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1. Climate Change: Reasons, Its Impact on Environment and Future Aspects

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Abstract:

Climate encompasses the statistics of various meteorological elemental measurements, such as temperature, atmospheric pressure, moisture, wind, rainfall pattern, atmospheric particle count, and many more in a given area over a long period of time. Long term shifting of weather is termed as climate change which is responsible for disturbance in natural environmental equilibrium. Change in climate can be caused by both natural and human caused activities like emission of greenhouse gases, cutting down forests, various fertilizers in agricultural field causing soil pollution, hazardous chemicals disposals and many more. It adversely affects ecosystem and biodiversity.

This causes global warming, rising in sea level, economic losses, poverty etc. and creates difficulties for survival of all kind species including human beings too. This chapter endows climate change types, both natural and anthropogenic reasons, its impact on environment, future aspects and some solutions to control it.

Keywords: *Climate change, natural and anthropogenic activities, greenhouse gases, wind power.*

1.1 Introduction:

"The good thing about science is that it's true whether or not you believe in it" (statement of Neil de Grasse Tyson) it is the best cumulative attempts to secure a healthy life, and to provide good habit and healthy habitat. But there are copious atmospheric parameters, namely relative humidity, surface temperature, precipitation, speed of wind, cloudiness, level of sea, ice or snow cover, and moisture in land etc. of interest and important to researchers and people on earth planet as these directly or indirectly affect people's comfort, food, transportation, etc.

Climate encloses the statistics of various meteorological elemental measurements, such as temperature, atmospheric pressure, moisture, wind, rainfall pattern, atmospheric particle count, and many more in a given area over a long period of time. It is the condition of weather in a particular area over a long time, according to WMO (world meteorological organization) the time is generally 30 years or more. On the basis of weather changing on Earth, climates are generally divided in five main types of climates.

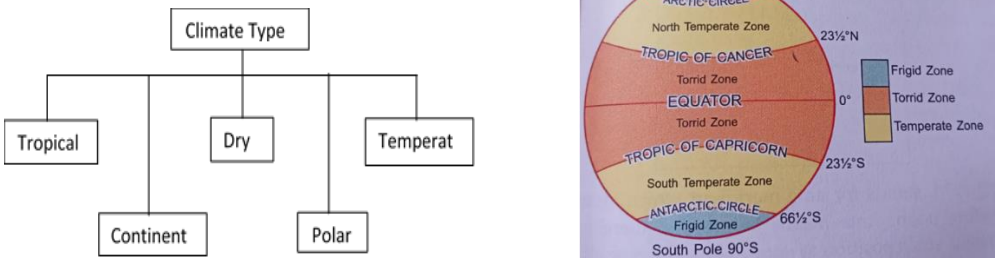

Figure 1.1: Different types of Climate on Earth

1.2: What Does Meant By Climate Change And Causes Of It?

Prolonged shifting of weather patterns and temperatures is called as climate change which has been changing since four & half billion years on this global surface and now became one of the greatest challenges of our survival. As NASA's report indicates that Earth's average surface temperature has increased about 1.8F during the 20th century.

Scientists have interpreting several climate changing factors by numerous indirect measures of climate, namely lengths of glacier, ice cores, tree rings, fossil pollen remains, ocean sediments, and by studying changes in the earth's orbit around the sun for the analysis of climate which shows that it varies naturally over a wide range of time scales. For determination of the present position and the predictions of the upcoming state of earth's climate, chemistry contributes the crucial role due to presence of copious chemically active agents that force earth's climate.

Various chemical processes in the atmosphere determine the abundances and properties of atmospheric forcing agents. Most prominent forcing agents are sulphate and nitrate aerosols. Burning of coal and oil associated with industrial Sulphur dioxide form sulphate aerosols.

Similarly, burning of fuels, nitrogen containing fertilizers such as urea, NH_4NO_3, Ca $(NO_3)_2$, ammonia used for cultivation purpose and smog that comes out of the tailpipes of automobiles are mainly responsible for nitrate aerosols.

