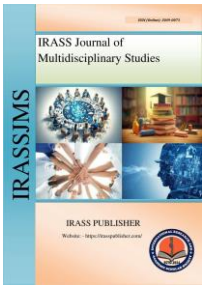
IRASS Journal of Multidisciplinary Studies
Abbriviate Title- IRASS J Mul Stud
ISSN *(Online) 3049-0073*
https://irasspublisher.com/journal-details/IRASSJMS
Vol-2, Iss-2(February-2025)



Zero Carbon Emission must be achieved at the Earliest for Sustained Growth of Our Planet Earth

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Article History

Received: 26/ / 01 / 2025

Accepted: 09 / 02 / 2025

Published: 13 / 02 /2025

Abstract: In 1750, man-kind moved from agriculture and artisanship era to Industrial era.Carbon dioxide was 280 ppm in the pristine atmosphere. Today man made activities have enhanced the concentration of Carbon Dioxide to 400ppm resulting in Global Warming and Climate Change.The devastating effects of Global Warming and Climate Change are: erratic weather patterns: heat waves, floods, severe storms and hurricanes,loss of polar ice and rising sea levels. Apart from Carbon Dioxide there are water vapour, methane, nitrous oxide and florinated gases. Seeing the formidable challenge to sustainable development strategy The Paris Agreement was signed in 2015 an International Treaty on Climate Change to which 196 Nations and Governments were signatory at COP21. Under Intergovernmental Panel of Climate Change [IPCC] 90 countries are covered and 80% global emission are set on zero emission path.At COP26 Glasgow Climate Pact was signed in which India declared a 5 point agenda for achieving net zero emission by 2070. At COP28 Resource Hub, 28th Annual Climate Climate Change conference in Dubai, UAE, 2023 held. 150 countries participated. In 2023, Convention on Biological Diversity was held and High Sea Treaty was signed in June 2023. Frame work convention on Climate Change is keeping track of Climate Change Aid to developing countries . Pathways to zero emission and limiting Global Warming to 1.5 degree centigrade above pre-industrial level have been laid down in Climate Change Conferences. Urban Heat Islands have to be dealt with tailored city specific action plans. Nitrous Oxide in Agriculture has to be dealt with by Organic Farming.Water produces 95% of Green House effect. The Water cycle has to be regulated. Indian agenda to help Paris Agreement to achieve its Sustainable Strategic Goals is described.

Keywords: Urban Heat Island; Carbon Dioxide; Methane; Nitrous Oxide; Florinated Gases.

How to Cite: Sharma, B. K., (2025). Zero Carbon Emission must be achieved at the Earliest for Sustained Growth of Our Planet Earth. *IRASS Journal of Multidisciplinary Studies, 2(2),8-16*

1. Introduction

In 1750 man-kind moved from agricultural and artisan era to Industrial era. Before this transition Earth's atmosphere was in pristine state. Carbon Dioxide was at optimum level so as to keep Earth warm enough for life and human habitation. If carbon dioxide was not there Earth would be at minus 20°Centigrade. Carbon Dioxide acts as a green house gas. IR part of the solar spectrum delivers heat to the planet Earth. This heat is trapped by carbon dioxide and re-radiated in all directions to keep the planet warm. But after 1750 when Industrial era started a dramatic change occurred. Before 1750 carbon dioxide was present in harmless quantity namely 280 ppm which was enough to keep Earth warm for plant and animal life. But today in 2018 carbon dioxide presence is 400ppm. Thus causing dangerous amount of global warming leading to climate change and serious damaging consequences. This increase in atmospheric presence of carbon dioxide is caused due to modern agricultural and industrial activities. If this remains unchecked the presence of carbon dioxide will increase at 2 to 3 ppm per year cumulatively adding to 900ppm by 2100 which will result in 4.8°C temperature rise above the pre-industrial era.

Nomenclature

- IR- infra red;
- UV - ultra violet;
- GHG - Green House Gas;
- GWP - green house warming potential;
- C - centigrade;
- PPM- parts per million;
- NOAA - National Oceanic and Atmospheric Administration;
- ERA - Environmental Protective Agency;
- IPCC- Intergovernmental Panel on Climate Change;
- NDC- nationally determined contributions;

