-and-trade system [6]. Carbon pricing is the economist's ideal method of addressing climate change. Such pricing might be accomplished through regional or local explicit carbon taxes or cap-and-trade emissions trading systems (ETS), which are progressively gaining global recognition [5]. A carbon tax sets the carbon price directly, rather than the level of abatement, while an ETS sets the extent of reduction, but the pricing is controlled at the carbon market [5].

1.4.1.1 Carbon Tax

Carbon tax is the tax paid on carbon content of hydrocarbon (HC) fuel or CO2 generated from these fuel on combustion. This could also be referred to as the social cost of carbon, if the tax paid on these fuels are equivalent to the social cost, business parastatals and other end- users would be discouraged from using them hence minimizing the use of fossil fuels in the most optimum and efficient manner [6]. Carbon tax could also come up in form of removal of pricing grants for the extraction and usage of traditional fuels [5]. In June 2014, about 40 national and more than 20 subnational wards in South Africa were occupied with carbon pricing of divers range and equipment configuration, encompassing about 12% of the annual global GHG emissions [5].

Carbon tax guidelines usually required an organization to make a particular commitment with regards to decrease in air or water pollution for each facility it possesses, regardless of whether a facility or some companies do not meet up with the limit [6]. Carbon taxes were introduced in countries like Norway, and in 1991, this was adopted by some other European countries [6]. In 2012, Australia presented a $24 per metric ton carbon charge for chief industrial emitters and some government parastatals, and much of the revenues raised were circulated to the general public in form of reduced income tax, increased pension and welfare packages. By mid-2014, the tax had cut carbon discharges by as much as 17 million metric tons [6].

1.4.1.2 Cap-and-Trade Emission Trading System (ETS)

Cap-and-trade emission trading system (ETS) is a market based environmental standard focused on reducing pollution, and ensuring that the targeted level of emission is achieved at the least possible cost. It is one of the globally accepted strategy of GHGs emission reduction embraced by the EU Emission Trading System in 2003 [6]. The European ETS is the largest ETS, founded in 2005, and covering over 40 % of yearly GHG discharges from power creation and energy consuming and emission intensive large-scale industry across the EU-28 countries. The cap-and-trade system is a scheme in which the governmental agency set a threshold limit for industries on the emissions of specific pollutant [6]. The governmental agency implements the cap by issuing a limited number of permits, which allows the emission of air pollutants to a certain level [6]. In other words the concerned authority sets a cap on cumulative emissions, at that point issues permits for amounts that exceeds that cap [15,16]. These permits could then be traded with in the secondary market [6]. Industries that are able to efficiently manage and reduce their emissions below their allocations can sell those permits to other organisations that find lowering emissions more expensive [6,15]. The apportioned licenses are gradually reduced in specific fashion, resulting in the overall reduction of the pollution level [6].

The essence of this scheme is to sensitize the industries and other stakeholders in the market about the possibilities of further increase in the price of the pollutants and the rising necessity of investing in a long-term innovations that can reduce or replace CO2 [6]. For instance, the EU enacted their Emission Trading System to meet the target of 8% below 1990 levels between 2008 and 2012 which they had committed to under the 1997 Kyoto Protocol, however 14% reduction in emission in the participating countries was achieved. The successful achievement of this goal had further prompted the commitment of the EU members leading to the 2014 announcement of cutting GHG emissions to 40% below 1990 levels by 2030 [6].

The cap-and-trade and the carbon tax system are similar strategies used in reducing emissions into the atmosphere, however, the cap-and trade system is more flexible, economically efficient, and business friendly relative to the regulatory-determined carbon tax. Many other countries are beginning to embrace cap-and-trade system. In 2011, China launched pilot carbon trading in cities and provinces, including Beijing, Shanghai, and Shenzhen along with Guangdong and Hubei Provinces, and subsequently announced the launch of its national market in 2016 with the intention of attaining the CO2 peak by 2030. In a bid to reduce GHGs emissions, the Chinese have begun to establish price reforms on energy, strong fuel economy standards, and intensified effort in deploying clean energy innovative, hence making them world leaders in both manufacturing and utilizing solar and wind energies [6]. China has committed to “increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030 [6]. The South Koreans launched a program in 2015, with the intention of cutting GHG emissions to 30% below the current levels by 2020.

Both carbon tax and cap-and-trade Emission trading systems are good strategies of reducing GHGs emissions, however, the wealthiest in society benefit more from both traditional fuel grant and the existence of external influences at both regional and global levels, since energy usage and related emissions rises with wealth [5]. Globally, about 80% of such sponsorships often favour the wealthiest and 40% of the populace the adoption of low-carbon innovations. Thus the use of both carbon pricing and removal of fossil fuel subsidy may be regressive, as the poorest in the population spend majority of their income on energy, hence, reduced taxation of the low paid may partially settle this situation in the industrialised economies [5]. Other strategies like availability of power saving strategies for poor households, or the launching of electricity tariffs distinguished by utilization rate, are also viable solutions [5]. This is quite different in developing countries. Unlike other territories where the main problems hinge on how to minimize carbon discharges, Africa rather focuses on adjustment of production to changing, and mostly deteriorating, opportunities [16].

1.4.1.3 Clean Development Mechanism (CDM)

Clean Development Mechanism (CDM) serve as an institution that focuses on earning income through CO2 reduction emissions [16]. CDM is a private sector initiative which allows industries in the high income nations to comply with their domestic emission targets by financing emission reduction projects in low-income countries, where expenses are often cheaper. In the process, one carbon emission reduction credit (CER) is awarded to the party involved per tonne of GHG saved. The CERs in turn can be sold on any of the international carbon exchanges [14].

Unfortunately, underdeveloped continents like Africa scarcely partake in the scheme which involves trading with $2 to $3 billion per annum through the CDM with just 2% ascribed to Africa. As of 2008, only 21 CDM projects out of about 1000 global projects were given to Africa. Examples of the CDM projects include gas recovery project in Nigeria and the West Nile Electrification project in Uganda [16].

