Mitigation Strategies to Greenhouse Gas Emission Control: A Database for Emission Factors

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Abstract— With the advancement of Industrial Revolution, the anthropogenic activities have brought about increase in the quantities of greenhouse gases (GHGs) into the atmosphere leading to various climatic changes. The climate change is mainly caused by production of GHG emissions in the atmosphere. As the major population of the world seems to agree with the concept of 'human development' including the 'environment' factor, the various attempts for sustainability is not found to be interesting or beneficial. Therefore, the main motto of the world is to improve the standard of living by attaining suitable measures. However, most of the population on earth still do not get 'bare minimum' for development; the humanity faces the challenge of the "Climate Change". Various efforts need to address climate change through mitigation of GHG emissions and building of adaptive capacities to deal with the severe impacts of climate change.

Key words: Greenhouse gas (GHG); carbon footprint; climate change; Carbon Capture and Sequestration; Poverty mitigation

I. INTRODUCTION

Climate change is the main circumstances faced at present and it adds substantial pressure to our societies and to the environment as well. The impact of climate change has brought about drastic influence as it threaten food production due to shifting weather patterns and the upcoming flood by rising sea levels. Without drastic action today, adapting to these impacts in the future will be more difficult task and cost effective too.

The present paper depicts the data of greenhouse gas emission control and raises the related issues.

II. SOURCES

A. *Greenhouse Gases and Human Activities:*

French physicist Joseph Fourier was the first person to give the term "Greenhouse Effect" [1]. The greenhouse effect is the process where absorption of infrared radiation results in the trapping of heat through the atmospheric gases such as carbon dioxide, nitrous oxide etc. leading to heating of Earth's surface [2]. It is responsible for climate changes. According to the information of Intergovernmental Panel on Climate Change (IPCC), the increase in concentrations of greenhouse gases brought about by human activity such as fossil fuel burning, industrialization, deforestation and land degradation brings about the increase in the global temperature.

The chief greenhouse gases responsible for global warming are cited below.

1) Carbon Dioxide (CO_2):

It has been estimated that about 18 billion tonnes of carbon dioxide have being introduced into the troposphere annually. This gas absorbs heat and keeps the atmosphere warm. It has been estimated that CO_2 is 55% responsible for global warming.

2) Water Vapour:

It is another nuisance substance responsible for global warming which is detected in recent years. Though, 70% of earth's surface is covered with ocean, huge amount of water vapour evaporates into the atmosphere. It has been estimated that about 14000 cubic km. of water is available as water vapour in the atmosphere at any point of time. Water vapour retains heat and contributes significantly to global warming.

Chlorofluoro Carbons (CFCs): These are anthropogenic, colourless, odourless, easily liquefiable gases responsible for global warming. It is the stable compound and its residence time in atmosphere is around 100 years.

3) Nitrous Oxide (NO_2):

This gas also known as laughing gas decomposes slowly and accumulates in the atmosphere. In 1950, its concentration was 280ppb in the atmosphere and in about 50 years, its concentration has increased to about 400 ppb. NO2 accounts for about 5 to 6% of the total global warming.

Sink for N_2O: Sink for N_2O is stratosphere where N_2O is photochemically converted into nitric oxide which is capable of depleting ozone (O_3).

4) Methane (CH_4):

Methane is produced when organic matter decays under anaerobic conditions. The concentration of this gas is rising in the atmosphere with rapid pace. Huge quantity of methane is produced in agricultural fields. During 1950s its concentration was 1.1 ppm in air but the concentration increased to about 2ppm in 1990. Approximately 15% of global warming is attributed to methane. Sink for methane decomposition in oxidation via hydroxyl radicals in the troposphere.

$$CH_4 + {}^*OH \longrightarrow {}^*CH_3 + H_2O$$
$$^*CH_3 + O_2 \longrightarrow {}^*CH_3OO$$
$$^*CH_3OO + NO \longrightarrow {}^*CH_3O + NO_2$$
$$^*CH_3O + O_2 \longrightarrow CH_2O + {}^*HOO$$

Fig 1:

Oxidation depends upon the availability of *OH radical. Small amounts of CH_4 are lost when taken up by soils and by leakage into the stratosphere.

B. *Atmospheric Chemistry:*

The greenhouse gases are removed from the atmosphere by chemical processes within the atmosphere other than the two green house gases such as CO_2 and N_2O. The pollutants and the green house gases with one or more H atoms like CH_4, HFCs and HCFCs are eliminated by the reaction with hydroxyl radicals (OH). All these process of removal takes place in the troposphere which is the lowermost part of the atmosphere where the reaction of greenhouse gases N_2O, PFCs, SF_6, CFCs and halons do not occur at all. Instead of it the gases are destroyed in the stratosphere or the layer above it.

In 1997, the Kyoto Protocol (KP) has been signed which explains about the five kinds of greenhouse gases (GHGs) other than the CO_2, such as methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Nitrogen trifluoride (NF3) was entered to the GHG index in the second commitment period of KP, held in the Durban negotiation. Therefore in the United Nations Framework Convention on Climate Change (UN-FCCC) the six different types of non-CO_2 GHG was noticed and it was broadly classified as CH_4, N_2O, and fluorinated gases (F-gases). CH_4 and N_2O are naturally present in the atmosphere which increases due to the human activities in various forms but the F-gases are completely produced by human being in an elongated form.