- COP21 - UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015;
- COP26 - Glascow Climate Pact was signed on five year anniversary of Paris Agreement;
- COP 28 - Resource Hub. The UN's ***28th*** annual climate change conference (***COP28***) was held in Dubai, United Arab Emirates from November 30-December 12, 2023. WRI's experts closely tracked;
- WRI - World Resource Institute;
- EV - Electric Vehicle;
- BU - billion unit;
- GW - giga watt (10^9 Watt);
- UN FCCC -United Nations Frame work
- Convention on Climate Change ;
- ITLOS - International Tribunal for the Law of the Sea;
- COSIS-Commission of Small Island States on Climate Change and International International Law;
- UNCLOS- United Nations Convention on The Law of the Sea;
- ICJ - International Court of Justice;

ECHR- European Convention on Human Rights;

1.1 Carbon Dioxide is just one of the several Green House Gases.

GHG are carbon dioxide, water vapour, methane, nitro us oxide leading to acid rain and fluorinated gases. Air conditioners, Refrigerators produce hydro-fluoro carbon. They are produced in small quantities but have a higher green house warming potential (GWP).

The GHG will cause global warming by 2.8°C above the pre-industrial level by the end of this century even with current climate policies in place. Carbon Dioxide dissolves in oceans as a result pH factor has dropped from 8.21 (1750) to 8.10 (2020). This is equivalent to ocean acidification

Table 1 gives the green house gases, their respective GWP and their percentage presence in the atmosphere.

1.2 The International agreements for limiting global warming due to green house gas emission

I. The Paris Agreement in 2015

- The Paris Agreement is a **legally binding international treaty on climate change**. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. It entered into force on 4 November 2016.
- The cost and benefits of transitioning to a net zero emission economy must be distributed equitably.
- IPCC (Inter Governmental Panel on Climate Change) has assessed different pathways for carbon removal.
- Under IPCC 90 countries are covered where 80% of Global Emissions are covered by net zero target.
- Climate Watch Net Zero Tracker shows how these targets were set. This is called nationally determined contributions (NDC).
- Long Term Low GHG emission developed long term strategies.

This includes domestic laws;

- Government policies and high level pledges from head of state.
- 198 countries joined this pledge.
- This covers 18% of global emissions.
- 26 Parties have net zero target in Law;
- 54 Parties have net zero target Policy Douments;
- Net zero targets in political pledges by 17 parties.
- 101 Parties have no documents.

II. COP26 Glasgow Climate Pact

- COP26 Glasgow Climate Pact was signed on fifth year anniversary of Paris Agreement.
- The pact urges countries to move towards transitioning to net zero emission by as around mid-century taking into account of different national circumstances. There is notable increase in perceived urgency.
- Alignment of near term emission reduction targets for goals with long term net-zero goals.
- In 2021, at COP26 Climate Summit in Glasgow India announced 5 point agenda to reverse Climate Change.
- By 2030- 500GW non-fossil energy capacity will be installed
- By 2030- reduction of 1 billion tonnes of GHG
- By 2030-Reducing Carbon Intensity by 45% over 2005 level
- By 2030 - 50% will be renewable
- By 2070 net zero emission will be achieved by India

III. *COP 28 Resource Hub*

- 28th Annual Climate Change Conference was held in Dubai, UAE, from November 30 to December 12, 2023.There were 85,000 participants, 150 head of states and governments, national delegations, civil societies, businesses, Indegenous Peoples, Youth.
- Global stocktaking of World's efforts to address climate change under Paris Agreement.
- It signalled the " the beginning of the end" for the fossil fuel era by laying the ground for swift , just and equitable transition to zero emission economy. It was suggested to increase loss and damage funds. accelerating international initiatives to improve production systems' resilience. connecting conservation of nature with climate action. increasing the use of workable climate solutions.anticipating the COP28 talks on the framework for more transparency. It laid the ground for a new era of Paris Agreement.
- Countries must take concrete steps to ensure climate change reversal. if they are to effectively address the challenge at hand.

IV. The convention on Biological Diversity

- Under the convention on Biological Diversity it has been pledged to protect marine areas 30% of global sea by 2030. High Seas (beyond national control) comprise 2/3 area of the surface area of planet's ocean.
- Presently there is no international policy mechanism for biological conservation in these areas.
- In June 2023 High Sea Treaty was adopted at UN Convention the law of the sea.

- In 2025 it will be implemented. 60 Nations have signed this Treaty[2].
- Climate Change is a threat to this treaty.

V. Frame work Convention on Climate Change (UN FCCC)

- Frame work Convention on Climate Change (UN FCCC) keeps track of the pledge.
- A program to help developing nations fight climate change in funneling billions of dollars back to rich nations.
- Developed Nations have pledged $100 billiuon per year to poorer nations to help reduce emissions and cope with climate change .
- The pledge was made in 2009.
- It was reaffirmed in 2015 at Paris Climate Agreement.
- $353 billion in the period 2015-2020 have been given.
- In 2020 to 2022 another $200 billion has been released.