Both climate forcing agents and climate are influenced by chemistry. For prediction of climate systems in the atmosphere chemical processes play important roles as some gas phase chemical processes used for determination of greenhouse gas's lifetime, to control the abundance of ozone, used to find abundance and optical properties of different aerosols, etc.

Climate change adversely affects biodiversity, meteorology, and functioning of ecosystem. On the basis of natural and activities caused by human, climate change can be divided into two parts where the latest report of IPCC (Intergovernmental Panel on Climate Change) states that human influence has warmed the atmosphere, ocean and land around 85% greater than the natural reasons.

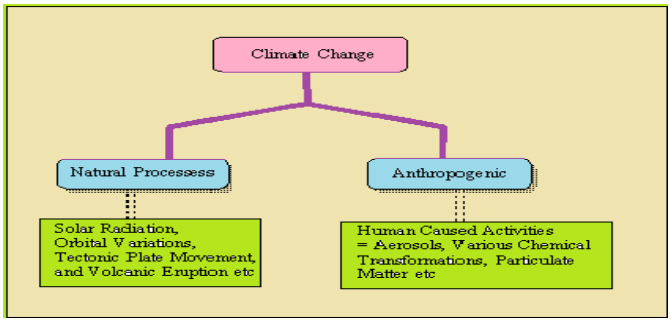

Figure 1.2: Types of Climate Change.

1.2.1 Natural Processes:

These processes are always altering our planet's climate, but currently natural causes alone cannot explain climate change. Climate change contributor natural forcing are:-

a. Variation in our planet's orbit and rotation: It has a massive impact on climate change for instance, the amount of summer sunshine on the Northern Hemisphere, which is affected by changes in the earth's orbit, appears to be the primary cause of past cycles of ice ages, in which the earth has experienced long periods of cold temperatures (ice ages), as well as shorter interglacial periods (periods between ice ages) of relatively warmer temperatures[1]. At the peak of the last interglacial period, however, the average global temperature was at most 2°F warmer than it is today[2].

b. Solar radiations and changes in solar activity: Solar energy variation alters the temperature of our planet and also the intensity of the solar light that reaches the earth's surface nevertheless, it is not so strong enough to change our climate. Increase in solar energy causes the warming of atmospheric layer.

c. Volcanic eruptions: Volcanic eruption generates aerosol particles that contribute to decrease the earth's temperature (such as SO_2; cooling aerosols[3], which reflect the solar radiations back to the space and cool the earth's surface) but they also release carbon dioxide, which is responsible for earth's warming[4]. Reported data's indicated that carbon dioxide produced by volcanoes is approximately 80 times less than the human activities. So we can say these are not a leading cause of global warming but have a noticeable role that cannot be avoided.

d. Variation in Concentration of Naturally Occurring Carbon Dioxide: The concentration of CO_2 varies with cooling and warming of ocean and earth's surface[5]. Level of CO_2 is higher during the period of interglacial warming, and lowers during cool glacial period[6&7]. Variation in concentration performed climate's positive feedback by increasing the change in temperature caused by long-term shifts in the earth's orbit.

e. Earth's Reflectivity Variation: The amount of sunlight absorbed or reflected by the planet is determined by the surface and atmosphere of the planet. Murk things and surfaces such as the ocean, woods, and soil absorb more light, whereas light-colored objects such as snow and clouds reflect sunlight. Around 70% of the sun's energy is absorbed by the earth. Melting of polar ice caps, glaciers and many other natural changes in the earth's surface contributed a lot to change the climate and also changes earth's reflectivity too.

f. Natural Cycles:

- **Milankovitch cycles** – Earth changes its path and the tilt of axis slightly as it revolves around the sun, called Milankovitch cycles which affect the amount of sunlight that falls on Earth and also cause the change in temperature of Earth. But, these cycles take place over tens or hundreds of thousands of years and are unlikely to be causing the changes to the climate that we are seeing today.

- **El Niño Southern Oscillation (ENSO)** – ENSO is a trend of shifting in temperature of waters in central and eastern tropical Pacific Oceans. The global temperature rises during an 'El Nino' year and falls during a 'La Nina' year. For a short period of times (months or years) these patterns can influence the global temperature, but current steady warming couldn't be explained by them.

