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Carbon Dioxide – The Frontline Greenhouse Gas

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Abstract - The sun is the star at the center of the solar system and is the primary energy source for life on earth. Greenhouse gases in an atmosphere like Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Water vapour (H_2O), and Ozone (O_3) help to maintain balanced temperature on earth through a phenomenon called as greenhouse effect. This ensures survival of life on the planet earth. Without greenhouse effect the average temperature of the earth would be very cold at -18°C, water would not exist in liquid form, and as a result the earth would have been incapable to support life. Human use of fossil fuels is the main source of excess greenhouse gases in the atmosphere which now far exceed pre-industrial levels over the past 650,000 years. Due to this there is an increase in the global temperature leading to climate change. The term climate change can be comprehensively understood as "a statistically significant variations in the earth's average weather, including changes in temperature, wind patterns and rainfall, especially the increase in the temperature of its atmosphere that is caused by the increase of greenhouse gases like carbon dioxide, methane, nitrous oxide, ozone etc. in the atmosphere due to the anthropogenic activities such as generation of energy from fossil fuels (for electricity, industry, transportation etc.), deforestation, agriculture, land use change etc." Climate change has become the most predominant issue of the 21st century as it has deeper global impacts on the earth threatening the very existence of life on it. Carbon dioxide (CO_2) is the frontline greenhouse gas that contributes a large i.e., around 60% to climate change. The main human source of carbon dioxide is the use of fossil fuels (coal, petroleum and natural gas) in different human sectors. The present paper attempts to profile the carbon dioxide in the context of climate change.

Key Words: Greenhouse Gases, Greenhouse Effect, Climate Change and Carbon Dioxide.

I. INTRODUCTION

The sun is the star at the center of the solar system and is the primary energy source for life on earth. The survival of life on earth depends on the absorption of incoming solar radiation from sun which warms its surface. It is a burning star so hot that one can feel its heat from over 150 million kilometers away. The enormous effect of the sun on the earth has been recognized since prehistoric times, and the sun has been regarded by some cultures as a deity.

Greenhouse Gases

Greenhouse gases in an atmosphere absorb and emit thermal infrared impinge on earth by sun. This process is the fundamental cause of the greenhouse effect. In order, the most abundant primary greenhouse gases in the Earth's atmosphere are Water vapour (H_2O), Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O) and Ozone (O_3). These gases greatly affect the temperature of the Earth; without them, Earth's surface would average about 33 °C colder than the present average of 15 °C.

Greenhouse Effect

Of the total incoming solar radiation (heat) covering all wave lengths that impinge upon earth, about 50% (mainly infra red and visible light) reach the surface of the earth and are absorbed by it. A further 20% of the incoming light is absorbed by gases Ultra Violet (UV-short wave length 100 to 400 nm) by ozone present in the stratosphere and Infra Red (IR-long wave length 700 nm to 1 mm) by carbon dioxide and water vapour in troposphere. The remaining 30% is reflected back into space by clouds, ice, snow, sand and other reflecting bodies without being absorbed. Like any other warm body, the earth emits energy immediately after the

absorption. Indeed the amount of energy that the planet absorbs and the amount that it releases must be equal to keep temperature constant. The emitted energy is neither visible nor UV light, rather it is infra red light. This is called the thermal infra red energy since this energy is a form of the heat.

The atmosphere (troposphere) contains gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapour (H_2O), ozone (O_3), chlorofluorocarbons-12 **(**CCl_2F_2), HCFC-12 ($CHClF_2$) tetrafluoromethane (CF_4), hexafluoroethane (C_2F_6), sulphur hexafluoride (SF_6), and nitrogen fluoride (NF_3). They all together called as atmospheric gaseous blanket among which water vapour, carbon dioxide, methane, nitrous oxide are called as natural greenhouse gases as they have been existed naturally in the atmosphere. They allow incoming solar radiation to pass through but trap the heat emitted by the earth surface. They are more absorbent with to thermal infra red light of specific wave lengths and so not all the infra red emitted from the earth's surface and atmosphere which escapes directly in to space.

The greenhouse gases have radiative properties. So these gases shortly after the absorption of the emitted thermal infra red light of specific wave length from the earth, re-emit it completely and randomly in all directions. Thus some thermal infra red redirected towards the earth's surface. It is this phenomenon raises the average temperature of earth from –18 °C to + 15 °C and is vital for life on the earth. It is analogous to a green house which traps heat and its glass walls do not allow the heat to go out there by increasing the inside temperature. Hence, this effect is called as greenhouse effect. The gases which are responsible for this effect are called as greenhouse gases. Greenhouse effect was discovered by Joseph Fourier (1824), reasoned from experiments by John Tyndall (1859) and quantitatively reported by Svante Arrhenius (1896). It helps to maintain balanced temperature and thereby ensures survival of life on earth. Without it the average temperature of the earth would be very cold at -18°C, water would not exist in liquid form, and as a result the earth would have been incapable to support life.

