Global Warming and Climate change, causes, impacts and mitigation

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Review

Global Warming and Climate change causes, impacts and mitigation

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Abstract

According to NASA and IPCC, Global temperature has increased by 1.4 ^{o}F since 1880, CO_2 levels has reached 400.71 parts per billion, loss of world's forest cover between the period 2000 and 2012 is 1.5 million square km, reduction of land ice 287 billion metric ton per year, sea level rise is 3.2 mm per year and loss of arctic ice cover at the rate of 13.3% per decade. Increasing risk of irreversible changes due to large scale shift in the climate system such as several sensitive species such as ocean corals, aquatic birds, reptiles such as sea turtles and amphibians are facing extinction, failing of crops cause famine in many East African countries, decrease in potable water in Mediterranean and Southern Africa and increasing intensity of extreme events such as forest fires (Australia and Indonesia), flooding(Bangladesh) , storm events (tornadoes and hurricanes in USA), droughts (Sahal region) and deadly heat waves (in India 2015) recorded in many parts of the world. Anthropogenic release of greenhouse gases CO_2, CH_4, water vapour, N_2O, O_3, HFCs, PFCs and SF_6reflects a portion of solar energy back to the earth, this increases the temperature, causes changes in ocean currents, seasonal weather patterns and ultimately changes the climate. Deforestation reduces the CO_2 sink and it further enhances the greenhouse effect. Several mitigation methods such as use of alternative green energy sources, reducing the use of fossil fuels, use of greenhouse gas reduction techniques during the emission, carbon capture & carbon sequestration, afforestation, reforestation, protection of existing forest reserves, silviculture and agroforestry are being facilitated by several international, government and non-governmental organizations. Climate change issue can be handled either adapting to the change or disaster risk reduction. UNDP has suggested a three step method to work on Carbon finance consist of removal of barriers to climate friendly technologies, establishing efficient host country procedures for clean development mechanism (CDM) and develop projects via millennium development goal (MDG) carbon facility. An Integrated Territorial Climate Plan (ITCP) was designed for regional governments to plan their activities including financing climate change mitigation process. This paper briefly evaluates anthropocene global climate change and its human solutions.

Key words: Climate change, global warming, climate change mitigation, impacts of global warming, climate change impacts, carbon capture, sequestration of carbon, climate change disasters, Anthropocene

Introduction

Naturally variation in solar irradiance, variations in orbital parameters of earth and volcanic activities cause climate change. Portion of incoming solar energy reflects back to space. However, a portion of such outgoing energy is absorbed by atmospheric gases this also helps to keep the temperature warmer (this is the reason earth is warmer than moon) In case if this natural heat trapping properties are not available the average surface temperature of the earth would be about 33^{o}C lower (IPCC, 2001) the gases which trap the heat energy is known as greenhouse gases. Recent decades, after the industrial revolution the amount of greenhouse gases (GHG) in the atmosphere has greatly increased due to human emission of GHG and removal of natural sinks such as deforestation and oceanic pollution. This process of increase in greenhouse effect causes warming of the earth surface and alters the energy transfer between atmosphere, space, land and the oceans. This phenomenon is referred as global warming. In addition, solar energy or temperature is the driving force of earth's weather pattern as it drives the wind, ocean currents, humidity pattern, movement of clouds,etc, thus, the global climate get changed. This also intensify the effect of natural disasters such as storms, flooding rain, landslides, drought, land degradation and agricultural loss, species loss and epidemics.

Greenhouse gases give positive radiative forcing (net increase in the energy absorption by earth) due to increase in radiatively active natural greenhouse gases such as CO_2, CH_4, water vapour, N_2O, O_3. In addition HFCs, PFCs and SF_6 are anthropogenic in origin and are accounted in national greenhouse gas inventories. There are several gases influencing the global radiation budget such as CO, NO_2, SO_2 and secondary pollutants such as tropospheric ozone (formed in reaction with volatile organic compounds with oxides of nitrogen under UV radiation). Begin with industrialization burning of fossil fuel alone causes 30% increase in the concentration of greenhouse gases (GHG).Earth's surface temperature has risen by 0.18^{o}C during last century and the projected rise of current (21st) century is ranging between 1.1 and 6.4 ^{o}C (IPCC, 2007). In the period ranging 1750-2001 increase in CO_2 was by 31%, 150% for methane and 16% for nitrous oxide in the atmosphere.

Are we long way from Global warming Oblivion?

Several million years ago earth's CO_2 level was greater than 1000 ppm and the average global atmospheric temperature during the evaluation of mammals and dinosaurs was about22^{o}C whereas today's global average temperature is 15^{o}C (MacRae, 2008) see figure 1. Several parts of Arctic and Antarctica were ice free and flourished with ancient trees and animals. Sea level about 55 million years ago was 100m higher than now. Norwegian Island Svalbard has fossil evidences of massive pantodont creatures, sequoia type trees and beasts like crocodile were living in now frozen Svalbard. If current increase of CO_2 (mainly anthropogenic) continues in the same level it will reach 1000 ppm by the year 2100. However, global warming is not a new issue, it happens since prehistoric times. Ancient warming was natural and it was due to volcanic activities and thawing of frozen methane alone (Adapted from Doyle, 2007).

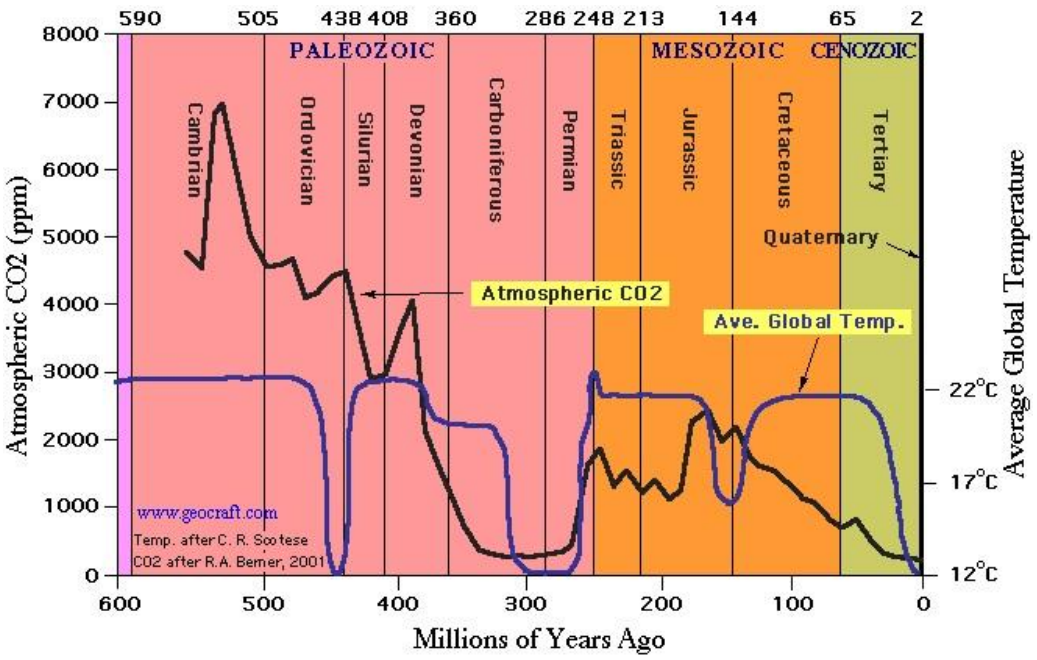

Figure 1: Global Temperature and CO_2 levels over 600 million years (Source: MacRae, 2008)

Global warming and Climate change

Global warming and climate change refer to the increase in average global temperatures due to the increase in greenhouse effect by the increase in the greenhouse gases. Natural events such as forest fires, volcanic eruptions, methane release from thawing of permafrost on the ocean floor and release of methane gas from cattle, wet lands and anthropogenic sources of exhausts from all kinds of combustion, industrial production of greenhouse gases, agricultural water lodging activities such as paddy cultivation artificial wet lands and deforestation. Warming of the earth causes rapid changes in pre-existing weather pattern. According to National Oceanic and Atmospheric Administration (NOAA) there are several indicators those changes with the warming world.