Some reasons for the less participation of low-income continents in the CDM projects include:

- Limited capacity to organize and implement reliable CDM proposals due to their detailed, complex nature and financial requirement.
- Financial incapacity to justify the high transaction cost required
- Lack/ inadequacy of sophisticated energy and industrial requirements

Africa has potential for hydro and generation of power source from natural source of methane, but all these are not covered by CDM. It is therefore of paramount importance for Africa to develop technologically and financially so as to be more active in the CDM scheme [16]. Another way forward is to broaden the scope of CDM so that areas covering potential African projects such as power sector, waste disposal and deforestation could be incorporated [16].

1.4.2 Regulatory Policy

Regulatory Policy focuses on the establishment of regulatory guidelines targeted at curtailing GHGs emissions. Regulatory policies include fuel economy standards for vehicles, energy efficiency guidelines for appliances, renewable energy standards that necessitate the incorporation of a minimum level of carbon-free sources into electricity or vehicular fuel cutting down the CO2 emissions from the various facilities like electric power plants [6]

1.4.3 Forestry/Land-Use Policy

Forestry/land-use policy centers around land and forestry policies aimed at lowering GHG emissions from deforestation and agrarian practices. For instance, Brazil, have made huge decreases in their net emissions from deforestation. Currently, deforestation and other land-use changes are responsible for about 10% of global GHG emissions [6].

1.4.4 Technological Policies

Technological policy deals with research-based guidelines aimed at subsidizing and improving the performance of low carbon energies. This incorporates fundamental investigation into green technologies, new materials and applied innovative research and development of advanced energy efficiency methodologies, such as LED lighting, solar panel, and a lower-cost electric vehicle battery. This policy also incorporates the sponsoring of research and development on and commercializing low-carbon energy system such as coal plant with carbon capture and storage [6]. To promote dissemination, enhancement and subsidizing of low developed innovations, private financing is likewise needed. For new innovations, sound research and development (R&D) efforts are imperative [5]. In the USA, Gunderson Health has increased efficiency by 40%, saving $2 million annually, while deploying solar, wind, geothermal, and biomass to significantly reduce its carbon footprint and end its dependence on fossil fuels [5].

2. THE CONCEPT OF GREEN TECHNOLOGY

Green technology is a general name that describes the application of science and technology to produce clean goods and services. Green technology is identical to cleantech/eco-tech which obviously refers to services and goods that can be produced efficiently while generally reducing cost, energy utilization and adverse environmental impacts. Green tech is the utilization of alternative fuel resources and machineries that are safer than conventional fuels and has the potential of resolving the present energy chaos and remediate the environment.

Although the concept of green technology is relatively a new field, it has stirred lots of attention from the research community, industrial and academic sector owing to its promising potential of reducing the use of conventional fuels and its adverse environmental impacts. The main objective of green technology is to ensure safety of the earth, produce a balance to lopsided energy demand and supply and preserve the environment.

New green technological approaches demonstrate the potential to resolve difficult challenges faced by the environment and global energy crises across the world in this 21st era. The most efficient methods are categorized into the following headings: Renewable energy, Clean Water¸ Clean Air, transportation, energy efficient building, recycling, agriculture and coorporate Green Tech.

The traditional energy tandem materials and resources are prone to risk that are detrimental to the ecosystem. Also, the development of current technologies combined with the increasing pressures of population needs/demands has led to rapid growth of industrial evolution and urbanization. This has a visible consequential pressure on nature and has become rapidly intense which has resulted to significant upsurge in industrial pollution, deterioration and contamination of the environment. During the last few decade, the environment has deteriorated in a manner that has not been experienced before in the history of humanity. At present, the environment is exploited at a faster rate and time than it would take for it to be refilled by nature. The type and magnitude of environmental challenges which results in the deterioration of the environment are diverse and interdisciplinary [17].

It is broadly known that there are some problems that are global in nature such as climate change, global warming, ozone depletion, biodiversity loss, forest fires, and extinction of endangered species. While local environmental challenges are water contamination and pollution, land degradation, vehicular and air pollution, domestic solid waste, industrial hazardous waste, soil degradation, deforestation and loss of biodiversity [18,19]. Humankind are both causes and causality of environmental degradation. Various technologies and traditional method have been utilized by mankind to exploit the environment which has resulted in indescribable variation in the ecosystem. For example, the utilization of irrigation and dams, the use of additives and chemicals to the soil and other conventional methods to improve crop yield has also played a major role in environmental degradation. Actually, the misuse of natural resources and developmental sustainability challenges have multifaceted causes and consequences [20].

Having underscored the potentially damaging effects of environmental hazards, a thought provoking question is to whether our action should focus on the prevention of its rate and magnitude with the utilization of decarbonizing strategies and economic activity or by adapting to its inevitable drawbacks (e.g. by intensifying the resistance to adverse weather conditions, heat waves and life-threatening draught). Preventive approach which include both mitigation and adaptation strategies are viable options. Nevertheless, the main approach to sustainability is prevention of environmental problems. The ideal way to tackle environmental hazards is to prevent its creation. That is why the utilization of Green technological approach may take a major lead in the prevention of environmental problems and its totality. Preventing problems is more affordable than fixing it, this is a preliminary ideology for effective and economically feasible manufacturing procedures.