Fossil Fuels and Greenhouse Gases

Fossil fuels are formed by natural processes such as anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels contain high percentages of carbon and include coal, petroleum and natural gas. Human use of fossil fuels is the main source of excess greenhouse gases in the atmosphere which now far exceed pre-industrial levels over the past 650,000 years. In addition the amount of manmade compounds like chlorofluorocarbons and its substitutes sulphur hexafluoride etc. are on rise. Due to this there is an increase in the global temperature leading to climate change.

Climate Change

The term climate change is defined in the following way:

United Nations Framework Convention on Climate Change (UNFCCC)

Climate change can be defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

Intergovernmental Panel on Climate Change (IPCC)

Climate change refers to "any change in climate over time, whether due to natural variability or as a result of human activity."

Thus the term climate change can be comprehensively understood as "a statistically significant variations in the earth's average weather, including changes in temperature, wind patterns and rainfall, especially the increase in the temperature of its atmosphere that is caused by the increase of greenhouse gases like carbon dioxide, methane, nitrous oxide, ozone etc. in the atmosphere due to the anthropogenic activities such as generation of energy from fossil fuels (for electricity, industry, transportation etc.), deforestation, agriculture, land use change etc." Given the wide range of impacts beyond temperature variations, scientists prefer the term climate change over the term global warming.

Impacts of Climate Change

Climate change has become the most predominant issue of the 21st century. Being a manmade disaster it has the following deeper global impacts on the earth:

- Rise in the Global Surface Temperature.
- Extreme Weather Events (Heat Waves, Rainfall Patterns Affected, Storms, Hurricanes, Cyclones and Flooding, Drought).
- Desertification.
- Wild Fires.
- Shrinking of Glaciers.
- Polar Regions under Threat.
- Heating of Glaciers in Greenland.
- Sea Level Rise.
- Destruction of Coral Reefs and Marine Ecosystem.
- Ocean Acidification.
- Undue Change in Ocean Currents.
- Agriculture and Food Security in Jeopardy.
- Bio-Diversity under Threat (Disruption of Ecosystem, Global Movement of Plants and Animals, Polar Animals are at risk, Invasion of Antarctic Ecosystems by King Crabs etc.).
- Human health (Death Toll, Heat waves, Vector Borne Diseases, Allergy Attacks, Water Contamination) etc.

Carbon Dioxide

Carbon dioxide (CO_2) is a colorless and odorless gas. It is the primary source of carbon in life on Earth. It is a naturally occurring chemical compound composed of a carbon atom covalently double bonded to two oxygen atoms. It exists in Earth's atmosphere as a trace gas at a concentration of about 0.04 percent (404.16 ppm) by volume. Natural sources include volcanoes, hot springs and geysers and it is freed from carbonate rocks by dissolution in water and acids. Because it is soluble in water, it occurs naturally in groundwater, rivers and lakes, in ice caps and glaciers and also in seawater. It is present in deposits of petroleum and natural gas.

The concentration of atmospheric carbon dioxide in Earth's pre-industrial atmosphere was regulated by photosynthetic organisms and geological phenomena. As part of the carbon cycle, plants and algae (both are Eukaryotes) and blue green algae (Prokaryotes) use light energy to photosynthesize carbohydrate from carbon dioxide and water and release the oxygen. It is produced by all aerobic organisms when they metabolize carbohydrate and lipids to produce energy by respiration. It is also produced during the processes of decay of organic materials, combustion of wood, carbohydrates and fossil fuels such as coal, peat, petroleum and natural gas.

Contribution of Human Sectors using Fossil Fuels to Carbon Dioxide

Carbon dioxide is the major greenhouse gas that contributes a large i.e., around 60% to climate change. The main human source of carbon dioxide is the use of fossil fuels (coal, petroleum and natural gas) in power stations, industrial processes, transportation, residential, commercial etc. In addition fossil fuel retrieval, processing and its distribution, the burning of solid waste, trees and wood products leads to increase in it.