Factors increases with global warming

- Temperature of land
- Sea surface temperature
- Troposphere temperature
- Temperature over oceans
- Ocean heat content
- Sea level
- Humidity

Factors decreases with global warming

- Glaciers
- Snow cover

- Sea ice

Greenhouse effect

Weather and climate of the earth is driven by the sun's energy. Solar radiation heats the earth surface, and in turn earth radiates the energy back into space. Some gasses of the atmosphere traps some of the outgoing energy and retains heat. This causes to an increase in the global temperature and also causes subsequent changes in the weather pattern. Gases which trap the heat energy are known as greenhouse gases; all greenhouse gases are positive radiative forcing agents and are capable of disturbing the energy balance in the atmosphere. Global warming potential (GWP) of a gas is a measure of cumulative radiative forcing caused by unit volume of gas over a given period of time, GWP values for gases are measured with reference to the GWP of the CO_2. If GWP of CO_2 over a period of 100 years is 1, then GWP of methane is 34 (see table 1).

Table 1 GWP values and lifetimes

Greenhouse Gas	**Lifetime (years)**	**GWP time Horizon 100 years**
Methane	12.4	34
HFC-134a (hydro fluorocarbon)	13.4	1550
CFC-11 (chlorofluorocarbon)	45.0	5350
Nitrous oxide (N_2O)	121.0	298
Carbon tetra fluoride (CF_4)	50000	7350

(Source: Myhre*et al.,* 2013)

Since 1880 Earth's average temperature has warmed by 0.8°C (1.4°F). This has reached a peak in 2014 even though it is an El-nino neutral year. The warming of earth has been increasing more steeply during the last three decades (see figure 2). ('NASA,' 2015)

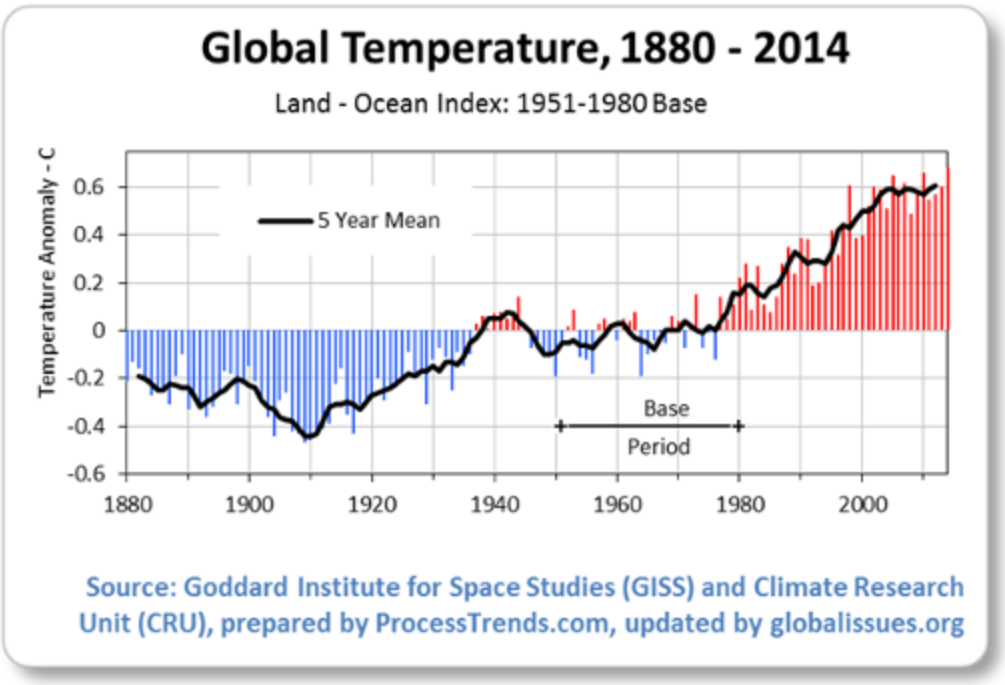

Figure2: Global temperature in the period between 1880 and 2014. ('Anup,'2015)

According to John Cook, writing the popular Skeptical Science blog (2010), 10 indicators of a human finger print on global warming were observed. They are shrinking thermosphere, rising tropopause, less oxygen in the air, release of 30 billion tons of CO_2annually, nights warming faster than days, more fossil fuel carbon in coral, more heat return to earth, more fossil fuel carbon in the air, cooling of stratosphere and less heat escape to the space (see figure 3).

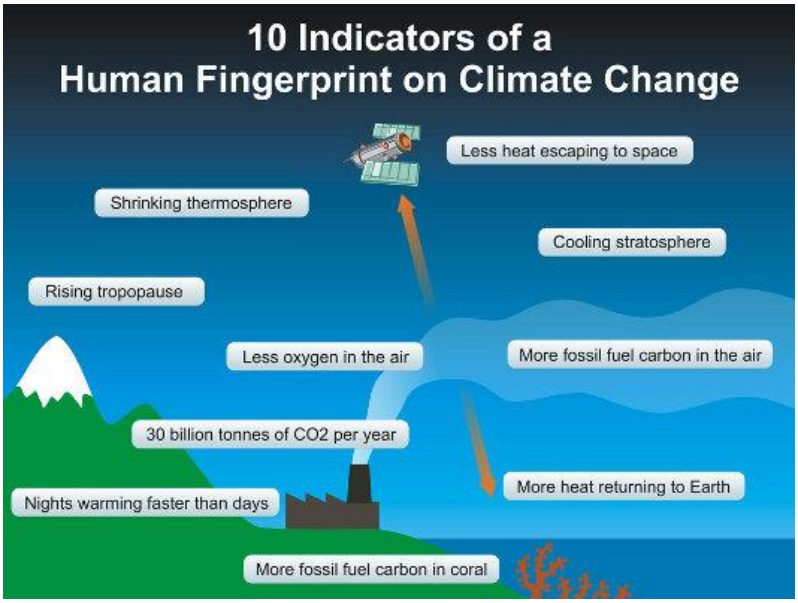

Figure 3: Tenindicators of a human finger print on climate change

(Source: 'John,' 2010 as cited in 'Anup,' 2015).

Throughout the history earth's climate has changed several times before. For the last 650, 000 years our planet has underwent several glacial advance and retreats including catastrophic events, these changes were occurred due to the small variation in solar energy received by earth during such events and often changes the global atmospheric CO_2 levels. After the last ice age (7000 years ago) modern climatic era begins with the emergence of human civilization. Last three decades has shown a rapid increase in global atmospheric CO_2 levels, which never happened before (see figure 4, 5&6).