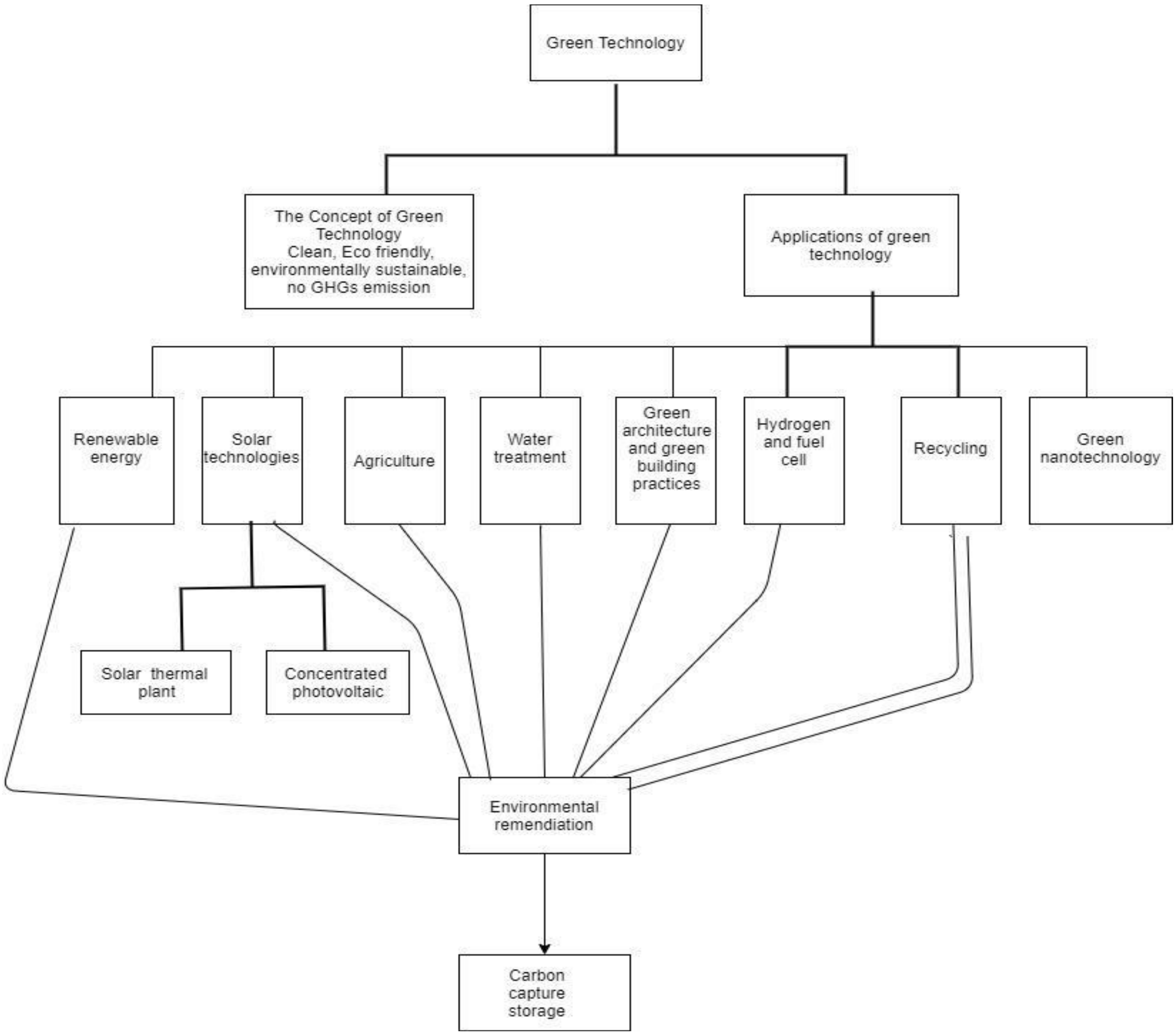

Figure 3: Green Technology

Green technology is an improved application of technique, equipment's and products in a way that leads to the conservation and preservation of the environment, decreased harmful atmospheric effects, reduced depletion or deterioration, zero level GHGs emission, induces environmental safety and preserves all life forms, enhances the utilization of energy forms that are renewable and conserve the utilization of energy resources that are natural (see Figure 3)

Rani et al reported on the overview of green technology on nanotechnology, they reported on the importance of utilizing technologies that permits material engineering of small size particles in the medical, clothing industries, water purifying companies, electronic industries, solar companies in an environmentally friendly, clean, nontoxic and developed manner. [21]

Monu et al repoted on the advantages and disadvantages of green technology, they highlighted the four pillar of green technology policy as energy, environment, economy and social. The study reported that the major goal of green technology is meeting societal needs without depleting or damaging the environment, natural habitat and resources. The study suggested that government and energy cooperation should shift attention on manufacturing and producing products that are reusable in other to maintain a clean environment. They listed the advantages of green technology as it's use does not emit harmful substance to the environment, green technology is benficial to the environment and the economy, less maintenance are required by green technology, it is readily abundant, the utilization of green technology reduces the emission of CO_2 and subsequently reduces global warming while the shortcomings reported in their study is high costs of execution or implementation, limited information are available on the use of green technology, inadequate skill and technical knowhow on green technology. [22]

Zaffar et al reported that green technologies is key towards sustainable development, the study reported that green technology has a positive impact potential towards urbanization, economic growth in the society and in meeting economic sustainability demands. They highlights the merits of green technology as waste management, water recycling air purification and the utilization of conservative energy devices [23].

3. APPLICATION OF GREEN TECHNOLOGY

3.1 Renewable Energy Sources

The world cannot depend on petroleum products/traditional fuels perpetually to run homes, cars and industrial facilities. Green tech incorporates the transformation of renewable resources, like solar light, wind and water to energy that we can utilize. Solar panels, wind turbines and geothermal wells are generally templates of technological innovations that can replace the demand for coal and oil.

According to IRENA, "Renewables are important for us because they offer decentralized solutions, they can support multiple applications such as lighting, cooking, heating, cooling and drying".

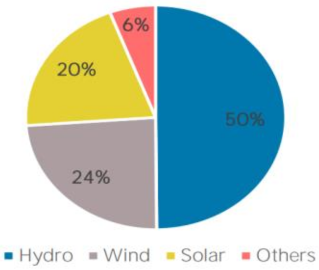

Figure 4. Renewable energy percentage

Renew able energy is the most rapid growing source of energy, accounting for around half of the increase in energy.