C. Key indicators of global climate change:

The five key indicators show vital signs of global climate change of our blue planet. They are as followed:

1) Arctic Sea Ice:

Arctic sea ice now declining at a rate of 11.5 % per decade relative to the 1979 to 2000 average. Arctic sea ice reaches to its minimum level each September.

2) Carbon Dioxide:

CO_2 is an important heat-trapping (GHG) gas which is released through human activities such as deforestation and burning fossil fuels as well as natural processes such as respiration and volcanic eruptions.

3) Global Temperature:

In 1880 there was an increase of 1.4 deg. F(170°C) temperature, but the year 2013 tied with 2009 and 2006 for the seventh warmest year.

4) Sea Level:

Sea level rises up to 3.16mm per year which is caused by two factors related to global warming such as the water added to it coming from the melting of land ice and the expansion of sea water as it warms up.

5) Land Ice:

Data from NASA's Grace Satellite shows that the land ice sheets in both Antarctica and Greenland are losing its mass .The continent of Antarctica has been losing with more than 100 cubic km of ice per year since 2002.

III. EMISSIONS OF GREENHOUSE GASES

The emissions of Greenhouse gases in the form of carbon dioxide, methane and nitrous oxide are enormously emitted from anthropogenic activities at national level through these major sources such as (1) deforestation (2) automobile, (3) agriculture, (4) cement industry and (5) organic waste

A. Deforestation

The primary source of CO_2 emissions is the extensive use of fossil fuel, but the removal of trees from forested land has also contributed in large extent. Slow and uncertain deforestation in the developing countries is regarded as a low-cost technique for eliminating global GHG emissions.

1) Challenges in Reducing Forest-Based Emissions:

For the cost-effective role in the support of forest preservation playing an indigenous effort to eliminate global GHG emissions, three broad challenges are considered which are as followed:

- For greatest carbon stores from the woodland the helpful estimations changes ought to be gotten.
- To lessen downright woods based discharge the organizing of motivations ought to be demanded.
- Improving of administration in creating nations better results.

2) Policy Approaches for Reducing Forest-Based Emissions:

Two distinct categories pursued for the approaches to support forest-based mitigation in developing countries are given below:

- Providing both the budgetary and specialized help with safeguarding timberlands to governments inspired by it.
- For the diminishments in woodland based greenhouse gas emissions, the interest in the private segment should be made coherent.

The potential effect of funding on governance in developing countries is not clear since it depend on how governments implement the gain of the costs they acquire in designing and implementing policies to preserve forest in an adequate manner without any harm to the society.

B. Automobile

Emissions of greenhouse gas from light-duty and use of petroleum can be minimised by increasing the efficiency of the energy in vehicles, travelling to be shifted through more efficient modes, lessoning of the travelling by the changing fuels, or increasing the capacity of the vehicle in term of occupancy.

1) Policies to improve fleet fuel efficiency:

The policies for improving the efficiency face some barrier where the first three barriers are market imperfections and the last one is just a characteristic of transportation technology and markets.

- Under-priced fuels and transportation facilities
- Difficulty in creating rational decisions
- Difficulty in capturing the market advantages of technology developments
- Trade-off between fuel potency and competitory vehicle attributes

2) Technologies to improve vehicle fuel efficiency:

It has been greatly notice that new efficiency technologies will enter the fleet and that technologies recently will empower the gain in market share.

The most important technologies for improving the efficiency are as followed:

- Material replacement
- Reduction in aerodynamic drag
- Best automatic transmissions
- Reducing friction engine
- Variable Valve Timing

- Direct Injection Stratified Charge (DISC) Gasoline Engines
- Turbocharged DI Diesel Engines
- Advanced Tires
- Hybrid Electric Powertrains
- Proton Exchange Membrane (PEM) Fuel Cell Powertrains

It has been found that there are different measures to increase research and development possessing high potentials to pay for large dividends in reducing the costs of technology and increasing the overall performance. It contains major number of extent promising the high gain in efficiency with DI engines, hybrid drive-trains, and fuel cells as exclusive examples.

C. Agriculture

Agriculture plays a significant role in reducing GHG in different ways such as reducing emission through beneficial management practices, removing emission by carbon sequestration and using biomass energy in the form of animal waste or plant biomass for energy. Various strategies can be taken into accounts which are as follows:

- Mid-season waste
- Fertilizer Application
- Off season Integration of Rice straw
- System of rice Intensification (SRI)
- Replacement of roughage with concentrates
- Solutions to N_2O Emission
- Solutions to CH_4 Emission
- Replacement of bio fuels for fossil fuels

The crucial sources of GHGs are emission from flooded rice fields, enteric fermentation, manure management, burning of agriculture residues, biomass burning, etc. The actions for mitigating GHG emission takes place through different agents such as midseason drainage, off-season incorporation of rice straw, substituting urea with ammonium sulphate, replacement of roughage with concentrated feed, use of dome digester, tillage and residue management, practicing the use of bio-fuel in place of fossil-fuels, application of high efficiency fertilizer and artificial as well as participatory woodlot plantation. It has been noticed that the above proposals prefer bottom-up approaches incorporating all the recommended stakeholders and it is determined for reducing considerable amount of GHGs from the specific sectors and it is highly preferred to be safe and cost effective.