Deforestation is another significant source of greenhouse gases, because fewer trees mean less carbon dioxide conversion to oxygen. Thus loss of forests leads to loss of natural carbon sink. In addition deforestation leads to increase in soil erosion, which exposes organic matter to rapid oxidation, thereby producing carbon dioxide. Agriculture releases carbon dioxide into the atmosphere by causing oxidation of carbon compounds in the vegetation or the soil. Cement industry is also one of the primary producers. Carbon dioxide is emitted from the calcination process of limestone, from combustion of fuels in the kiln and from power generation. The following table shows the production of carbon dioxide by the human sectors using fossil fuels:

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Table 1: Contributions of Human Sectors to Carbon Dioxide

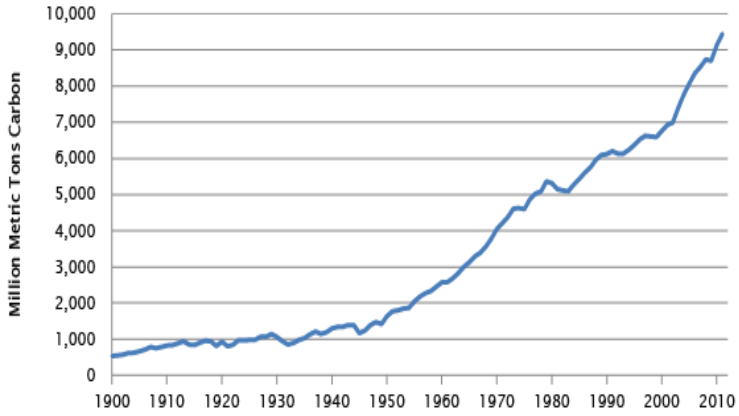
Sl. No.	Human Sector	Percentage of Contribution to CO_2
1	Coal Based Electricity	29.5%
2	Industrial Processes	20.6%
3	Transportation	19.2%
4	Residential, Commercial and Other Sources	13.2%
5	Land use and Biomass Burning	9.1%
6	Fossil Fuel Retrieval, Processing and Distribution	8.4%

(Courtesy: https://en.wikipedia.org)

From the above table it can be seen that coal based electricity remains the top contributor to carbon dioxide.

Emission Scenario of Carbon Dioxide

The concentration of carbon dioxide was 280 ppm (parts per million) in pre-industrial times (1750) and has risen to 404.16 ppm (February 2016) as reported by Mauna Loa Observatory, Hawaii (Scripps) on March 2, 2016. The present level is higher than at any time during the last more than 8,00,000 years. According to the IPCC Special Report on Emission Scenarios, by the end of the 21st century, we could expect to see carbon dioxide concentrations of anywhere from 490 to 1260 ppm (75-350% above the pre-industrial concentration). The following graph shows the global carbon dioxide emissions from fossil fuels during the period from 1900–2011.



Graph: Global Carbon Emissions from Fossil-fuels 1900-2011

(Source: Boden, T.A., Marland, G., and Andres R.J. (2015). Global, Regional, and National Fossil-Fuel CO2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, doi 10.3334/CDIAC/00001 V2015)

Global carbon emissions from fossil fuels have significantly increased since 1900. Since 1970, CO2 emissions have increased by about 90%, with emissions from fossil fuel combustion and industrial processes contributing about 78% of the total greenhouse gas emission increase from 1970 to 2011. Agriculture, deforestation, and other land use changes have been the second-largest contributors.

Electronic Data-Gathering, Analysis, and Retrieval system (EDGAR) Database

EDGAR database created by European Commission and Netherlands Environmental Assessment Agency released the 2014 annual carbon dioxide emissions estimates (in thousands of carbon dioxide tonnes) along with a list of emissions per capita (in tonnes of carbon dioxide per year) from same source. The data only considers carbon dioxide emissions from the burning of fossil fuels and cement manufacture, but not emissions from land use, land-use change and forestry. Emissions from international shipping or bunker fuels are also not included in

national figures, which can make a huge difference for small countries with important ports. The top 10 largest emitter countries accounted for 68.2% of the world total. Other powerful, more potent greenhouse gases are not included in this data, including methane.

Table 2: List of Countries by 2014 Carbon Dioxide Emissions Estimates

Country	CO_2 Emissions (Kt)	Emission per Capita (t)
World	35,669,000	5.0
China	10,540,000	7.6
United States	5,334,000	16.5
European Union	3,415,000	6.7
India	2,341,000	1.8
Russia	1,766,000	12.4
Japan	1,278,000	10.1
Germany	767,000	9.3
International Shipping	624,000	-
Iran	618,000	7.9
South Korea	610,000	12.3
Canada	565,000	15.9
Brazil	501,000	2.5
Saudi Arabia	494,000	16.8
International Aviation	492,000	-
Mexico	456,000	3.7
Indonesia	452,000	1.8
United Kingdom	415,000	6.5
Australia	409,000	17.3
South Africa	392,000	7.4
Turkey	353,000	4.7
Italy	337,000	5.5
France	323,000	5.0
Poland	298,000	7.8

(Courtesy**:** https://en.wikipedia.org)

From above table it can be seen that presently China is leading in the carbon dioxide emissions at global level.