Solar power is the use of the sun's energy to generate electricity. "The sun could be the world's largest source of electricity by 2050, ahead of fossil fuels, wind, hydro and nuclear," according to two 2014 reports from the International Energy Agency [6].

Green tech can be employed in methods designed to conserve energy, for example energy-efficient light fixtures. Green tech is likewise employed to generate renewable fuel sources that are cleaner than traditional fuels. Conventional fuels usually generate waste as a by-product of their production. Solar, wind, and hydroelectric dams are all examples of green tech because they are lesser risk to the environment and do not generate fossil fuel waste by-products. Aside the environmental gains of these renewable energy sources, they can likewise be employed to power a home or a utility power plant.

3.2 Solar Technologies

The sun is an enormous source of energy which supply energy to nature, the sun can be used as a green source of energy because it is clean, renewable and environmentally friendly. The sun is the most appropriate source of energy which supplies directly or indirectly other form of energy resources which are wind and hydro and had the least environmental concern that is, it's use is not accompanied with the release of GHGs emissions and does not contribute to climatic change effects [25]. Photovoltaic cells are utilized in harnessing solar energy. Photovoltaic cells operation involves the use of photoelectric effect to convert photons from sunlight into electricity (See Figure 6)

Renewable generation capacity by energy source

Toward the end of 2018, worldwide renewable generation capacity added up to 2 351 GW. Hydro represented/covered the biggest percentage of the worldwide total, with a total power of 1 172 GW. Wind and solar energy represented the majority of the rest, with wattages of 564 GW and 486 GW respectively. other alternative sources of energy included 115 GW of bioenergy, 13 GW of geothermal energy and 500 MW of marine energy (tide, wave and ocean energy) [24].

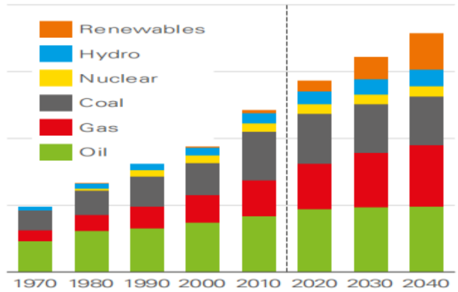

Figure 5. Energy resources according to years.

Figure 6: Solar Technologies [26]

Solar technologies are used in solar thermal plants, concentrating PVS and so on

3.2.1 Solar Thermal Plants

Solar thermal power plants are technologies which utilizes solar heat energy from sunlight, direct solar radiation are harnessed from sunlight through collectors in the solar thermal power plant architecture to generate water heating at temperatures that are low. The large scale application involves the use of solar concentrators (See Figure 4) by parabolic mirrors to provide high temperatures which are in turn utilized for direct and indirect heating processes especially for conventional heat engines [25]

3.2.2 Concentrated Photovoltaic (CPV)

Concentrated photovoltaic (CPV) technology utilizes optical devices which include lenses/mirrors to concentrate direct solar radiation onto a multi-junction semiconducting material to generate electricity as shown in Figure 7 [27]. CPV systems are characterized based on the degree of concentration of solar radiation measured in suns. The range of the solar concentration factor is 2 to 100 suns (low to medium concentration) and measure up to 1 000 suns (high concentration) as presented in Table 2. The orientation of the lenses/mirrors must be permanently in the sun's direction using single or dual-axis tracking system for it to be efficient. Low to medium concentration systems are associated with silicon solar cells, although their efficiency is reduced at higher temperatures, while high concentration systems (beyond 500 suns) are usually hinged with multi-junction solar cells made by group III and V semiconductors including GaAs or In GaAs (1.4 eV), Ge (0.67 eV), and In Gap (1.85 eV) [28]. Theoretical efficiency of 59 % can be achieved with multi-junction cell with band gaps of 0.74, 1.2 and 1.8 eV [28]. Laboratory efficiency of more than 40 % has been achieved with CPV based on multi-junction solar cells [29] while silicon-based commercial CPV modules gives efficiency in the range of 20 % to 25 %. The multi-junction CPV cells are utilized for space applications or solar cell with relatively small area solar with concentration of sunlight owing to their complexity and high cost [30].

Table 1: Description of concentrating photovoltaic cell classes [31].

Class of CPV	Typical Concentration Ratio	Tracking Systems	Type of Converter
High concentration PV (HCPV)	300-1000	Two-axes	III-V multi-junction solar cells
Low concentration PV (LCPV)	< 100	One or two-axis	c-Si or other cells

The limitations of the CPV cell are the high costs of focusing, tracking, and multi-junction solar cells. CPV modules rely on direct sunlight, they require clear skies and high direct solar irradiation for optimal performance and can only be used in certain regions.

Figure 7: Concentrated PV systems [32].

3.3 Agriculture

Green agriculture technology refers to a food supply chain without causing any harmful effect of climate change in the appearance of increasing food demand and global population. The main aim of green technology in agriculture is to achieve the security of food and nutrition via balancing between trade and domestic production. Contributing to achieving enough supply of food to humanity, guarantee a decent livelihood in the local settlements and the utilization of technical and domestic approach to improve food production while maintaining the ecosystem. Green technology can be achieved through the application of the ecological system to agricultural, forestry and fisheries administration in a manner in which the food and nutrition needs of the society can be addressed without endangering the benefit of the upcoming generation, terresstial, acquatic and marine ecosystems. The agricultural segment comprising of livestock, crops, fisheries, forestry, and processing of food is key to transition to green economy. 60% of terrestrial lands are occupied by crops, forest and pastures. 70% of global freshwater are used by the agriculture sector, the agriculture sector is also responsible for livelihood of about 40% of the population of the world. The agricultural sector is largely dependent on resources that are natural for their production and jeopardize the environment.