D. Cement Industry

Cement is considered as one of the most essential building materials all around the world. It is mainly used for the production of concrete in the construction field. Concrete is a mixture of inert mineral aggregates formed from the combination of sand, gravel, crushed stones, and cement. Cement production is an intensive process requiring high energy which is estimated at about 2% of the global primary energy consumption and almost 5% as the total global industrial energy consumption where the cement industry contributes to about 5% of total global carbon dioxide emissions.

E. Organic Waste

The treatment of the organic waste is generally agreed to be used as biological technologies in the process of emission where compost with the aerobic biological stabilization of organic wastes is found to be most promising constituents. The quality and quantity of materials and the variety of compost waste is increasing with rapid pace and popularity to meet the demand of the process involved.

Composting is an environmental friendly waste treatment process where organic matter is biologically degraded to generate valuable substances. The organic matter in the waste substances are consumed by aerobic thermophilic and mesophilic microorganisms as substrates and they are converted into mineralized products such as CO_2, H_2O, NH_4^+ or stabilized organic matters [3]. Similar to compost method, vermi-composting process is also a biological decomposition of organic waste to produce stabilized organic fertilizer in the form of vermi-compost. Vermi-composting processes involve interactions between earthworms and microorganisms to degrade organic waste in a rapid way and generate the product fastly [4]. The differences between composting and vermi-composting process is shown in the Table1 given below. The advantage vermi-composting process in terms of the length of the biodegradation process is that it requires less time duration to produce a good quality fertilizer [5].

Emissions of considerable amount of GHGs during composting and vermi-composting processes are leads to another pollution form such as greenhouse effect which in term of pollution is of great mismanagement. The agronomic value of the compost is lesson down when the loss of carbon (C) and nitrogen (N) takes place during the process of composting. The energy needed for the composting process in the machinery use and the biodegradation process liberates the GHGs in the form of CO_2, methane and nitrous oxide. The maximum amount of carbon releases CO_2 but only less than 6%of carbon accounts for methane and is regarded as the significant GHGs for the atmosphere. Since there are significant benefits of composting, the GHG are generated and emitted to the atmosphere during the respective process endlessly contributing to global warming.

Parameters	Composting	Vermicomposting
Type of Process	3 stages: Initial activation phase, thermophilic phase and mesophilic phase	Mesophilic stage
Organisms involved in biodegradation	Microorganisms	Earthworms and microorganisms
Organic waste characteristics	Sorted organic waste, combination of waste with similar decomposition rate	Not hard, oily, salty, acidic and alkaline
Initial C/N ratio	Between 20 and 50	30: 1 (ideal proportion)
pH	No requirement	Between pH 5 to 8
Moisture content	Coarse organic waste: 70-75%	40-55% (Preferable)

	Fine organic waste: 55-65%	
Product characteristics	Texture is coarser and may contain heavy metals	Texture is finer and heavy metals accumulated in earthworm bodies

Table 1: Differences between Composting and Vermicomposting Process.

IV. REDUCTION OF CARBON DIOXIDE EMISSIONS

Emissions of carbon dioxide are reduced by the following methods:

- Improvement in the productivity of energy amid the procedure
- Shifting to a more energy efficient procedure
- Replacing high carbon fuels by low carbon fuels
- Applying lower clinker/cement ratio
- Application of alternative cements
- Removal of CO_2 from the flue gases

The waste in spite of the fossil fuel can be responsible for reduction of CO_2 emission through 0.1 to 0.5 kg/kg cement by weight. The CO_2 emission can also be reduced by an end-of-pipe technology but for recycling of CO_2 the most important method is combustion which takes place under oxygen control.

V. RADIATIVE FORCING OF CLIMATE CHANGE

The process of radiative forcing can be represented mathematically as the equation given below. Fig 1 shows that the incoming energy is absorbed and outgoing energy is radiated which is exist in the topmost layer of troposphere i.e. in the tropopause. In the beginning, the system was balanced as the energy absorbed was equal to energy radiated.

$$Q_{abs} = Q_{rad} \quad (1)$$

Later on when the system was changed by addition of radiative forcing energy ΔQ (W/m^2), to the incoming absorbed energy, the new equilibrium is formed where the delta represent the changes in the quantity.

$$\left(Q_{abs} + \Delta Q_{abs}\right) + \Delta Q = \left(Q_{rad} + \Delta Q_{rad}\right) \quad (2)$$

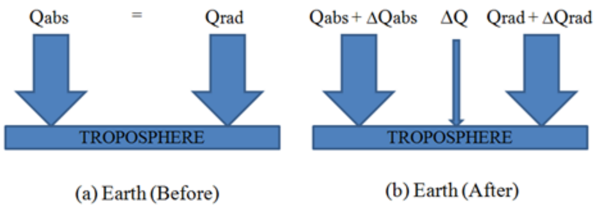

Fig. 1: Radiative Forcing, ΔQ, Perturbs the Balance Between Incoming Solar Energy Absorbed, Q Abs, and Outgoing Radiant Energy, Q Rad.(A) the Balanced Subsystem Before Perturbation (B) The Balanced System After Radiative Forcing is Added.

Subtracting (1) from (2) gives

$$\Delta Q = \Delta Q_{rad} - \Delta Q_{abs} \quad (3)$$

A. *Estimating CO_2 Emissions through Kaya Approach:*

The leading postulation on which the chances of carbon dioxide emission depends are population growth, economic factors, energy technology, and carbon cycle on itself.

One of the common approaches for solve the problems related to environment is by starting with fulfilling the impacts on behalf of population, affluence and technology and it is generally referred as the IPAT identity.