1.3 Irrefutable evidences for Climate Change to convince the climate change deniers.

Emission of Green House Gasaes (GHG) invariably lead to Global Warming and Global Warming leads to Climate Change.Recently we have seen specific examples of Climate Change such as erratic weather pattern, heat waves, floods, severe storms and hurricane, loss of polar ice and rising sea levels. This will get worse with global warming.

Drought, Flood and extreme weather events recurring in an unusal fashion.

Marine Species are already on the move as water warms up. Conservation must take this into account. Iconic sword fish is moving its range north as waters warm due to climate change. Corals are frying in Florida.Billions of snow crabs dead in the Arctic.

Global warming is leading to rise in sea level.By the end of this century if global warming continues unabated sea level will rise by 6.6 feet. Since reliable reord keeping began in 1880 sea level has risen by 8 inches.

Recently we have seen specific examples of Climate Change such as erratic weather pattern, heat waves, floods, severe storms and hurricane, loss of polar ice and rising sea levels. This will get worse with global warming.

.In 2023, scientists in Antartica noted a rise of 38.5°C above seasonal average.. Temperatures are moving into uncharted territory. It seems world has crossed the tipping point.Our World in Data shows that long term challenges have been effectively dealt with [3]. There have been challenges in the past which have been effectively dealt with . So we can definitely overcome this new challenge of global warming and climate change.

The critical challenges in the past have been:

- Reducing child mortality, reducing maternal mortality, reducing extreme poverty, improving education and increasing life expectancy.
- We have solved acid rain and ozone layer depletion in the past.
- Air polllution causes 9 million deaths every year.London and Beijing have reduced air pollutions.
- In 1900 UK emitted 10 tonnes of emission per capita and US emitted 14 tonnes per capita.
- By 2012 the pollution has been reduced to 4.9 tonnes per capita.
- Since 2012 the pollution per capita has steadily been falling.

In 1960, Solar Panels were prohibitively expensive. In outer space for satellites they were the only option. Through research and developent solar panels have become cheap and ubiquitous. Better technology has led to falling prices.The emerging economies are directly leap frogging into Solar Panel era without taking fossil fuel route.

People's action, Greta Thunberg being the foremost, has led 127 countries to sign Paris Agreement which pledges to zero emission by 2050.

1.4 Pathways to Zero Emission and limiting Global warming to 1.5°C above pre-industrial level by mid century

- Transportation contributes 1/6 of of global GHG. By concerted efforts Electric Vehicles (EV) are being introduced.
  - In 2020 2% were EV.
  - In 2022 14% were EV.
- In every country cycling, pedestrianism,and Public transportation is being introduced to reduce GHG.
- Cement,,Steel and long distance transport still need carbon innovation.
- In 2019, Electricity and Heat Production contributed 34% GHG
- Industry contributed 24% GHG
- Agriculture, Forestry and land use contributed 22% GHG;
- Transportation(based on gasolinee and diesal) contributed 15% GHG;
- Buildings contributed 6% GHG.
- In 2020, the biggest 10 GHG emitters are: China, USA,India, EU, Russia, Indonesia,, Brazil,Japan, Iran and Canada. They together account for 67% of Global GHG.
- Proper policy formulations such as
- EV,car free choices,better Public Transpoty,taking fewer flights, using low carbon energy, supporting refurbishing and circular economy(use--repair---reuse)
- Digitalisation of Society holds great potential for circular business models:
  - Sharing economy because of inter-connectivity(instant exhange of goods and services)
  - Car Pools and Car Sharing(traffic congestion reduced and emission reduced)
  - Renting bicycles for short distance commuting;
  - Linear consumption model(use and throw) must be replaced by use-repair-reuse
- We should aim at
- Poverty reduction;
- Crop resilience;
- Emergency Communcation Networks (Early Warning and Forecasting Methods);
- Building Climate resilient infrastructure;

1.5 " Cities warming due to effect of Urbanization, climate change,"[4]

Cities are warming at a rate that is almost double that of the countryside:

- urbanization at the local level is contributing to 60% more warming;
- Climate Change causing 40%;

On 28th and 29th May 2024 temperature in Delhi was higher than 50°C.