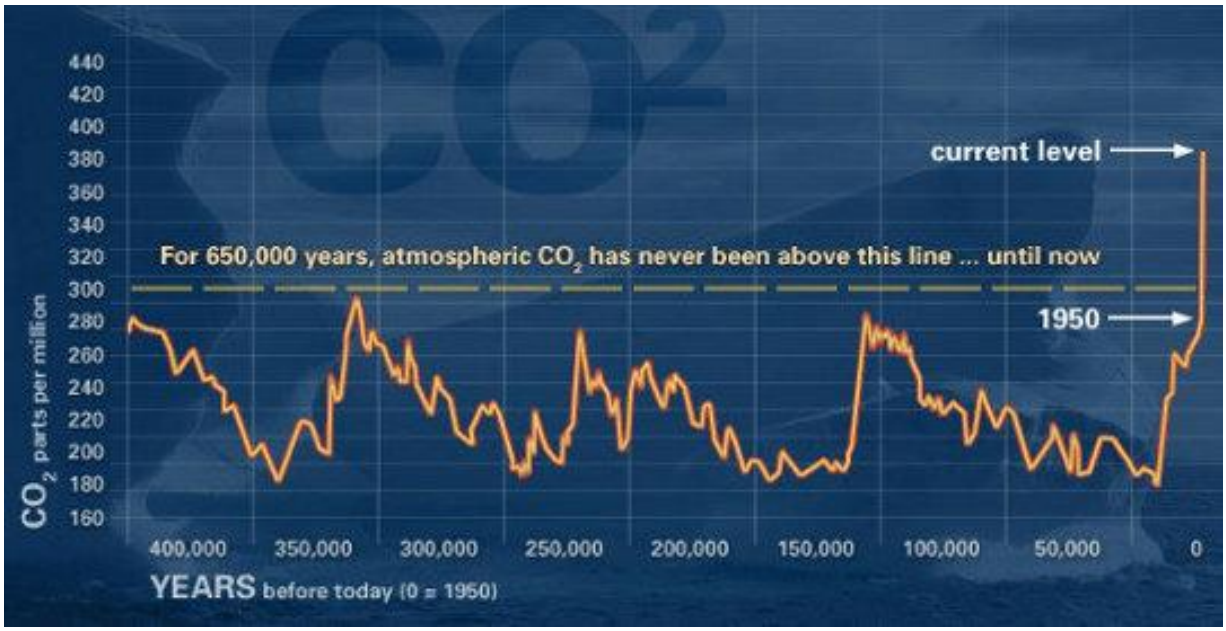

Figure 4: Global CO_2 level throughout world's history Source: NOAA via Shah (2015)

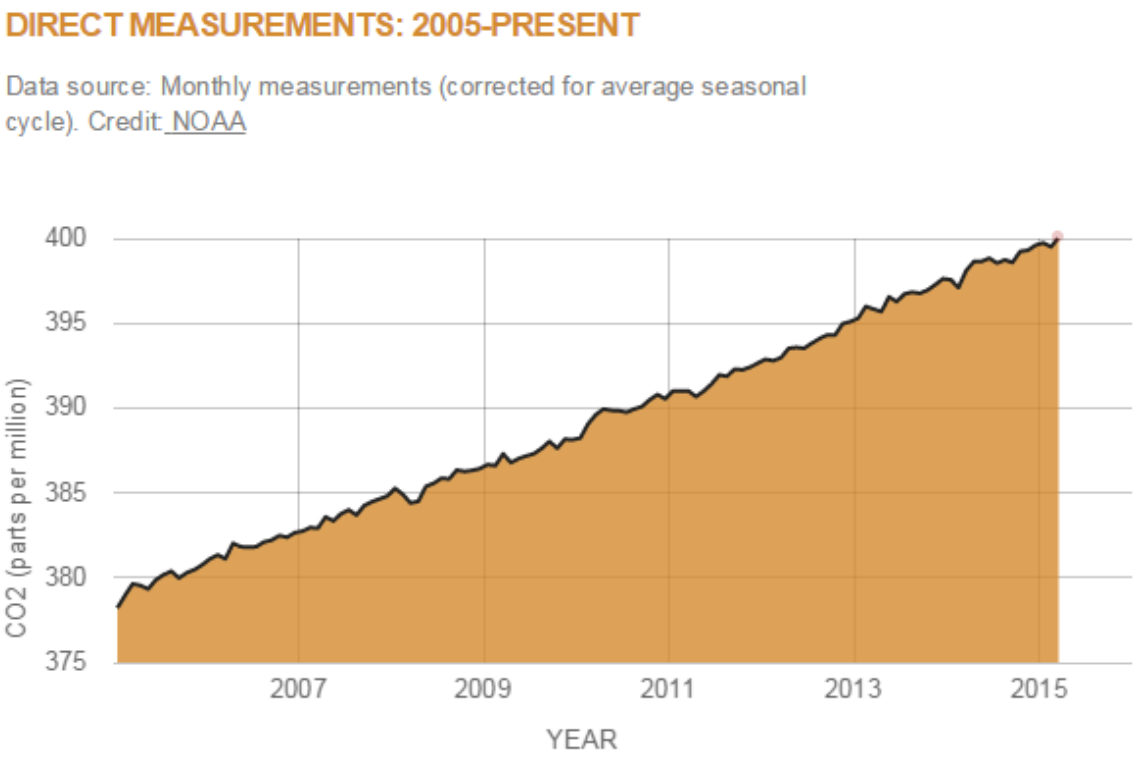

Figure 5: Increase in global CO_2 concentrations (Source: 'NASA Global Climate Change,' 2015)

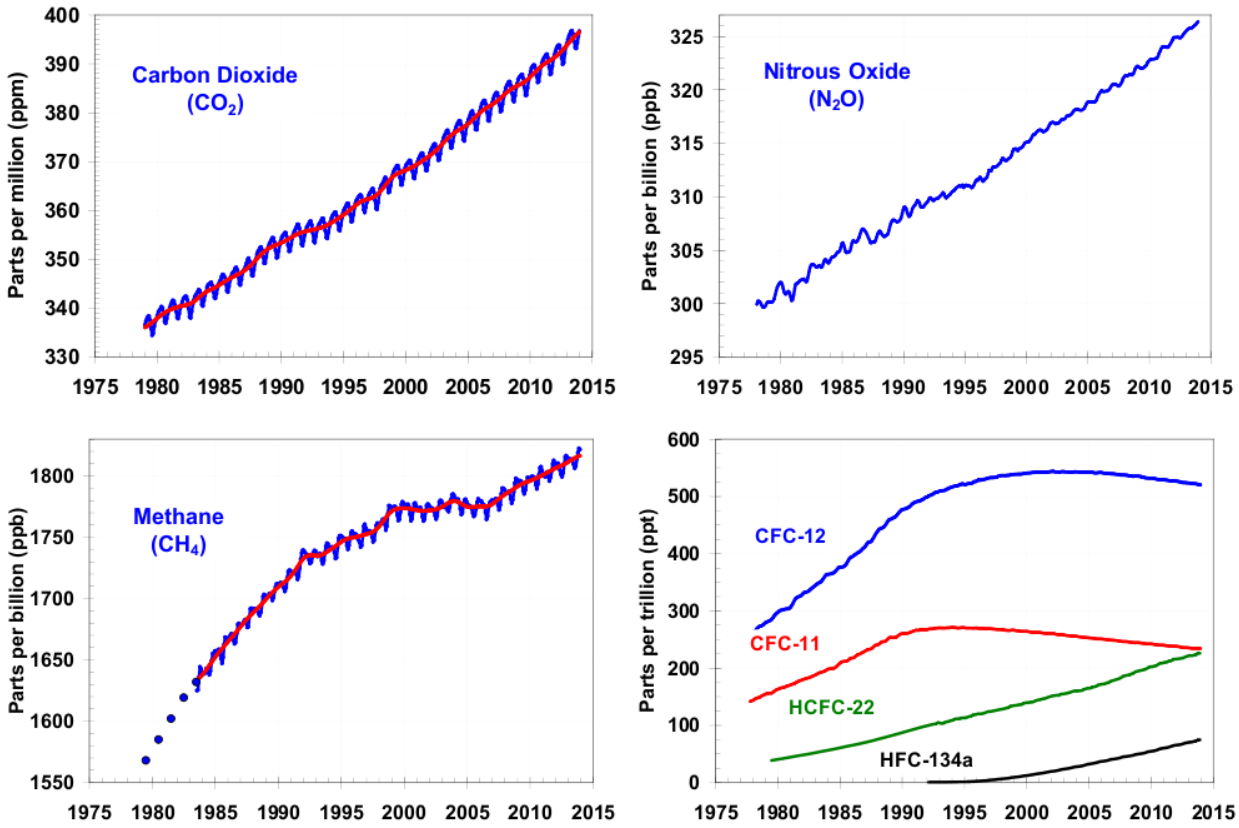

Figure 6: Concentration of Main Greenhouse gases ([Etheridge *et al.,* 1998], adjusted to the NOAA calibration scale [Dlugokencky *et al.,* 2005]as given in 'James and Stephen,' 2014).