1.2.2 Anthropogenic Process:

As scientific evidences indicating that natural processes contribute to change the climate but are not the primary cause.

Today the most responsible cause of climate change is human activities and these activities substantially change the climate. Human caused forcing that responsible for change the climate are as follows:

- **Greenhouse Gases (GHGs):** In this industrial revolution era, activities caused by human such as power and heat generation by combustion of fossil fuels, production of goods (iron, steel, clothes, etc.), transportation, production of food materials, residential and commercial power buildings, and many more have produce excess of carbon dioxide, methane, nitrous oxide, and other greenhouse gases into the atmosphere, which alter the earth's temperature and play as a major governing factor for change in climate[8&9]. In 2020, U.S. Environmental Protection Agency summarized percentage of greenhouse gases emitted and also their percent contribution in different economic sectors as represented in **Figure 1.3**. These are all heat trapping gases, which trap and prevent heat from escaping back into space as the sun shines down on the Earth, similar to how heat is trapped by glass in a greenhouse. Higher heat trapping is caused by increased greenhouse gas emissions. This stored heat is creating an increase in Earth's temperature, which has hazardous consequences like melting ice caps, rising sea levels, and flooding. Reports showed that concentration of CO_2 in the atmosphere has been more than there ever has been in at least the past 2 million years[10]. Carbon dioxide levels increased by 40% between the twentieth and twenty-first centuries. Lots of human caused activities produce greenhouse gases such as,
- **Combustion of fossil fuels** – Burning of fossil fuels like oil, gas, and coal release carbon dioxide into the air which has been stored under-ground for thousands of years. As much as fossil fuels are burned more the release of CO_2 occur, this directly increases the global temperature. During fossil fuel combustion, exothermic reaction occurs which produces CO_2 and heat as follow:

$$O_2 + \text{Fuel / Hydrocarbon} \longrightarrow H_20 + CO_2 + \text{Energy}$$

Similarly, during microbial metabolic process production of methane and carbon dioxide gases occur and aerobic metabolism produces carbon dioxide;

$$CH_3COOH \longrightarrow CH_4 + CO_2$$

$$6O_2 + C_6H_{12}O_6 \longrightarrow 6H_2O + 6CO_2 + \text{Energy}$$

- **Power production –** It also causes a large chunk of global emission as most of electricity is generated by burning of fossil fuel namely coal, oil, natural gases etc, which produce CO_2, nitrogen oxide, in environment. But nowadays, wind, solar and other renewable sources gained more attention for power generation as these are very low or no greenhouse gases emitting or pollutant free sources.
- **Cutting down forests** – Trees and forests remove carbon dioxide from the atmosphere as they are natural eco-cleaners and stored it with them. When they are cut down so quickly than there will be no trees to absorb carbon dioxide on the earth. Furthermore, when we burn trees, the carbon they hold is released. Reported data's indicate that in a year, approximately 12 million hectares of forest are destroyed and tentatively ¼ of the GHGs emissions are emitted by combined deforestation, agricultural and other land use changes.
- **Use of pesticides and other fertilizers in Agriculture** – Planting crops and raising livestock produces a variety of greenhouse gases into the atmosphere. For example, methane a greenhouse gas which is 30 times more strong as compared to CO_2 and nitrous oxide (used in fertilizers), is 10 times worse than carbon dioxide and over 300 time's stronger greenhouse gas.
- **Production of Cement** – It also changes climate as produces approximately 2% of our entire carbon dioxide emissions. With increasing population followed by urbanization lands are converted into big buildings, which increase the consumption of cement and its production increases CO_2 emission in environment.