- The city's altered aerodynamics and thermodynamics characteristics tend to trap more heat;
- Climate Change is causing significant increase in temperature;
- The average nighttime land surface temperature in all 141 Indian cities is rising by 0.53°C per ten years;
- Even big metro and megacities are not as affected by urbanization-driven warming as Tier II cities in the country's east;

For cities with significant heat exposure, customized city-specific action plans are required for sustainable urban expansion [5].World Meterological Organization has announced that 2023 was hottest ever and Global Average Temperature reached 1.45°C higher than pre-industrial level.The city becomes Urban Heat Island (UHI).This exacerbates the Global Warming.The concrete structure and termac roads retain the heat which stays trapped inside the urban bubble along with air-pollutants.Lack of green space and waste heat from coolers and ACs add to UHI.

Short Term measures:

- Early warning bulletins;
- Staggered work hours at outdoor construction sites with shaded areas and temporary shelters;
- Strategic provisioning of drining water and oral re-hydration salts;

Long Term Measures:

- Increasing green covers;
- Urban forests;
- Large green and park avenue and other trees;
- Well distributed green ares influence local micro climate;
- Reduce air pollution;
- Promote health and well being;
- Tree lined and shaded walkways plus tracks promote pedestrians, cyclist and itierant workers;
- Encourage non motorized transport;

Hence green areas are imperative for sustainable urban development by UN habitat. The latter recommends that green spaces be available to every citizen within 300 meters of their residence.

Singapore is a densely populated city state still it has 47% green cover.

Most European cities have 30% green cover.

Banguluru, Mumbai, Delhi have 20% green cover.

Chennai has only 12% green cover.

Congested , poorly ventilated localities and informal settlement of urban poor suffer the most due to UHI.

Increasing green cover to well distributed 25% could reduce UHI by about 1.5°C.

This could absorb 10% of carbon dioxide. And move towards net zero future.

Use of energy efficient ACs and coolers will reduce UHI by 1.5°C.

Thermostat setting at 25 °C at offices and commercial buildings will bring down electric consumption.

ACs and other appliances should be switched off from mains and not by remote. This could result in 25% saving on electricity consumption.

Building should be built according to building green codes , This will lead to reduced ACs and reduced waste heat.

Total energy saving will rise to 40 to 50% and reduced temperature of UHI by 3°C

A co-benefit will be emission reduction in Power Plants.

UHI can be further optimized by the following measures:

- Permeable pavings and walkways using alternative materials;
- Increased shrubbery along side walks;
- Berms and dividers;
- Reflective paints on roofs, walls and streets;
- Urban Hill Islands can be further optimized by
- Sharp reduction in personal vehicles;
- Scaling up of Public Transportation with electric buses.

1.6 **'Forgotten' green house gas levels surge 40% since 1980**

Anthropocene Nitro us Oxide emissions have increased massively over the last 40 years.The fertilizer that supports half of the food we consume has become one of the leading drivers of human influenced GHG emission . China, India, US, Brazil and Russia are the biggest contributors. New Global Nitrous Oxide Budget Report states. Nitrogen Fixation by leguminous plants have reached a dangerous tipping point in terms of cost benefit. Nitrogen Fertilizers (Urea,, NPK, Ammonium di-Phosphate) plus cow dunk produce 3/4 of nitrous oxide emissions. In atmosphere it is 300 times more powerful in global warming as compared to carbon dioxide (see Table 1) and nitrous oxide will deplete ozone layer also. Since 1980 its presence has been boosted 40%.

Temporal research shows nitrous oxide accumulation has accelerated in last four decades. Growth rates over the past three years 2020 to 2022 are 30% higher than any previous year. Since 1980 Fossil fuels , industry wastes and waste water and biomass burning also contribute to nitrous oxide. Population demands and growing economies provide a massive trigger for these emissions.

For net zero emissions pathways consistent with the Paris Agreement to stabilize global temperature below 2°C above pre industrial level, anthropological emission need to decline on an average by 20% by 2050 from 2019 level. The fertilizers need to be used more efficiently to mitigate emissions without compromising crop yields.

How can we make make food system more nitrogen efficient?

Earth System Science Data:

Agriculture is the second largest source of Climate Change pollution. Both manufacturing and applications of fertilizers have a heavy GHG emissions. One of the main nutrients of plants is nitrogen but it cannot be taken directly . It can be taken as ammonia from soil.

Ammonia is the second most commonly produced chemical in the World and used extensively as fertilizers but it leaves a huge foot print GHG. Ammonia manufacturing requires high pressure and high temperature and all the energy comes from fossil fuels. Ammonia manufacturing contributes 1 to 2% of world wide carbon dioxide emission.