The contribution of current agricultural practices is one third of the greenhouse gas emissions across the globe, practices with good management can result in a decarbonized economy and also results in the achievement of clean environmental activities and the production of energy resources that are renewable. The agricultural sector can also be the major driver of economic growth and generation of green jobs of the order of millions mostly in the countries that are very poor, the security of food and nutrition will need to be accomplished as a major part of green economy. This is owing to the fact that food and agricultural system are subject to threats from climate change, poverty and the degradation of resources, green economy is designed to tackle these problems. In a world that is constrained of resources, only a system of economy that leads to enhanced well being of humans and social equity while reducing significantly the scarcity of the ecosystem and environmental risks will be able to provide security of food for more than nine billion people, by 2050 [33]

3.4 Water Treatment

Water is an essential element in life. In our world, several regions suffer from water contamination and scarcity. Water treatment is the act of removing undesirable contaminants from water. Undesirable substances may include biological, chemicals and even physical pollutants making it viable to be used in other applications. Water treatment is the solution preferred by many developing countries to reduce water stress. This solution may be focused on different perspectives depending on applications such as industrial and human activity [23]

Today, the practice of green chemistry give rise to the production of chemical and new techniques in a manner that retain and enhance effectiveness while reducing toxicity. Auxiliary constituents are utilized by manufacturing processes and chemical which are not part of the finished product.

The production or utilization of elements and substances which are harmful to environments of humans should be completely avoided or minimized where there is a strong relationship between environmental chemistry and green chemistry. The use of additives that are environmentally acceptable for the treatment of water treatment is one major area where green chemistry is applicable [34].

Green chemistry method for water treatment involves environmentally acceptable processes in the chemical industry, green sustainable technology entail a paradigm shift from conventional concepts or processes that focus largely on chemical yield to clean and environmentally sustainable, economically valuable concepts of eliminating waste at in water or water source while avoiding the usage of toxic or hazardous substance [35].

3.5 Green Architecture and Green Building Practices

Residential and commercial buildings utilize one third of energy that are generated globally and two thirds of electricity, building practices produce high amount of CO2 emissions that are disastrous. Also waste products are generated during building constructions and operations, this can contaminate the environment, air quality and affect the health of the workers. Green design or green architecture is a building approach that reducing the dangerous effect on the environment and on the health of human being. The "green" architect or designer ensure that he safeguard water, air, and earth by selecting building materials and construction practices that are ecologically-friendly [23, 34, 35] Green building entails the application of green materials and green technology that are environmentally friendly in building design although green building are costlier than conventional buildings, they are economically beneficial and does not contributes to GHGS emissions unlike conventional buildings, their operational cost is reduced and they enhance a sustainable environment. Green buildings addresses water conservation, waste management, non-toxic materials, energy efficiency, environmental impact, recycled and reused materials [23]

3.6 Hydrogen and Fuel Cells

A lot of research has suggested hydrogen and fuel cells as a very attractive alternative to fossil fuel, hydrogen cells is a viable option for deep decarbonization of the world energy system. Hydrogen fuel is an essential element of a decarbonized and sustainable energy system to generate secure and cheaper non environmental polluting energy. Hydrogen and fuel cells can be produced in large-scale [36]. Fuel cell vehicles has begun, and fuel cells are utilized to power and to heat hundreds of thousands of homes. The major difference since the last hydrogen ‘‘hypecycle’’ in the 2000s is that there is a scale up in manufacturing and cost reduction which lead to the commercialization of hydrogen and fuel cell in many sectors. from portable electronics and backup power to fork-lift trucks. Hydrogen council is recently formed by thirteen international cooperation to place hydrogen as one of the major solutions to the transition of energy. Hydrogen can be obtained from feedstocks processes; it has many useful applications without fuel cells while fuel cell can function using other fuels than hydrogen. Hydrogen and fuel cells can make a significant contribution in several ways across the entire energy system. Infrastructure for hydrogen may be costly but the pathways comprises of various low-cost incremental routes after established networks. [36]

3.7 Recycling

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. - Brundtland Commission, Our Common Future, 1987

According to the Brundtland (1987) meaning of sustainability, it is evident mankind doesn't utilize resources in an eco-friendly approach. In short, resources are utilized so that upcoming generations will be adversely affected.

Recycling is to utilize materials that have already been used in manufacturing of new products, which is one of the three golden rules of sustainability that include reduce, reuse, and recycle. Since crude materials often originate from our most important forests and natural resources, recycling can reduce the demand for raw materials. It also cut back the requirement for extracting, refining and processing crude materials, all of this generate air and water pollution. It decreases greenhouse gas emissions, which assists to tackle climate change.

Material is restored without saving the initial state of used product. With recycling, used products gain commercial relevance once more [37]. Products manufacturing from recycled materials demands lesser energy than making them from new crude materials. It's much better to reuse existing products than to destroy another person's locale or land in the quest for new crude materials.

The enthusiasm for gathering waste resources like paper and reusing them in manufacturing industry has been increased worldwide. Adverse effect in tough environmental challenge in the most recent years has created increasing awareness for recycling. Also, more prominent awareness level about environmental condition and new found scientific discoveries which proposes that cellulose can be utilized commonly to manufacture paper brought about this more significant level of enthusiasm for recycling [38]. In broader terms, recycling is a strategy which is applicable to wastes that cannot be utilized once more or whose formation cannot be hindered [39] .

Green tech is employed in the recycling procedure, together with waste incineration. Reusable material can be utilized when producing plastics, fertilizer, and fuel. Clean tech can likewise be a section of the fabrication processes, for example, procedures to reuse water or waste in the production process.

3.8 Green Nanotechnology

Green nanotechnology (Green nanotech) is a rapid growing area of science which functions on the size of one billionth of a meter, or a nanometre. Materials are maneuvered in manners that will revolutionize the manufacturing industry. Green nanotech requires principles of chemistry, physics and engineering.