1.2.3 Major Green House Gases are:

- **Carbon dioxide (CO_2):** CO_2 levels are rising mostly as a result of fossil fuel consumption, cement manufacture, deforestation, power generation, and other land use changes. CO_2 emissions are the single most significant factor to global warming. Reports indicating that presently due to human caused activities more than thirty billion tons of CO_2 released into the atmosphere every year. When the Greenland ice sheet melted completely, the worldwide average sea level rose by about seven meters as reported by Lowe and co-authors. Furthermore, a huge amount of CO_2 in the atmosphere causes significant ocean acidification ($pH<7$)[11]. Continued increases in acidity will have a significant impact on biogeochemical cycling and the marine ecosystem.
- **Methane (CH_4):** Agricultural cultivation, growing paddy rise, and livestock emissions are major human caused activities that cause the increased concentration of

methane[12&13]. Due to these activities the level of CH_4 has risen very rapidly and according to the latest report of UNEP (United Nations Environment Program) and climate and clean air coalition, the methane released from cutting, farming would be the key in the battle against climate change. It is eighty times more potent at warming than carbon dioxide, over a period of 20-years. L.A. Berbisi et. al.[14] reported an article on methane leakage from evolving petroleum system that's present today's warming trend attributed to increase in atmospheric concentration of methane and CO_2.

- **Nitrogen oxide (NO):** With increased population and agricultural activities such as the use of nitrogen-based fertilizers and other land modifications, the concentration of NO has been risen rapidly, as from the start of industrial revolution it has been increased approximately 20%. Current reports indicated that concentration of nitrous oxide has increased from 270 ppb to 332 ppb, in 2019. As it is more potent than carbon dioxide (CO_2) and increased by 30% from 1980 to 2016 (Nature October 7, 2020), now among all greenhouse gases, it is third-most abundant ghg after CO_2 and methane responsible for global warming[15]. Inhalation of nitrogen oxides is harmful due to their adverse impact on the respiratory system. Respiratory related diseases, particularly asthma caused by breathing in air with higher concentration of NO_2. It enhances the greenhouse effect by capturing radiations from the Earth's surface and subsequently increases the temperature of troposphere[16]. As NO_2 and other NO_x are very reactive species, they interact with H_2O, oxygen and other chemicals in the atmosphere and form nitric acid, particulate matter and ozone, and also cause acid rain as represented in following reactions:

$$NO_2 + H_2O \longrightarrow HNO_3 + NO$$

$$2NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$$

$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO \text{ (Overall Reaction)}$$

$$2NO + O_2 \longrightarrow 2NO_2 \text{ (key step in photochemical smog formation)}$$

$$NO_x + \text{VOCs (Volatile Organic Compounds)} \xrightarrow{\text{Sunlight \& heat}} \text{Ozone}$$

Acid rain harms sensitive ecosystems such as lakes and forests. For reduction of emissions of NO_2 and NOx in atmosphere, EPA's applied national and regional rules that will help state and local governments meet the National Ambient Air Quality Standard (NAAQS).

Halocarbons: halocarbons commonly named as CFCs (chlorofluorocarbons), are used in refrigerators and fire retardation processes. CFCs are very harmful for our environment as they damage the ozone layer. In presence of sunlight they break up into their molecules with releasing of chlorine (Cl) and this released chlorine is react with ozone (O_3) to form chlorine monoxide (ClO) and oxygen (O_2). ClO molecule further reacts with monooxygen (O) to give oxygen molecule and chlorine, which can destroy another molecule of ozone (O_3), creating the catalytic cycle of chlorine.

$$Cl + O_3 \longrightarrow ClO + O_2$$

$$ClO + O \longrightarrow Cl + O_2$$

Presently, the production of CFCs has been interdicted, so their impact is starting to decline but their replacements are also potent greenhouse gases and their concentration increases continuously.

- Changes in land use: Forests, farms, cities, and other lands alter both warming and cooling effects locally by changing the reflectivity of Earth's surfaces (affecting how much sunlight is sent back into space) and by changing how wet a region is with changing the way of people to use these lands17.
- Emissions of pollutants (other than greenhouse gases): Some industrial and agricultural processes emit pollutants that produce aerosols (small droplets or particles suspended in the atmosphere).
  Most aerosols cool Earth by reflecting sunlight back to space. Some aerosols also affect the formation of clouds, which can have a warming or cooling effect depending on their type and location. Black carbon particles or soot produced when fossil fuels or vegetation are burned generally has a warming effect because they absorb incoming solar radiation.