Table 2: Major sources of Greenhouse gases

Sector	**Activities**	**Gases**
Energy	Forest fuel combustion Natural gas leakage Industrial activities Biomass burning	**CO_2, CH_4, N_2O, O_3**
Forest	Harvesting Clearing Burning	**CO_2, CH_4, N_2O**

Agriculture	Paddy fields Animal husbandry (ruminants) Fertilizer usage	**CO_2, CH_4, N_2O**
Waste management	Sanitary landfill Incineration Biomass decay	**CO_2, CH_4, N_2O, O_3, CFCs**
Industrial	Metal smelting & processing Cement production Petrochemical production Miscellaneous	**CO_2, CH_4, N_2O, CFCs, SF_6, CF_4, C_2F_6**

(Source: Kemp, 2004)

CO_2 as greenhouse gas

Swedish chemist Svante Arrhineusis the first person who predicted the rise of temperature as the CO_2 concentration in the atmosphere rises his findings were published in 1896 (Hulme, 1997 as cited in Kemp, 2004). CO_2 contributes for 56% of global warming, as other geochemical cycles CO_2 also used to be a self-regulating one, until the anthropogenic vast emission and deforestation alters the balance. Major source of $CO_2$is fossil fuel burning it contributes more than75% of atmospheric CO_2 in 1990s, further chemical changes during production of lime, cement and ammonia augment and increasing litter and garbage decomposition are other anthropogenic means. Natural sources such as volcanic eruption and forest fires account for large efflux of CO_2.Increased deforestation, degradation of oceanic algal photosynthesis due to marine pollution also reduces the uptake of $CO_2$from the atmosphere, according to Dr. Michael Gunson and Dr. Charles Miller of NASA on Global climate change, current CO_2 levels exceeds 400 ppm (400.06 in March 2015) and expected to reach 450 ppm or more and the rate of increase is more than 2.75 ppm /year ('NASA GCC,' 2015).

Methane

Methane naturally exists in the atmosphere mainly from anaerobic decaying process in natural wetlands, methane has GWP of 21 and its radiative forcing is 11%, its rate of increase in the atmosphere is twice the rate of CO_2. However, life span of methane is relatively shorter than that of CO_2 as it reacts with hydroxyl radicals and produce water and CO_2 (which are less potent greenhouse gases than methane). Anthropogenic sources account for half of its release to the atmosphere. Agricultural activities, increased number of cattle and pig dairy farming and non- dairy cattle(ruminants releases methane through their digestive process), termite concentrated areas such as tropical grass lands and forests releases considerable amount of methane to the atmosphere (Crutzen*et al*., 1986), forest fire events contributes a large amount of methane efflux particularly during ENSO.Paddy cultivation and various other cultivation produces flooded wetlands which generate methane during anaerobic decomposition. Coal mining process, leakage through the pipelines and drilling for oil are major anthropogenic sources (Hengeveld, 1991 as cited in Kemp, 2004). Anaerobic decaying of landfill organic wastes and piling of garbage and fertilizer are another source of methane, venting, flaring at oil and gas wells, enteric fermentation, biomass burning and burning of fossil fuels are few other anthropogenic sources. In addition, huge amount of methane is trapped in higher latitude permafrost and in deep ocean sediments as methane hydrates and clathrates. With the effect of warming permafrost is about to melt and temperatures of oceans gradually increases, this causes decaying of clathrates and release of methane, such methane release are observed in pacific ocean floor and Siberian permafrost (Ruddiman, 2001). Hydroxyl reduction of methane also minimized due to the reactions with other pollutants such as CO ('NASA GISS Institute on Climate and Planet,' 2010).Emission from natural sources alone account for ~180-380 Tg per year. Current total methane emission has risen to~450-500 Tg per year which is twice the amount of pre-industrial times.

Nitrous oxide

It is the third highest greenhouse gas. N_2O has the varying growth rate of 0.1–0.7 % per year (Saikawa*et al.*, 2014) GWP of N_2O is 298 and it accounts for 6% of total radiative forcing by greenhouse gases (IPCC, 2001as cited in Kemp, 2004). N_2O released from fertilizers mainly during the intermittent stages of nitrification and denitrification, breakdown of nitrogen from livestock manure and urine account for 5% of global efflux. Transportation is another major source, supersonic engines and rockets releases of N_2O. Nitrous oxide is released as a byproduct during industrial production of nitric acid mainly in the production of inorganic fertilizer and adipic acid used in the production of fibers such as nylon. ('EPA overview of greenhouse gases,' 2015)

CFC in global warming

Halogenated carbons such as CFCs were used as refrigerants, insulating foams, aerosol sprays. Its GWP is 12,000 its radiative forcing is 24% (IPCC, 2001as cited in Kemp, 2004). However, use and production of CFC is completely banned by Montreal protocol thus current levels of global CFC in the atmosphere are declining.

Effects of global warming

Sea level rise

This is caused by two factors such as addition of water from melting ice land and expansion of sea waters as it warms. Rate of increase in sea level is 3.19 mm per year (Shaftel, 2015), this causes loss of low lying land, submergence of island states in Indian and Pacific ocean might disappear completely, loss of valuable habitats and beaches e.g.: nesting beaches of sea turtles get disappeared and this may affect the already endangered sea turtle population (see figure 7).