Only half of nitrogen gets utilized by the plant the remaining half gets broken down by microbe in the soil releasing the potent GHC nitrous oxide. Nitrous oxide is only a fraction of world wide GHG emission but is more potent in global warming 300 times more than carbon dioxide (See Table 1) .

The only way to reduce fertilizer without reducing the crop yield is ORGANIC FARMING.

This reduces GHG. Fossil fuel based fertiliuzers and synthetic pesticides are prohibited. This improves soil carbon sequestration .

Soils are made in part of broken-down plant matter. This means they contain a lot of carbon that those plants took in from the atmosphere while they were alive. Especially in colder climates where decomposition is slow, soils can store—or "sequester"—this carbon for a very long time. If not for soil, this carbon would return to the atmosphere as carbon dioxide (CO2), the main greenhouse gas causing climate change.

Soil Microbes are critical to carbon sequestration

- Organic farming rely on composting , crop rotation and narural inputs to maintain and improve soil health.
- By Organic Farming water percolation improves 15 to 20%, replenishes ground water and helps crop perform well in extreme weather conditions - drought or flooding.
- Organic yield can be 40% higher in drought years.By forgoing most fossil fuel based inputs organic farmers are more resilient and adaptable not only to stressors related to climate change but also to other disruptive global stresses.

We have to go for fair, healthy and environmental friendly food system therefore Farm to Fork strategy has been adopted in EU---the green deal.

- Sustainable food systems have to be developed.
- Healthy people , healthy societies will lead to healthy sustainable planets.
- Food and Agriculture Organization of UN (FAO)
- Central to achieving Strategic Development Goals (SDG)

\Our food system is in grave danger and has to become more resilient and sustainable, as seen by the rising frequency of droughts, floods, forest fires, and new pests.

1.7 Water Vapour produces 95% of Green House effect on Earth

Data from satellites, weather balloons and ground measurements confirm that the amount of atmospheric water vapour is increasing as the global warming is setting in. UN Inter Governmental Panel on Climate Change Sixth Assessment Report states that total atmospheric water vapour is increasing 1 to 2% per decade. For every degree centigrade Earth atmospheric temperature rises, the amount of atmospheric water vapour rises by 7% according to the law of Thermodynamics. Water vapour doubles the warming effect by Carbon Dioxide alone.

There is a positive feedback cycle:

- Global warming leads to more water vapour, this leads to greater global warming.
- Thus water vapour helps maintain global warming at twice the level due to carbon dioxide alone.

All the GHG except water vapour are non- condensable hence their concentration is unaffected and remains stable inspite of global temperature changes but water vapour is condensable hence water vapour can condense to water droplets and water droplets further condense to snow and ice. If non-condensable GHG were not increasing due to man made activities and if no global warming them the atmospheric water vapour would be unchanged from the pre-industrial level.

Table 2 gives the major long lived GHG and their characteristics. Excess of Carbon Dioxide is absorbed by ocean surface. Remains in atmosphere for 1000 years.

1.8 Indian Effort towards fulfilling the Paris Agreement.[6,7]

In 2024,out of 13GW.the generation capacity of 6 GW was added in the first quarter of this year. 71.5% was renewable energy. Coal based power generation fell below 50%. Ministry of Power, Govt of India. In 2023-24, 1750 Billion Unit (BU) was generated which was 7.2% increase over 22-23. This 1750 BU (total generation) = 1324BU is coal based +156.7BU hydal+46.10BU nuclear+8BU imported from Bhutan+215BU renewable (wind + solar). June 2023, installed capacity 400GW and peak demand 230GW; Wide range of fuel is used: coal, petrol, diesal, and gas - these are fossil fuel; Renewable are Solar, Wind, bio mass, industrial waste, and large/small hydal plants.

- 2022-23 share of non fossil was 25.44%
- 2023-24 share of non fossil 22.215%;

In 2021, at COP26 Climate Summit in Glasgow India announced 5 point agenda to reverse Climate Change:

- By 2030- 500GW non-fossil energy capacity will be installed;
- By 2030- reduction of 1 billion tonnes of GHG;
- By 2030-Reducing Carbon Intensity by 45% over 2005 level;
- By 2030 - 50% will be renewable;
- By 2070 net zero emission will be achieved by India;

Data of Ministry of New and Renewable energy share on May 31st 2023:

179GW total renewable energy capacity installed = 67GW Solar + 43GW WIND+remainder from small hydal, biomass, and other resources.

2019---6% of energy mix was LNG

2030---15% of energy mix will be LNG.