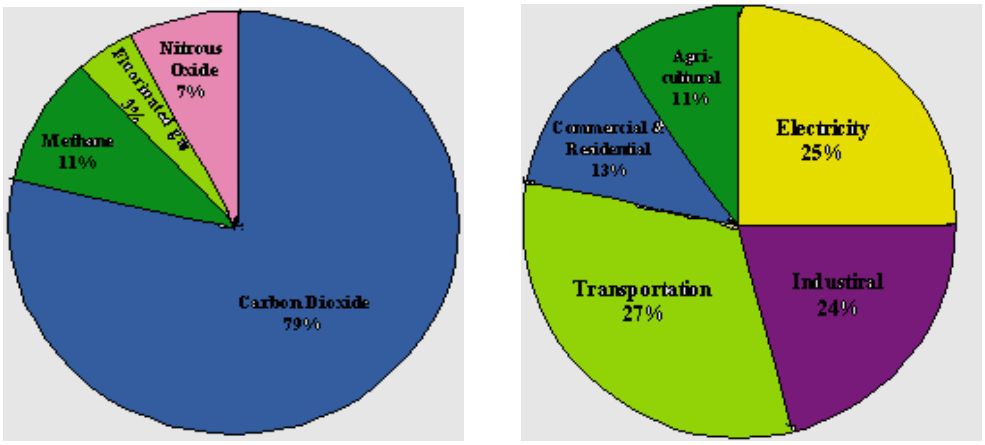

Figure 1.3: U.S. EPA reported on % emission of different greenhouse gases & Their % in different economic sectors (2020)

Impacts of Climate Change:

Climate change created a new challenge for survival of all species and people's livelihoods and adversely alter our health, environment, and economy as it is responsible for worse, dangerous weather events namely more frequent and intense drought, storms, sea level rising, heat waves, glaciers melting and ocean's rising temperature that can harm directly animals, destroy their places, and wreak havoc on people's livelihoods and communities[18].

Figure 1.4 representing overall impact of climate change and various impacts of climate changes are as follows:

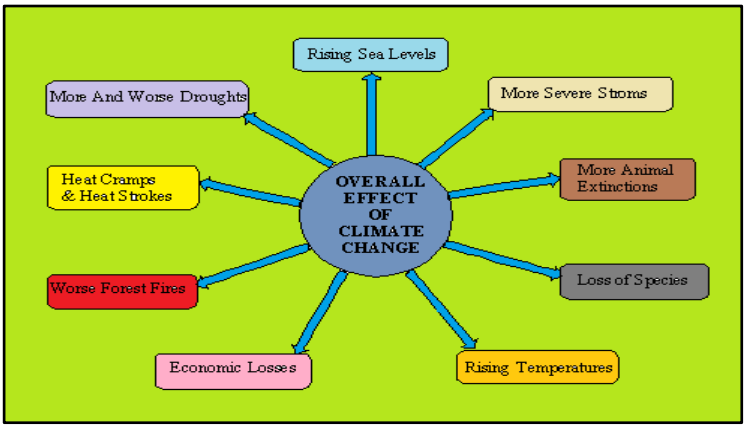

Figure 1.4: Overall Impact of Climate Change.