Environmental Impact= (Population) × (Affluence) × (Technology) (4)

The application of IPAT for carbon emission through various energy sources is commonly known as the Kaya Identity.

C = Population × GDP / Person × Primary Energy / GDP × carbon / Primary Energy (5)

Where

C = Carbon Emission rate (GtC /yr)

GDP / Person = GDP/P = Per-capita gross domestic product ($/person/yr)

Primary Energy / GDP = PE / GDP = Primary energy intensity, (EJ/$)

Carbon/Primary Energy=C/PE=carbon intensity, (GtC/EJ)

Equation (4) is an important aspect for motivating carbon emission through energy which includes economic and population scenarios along with the two leading factors such as energy intensity and carbon intensity. Carbon intensity is introduced before so in this context the energy intensity is discussed and it is the amount of energy required to generate a unit of economic activity estimated by gross domestic product (GDP). The energy intensity is regarded as substitute for the energy efficiency of any country. The example for it is as given Japan needs just half the energy to produce a unit of GDP, which is generally twice as that of US. But there is only the notion in reality, condition at both the places are something else. In US the larger houses are to be kept warmer in severe winters so if more energy is required it have to look after the factor that homes are better insulated or not. Japan is a small, densely populated country with relatively short travelling distances, so transportation energy would be less compared to other countries but with an equivalent level of transportation efficiency.

The Kaya identity of 2010 is shown below for identification:

C = 6.9×10^9 people × \$4,605 / person-yr × 14.9EJ / $\$10^{12}$ × 0.016 GtC / EJ = 7.6 GtC/yr (6)

B. *Global Warming Potential (GWP):*

When the comparison between the cumulative global warming impact and specific period of time is been made there needs to be some exclusive factors which guides the working that is called as The Global Warming Potential (GWP) of greenhouse gases and simultaneously going on with the emission of an equal mass of CO_2.The three factors that affects the GWPs are as such:

- The force associated with the addition to the atmosphere of a unit mass of each greenhouse gas.
- The estimation of the rate at which the unit mass injected decays over time.
- The cumulative radiative force that the unit addition to the atmosphere will have for some duration in the future.

The GWP index can be used by the help of following illustration:

- Combining the GWP with the estimation of the cost made for restricting the emissions of greenhouse gases of the individual country on their own, for the least cost approach to prevent the climatic change.
- GWPs are helpful in smooth progress of emission reduction in various countries. The condition is that countries have to decide for the least cost effective way to compensate the CO_2 emission reduction which in turn may be beneficial for reduction of emissions of CH_4 in another. The process of buying and selling international carbon emission basically leads to technology and economic transfer between the developing countries.
- The ranking of each country on their own contribution as per the climate change can be made easily possible. The scientific goal can be established on the basis of ranking made for the future reference and reduction would be possible to large extent.

Calculating the GWP

GWP is mathematically estimated as first imaging an impulse function where 1kg of the greenhouse gas and 1kg of CO_2 are emitted in the atmosphere simultaneously. It is found that as that the concentration of each gas decrease with respect to time, the radiative forcing also follows the same trends.

The mathematical expression of the GWP of a greenhouse gas is given below;

$$GWP_g = \frac{\int_0^T F_g . R_g(t) dt}{\int_0^T F_{CO_2} . R_{CO_2}(t) dt} \quad (7)$$

Where

F_g = radiative forcing efficiency of the gas $(W/m^2)/kg$

F_{CO_2} =radiative forcing efficiency of CO_2, $(W/m^2)/kg$

$R_g(t)$ = fraction of the 1 kg of gas remaining in the atmosphere at time t

R_{CO_2} = fraction of the 1 kg of CO_2 remaining at time t

T = the time period for cumulative effects in years

For some of the greenhouse gases, R_g is represented by the of a simple exponential decay function.

VI. Carbon Sequestration: A Bird's Eye View

Carbon sequestration is the storage of atmospheric carbon dioxide and carbons from other sources available to mitigate and reschedule the global warming to compensate with its effects and get rid of the climatic changes. It can serve as a helpful contrivance for lessoning the carbon emissions through fossil fuel combustion and it may also be effective for stabilizing the atmospheric CO2.

The five methods of sequestration methods are

- Oceanic sequestration
- Land ecosystem sequestration
- Sequestration in Geological repository
- Advanced biological process
- Advanced chemical process

A. *Oceanic sequestration*

The numerous of storage facility is available for carbon sequestration in the ocean. The two techniques are under practice for the carbon sequestration from the ocean such as (i) direct injection of carbon dioxide, and (ii) iron fertilization.

The intake of ocean carbon is approximately estimated as 2±0.8 Gigatons Carbon (GtC) per annum which was quite astonishing as the Researcher imagined it to be in the next 1000yrs. About 90% of the carbon emission diffused in the seas as estimated in the present era. Such process of emission through is generally termed as biological pump.

1) *Direct injection:*

Direct injection is the process of capturing of CO2 and transporting it through the narrow tubes by ending it up into ocean sequestration. The carbon is generally stored for more than 1000 of years. The deposition of CO2 occurs below 1000m depth in the thermo-cline zone.

The direct injection can be installed by different methods which are categorized as medium depth (1000-2000m), high-depth (<3000 m) and sequestration at the undersea layer. The process acts as more efficient when it goes deeper inside. Fig.2 shows the ocean carbon sequestration as given below.