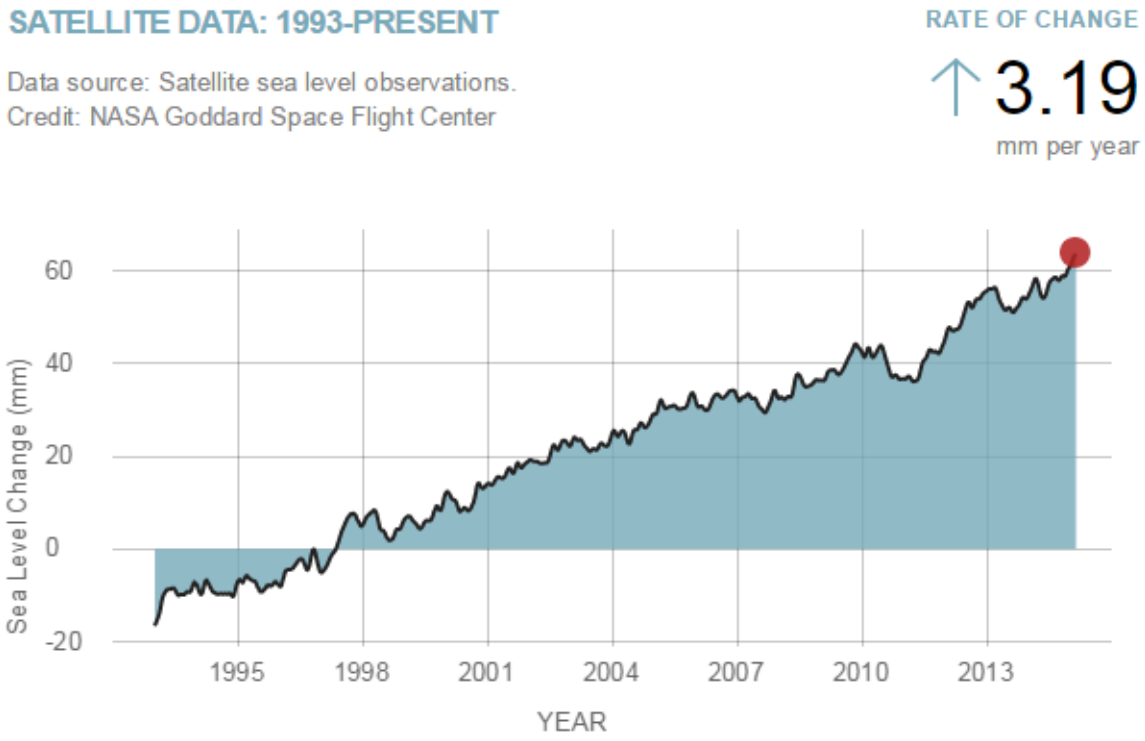

Figure 7: Sea level change (Source: NASA Global Climate Change Land ice (2015)

Warming oceans

Heat is absorbed by the oceans affects the top 700 m of the sea. Since 1969 oceans shows warming of 0.302 ^{o}F.

Shirking ice sheaths

Ice sheaths in Green land and Antarctica has shown decline in their mass. Greenland lost 150-250 cubic km of ice per year in the period between 2002 and 2006 and Antarctica lost about 152 km of ice in the period of 2002 to 2005. According to the 'NASA-GCC-Land ice' (2015) the loss of ice mass in Antarctica is at the rate of 147 billion metric tons of ice per year since 2003, this is 258billion metric tons per year in Greenland.

Declining Arctic sea ice

Snow plays a vital role to the environment by reflecting the sunlight back this helps to reduce

the warming, in addition, melting seasonal snow provides fresh water for the life and accrued soil moisture helps the growth of vegetation. However, increase melting of ice by global warming leads to spring time floods. According to the satellite data amount of spring snow cover in the northern hemisphere has declined over the last five decades. Arctic sea ice is declining at the rate of 13.3% per decade. According to the satellite data, the lowest arctic ice extent was recorded in 2012 (see figure 8).

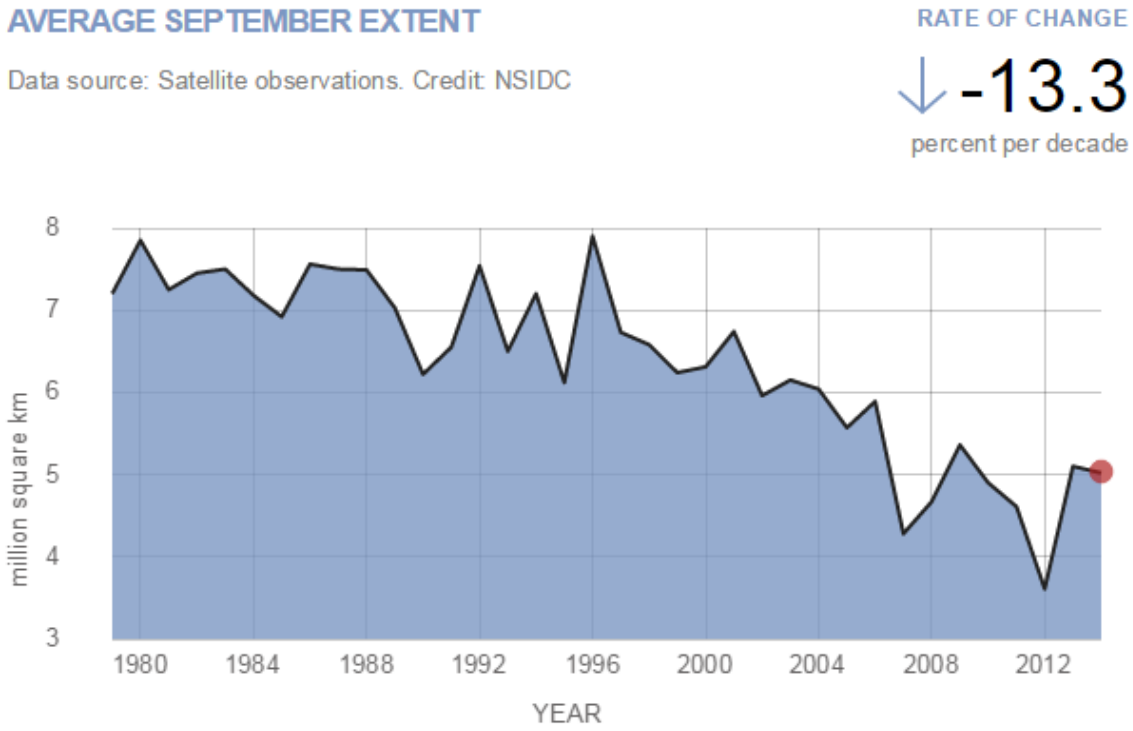

Figure 8: Decreasing arctic sea ice (Source: 'NASA GCC arctic sea ice,' 2015; 'NASA earth observatory,' 2000)

Antarctic melting and loss of ice shelf.

Antarctic ice shelves accounted for a mass loss of1,089 trillion kilogram ice per year in the period between2003 and 2008. Warm ocean waters melt the ice sheet from underneath (basal shelf melt) accounted for 55% of the ice shelf melts, it also changes the ocean currents. ('Shaftel,' 2015) see figure 9.

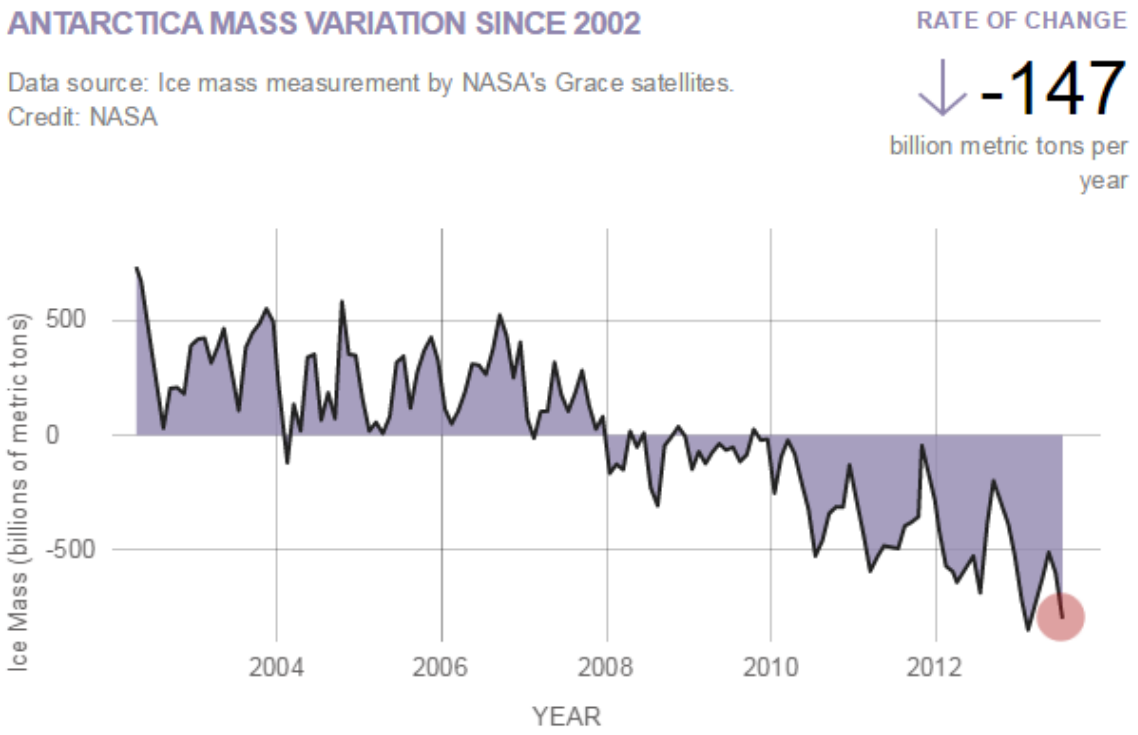

Figure 9: Antarctica mass variation (Source: 'NASA Global Climate Change Land ice,' 2015).