- **Warmer temperatures:** With increasing the concentration of greenhouse gases global surface temperature is increases[19& 20] as reported data's indicated that the last decade (2011-2020), was the warmest decade than the previous decades and surface is warming in ascending mode in each decade since 1980s. It causes various health related issues like heat-related illnesses, dehydration, sunstrokes and makes working outdoors more difficult. It enhances forest fires start more easily and spread furiously. Heat wave's frequency, intensity and duration have also been increased due to heat warming[21].
- **Water Quality:** Weiwei et al[22] reported a research article expressing the negative impact of climate change on quality and quantity of water as well as drinking water. Today, land and water have combined been contaminated fiercely due to increased chemicals and poisonous substances in the environment, oil spills, uncontrolled dumping of radioactive substances and hazardous wastes, unsustainable logging practice's damages, pesticides and other agricultural chemicals, various air and water pollutants, natural habitats illegal dumping, river dumping and many more[23]. Even with growing household water supply and wastewater collection, only one-third of wastewater is treated. This means that severe pathogen pollution is estimated to affect about one-third to one-half of Asian river stretches. Water availability for irrigation and increased drinking water demand for survival are two basic needs on this planet.
- **Warming and rising of the ocean:** As climate change causes global warming which is responsible for melting of Iceland's and due to this sea level gets warmer and rises day by day[24&25]. NASA report said that approximately ten percent world's population lives in areas where, there about nine meters above sea level. This increased level imperiled ecosystem, coastal and island communities. Additionally, sea absorbs CO_2, and this absorption increases acidity of oceans, which is harmful for survival of marine species and coral reefs[26]. Due to increased glaciers melting and floods, mud slides and severs landslides, a number of disasters of hydro-metrological origin have increased significantly.
- **Increased health risks:** Change in climate is one of the greatest health threats for us. It causes several health problems through forced displacement, air pollution, and extreme weather events. Data's indicated that approximately thirteen million people die in every year due to adverse environmental factors. It also worsens air and water quality and that spread various diseases and alter the ecological society[27&28].

- **More severe storms:** Due to increase in global warming followed by climate change, evaporation of moisture increases, which aggravates excessive rainstorms and flooding and also causing more violent storms[29]. Currently, with increasing global surface temperature intensity and frequency of cyclone, hurricane, heavy rain storms, tempest, typhoons and many other violent storms increased and destroyed lots of shelter and communities, causing deaths and huge economic losses.
- **Shifting in ecosystem and loss of species:** Change in climate causes loss of various species and change in ecosystem as these risks depend on global temperature and increase as temperatures climb. Forest fires, excessive variation in weather, invasive pests, diseases, and many other threats caused by climate change responsible for various species survival issues and their relocation. Data's showed that the world is losing species at a rate thousand times greater than at any other time in recorded human history. These influence the plant and animal species and the timing of their lifecycle events, such as migration and reproduction[30].
- **More and Worse drought:** With changing climate water availableness is also changing which making its insufficient distribution in many places. Shortage of water exacerbated by global warming in water-stressed areas, increasing the danger of agricultural droughts that harm crops and ecological droughts that make ecosystems more vulnerable.

  Desert and soot storms also are caused by droughts, which can transport billions of tonnes of sand across continents. Deserts are increasing, diminishing agricultural land. Many people are now at risk of running out of water on a regular basis. Frequency and intensity of excessive weather events increased such as heat waves, violent storms, droughts, and floods increases cause property losses, costly societal disruptions, and make insurance less affordable.

- **Not enough food:** Climate change and an increase in lavish weather events are among the factors contributing to a global increase in hunger and malnutrition. Fisheries, crops, and livestock may perish or become ineffective. Marine resources that feed billions of people are at peril as the ocean becomes more acidic. Food sources from herding, hunting, and fishing have been interrupted in several Arctic regions due to changes in snow and ice cover. Heat stress can deplete water and pasture lands, resulting in lower crop yields and livestock losses.
- **Economic loss and Poverty:** Climate change exacerbates the variables that cause and maintain poverty. Floods have the potential to devastate homes and livelihoods in urban slums. Working outside in the heat might be difficult. Crops may be affected by water scarcity. Approximately twenty three million people displaced due to weather-related incidents per year in the last decade (2010–2019), leaving many more endangered to poverty. Most of species from nations that are most endangered to climate change, and tiniest prepared to adapt to its effects.
- **Variation in rainfall pattern**: Rainfall pattern and amount as well as stream flow timing and amount get changed due to climate change which can affect water supplies and water quality and the production of hydroelectricity[31].

  Riebeek[32] reported that due to warmed surface temperature caused by global warming rainfalls became more intense and extreme.