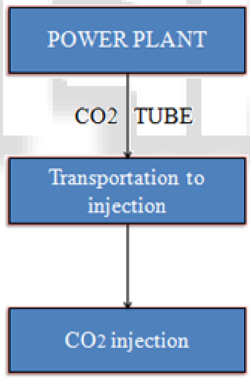

Fig. 2: (Basic Flow of Ocean Sequestration)

2) *Iron fertilization:*

The phytoplankton sequestrates carbon in the form of carbon cycle into the ocean in the natural way. The substances such as iron, nitrogen and phosphorous are considered most promising as carbon minimization technique due to the reinforcement of the biological cycle. At oceanic medium with the increase or decrease of nitrogen, phosphorous and iron contents, the phytoplankton biomass can additionally increase or decrease. IRONEX I and IRONEX II experiments carried at US Department of Energy presented that the delivery of 500kg of iron into 72km in the Pacific Ocean and resulted in a 30 times increase of the phytoplankton biomass. It also noticed that Low-scale iron fertilization was incorporated in the fish cultivation industries.

It was suggested that lacks of technical and biological limitation were there to implement the mechanism to develop the understanding. The study reveals that if the restriction is resolved, the iron fertilization may be helpful in future prospect.

B. Land ecosystem sequestration:

More than 50% of the forest is under tropic region with high rates of deforestation being carried out along with the land conservation process. The tropical deforestation with the land utility had brought significant results on the carbon cycle enhancing the rates of carbon emission in the atmosphere which had lead to the loss of carbon accumulation below and above ground, even it has reduced the storage capacity too. The tropical forest biome is referred as a net source of CO2 to the atmosphere when it is compared to mid and high latitude forests and acting as a sinks for atmospheric CO2.Clarke reported in his study that photosynthetic activity by plants was captive enough to mitigate anthropogenically produced atmospheric CO2 to large extent over wide area. In the present scenario it is found that identifying C sequestration mechanisms in the environment with the international protocols for tracking C sequestration is continuously developed and various proposal have been undertaken for managing forest lands for carbon storage. Carbon sequestration is hopefully considered as forest management strategy with numerous of economic implications, with the advent of "carbon credits." The Carbon credits are awarded to the companies as well as the country that perform to its excellence by allowing the carbon emissions to go at the negotiated level in international treaties in exchange for a proportional C sink established on the landscape.

Various techniques have been implemented to increase the carbon content in the soil and sub-soil such as 1) Enhancement of carbon density in soil, 2) increase of the mass and the depth of the trees roots, and 3) minimizing the decay rate

C. Sequestration in Geological repository:

The long term geological repository for carbon sequestration may be in the form of aquifers, petroleum fields and carbon deposits were the carbon are sequestered by employing three basic mechanisms that starts with carbon to be blocked at its gaseous form below the low permeable mineral, the same method used in natural gas storage is implemented here too which may in turn serve as very beneficial one.

The geological storage of carbon is of three types, they are as followed:

- Depleted or active oil/gas repositories
- High depth liquid arrangement and saline development
- In depth carbon dive and coal-bed methane development

D. Advanced biological process:

The process serves as the natural biological processes of carbon sequestration involving the application of new organisms and genetic improvement of land and aquatic bacteria, plants or animals. The following procedure is practised:

- Better comprehension of hereditary and and biodiversity
- Improvement of new injection system of geological carbon sequestration through microorganisms
- Improvement of option polymer bacteria or hereditary enhanced improved plants and so forth.

E. Advanced chemical process:

The advanced chemical processes are newly develop technique for carbon sequestration with an objective to convert the captured CO2 into long-term aggregates storing it efficiently in the earth's soil or water rendering high value of interest. The limitation put forward for this technology is that the stored carbon will be under pressure, without any mixtures at ambient temperature. The carbon sequestration needs the main approach in the form of transformation of carbon into aggregates such as MgCO3 but the problem with this is that materials do not have good market value and they are generally used in the refilling of magnesium mines. Therefore, ocean is the only sources where carbon is captured in the form of CO2 clathrate. Lastly the carbon released in this process is finally transformed into rubber or the plastic.

VII. LONG TERM SECURED SEQUESTRATION

The main aim of employing this technique is to transform the carbon into products that are stored safely for a long period of time. The process is based on assumption of the natural CO2 chemical transformation namely the rock corruption creating calcium and magnesium carbonates or the dissolution of the carbon into the oceans. Certain procedures are to be followed as given below:

- The transformation of natural silicates for the production of geological stable ores of carbonates and silicon

$$(Mg, Ca)_x Si_yO_{x+2y} + CO_2 \longrightarrow x(Mg, Ca)CO_3 + ySiO_2$$

Dissolution of CO2 into oceans

$$CO_2 + 2H_2O \longrightarrow H_3O^+ + HCO_3^-$$

- As CO2 is in acidic nature, they can be sequestrated with the use of an alkaline compound.

VIII. CARBON IMPRISON/CAPTURE

Carbon capture is the isolation of carbon and its storage by allowing it for further treatment. The process involves are dependent on the carbon source and its form along with its compatibility with the sequestration method. On the basis of latest research and propaganda, the carbon capture techniques are revealed to follow the steps given below:

A. Low temperature distillation
B. Chemical absorption utilizing solvents
C. Physical absorption on solids
D. Gas separation films
E. Mineralization and bio mineralization

A. Low temperature distillation:

Low temperature distillation is employed for the liquefaction process and capture of carbon from exhaust gases with high carbon content present as 90% or above which serve as an economically viable method.