1.9 International Tribunal for the Law of the Sea.[8]

In international climate change litigation, the International Tribunal for the Law of the Sea's advisory opinion represents a high point. COSIS sought the UNCLOS parties' specific climate change mitigation duties. IN light of the ICJ's upcoming advisory proceedings on states' obligations with regard to climate change, the ITLOS advisory opinion garners increased attention. The Tribunal made it very evident that in accordance with UNCLOS Article 194(1), "the parties have specific obligations to take all necessary measures to prevent, reduce and control marine pollution from anthropogenic greenhouse gas emissions". This has undoubtedly caused the emission of carbon dioxide, which is classified as a substance or energy that negatively impacts the marine ecosystem. Seawater gradually becomes more acidic as a result of the sea's absorption of about 25% of carbon dioxide. Furthermore, the water absorbs 90% of the energy produced by global warming, raising ocean temperatures and raising sea levels. The best available science, the pertinent guidelines and standards found in the 2015 Paris Climate Change Agreement, the UN Framework Convention on Climate Change, and the objective of 1.5°C rather than 2°C for the world average temperature must all be taken into consideration when determining the required actions that COSIS must take. This implies that all pollutions(GHG) must be prevented and GHG emissions must cease immediately. ITLOS has clarified that the states donot have unfettered discretion in addressing climate change. Here the decision of the Netherlands Supreme Court in *Uganda Foundation* vs *The Netherlands* is worth studying. In this case, the Court determined that the Netherlands had to cut its GHG emissions by 25% below the 199 level by 2020 in order to meet a general mitigation commitment derived from the ECHR (instead of the government's pledge of 17%). The court identified this this target largely by relying on scientific estimates and the least cost method of achieving the 2°C temperature goal in the 2015 Paris Agreement. Advisory opinion lacks legal force but as authoritative judicial pronouncement it has a moral pressure on the party concerned.

1.10 Mathematical Model for calculating the Global Warming as a result of Carbon Dioxide emission

Energy Balance Model (EBM) :

Heat absorbed by Earth = (1-α)S ……1

Where S = Incident sunlight = 342 W/m^2 and α = albedo of Earth = radiation that is reflected by Earth surface = 0.31;

Heat radiated back to outer space = e×σ×T^4……2

Where e is emissivity of Earth = 0.605;

σ is Stefan Boltzmann Constant =$5.67\times10^{-8} Wm^{-2}K^{-4}$

Equating Eq 1 and Eq 2 we get:

(1-α)S = e×σ×T^4……3

Solving Eq.3 we get :

T= energy budget equation = $\sqrt[4]{\frac{(1-\alpha)S}{e\sigma}}$ ……..4

Inserting the values of S, e, σ and σ

Equation 4 gives T = 288 Kelvin equivalent to (288-273)= 15°Celsius or 15°C.

If carbon dioxide concentration in atmosphere doubles the level at Industrial Revolution the green house effect will increase the retention of heat and imbalance will occur. Othere things remaining the same the Earth's surface temperature will increase by 1.2°C and to restore the energy balance Earth's surface temperature will become 15 +1.2=16.2°C.

While studying the global warming of Earth following factors have to be studied:

- Water vapour feed back;[Figure1]
- Cloud feed back;[Figure 2]
- Ice albedo feed back;[Figure 3]

All these feed backs contribute to Earth's average surface temperature rise up to 2 to 4.5°C.

Water vapour increase leads to greater green house effect.

Melting ice and glaciers lead to less albedo.

Changing cloudiness leads to changing green house effect. Thick low clouds reduce the sunlight reaching Earth's surface. High clouds increase the green house effect. The various feed backs would amplify the temperature rise. Temperature would rise between 2 and 4.5°C before equilibrium is restored.

Since 1950 effect of carbon dioxide , methane, halocarbon, nitrous oxide and stratosphere/troposphere ozone have been studied.

Small amount of energy has gone into warming the oceans including deep oceans.

Some heat is lost as IR radiation out in space.

IR is reflected by aerosols (pollutants in the troposphere).

Deforestation changes the reflectance of Earth's surface.

Sun's incident light changes with the seasons of the year. We will discount this.

We will focus on changes by man made activities:

Carbon dioxide level affect emissivity of Earth.

Albedo is effected by soil and vegetation.