Nanotechnology applies to the use and modification of extremely small particles in the order of one billionth of a metre (i.e. 10−9) called nanoparticles. Based on their physiochemical properties, Nanoparticles (NPs) can be generally grouped as organic nanoparticles (such as carbon-based materials, Polymeric NPs and Ceramics NPs) and inorganic nanoparticles (e.g. semiconductor NPs, metal and metal oxide NPs such as silver, zinc oxide)[40-43]. In addition, NPs characteristics depends on general shape which can be classified into various dimensions such as, zero-dimensional (0D), one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D) classifications [44] .

Nanoparticles have gathered momentum in the science domain due to the reinforced properties of materials in the nanosized. These properties and efficacy of nanotechnology-based materials make the use of nanoparticles more sustainable than traditional approaches of cleaning the environment.

Applications of nanoparticles
The applications of nanotech has spread across many disciplines owing to improved properties of materials that are different from their bulk counterpart [45]. Recently, research in nanotech has reached nearly all fundamental disciplines including environmental remediation [46]. As a result of physiochemical nature and the antimicrobial potential of nanomaterials, they are largely employed against different pathogenic microbes and in healthcare, crop protection, water treatment, food safety, and preservation of food [43,47]. Processing of dyes employing biosynthetic nanomaterials presents a sustainable, low-cost and clean alternative by removing complex machinations and formalities [48].

Various other metallic and metal oxide NPs (like Silver NPs, Gold NPs) have also been published in several journals to display efficient catalytic properties towards degeneration of toxic dyes [49].

Nanotech has risen to be a useful strategy for clean-up of oil and gas pollutants as it has the possibility of minimizing the remediation costs and time of massive waste sites and mitigate concentration of pollutants at the scene [50].

With the scientific society and world always in wait for viable approaches for reducing environmental challenges, the removal of harmful precursors and high cost together with harmful strategy has put green nanotech as the forerunner for environmental application.

Based on the literature available, it is obvious that green synthesis of NPs serves two objectives. First, it offers a clean, harmless, ecological technique of fabrication of nanoparticles by removing harmful precursors and toxic wastes and secondly, it functions as an efficient and viable method for environmental clean-up.

4. Environmental Remediation

The rising demand for newly approaches of research in cleaner environment through economic sustainability and eco-friendly means has driven researchers to the use of Greentech as a leading sustainable alternative.

According to ASTM [51,52] , Sustainable remediation based on guidelines, involves coordination of the resource consumption of the remediation effort with the advantages accomplished regarding the economic feasibility, conservation of natural resources and biodiversity, and the improvement of the quality of life in surrounding communities.

Environmental degradation is definitely one of the fundamental issues that faces world presently. Modern technologies are continually being investigated for the clean-up of pollutants of the air, water, and soil [53]. These are the few examples; particulate matter, heavy metals, pesticides, herbicides, fertilizers, oil spills, toxic gases, industrial effluents, sewage, and organic compounds regarding contaminants [54,55]. Various kinds of materials can be used in environmental clean-up and in consequence very diverse approaches can be harnessed for this purpose.

Further dimension of green innovation includes eliminating contaminants from the soil, air and water. These procedures extend from chemical to biological. Industry is liable for a significant part of the pollution and the government has to increase more strict regulations/guidelines to control it. Clean tech is utilized in forms that filter the air by minimizing emission of carbon and gases that are discharged into the environment from production plants.

It is crucial that the materials employed for the remediation of contamination are not another contaminant themselves after they have been utilized. Therefore, to avoid this problem, cleantech materials are keen interest for this area of use.

Environmental remediation depends largely on utilizing different techniques (such as adsorption, absorption, chemical reactions, photocatalysis, and filtration) for the elimination of pollutants from various environmental media (like air and others)

4.1 Carbon Capture and Storage

Preventing hazardous environmental change may well be attainable owing to research suggesting there is sufficient space underground to store all the CO2 taken from the air to keep atmospheric temperatures stable.

Carbon Capture and Storage (CCS) is a technology that can capture up to 90% of CO2 emissions generated from the utilization of coals in production of electricity and manufacturing operation, inhibiting the CO2 from penetrating the environment. The CCS chain comprises of three sections; capturing the CO2, transporting the CO2, and storing the CO2 emissions in underground depleted oil and gas fields or deep saline aquifer formations.

CCS together with other interventions such as nuclear power, renewable energy are carbon abatement technologies that have greatest decarbonisation potential to take CO2 out of the atmosphere [5,56].

The capture and storage of CO2 underground is one of the major aspects of the Intergovernmental Panel on Climate Change's (IPCC) accounts on how to keep global warming below 2°C above pre-industrial levels by 2100 [57]. However, the world adoption of CCS is very slow due to the cost of building capture plant is expensive and the hypothetical future problem of CO2 leaking out of storage site.

5. CONCLUSION

Environmental problem has certain impacts on human quality life. Globally, the living condition of present and future human populations relies on environmentally sustainable ways of living. Environmental clean-up relies mainly on employing different technologies including the aforementioned ones for the removal of pollutants from various environmental media (water, air and soil). The paradigm shift advocated by researchers and environmentalists to tackle the challenges of environmental degradation requires the use of Greentech that generate eventually a desirable sustainable revolution.

Our review indicate various ways in which the environmental remediation program may assist to expedite the response to climate change and environmental degradation. Although the threats are great but there are huge opportunities for technological invention especially the Greentech to offer sustainable solutions. Failure to act now is tantamount to environmental disaster.

Furthermore, continuing exploitation and extraction of environmental resources that are conventional will definitely lead to ecological decay as we are experiencing today. Therefore, clamouring for environmental conservation and sustainability should solely focus on clean energy and environmental remediation that is not contaminated. These remediation technologies are well explained in this review. In a nutshell, Greentech proffer the solution to climate change and take the lead in preventing environmental problems resulting to a sustainable environment.