1.3 Future Aspects of Climate Change:

On the basis of various observations, theories and modellings, scientists have made projects on future concern of climate change, but several factors alter the ideology such as;

- We cannot predict how much CO_2 human activities will be emitted in upcoming future, as this depends on factors such as how the global economy develops and how society's production and consumption of energy changes in the coming decades.
- With current understanding of the complexities of how climate feedbacks operate, there is a range of possible outcomes, even for a particular scenario of CO_2 emissions.

But all model projections indicate that the temperature of Earth will increase continuously to warm considerably more over the next few decades to centuries. Fourth assessment report of IPCC (International Panel on Climate Change) indicated that if there were no technological or policy changes to reduce emission trends from their current trajectory, it will impact overwhelmingly negative on the global surface.

As sea levels are rising and oceans are becoming warmer, more intense droughts, and many other impacts caused by climate change increases hunger, water stress, flooding, extreme weather, and adverse impacts on biodiversity and human health. These challenges can be reduced or quenched by stopping deforestation, implementing advance policies to fight climate change, implementing strict less or no carbon emissions rule on economic sector businesses, helping people and nature to get adapted according to the changing climate.

1.3.1 Some Solution to Control Climate Change:

The main aim is to protect the global surface from degradation and take urgent action on climate change with sustainable development. Here we will discuss some solutions of climate change.

- **Replacement of nonrenewable resources by renewable resources for power generation**: As crude oil, coal etc. fossil fuels are limited in stock and their consumption is increased rapidly with increasing population for power and electricity generation. These resources are not renewable and emit ghgs by the combustion reactions so scientists have invented new ideas for power generation that can give us power with sustainable environment.

  For example replacement of batteries with fuel cells which are cheap, clean energy source as emit zero or very low greenhouse gases, and showing higher efficiency than batteries.

- **Wind power**- EPA said that wind power is the booming energy resource in the world since 1990. Wind turbines are used to generate electricity the turbines don't need water to operate but use the draught, a renewable source of energy. So, it has little or no impact environment.
- However, we are facing some challenges with wind power, out of which one is that bats and birds getting killed from flying into the spinning blades.

Solution of this problem is to building wind turbines keep away from areas where there is a high assemblage of migrants.

- **Methane leaks-** Methane that contributes to advancement of climate change. Natural gas and petroleum systems are main sources of methane emission. Solution of methane leaks is to upgrade equipment that is used in transferring, storing, producing oil and gas.
- **Excess amount of CO_2-** Li, Yao[33], reported a research article representing nitrogen doped porous carbon nano fiber webs as efficient CO_2 capture and conversion and developed two ways to reduce the excess amount of CO_2 form atmosphere (1. Chemical absorption and 2. Adsorption). In chemical absorption amine – ammonia aqueous solution is used to capture as much CO_2 as possible. And in adsorption process several solid adsorbents can be used to better capture of CO_2 such as mesoporous silica, metal organic framework, zeolites, and microporous carbons.

1.4 Conclusion:

We need to focus on decline in global emissions of carbon to control the adverse impact of climate change on this planet as it increases global surface's temperatures, changes precipitation patterns, causes ocean acidification and sea level rising and responsible for increasing intensity and frequency of extreme weather events. As data's indicate that India is the fifth most vulnerable to climate change globally and lost thirty seven billion dollars due to climate change (almost twice than what it lost in between 1998-2017), in 2018. For this we must stop deforestation as they are home of various species and wild animals, and also absorb carbon dioxide (CO_2), a major source of pollution that causes climate change. To tackle these issues government must play a central role.

National and international government must ensure that global climate change agreements reduce forest destruction and degradation and protect livelihood of communities and wildlife and must work on that. For example, in the United States, WWF working to advance policies that reduce carbon pollution, developing clean energy sources like wind and solar to support clean energy technologies, prepare for the effects of climate change, and curb deforestation, business sector with reduction in carbon emissions and advance projects to protect their resources from climate impacts, and ensure the sustainability of their core business. As well said by Mahatma Gandhi that "Earth provides enough to satisfy everyman's need but not every man's greed" we must have a single mission to protect and hand on our planet to the next generation by controlling climate change.

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