North and South Poles have high albedo. This reduces with ice and glaciers melting.

i. *Computer Modelling*

The effects of global warming are evaluated using data and modeling. The Arctic's ice core data demonstrates a steady glacial cycle, and these findings indicate that the world is currently cooling generally. Ice ages and interglacial eras have been brought on by physical processes like Milankovitch cycles [Appendix I]. Since the concentration of greenhouse gases in our atmosphere is not included in Milankovitch cycles, which reflect the combined effects of changes in Earth's movement on its climate over thousands of years, they will not be covered by computer modeling of climate. GHG keeps the our planet habitable But today extreme changes are occurring outside the bounds of natural variation so we have to design mathematical model of Climate on Supercomputer that generate an accurate prediction of Climate in advance. Climate is a chaotic system where there are hundreds of millions of variables which affect one another in a non-linear feed back

relationship generating billions of degrees of freedom in the possible outcomes. Today we have developed capabilities which predict the weather and predict them well in advance. For this end atmosphere is split in small grid cells and average trends are calculated in each cell. There is a large uncertainty in the predictions.

ii. ***Building a Climate Model***

There are non-linear relationship between variables and these non-linear relationships cause the tipping point in the Climate where a slight shift can push Earth into entirely different climatic state. And this change may be so sudden that Earth may not be able to cope with these changes. To avoid tipping points we must fully understand the mathematical relationship between climate variables. Stephen Hawking [9] had commented,

" We are in danger of destroying ourselves by our greed and stupidity.We cannot remain looking inward at ourselves on a small and increasingly polluted overcrowded planet".

If we do manage to slow down or even reverse the damage caused by Climate Change, our unsung heroes will be the Mathematicians.

iii. ***The picture of Climate Modelling after 1970***

In 1970 Climate Model contained a limited number of variables such as carbon dioxide and rain fall. The lack of computers meant that these models could run for short periods of time. Then the era of supercomputers started and Climate modelling started in real earnest.

iv. Met Office Climate prediction Model HADCM3[10]

HADCM3 was used extensively for climate predictions, detection and attribution and other climate sensitivity studies.In 1999 this was the first climate model which required no artificial adjustments to prevent unrealistic climate predictions.

v. Climate predictive models such as NCAR from US and CCSR/NIES from Japan. [11]

Today countries across the globe have developed model such as NCAR from US and CCSR/NIES from Japan that produce climate trends upto 1000 years with incredible accuracy. But in order to make this climate modelling impactful on the societythe gap between science and policy makers must be bridged. To bridge this gap Game Theory must be used. Game Theory is a mathematical framework for analyzing strategies among competing players and is used to produce outcomes in a variety of situations including Politics.Game Theory could play a role in advising politicians on the smartest approach at reaching an International Agreement that honours the individual interest while safeguarding the sanctity of overall interest. Climate Change is a global challenge and the solution must be equally difficult if we want to safeguard the short term self interest without jeopardizing the long term future of Planet Earth. Average Global Temperature have increased over 1°C since 1880 and could increase by 4°C by the end of this century according to Met Office [12]. If this remains unchecked it will have a serious impact on our Planet. Hence to spur the public opinion for a galvinized action to reverse the Climate Change we must widely publicize that European heat waves in 2003 took a heavy toll of 20,000 people being killed.[13].

2. The Final Word on building a sustainable Planet

Our generation has the only chance to build a sustainable planet and for this unified action is required.

"One World Mathematics of Climate" is one such collective effort. It is an online platform which aims at gathering the best scientific minds from all over the world on the subject of how to achieve zero emission and zero climate change.

"Cambridge Zero Climate Change" is another collective effort for reversing the climate change. It is an eight day festival from 6th to 13th November each year offering a range of free events and sessions for all ages. It was held in 2020,2021,2022 and 2023.

Table 1.The various green house gases, GWP, percentage presence in 2017, sources and index with respect to 1990 [1].

GHG	GWP	Percentage in 2017	sources	GHG index 1990
Carbon Dioxide	×1	82%	Burning of fossil fuel (petrol,diesal, natural gas,coal).Deforestation and soil degradation (soil microbes help in carbon sequestration). The degradation leads to destruction of microbes.	1
Methane	×23	10%	Emitted during the production and transportation of oil, natural gas and coaL. Live stock release.Anearobic decay of organic waste in municipal solid waste land fills .	

Nitrous Oxide	×296	6%	Emitted by fertilizers in agriculture.	
Florinated Gas	×1000 or 10,000	3%	Used in refrigersation.	