B. Chemical absorption utilizing solvents

The physical or chemical absorption techniques are applied to capture the carbon from the flowing gas by utilizing the different solvent following the Henry's law. Since CO2 is acidic in nature and its chemical absorption technique is dependent upon neutralization reaction using base solvent such as alcaloamines, monoethanalomine(MEA), dietheloamine(DEA) and methyldietheloamine(MDEA). Carbon capture through chemical absorption is commercially used in the hydrogen generation industries where the carbon emission is high but yet this technique needs further development also.

C. Physical absorption on solids

This process is done on large surface solids where Zeolites one such example and are able to absorb efficiently gases such as oxygen, carbon and steam. Two basic processes are involved in this such as Pressure swear absorption (PSA) and the thermal swear absorption (TSA) where both are high expensive processes.

D. Gas separation films:

Various gas separation films are present such as polymer films, palladium films, inorganic porosity films, and metal or ceramic films etc. But the most effective and efficient gas separation films are the inorganic films which have great permeance and they are capability operated at high pressure and temperature and also in the acidic environment.

E. Mineralization and bio mineralization:

Carbon capture and storage by mineralisation (CCSM) is a technology employed for CO_2 emission reduction, where CO2 reacts with minerals to produce carbonates. It is regarded as a significant process as it possesses scalability for small/medium scale emitters, where geological storage may not be feasible [6]. CCSM offers a non-monitoring and leakage-free CO_2 storage option since it is thermodynamically stable in nature in the solid carbonates that are formed [7]. CCSM also faces some obstacles during its procedure; they are likely to be as low efficiency of mineral dissolution, slow kinetics, and energy intensive pre-treatment processes [8].

In some biological systems CO_2 are effectively utilized to produce biogenic materials. The bio mineralization is a process mimicking the process of forming various biominerals with well-defined composite structure [9,10]. The biogenic mineral component are produced from marine organisms, such as mollusks, coccolithophores, and corals through CO_2-utilization pathway using bio mineralization processes [11,12]. $CaCO_3$ is produced by such method which is commonly found in exoskeletons of algae, mussel shells, and sea urchin spines [13]. An industrial waste such as waste CO2 gas, alkaline solid wastes and wastewater were implemented as an approach to ex-situ carbonation as shown in Fig.3 and were proposed significantly. In the process the carbonates process, the gaseous CO_2 in flue gas was fixed as solid carbonates, whereas the wastewater was neutralized to a pH value of 6-7.

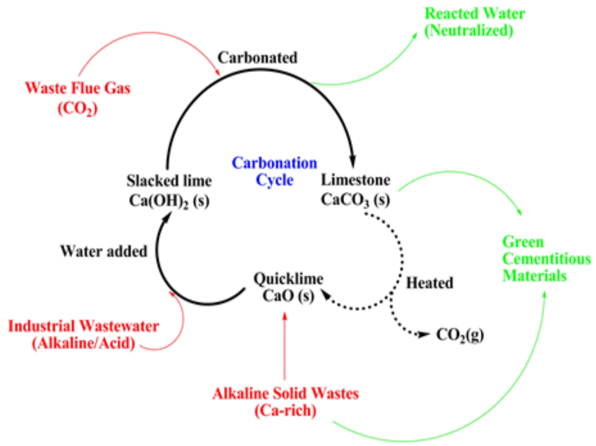

Fig. 3: Integrated Carbon Mineralization and Waste Utilization Through Accelerated Carbonation: An Innovative CCSM Process

IX. CARBON CAPTURE AND SEQUESTRATION FOR ENERGY SYSTEMS

CO_2 can be captured in various ways before or after combustion during the transformation of the fuel, or directly from the atmosphere by enhancing the natural sinks for carbon. These processes are mainly explored to use with power generation plant, but it has application in other energy-intensive industries such as oil refining and processing. A variety of technology options are potentially available in each category. Various technological options are also available in different category which is listed in Table 2.

The facilities provided depends on the technologies being applied to remove the CO_2 and the whether it is a long term storage technologies or not.

CO_2 Capture	CO_2 Storage	Carbon Sequestration
From the Energy System Central plant	Geological Storage – Depleted oil or gas fields – Deep saline reservoirs – Unminable coal seams	Terrestrial Carbon Capture and Sequestration – Soils – Trees
In production of energy carriers	Ocean storage – Mid-depth disersion – Deep lake – Hydrates	Ocean Carbon Capture and Sequestration – Fertilisation
	As a solid – Carbon – Solid CO_2 – As a mineral carbonate	Direct Recovery from the Atmosphere

Table 2: CC & S Technology Options

X. CARBON EMISSION REDUCTION TECHNOLOGIES

Combustion of coal in oxygen and carbon dioxide concentration can be directly processed where CO_2 exist as impurities and herein with air capture, a scrubbing process is needed. A various technologies has been investigated and put in use in the present scenario [14,15]. But yet most researched technology still needs improvement in terms of efficiency and cost reduction. The basic working principles and stages of maturity of such technologies are shown in Fig.4.