Glacial retreat

Glaciers are retreating almost everywhere such as Alps, Himalayas, Andes, Rockies, Alaska and Africa.

Extreme events

1. **Flood and landslides:** Both causes large death and injury in human population such events are increasing with the global climatic change in countries like Bangladesh, Khartoum, Netherlands, Egypt and Sudan.
2. **Hurricanes and Tornadoes:** ocean temperatures increasing due to global warming this subsequently increases the wind speed when maximum wind speed exceeds 74 miles per hour this is called hurricanes in Atlantic and typhoons in pacific. Tornadoes are more frequent in USA and it causes mass destruction to lives, properties and crops ('Union of concerned scientists,'2006).
3. **Droughts:** there are four types of droughts such as meteorological (low precipitation), agricultural (lack of moisture for crop growth), hydrological (surface & ground water supply below normal) and socioeconomic (effect in the economy due to water scarcity) such events are common in Sahal and East African countries such as Ethiopia and Sudan.
4. **Forest fires:** Are more common in Australia and Indonesia during El-nino events. Forest fires can naturally ignited

by lightening, volcanic eruptions, spark from rock falls and spontaneous combustion. Anthropogenic slash and burn agriculture and exotic / invasive oily plants such as eucalyptus and pine trees naturally causes fires. It has been estimated between 1850 and 1980 90-120 billion metric tons of CO_2 was released by forest fires ('earth observatory,' n.d.). (Adapted from McMichael, 2003).

5. **Heat waves:** heat waves killed more than 2500 people in India (by June 2015). Most affected regions are Andhra Pradesh, Telangana, Punjab, Uttar Pradesh, Odisha and Bihar. It also severely affected cattle and crop production.

Ocean acidification

Ocean acidification has lowered the pH of the ocean waters by about 0.11 units (SCOR 2009 as cited in 'Tech Ocean Science', n.d.)This is due to anthropogenic CO_2 emission, amount of CO_2 on upper layer of the ocean has been increasing by2 billion tons per year. Oceans have absorbed 1/3 of the CO_2 produced by human activities since 1800 and fossil fuel burning alone account for half of the CO_2 (Sabine *et al.,* 2004 as cited in 'Tech Ocean Science', n.d.).

If CO_2 emission levels continues unchanged, the future CO_2 levels will be high enough to lower the pH of ocean to 7.8 by the year 2100 (Royal Society, 2005 as cited in 'Tech Ocean Science', n.d.).

Effects on Biodiversity

Increased temperatures of land and ocean moved the habitat range of many species pole ward or upward from their current location such movements also accelerated by droughts and desertification. Species with restricted habitat requirement or sedentary (coral reefs) or limited climatic or geographical range (mountain top or Island habitats) are more vulnerable to climate change. This also may increase the net primary productivity as atmospheric CO_2 levels increases and opportunists (weeds) win the competition. Organisms of temperature dependent sex determination such as sea turtles, crocodiles, amphibians with permeable skin and eggs are more vulnerable. Species that are already at risk face extinction, many habitats such as wetlands, beaches, grass lands and sea grass beds disappear. Climatic change associated reduction in Arctic and Antarctic ice alter seasonal distribution, migratory pattern, nutritional and reproductive status of marine mammals, it also affect the plankton distribution this affect the marine food chain and loss of a key stone species make the entire food chain get collapsed. Long living species such as perennial trees slowly show evidence of climate change and they slowly get recover. Changes in phenology, breeding seasons, behavioural alterations and patterns of migration (e.g. in birds) are already observed (Adapted from Secretariat of the conservation on biological diversity (2003).

Effects on coral reefs:-Increasing temperature causes coral bleaching in various parts of the world and acidification of oceans affect the corals regard to their formation of skeleton, acidified waters cause difficulties in absorbing calcium from the water which is essential for

shell formation and it also dissolves the reefs ('Tech Ocean Science', n.d.).

Health effects

Direct physiological effect by heat and cold, high heat affects several in Indian states during the early 2015, sun stroke killed several, continuous exposure can causes skin damage, eye disease, adverse effect on immune system and skin cancer, temperature increases blood pressure, viscosity and pulse thus increases the death related to cardio vascular disease and increased stress and malnutrition also adversely affect the health.

Epidemics of water born and vector borne diseases occur as flooding increases breeding places of mosquito vectors and also breakage in water pipes, septic tanks, sewers, drainage and storm water gets leak and contamination in portable water sources.

Water borne diseases: Diarrhea, cholera anddysentery.

Vector borne diseases: falciparum malaria, vivax malaria, dengue, elephantiasis, yellow fever and west nile fever, rodent borne diseases plaque, Lyme disease and tick born encephalitis and hanata virus pulmonary syndrome. (Adapted from McMichael, 2003)

Pros and cons of global warming

Disadvantages

- Disruption of ocean circulation leads to unknown changes and effects in world climate.
- Increasing sea level causes flooding in low lying lands and evacuation
- In Mediterranean climatic regions such as Southern Europe, South Africa and Western Australia precipitation get reduced soil moisture levels decline and ultimately productivity goes down.
- Increase in desertification
- Abrupt weather changes affect the agriculture and results in food shortages
- Shortage of water in already water scarce areas.
- Starvation, malnutrition and increased deaths in the areas of food shortage
- More extreme weather and increased frequency of catastrophic events such as storms, typhoons and flooding events.
- Changes pollution and aeroallergen levels
- Increase in epidemics diarrhea, cholera, dengue and malaria
- Increased allergy and asthma rates due to earlier blooming plants
- Deaths may occur due to heat waves.
- Crop failure and pest out break
- Extinction of plants and animals
- Loss of plant and animal habitats
- Emigration increases from poor or low lying countries to rich and wealthier nations.

- Additional energy expenditure for cooling and excavation of ground water or bringing river water.
- Melting of permafrost leads to destruction of structures, landslides and avalanches
- Increased air pollution
- Permanent loss of glaciers and ice sheets.
- Cultural heritage sites get destroyed rapidly by increased extremes of weather pattern
- Acidification of oceans
- Earlier drying of forests leads to increased forest fires
- Economical imbalance and increased violence

Advantages

- Arctic, Antarctic, Siberia and other frozen regions of the earth experience more land for cultivation (opening of new lands) and more plant growth in favourable conditions.
- Northern Europe, Canada, Russia get benefited with increased harvest such as cereals, sugar beet, hay and potatoes.
- More sea transportation ways opens such as Canada's North West passage.
- Less energy and fuel requirement for warming up.
- Decrease in death due to freezing
- Longer the growing season could increase the agricultural production

(Farhan, 2015)

CO_2Mitigation

There are 3 basic ways suggested to lower the greenhouse effect. Firstly, stopping or reducing the emission of CO_2 into the atmospheres by ways such as use alternative green energy sources or renewable energy sources, upgrading the emission standards of the engine. Secondly, liquefying the CO_2 produced in the combustion and dump into the oceans, though it is a permanent disposal but it will result in ocean acidification which is currently becoming a major threat to aquatic life, thus underground injection or geologic sequestration and transportation/ storage of captured carbon in industries and power plants. Thirdly, lowering the atmospheric CO_2 levels (post emission control) this is done by increasing the sinks such as afforestation, reforestation and prevention of deforestation. Annually, about 2 billion tons of CO_2 ends up in oceanic organic deposits in sea floor.