REFERENCES

[1] International energy outlook 2019

[2] Len calderone 2019, Alternative Energy from solar, wind, biomass fuel cells and more

[3] Hannah Ritchie and Max Roser 2018, Fossil Fuels

[4] Zhongchao Tan, Air pollution and greenhouse gases from basic concepts to Engineering applications for air emission control, 2014, Green energy technology, springer

[5] The Lancet Commissions, Health and climate change: policy responses to protect public health, www.thelancet.com Published online June 23 , 2015 http://dx.doi.org/10.1016/S0140-6736(15)60854-6

[6] Joseph Romm, 2016, CLIMATE CHANGE What everyone needs to know

[7] M. De Sario, K. Katsouyanni and P. Michelozzi, Climate change, extreme weather events, air pollution and respiratory health in Europe, Eur Respir J 2013; 42: 826–843 | DOI: 10.1183/09031936.00074712

[8] Scott C. Doney, Mary Ruckelshaus, J. Emmett Duffy, James P. Barry, Francis Chan, Chad A. English, Heather M. Galindo, Jacqueline M. Grebmeier, Anne B. Hollowed, Nancy Knowlton, Jeffrey Polovina, Nancy N. Rabalais, William J. Sydeman, and Lynne D. Talley, 2012, Climate change impacts on marine ecosystems, Marine Chemistry and Geochemistry Department, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, Marine Science Journal, vol. 4 pp. 11-37.

[9] Schröter, D., Cramer, W., Leemans, R., Prentice, I. C., Araújo, M. B., Arnell, N. W., Bondeau, A., Bugmann, H., Carter, T. R., Gracia, C. A., Vega-Leinert, A. C. D. L., Erhard, M., Ewert, F., Glendining, M., House, J. I., Kankaanpää, S., Klein, R. J. T., Lavorel, S., Lindner, M., Metzger, M. J., Meyer, J., Mitchell, T. D., Reginster, I., Rounsevell, M., Sabaté, S., Sitch, S., Smith, B., Smith, J., Smith, P., Sykes, M. T., Thonicke, K., Thuiller, W., Tuck, G., Zaehle, S. And Zierl, B., Global Change Vulnerability Assessments: Definitions, Challenges, and Opportunities; The Oxford Handbook of Climate Change, 2012.

[10] Jamal Hisham Hashim, and Zailina Hashim, 2016, Climate Change, Extreme Weather Events, and Human Health Implications in the Asia Pacific Region, Asia Pacific Journal of Public Health 2016, Vol. 28(2S), DOI: 10.1177/1010539515599030

[11] Timothy Doyle and Sanjay Chaturvedi , 2012, Climate Refugees and Security: Conceptualizations, Categories, and Contestations; The Oxford Handbook of Climate Change and Society, *Edited by John S. Dryzek, Richard B. Norgaard, and David Schlosberg*

[12] Ali Cheshmehzangi • Ayotunde Dawodu, Sustainable Urban Development in the Age of Climate Change, 2019

[13] Tim Wheeler and Joachim von Braun, Climate Change Impacts on Global Food Security, 2 August 2013 Vol 341 Science www.sciencemag.org

[14] https://www.un.org/africarenewal/magazine/july-2008/africa-seeks-fair-share %E2%80%98green%E2%80%99-cash, 2008, Africa seeks fair share of 'green' cash

[15] John S, Dryzek, Richard B. Norgaard, David Schlosberg, The Oxford Handbook of Climate Change, 2012.

[16] Collier et al., 2008, Climate change and Africa

[17] Sankar, U (2009). *The State of Environment and Environmental Policy in India*, presented on Dr. S. Ambirajan Eighth Memorial Lecture on 18th March, 2009.

[18] United Nations (2010), The Millennium Development Goals Report 2010.

[19] Barun Kumar Thakur, Himanshu Sekhar Rout and Tamali *Chakraborty*, Environmental Degradation, Sustainable Development and Human Well-being: Evidence from India. *MANTHAN: Journal of Commerce and Management* 10 October 2014.

[20] Nwagbara, Eucharia N. , Abia, Raphael P. , Uyang, Francis A. and Ejeje, Joy A, Poverty, Environmental Degradation and Sustainable Development: A Discourse. Global Journals Inc (US) 2012.

[21] Rani K and Sridevi V. 2017. An Overview on Role of Nanotechnology in Green and Clean Technology. Austin Environ Sci . **2** 1026 1-4.

[22] Monu Bhardwaj and Neelam (2015). The Advantages and Disadvantages of Green Technology. *Journal of Basic and Applied Engineering Research* **2** (3)1957-1960.

[23] Zaffar A. Shaikh 2017 Towards Sustainable Development: A Review of Green Technologies. *Trends in Renewable Energy* **4** (1)*, 1-14.*

[24] The International Renewable Energy Agency (IRENA) www.irena.org/statistics 2019.

[25] Vijay Laxmi Kalyani, Manisha Kumari Dudy, Shikha Pareek 2015 Green energy: The need of the world *Journal of Management Engineering and Information Technology* **2** 2394 – 8124.

[26] Blanche Rossi 2019, Solar advantages and Disadvantages, Solar energy information. Climate solutions.US

[27] Global Energy Network Institute (GENI) Chu, Y. (2011). Review and Comparison of Different Solar Energy Technologies.1-52

[28] Chu J. (2012). Development of Photovoltaic Solar Cell Technology, 22, 4, 10-1434. International Energy Agency (IEA) (2010). Technology Roadmap: Solar Photovoltaic Energy, IEA/OECD, Paris.

[29] International Energy Agency (IEA) (2010). Technology Roadmap: Solar Photovoltaic Energy, IEA/OECD, Paris.

[30] Nature Photonics (2010), Future Perspectives of Photovoltaics, Proceedings of the Conference, Nature Publishing Group, Nature Asia-Pacific, Tokyo.