* The knowledge of GHG sources and sinks will help make informed policy, business and regulatory deceisions

Table 2. Life times of GHG and their characteristics.[From Table 8, A.I.IPCC fifth Assesssment Report Working Group I contribution]

GHG	Average Life time	100 year global warming potential
Carbon Dioxide	*	1
Methane	12.4 years	28 to 36 times
Nitrous Oxide	121 years	265 to 298 times
Florinated gases	Few weeks to thousands years	Varies; Highest Sulfur Hexo Flouride 23,500 times

*Carbon dioxide's lifetime cannot be represented with a single value because the gas is not destroyed over time, but instead moves among different parts of the ocean–atmosphere–land system. Some of the excess carbon dioxide is absorbed quickly (for example, by the ocean surface), but some will remain in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments.

**The lifetimes shown for methane and nitrous oxide are perturbation lifetimes, which have been used to calculate the global warming potentials shown here.

EPA

In contrast, a molecule of water vapor stays in the atmosphere just nine days, on average. It then gets recycled as rain or snow. Its amounts don't accumulate, despite its much larger relative quantities.

- ***Illustrations***

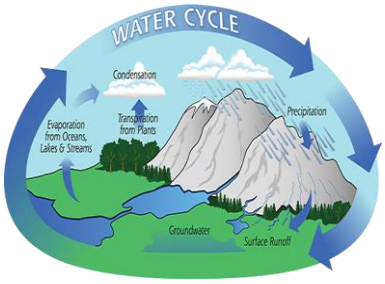

Figure 1. Water Cycle [Credit:NASA]

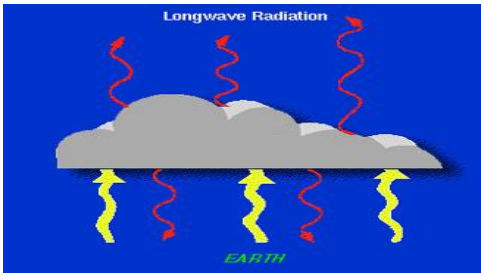

Figure 2. Cloud feed back [Credit NASA]

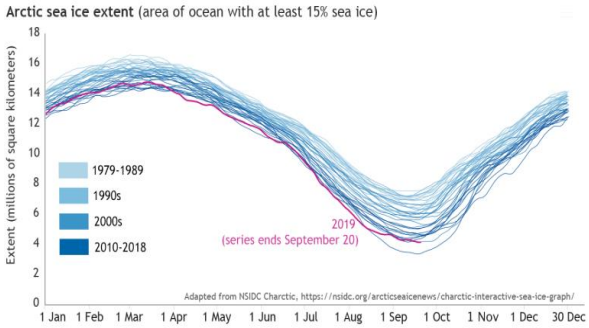

Figure 3.Ice albedo feed back.[Credit NASA]

Acknowledgements

The University Grants Commission of India's Emeritus Fellowship Scheme has enabled the ongoing study. The EMERITUS/2012-13-GEN-855/ grant number is used. I am grateful to the Director of IIT Patna for providing me with the infrastructure I needed to finish my thesis. I am grateful to the IIT, Patna team for their collaboration, which has included both material and moral support. I also thank my colleagues and the director of NIT, Patna, for their moral support as I continued my studies during the superannuation period. I also thank Prof. Bhola Ishwar, my D.Sc. supervisor, for helping me navigate this new area of astronomy and astrophysics. Last of all I acknowledge the inspiration provided by George Gamow and his book 'The story of Moon', Carl Sagan "COSMOS" and books by Issac Asimov which laid the groundwork of this paper while I was 18 years old just introduced to General Mechanics in 2-year Physics course in my first 2 years of 5-year B.Tech. integrated course at IIT,Kharagpur, in period 1962-67.

Appendix A. Milankovtich Cycles. These cycles include the shape of Earth's orbit around our Sun (the ellipticity of the orbit), the angle at which Earth's spin axis is tilted with respect to the normal of the orbital plane of Earth (the Earth's Obliquity Φ) and the direction that Earth spin axis is pointed (its precession). These cycles describe the collective effects of changes in Earth's movement on its climate over thousand of years.

Changes in orbital shape (eccentricity) follows a 100,000 years cycle.The orbital shape will affect the sunlight incident on Earth also known as insolation. This is a minor factor in seasonal change.

Changes in obliquity follows 41,000 years cycle. The obliquity varies between 22.1 degrees to 24.5 degrees. Obliquity decides the seasons.

Axial precession or wobble follows 25,771.5 years to 26,000years.

Ice Ages occur at 41,000years cycle. But subsequently it followed 100,000years cycle. It is not clear why this change occurred.

Using deep-sea sediment cores scientists found that that in past 450,000years ice-aes have occurred when undergoing different stages of orbital variations. The theory that they drive the glacial and inter-glacial cycles is well accepted by the scientific community. But these cycles do not affect the global warming.

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