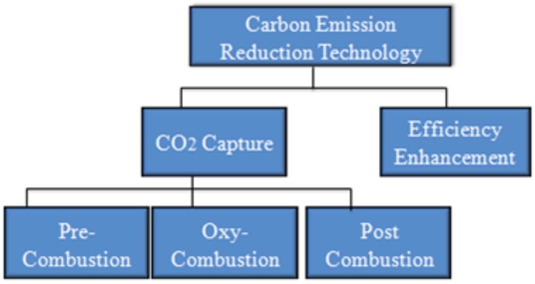

Fig. 4: Stages of Carbon Emission Reduction Technology

The challenges for CO_2 capture methods are faced in various stages are as follows. In oxy-fuel combustion capture they are as such (a) high energy consumption for supplying pure oxygen and (b) the lack of full readiness for this technology with little or no experience on a commercial basis. In pre-combustion capture, the challenges involves the following (a) high cost (b) insufficient technical knowledge for operating the system (c) lack of compact procedure for general operational execution; and (d) absence of improvement work for industrial application. For the post-combustion capture the challenges are as mentioned (a) requirement of additional energy for compression of captured carbon dioxide, (b) treatment process of high gas volumes due to low partial pressure and concentration in flue gas of CO_2 and (c) requirement of high amount of energy for regeneration of sorbent such as amine solution.

Large numbers of materials and methods to implement it have been suggested for Carbon Capture and Sequestration applications employed in post-combustion processes as substitutes for the traditional chemical absorption process. They are as follows: the utilization of membrane, physical absorbents, adsorption of the gases on solids by utilizing Temperature Swing or Pressure Swing (PSA/TSA) forms, hydrate arrangement, cryogenic refining, and the utilization of metal oxides for chemical-looping combustion and adsorption. A most significant technology of post-combustion carbon capture includes the absorption of carbon dioxide in amine solution used on industrial scale for a long period of time. For such method, varieties of other materials are also available.

Post-Combustion Carbon Capture is superior as it has various advantages such as:

- It is less demanding to coordinate into existing plant without expecting to significantly change the setup/combustion innovation of the plant.
- It is additional suitable for gas plants other than the Oxy-Combustion and Pre-Combustion plants.
- It is adaptable as its upkeep does not stop the operation of the power plant and it can be directed or measured.

Chemical Looping Combustion (CLC) is the method of combining power production with the capture of pure CO_2. The cost of CO_2 sequestration with the chemical- looping is less approximately 44-8/tonne C as compared to the cost of CO2 separation from typical flue gases which accounts to \$100-200/tonne C [16].

XI. CHEMICAL-LOOPING COMBUSTION TECHNOLOGY

Chemical –looping combustion technology (CLCT) is an original method where power production and CO_2 capture are essentially combined together by using an oxygen carrier (OC) and it comprises transferring oxygen from the air to the fuel avoiding direct contact among each other [17]. Interconnected fluidized bed systems are employed for the chemical-looping combustion technology as shown in Fig. 5.

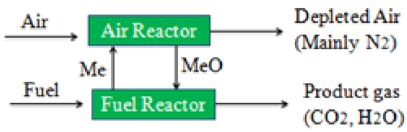

Fig. 5: Reactor Configurations for Chemical-Looping Combustion Technology

The OC particles are transported between an air reactor and fuel reactor. In the air reactor, the OC is oxidized with air and in the fuel reactor, the OC are reduced with fuel. The OC are alternately oxidized and reduced to ease the working the product gas consisting of CO_2 and water undiluted with the nitrogen gas. The oxidation of the OC is strongly exothermic in nature and so it can be used to heat air flow at high temperatures of around 1000-1200 °C and can drive a gas turbine also. During the regeneration of the OC with fuel such as natural gas, CO_2 and water are released without the production of nitrogen oxides (NOx) since the high temperatures associated with the use of flame is avoided during the process. OC is arranged of a metal oxide as an oxygen source and high reactivity in the oxidation/reduction cycles and due to this ability for the separation of CO_2, the CLCT a valuable tool in low-emission energy technology. The overall reaction is given as below:

Reduction: Mostly endothermic reaction (occuring at fuel reactor)

$$CH_4 + 4MO \longrightarrow CO_2 + 2H_2O + 4M$$

Oxidation: Exothermic reaction (occuring at air reactor)

$$M + (1/_2)O_2 \longrightarrow MO$$

Net/conventional combustion reaction

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Lewis and Gilliland [18] proposed the idea for high purity CO_2 production and prescribed the basic knowledge of the process. Later on Richter and Knoche [19] offered the principle of CLC process for increasing the thermal efficiency in fossil fired power plants. But yet, Ishida *et al.* [20] were the first ones to introduce the term of "Chemical Looping Combustion" in their thermodynamics study for reducing the loss of energy caused by conversion of fuel energy to thermal energy [21]. CLCT has various advantages as given below:

- Around 90% of CO_2 captures are carried at low cost
- Separation of water depends on cooling/compression of the product gas containing for the most CO_2 and water at procedure pressure
- No or next to no thermal NOX creation as a result of low temperature
- Compatible with sulphur and mercury capture innovations

- Heavy metals might stay with the ash
- Higher thermodynamic productivity
- No hot spots under fluidized bed innovation

As there are various advantages of CLCT, still few investigation are yet to be done on CLCT because it faces some challenges given below:

- Development of productive and stable oxygen carriers from business crude materials
- Informative gas-solid reaction kinetics and thermodynamics of chose oxygen carriers
- Application of innovation for solid fuels
- Enhancement of dust removal particularly in cases that solid fuels are utilized
- Designing dual reactors for CLC of gaseous and solid fuels.