Air quality and emission trading: US EPA has proposed to reduce greenhouse gas emission, reduce emission from new vehicle, reducing vehicular pollution via telecommuting and

series of programs conducted by US EPA to reduce the vehicular emission.

Emission control during Beijing Olympics, during the Olympic season 300,000 heavy emission vehicles (mostly trucks) were put away from the site, government encourage public transport, rules allow only some people to drive on certain days about 2 million vehicles are removed from roads. Mobile data collection of CO_2 and soot in the atmosphere was done. As a result the black presence of carbon gets down by 33% in 2008.

Methods of carbon capture in power plants and industries

Post combustion capture (PCC)

This method involves separation of CO_2 from flues gas, solvent **absorption** using ammonia such as aqueous pure amines or blends of amines, in Alstom's Chilled Ammonia Process (ACAP) aqueous ammonium carbonate to bicarbonate reaction is used. monoethanolamine (MEA) in aqueous solution is used to capture CO_2 usually from boilers, Aker Clean Carbon is a mobile amine based facility, amino acid salt processes is the second generation method, amino acid salts has high absorption capacity than amines.

Adsorption methods are using a material where the CO2 molecules get absorbed on to the solid surface e.g. 3X zeolites, this is comparatively advantages than liquid based absorption as regeneration energy is low, since the heat capacity of solid sorbent is lower than the aqueous solvents.

Membranes are used to separate the CO_2 selectively, since CO_2 has high permeability than any other substances in the flue gas, however, it requires a pressure gradient for the separation; this is achieved by pressurizing flue gas on one side of the membrane and vacuuming the other side (Adapted from Global CCS Institute, 2012).

Pre combustion de-carbonization

This is achieved by providing 'synthesis gas' (mixture of H_2 and CO) for combustion where CO_2 is absorbed completely. Thus, the combustion occurs in the absence of CO_2. CO in the synthesis gas easily gets converted into CO_2 which is then captured using solvent. Here a hydrogen rich fuel is produced that facilitate the efficient burning in the turbine and minimizes the CO_2 emission.

Transportation of captured carbon dioxide can be done easily by regular transportation or shipment in a compressed cylinder (IEA Greenhouse Gas R&D Programme, n.d.).

Carbon sequestration

Carbon sequestration is a process providing long term storage for captured carbon from industrial effluents, which helps to reduce the emission of carbon to Atmosphere as CO_2.

Captured compressed CO_2 can be injected underground using pipe line, suitable geological formation for CO_2 sequestration are depleted oil & gas fields, solid, porous rock such as sandstone, shale, dolomite, basalt, or deep coal seams and saline formations. More precisely one or more layers below cap rock could be the ideal place which prevents the upward migration of CO_2 after being injected (see figure 10) (Adapted from 'EPA CCS,' 2015).

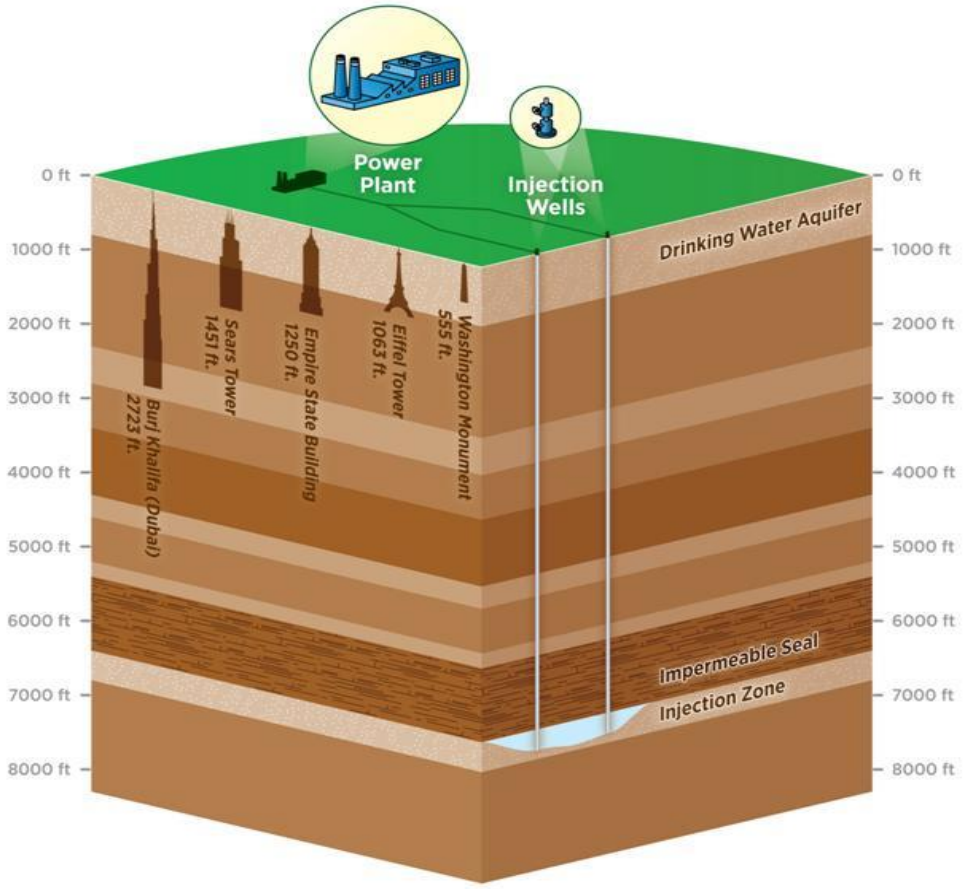

Figure 10: Geographical location of carbon sequestration injection zone (Source: 'EPA CCS,' 2015).

NO_x Mitigation

To reduce NO_x methods such as selective catalytic reduction process (SCR) which has the NO_x reduction rate up to 80% where injection of reactive chemicals such as ammonia reacts with NO_x and convert into N_2 and O_2, changing air to fuel ratio and changing the combustion temperature. In automobile NO_x reduction, catalytic converters are used e.g. three way catalytic converters (1. conversion of NO_x into N_2 and O_2, 2. conversion of CO into CO_2 3. conversion of hydrocarbons into CO_2 and water) ('Reducing Acid Rain' US EPA, 2012).

Absorption

It is selectively isolating the pollutant, here the gaseous pollutant dissolved in a liquid scrubbers are coming under this category. In flue gas Denitrification the mixing of nitrous oxides with water resulted with nitric acid compounds (which is a water and soil pollutant in liquid phase). In Selective Catalytic Reduction method ammonia is applied to the gas steam which reacts with the oxides of nitrogen at very high temperature (300^{o}C) in the presence of catalysts such as active Vanadium pentoxide and tungsten trioxide on a carrier of titanium which releases nitrogen and water.

Electrostatic precipitator

Negative corona is most preferred in industrial application as the industrial gases such as SO_2, CO_2, and H_2O have best ability to absorb free electrons and spark over voltage is higher in negative corona. However, negative corona generates higher level of Ozone, thus not used in air conditioners.