[31] Gerstmaier T., Röttger M., Zech T., Moretta R. Braun C. and Gombert A (2014). Five Years of CPV Field Data: Results of a Long-term Outdoor Performance Study, in: Proceedings of the 10th International Conference on Concentrating Photovoltaic Systems. (Albuquerque, NM, USA).

[32] Blog vertography.com. Concentrating photovoltaic technology.

[33] Greening the economy with Agriculture 2012. *Food and Agricultural operations of united nations.* Pg 1-4.

[34] Amany Ragheb, Hisham El-Shimy, Ghada Ragheb 2016 Green architecture: a concept of sustainability, Procedia - Social and Behavioral Sciences 216 778 – 787

[35] Fanie Buys & Roneesh Hurbissoon 2011 Green buildings: A Mauritian built environment stakeholders' perspective, *Acta Structilia* **18**(1), 81-101.

[36] Iain Staffell, Daniel Scamman, Anthony Velazquez Abad, Paul Balcombe, Paul E. Dodds, Paul Ekins, Nilay Shah and Kate R. Wa, 2018, The role of hydrogen and fuel cells in the global energy system Energy & Environmental Science

[37] ŞENGÜL, Ü. (2010) "*Recycling Of Wastes And Inverse Logistics*", Paradoks Ekonomi, Sosyoloji ve Politika Dergisi, Cilt: 6, Sayı: 1, pp: 73-86.

[38] ŞAHİN, H.T. (2011) "*The Effect Of Process Variables To The Efficiency and Quality of Paper Recycling*", Bartın Orman Fakültesi Dergisi, Cilt: 13, Sayı: 20, pp.101-109.

[39] Metin Yılmaz, RECYCLING COSTS: A RESEARCH IN THE WASTE PAPER INDUSTRY. European Journal of Accounting Auditing and Finance Research ,Vol.3,No.4,pp.58-68,April 2015.

[40] Pradhan S (2013) Comparative analysis of Silver Nanoparticles prepared from Different Plant extracts (*Hibiscus rosa sinensis, Moringa oleifera, Acorus calamus,*

[41] *Cucurbita maxima, Azadirachta indica*) through green synthesis method. M.Sc. Thesis. National Institute of Technology, Rourkela. http://ethesis.nitrkl.ac.in/4758/

[42] Lombardo D, Kiselev MA, Caccamo MT (2019) Smart nanoparticles for drug delivery application: development of versatile nanocarrier platforms in biotechnology and nanomedicine. J. Nanomater 2019:1–26. https://doi.org/10.1155/2019/3702518

[43] Khan I, Saeed K, Khan I (2017) Nanoparticles: properties, applications and toxicities. Arab J Chem. https://doi.org/10.1016/j.arabj c.2017.05.011

[44] Baranwal A, Srivastava A, Kumar P, Bajpai VK, Maurya PK, Chandra P (2018) Prospects of nanostructure materials and their composites as antimicrobial agents. Front Microbiol 9:422. https://doi. org/10.3389/fmicb.2018.00422

[45] Pokropivny VV, Skorokhod VV (2007) Classifcation of nanostructures by dimensionality and concept of surface forms engineering in nanomaterial science. Mater Sci Eng C 27:990–993. https://doi. org/10.1016/j.msec.2006.09.023

[46] Ramrakhiani M (2012) Nanostructures and their applications. Recent Res Sci Technol. 4(8):14–19

[47] Guerra FD, Attia MF, Whitehead DC, Alexis F (2018) nanotechnology for environmental remediation: materials and applications. Molecules 23:1760. https://doi.org/10.3390/molecules23071760

[48] Bajpai VK, Kamle M, Shukla S, Mahato DK, Chandra P, Hwang SK, Kumar P, Huh YS, Han YK (2018) Prospects of using nanotechnology for food preservation, safety, and security. J. Food Drug Anal 26:1201–1214

[49] Jyoti K, Singh A (2016) Green synthesis of nanostructured silver particles and their catalytic application in dye degradation. J Genet Eng Biotechnol 14:311–317. https://doi.org/10.1016/j. jgeb.2016.09.005

[50] Anupritee Das, Madhu Kamle, Ajay Bharti, Pradeep Kumar, Nanotechnology and it's applications in environmental remediation: an overview. Vegetos (2019) 32:227–237. https://doi.org/10.1007/s42535-019-00040-5

[51] Nnaji JC (2017) Nanomaterials for remediation of petroleum contaminated soil and water. Umudike J Eng Technol 3(2):23–29

[52] ASTM, 2013. E2876e13. Standard Guide for Integrating Sustainable Objectives into Clean-up. ASTM International, West Conshohocken, Pennsylvania.

[53] SURF, 2016. About the Sustainable Remediation Forum. http://wwwsustainableremediation.org/about/.

[54] Masciangoli, T.; Zhang, W. Environmental Technologies. *Environ. Sci. Technol.* **2003**, *37*, 102–108.

[55] Vaseashta, A.; Vaclavikova, M.; Vaseashta, S.; Gallios, G.; Roy, P.; Pummakarnchana, O. Nanostructures in environmental pollution detection, monitoring, and remediation. *Sci. Technol. Adv. Mater*. **2007**, *8*, 47–59.

[56] Fernanda D. Guerra , Mohamed F. Attia , Daniel C. Whitehead , and Frank Alexis , Nanotechnology for Environmental Remediation: Materials and Applications. *Molecules* 2018, *23*, 1760; doi:10.3390/molecules23071760.

[57] Imperial College London. "World can likely capture and store enough carbon dioxide to meet climate targets." ScienceDaily. ScienceDaily, 21 May 2020. www.sciencedaily.com/releases/2020/05/200521083551.htm

[58] Christopher Zahasky, Samuel Krevor. Global geologic carbon storage requirements of climate change mitigation scenarios. *Energy & Environmental Science*, 2020; DOI: 10.1039/D0EE00674B