Nature's Redress Mechanism towards Carbon Dioxide

Globally, the burning of fossil fuels produces around 21.3 billion tonnes of carbon dioxide per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tonnes of atmospheric carbon dioxide per year. Studies since 1961 show that the ocean has been absorbing more than 50% heat added to the climate and that ocean temperatures have increased at depths of around 3000 meters. Hence, their efficiency of absorbing CO_2 has been decreasing. Now about 57% of the CO_2 emissions go to the atmospheric level and the remainder contributing to ocean acidification. All this leads to grave impacts on global climate thereby threatening the very existence of life on the earth.

Carbon Footprint and Carbon Offsetting

Calculating the total carbon footprint is difficult due to the fact that CO_2 can also be produced naturally. It is for this reason that Wright, Kemp and Williams have suggested a practicable definition: "A measure of the total amount of CO_2 and CH_4 emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within their spatial and temporal boundary. Calculated as CO2 equivalent (CO2e) using the relevant 100-year global warming potential (GWP100)." Greenhouse gases can be emitted through transport, land clearance, the production and consumption of food, fuels, manufactured goods, materials, wood, roads, buildings and services. Most of the carbon footprint emissions for the average household in developed countries

come from "indirect" sources, i.e. fuel burned to produce goods far away from the final consumer. These are distinguished from emissions which come from burning fuel directly in one's car or stove, referred to as "direct" sources of the consumer's carbon footprint.

Carbon print of an individual, nation and organization can be measured by undertaking a greenhouse gases emissions assessment. Several online carbon footprint websites ask one to answer some basic questions about their diet, transportation choices, home size, shopping and recreational activities, usage of electricity, heating, and heavy appliances such as dryers and refrigerators, and so on. Then they estimate one's carbon footprint based on their answers. The mitigation of carbon footprints through the development of alternative projects such as solar or wind energy or reforestation, represents one way of reducing a carbon footprint and is known as Carbon offsetting.

Carbon Trading and Carbon Taxes

Carbon emissions trading is a form of emissions trading that specifically targets CO_2 (calculated in tonnes of CO_2 equivalent or tCO_2e) and it currently constitutes the bulk of emissions trading. This form of permit trading is a common method countries utilize in order to meet their obligations specified by the Kyoto Protocol; namely the reduction of carbon emissions in an attempt to mitigate future climate change.

A carbon tax is an environmental fee levied by governments on use of fossil fuels such as oil, coal and natural gas. The amount of the tax depends on how much carbon dioxide each type of fuel emits when it is used to run factories or power plants, provide heat and electricity to homes and businesses, drive vehicles and so on.

Many economists suggest that carbon taxes should be preferred to carbon trading. Counter-arguments to this are based on the preference that politicians may have for emissions trading compared with taxes. One of these is that emission permits can be freely distributed to polluting industries, rather than the revenues going to the government. In comparison, industries may successfully lobby to exempt themselves from a carbon tax. It is therefore argued that with emissions trading, polluters have an incentive to cut emissions, but if they are exempted from a carbon tax, they have no incentive to cut emissions. On the other hand, freely distributing emission permits could potentially lead to corrupt behaviour (World Bank, 2010).

Proponents of carbon tax argue that it is simpler to enforce than cap-and-trade programs. The simplicity of it has been proven effective in Canada – which enacted and implemented it in five months. Taxing can provide the incentives to develop cleaner technologies and also creates income for the government. Supporters of carbon cap-and-trade systems believe it sets legal limits for emissions reductions, unlike with carbon taxes. With a tax, there can be estimates of reduction in carbon emissions, which may not be enough to address climate change. A declining cap gives allowance for firm reduction targets and a system for measuring when targets are met. It allows for flexibility, unlike rigid taxes.

II. Conclusion

Carbon dioxide (CO2) is the primary greenhouse gas emitted mainly through burning of fossil fuels. It contributes significantly to climate change. Both adaptation and mitigation measures at macro and micro levels are needed to control its emissions. Adaptation refers to shaping of our lives to adjust to a warmer planet. The need for it is felt as carbon dioxide remains in the atmosphere for decades, while oceans store heat for centuries which ensures that no matter how much we cut carbon dioxide emissions now, our previous emissions will keep warming the planet for decades. Mitigation aims to slow rising temperatures by cutting carbon dioxide emissions. Measures at macro level should be taken up by Nations, governments, businesses and organizations where as measures at micro level should be taken up by individuals to offset carbon dioxide emissions which has been the frontline greenhouse contributing massively to climate change.

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