Flare and Thermo Oxidizers

Flare stacks are used for burning off the flammable gas release generally used in petroleum refineries, natural gas processing plants and chemical plants, this also used to release the pressure of the equipment, flares are designed for short term combustion. To avoid most hazardous methane release during fermentation in beer factories flares are used to burn and release in the form CO_2. Ground level flares are used in earth pits. Among thermal oxidizers regenerative thermal oxidizers are efficient up to 95%, the process is more simplified by the use of catalytic thermo oxidizers where the catalyst are used to reduce the ignition temperature and the reaction is employed in relatively low such as temperatures (reduction of 600 to 200 ^oC) there are ventilation air methane thermal oxidizer, thermal recuperative oxidizer and direct fired thermal oxidizer used for the relevant purposes ('Thermal oxidizer,' 2014).

Afforestation and Reforestation

Planting a tree is generally for establishing wind breaks, shelter belts, timber, fuel wood, flowers, nuts, vegetables, medicinal plants and wildlife. Maintaining or protection against forest degradation can be successful by planting, site preparation, tree improvement, fertilization, uneven aged stand management, thinning, pruning, weeding, cleaning, liberation cutting or other appropriate silviculture techniques, maintaining or increasing the landscape level carbon density using forest conservation strategies, longer forest rotations, fire management and protecting against insect pests (IPCC, 2007).

Most popular Afforestation and Reforestation programs

Forest plantation in a land which does not have any forest in last 50 years of history is Afforestation, if it has an occurrence of forest within last five decades then it is Reforestation.

- China annually increased its forest cover by 11,500 square miles, an area the size of Massachusetts, according to a report from the United Nations in 2011. China's Great Green Wall was designed to plant nearly 90 million acres of new forest (Jon, 2012).
- Reforestation in Korea: Between 1961 and 1995, stocked forest land went up from 4 million ha. to 6.3 million ha. Total timber rose from 30.8 million cubic meters in 1954 to over 164.4 million cubic meters in 1984. By 2008, 11 billion trees had been planted about two-thirds of South Korea is now clothed with forest.

- Reforestation in Tanzania: the Kwimbare forestation project: During the nine year period of the project's run, over 6.4 million trees were planted.

- Reforestation in Mexico: the Mixteca Region: Center for Integral Small Farmer Development in the Mixteca reforested with 1 million trees covers more than 1000 ha.

- Reforestation in the United States: the Appalachian Regional Reforestation Initiative: 60 million trees have been planted on about 87,000 acres of active mine sites in Appalachia under ARRI's guidance.

- Reforestation in Colombia: Gaviotas Villagers have successfully reforested about 20,000 acres as a result rainfall has increased by 10%. ('Sustainablog', 2011).

- Japan after World War II, have done intensive reforestation from 1950-1970, during that period professional silviculture spread out in every Japanese village. (Gerry, 2005)

Forestry projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol.

General features of this mechanism are reforestation of native forests, plantations for timber, agro forest or multipurpose tree plantations and healing barren lands. Kyoto Protocol governs Land use, land use, change and forestry (LULUCF) and modalities and procedures for CDM. Organizations such as International Tropical Timber Organization (ITTO) carried out the task according to the discussed strategies.

Role of International Tropical Timber Organization (ITTO)

International organizations such as ITTO, encourages conservation, sustainable development, use and trade of forest resources. It has 59 members represent about 80% of tropical forests and 90% tropical timber trade worldwide. ITTO collects analyses and circulates data on production and trade of timber and allocates funds since 1987. It has funded more than 750 reforestation and afforestation projects valued US$290 million. Donors are mostly Japan, Switzerland and the USA.

CDM projects

- Pearl River Watershed Management, China: This project proposes to alleviate local poverty and reduce threats to forests by afforesting 4,000 hectares in the Guangxi Zhuang. Project also includes half of the Pearl river basin.

- Pico Bonito Forest Restoration, Honduras: This is a pilot project on agroforestry to support small scale farmers of 20 villages with in the Pico

Bonito National park buffer zone of 2,600 ha. Main roles of the project are introducing agroforestry for small scale farmers, reforestation to promote conservation, establishment of sustainable commercial grade plantation.

- San Nicolás Afforestation project: This project includes both forest and agroforestry plantation in an abandoned pasture land of 8,730 ha. In San Nicolás, Colombia.

(Timothy, Sarah and Sandra, 2006).

Mitigation approaches for Global warming

1. **Energy:**

~ Increase energy efficiency in engines and boilers

~ Switching to low carbon fossil fuels such as natural gas

~ Introducing flue gas decarbonization and carbon sequestration

~ Increasing the use of nuclear energy

~ Increase the use of renewable energy sources

~ Conserve energy during the usage

2. **Industry:**

~ Reduce greenhouse gas emission such as methane

~ Reduce the material content of manufactured goods

~ Switch to energy efficient technology

~ Transferring and sharing technology mainly from developed to developing countries

~ Recycle

3. **Transport:**

~ Improving energy efficiency of vehicles

~ Reducing vehicle emission

~ Reduce the vehicle weight and size to maximize the performance

~ Changing land use patterns and life styles to reduce transport requirements

~ Integrate transport policies

~ Promote public transport option than personal vehicles

~ Promote greener vehicles such as electric cars

4. **Agriculture:**

~ Develop new management techniques to reduce tillage, recycling of crop residues, mixed cropping and avoid monoculture

~ Restoration of wetlands

~ Improve energy efficiency

~ Improve nutrition of ruminants and reduce methane generation

~ Reduce biomass burning

~ Manage fertilizer use to reduce nitrous oxide production

5. Forestry

~ Substitute burning of fuel wood for fossil fuels

~ Improve energy efficiency

~ Reduce biomass burning

~ Conserve CO_2 in living trees

~ Afforestation and reforestation

6. Government

~ Develop industrial land use plan to minimize energy consumption

~ Planning disposal of waste material to reduce production of methane and CO_2

~ Provide disincentives (tax) for excess energy consumption

~ Provide incentives for energy consumption and minimizing greenhouse gas emission such as reduce the taxes for electric and hybrid vehicles.

~ Improve energy efficient, recycling and proper waste disposal

Source: Kemp (2014)

Emission trading

It is an administrative approach of pollution control by giving economic incentives. Emission trading facilitates a market where parties can buy allowance or permits for emission of particular pollutant or credits given for reduction of pollutants. There are several emission reduction projects under cap and trade scheme, here a cap (limit) values is defined for GHG emission.

Kyoto Protocol, 1997

This is an amendment to the U.N. Framework convention on climate change, parties are committed to bring down the emission of six greenhouse gases (Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Hydrofluorocarbons (HFCs); Perfluorocarbons (PFCs); and Sulphur hexafluoride (SF_6)(UFCCC, 2014) or reducing their production as the listed gases cause global warming, parties agreed to fund research on climate change and promoting alternative energy sources in both developed and developing nations, it also includes several international partnerships such as Asia- Pacific partnership on clean development and Climate. First commitment period was between 2008 and 2012 here 37 industrialized nations and the European community committed to reduce GHG emissions to an average of 5% against 1990 levels. Then Doha amendment was added in 2012, here parties committed to reduce GHG emissions by at least 18 % below 1990 levels in the period from 2013 to 2020.

Conclusion

Global warming is an increasing environmental issue, earths average temperature has warmed by 0.8^{o}C**,** Annually 30 billion tons of CO_2 is being released to the atmosphere. Carbon capturing and sequestration methods are being widely used to minimize the CO2 level in the atmosphere. Clean development mechanism (CDM) developed under Kyoto protocol promote greenhouse gas emission reduction in

developing world. Integrated Territorial Climate Plan (ITCP) implementation, making green certification as mandatory, ensure the control of greenhouse gases, designing appropriate cap limits, spread the energy conserving techniques and appropriate pollution control mitigation strategies and increase public awareness on all known effects of global warming, funding more researchers and discover unopened areas of research, exploring impacts and finding mitigation are more importantly under evaluation by today's scientists, environmental sector organizations, governments and policymakers.

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