XII. CARBON FOOTPRINT

Carbon footprint (CFP) is an environmental term used to elaborate the capacity of greenhouse gas emissions from various sources such as beverages, fuel, water, gas etc. Wiedmann [22] gave the concept about the term CFP as the emissions of CO_2 caused both direct and indirect activity of the product during the whole lifecycle. The technologies related to carbon footprint estimation are yet to be discovered, as it is emerging as a significant aspect for greenhouse gas management. The idea of carbon footprint has infused and can be commercialized in all the sectors of environment, as the definitions and calculations of carbon footprints has some stability as shown in Fig.6.

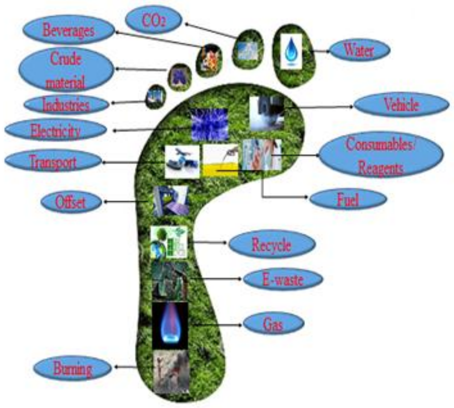

Fig. 6: The overview of carbon footprint

XIII. ADAPTATING & MITIGATING APPROACHES

1) Adapting to climate change: The susceptibility of the countries are reduced with the help of United Nations Environment Programme (UNEP) where it provides assistance to use ecosystem services for building up natural flexibility against the impact of climatic changes that occurs.
2) Mitigating climate change: UNEP supports in framing the sound policy, technology and investment choices by enabling the GHG emission reductions, and paying special attention on clean and renewable energy sources, energy efficiency and energy conservation.
3) Reducing emissions from deforestation and forest degradation (REDD): REDD is the process undertaken for developing the financial value to the carbon that are stored in forest by presenting the inducement to reduce emission in the developing countries from the lands covered by forest and invest less pathway of carbon. When the REDD+ crosses the limit it simplifies the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.
4) Enhancing knowledge and communication: UNEP is working progressively for the improvement of science on climatic change and raising the general awareness among the decision makers about the climate change and its impacts.

XIV. POVERTY MITIGATION

The change in climate may leads to reduction in poverty where it also refers to the change in development. The negative impacts of climate change are generally felt by the poor people or the under developed countries since the problem is universal. Those people are more helpless due to high dependence on natural resources where they cannot cope up with the climate change and its extreme cases. By re-establishing and maintaining the ecosystems, the communities can help themselves in the adaptation process as well as to support their life system which indeed depends on the these ecosystems. If the people shift towards the area containing low carbon they may be prone to reduce green house gas emission which may lead to improve their health problem and sustain good and healthy life with green jobs.

XV. CONCLUSIONS AND FUTURE ENDEAVOURS

Most of the developing countries are under the influence of the impacts of climate change and they are still helpless for the future prospect too. Among them many countries have adopted for the different plans to overcome the situation and have even finalised about implementing it. One of the agency is the National Adaptation Programmes of Action which they have being formulating developed countries. But yet the developing countries are still facing problems in implementing it due to various circumstances such as low human and financial capacity. At the workshop conducted for Africa, Asia and Latin America and an expert meeting for Small Island developing States in the year 2006–2007, the various areas was announced as the region for adopting the climatic change. The adaptation plans and the strategies for overcoming the situation need to be integrated into sustainable development planning and risk reduction planning at different levels namely community, local, national and international levels for an effective result. It has been found that very little work has to be incorporated to put the amenities for the poverty alleviation frameworks as they needs financial support as well as guidance. With the help of the international community by taking the stocks and good practice to implement the methods related to climate change would generally lead to develop the adaptation strategies for number of benefits. After all such process to be practised the developing countries still needs to undergo through the valuable strategies and programmes.

If the regular practised for implementation or adaptation is not done there is no sense of using any tools or technology, otherwise it would be just wastage of manpower as well as monetary power. The growth and development of any strategies should be to the limited extend or else it may cause certain upcoming issues related to it. It is truly said that human being should not only look forward for the present needs and necessity but also for the way those needs fulfilled. We also need to come in direct contact with the link to meet our demands and use the resources even how to dispose such resources for our wellbeing. For our better survival we need to work out for the consequences of climate on the nature and lesson our activities to reduce the disturbance to the climate.

REFERENCES

[1] J. B. Fourier, "Memoire sur les temperatures du globe terrestre et des espaces planetaires. Memoires de l," Academic Royale des Sciences, vol. 7, pp. 569-604, 1827.
[2] J. F. B. Mitchell, "The greenhouse effect and climate change," Rev. Geophys., vol. 27, pp. 115-139, February 1989.
[3] X. Qian, G. Shen, Z. Wang, C. Guo, Y. Liu, Z. Lei, and Z. Zhang, "Co-composting of livestock manure with rice straw: characterization and establishment of maturity evaluation system," Waste Manage., vol. 34, pp. 530-535, February 2014.
[4] Y. S. Sim, and T. Y. Wu, "The potential reuse of biodegradable municipal solid wastes (MSW) as feed stocks in vermicomposting," J. Sci. Food Agric., vol. 90, pp. 2153-2162, July 2010.
[5] S. Roy, K. Arunachalam, B. K. Dutta, and A. Arunachalam, "Effect of organic amendments of soil on growth and productivity of three common crops viz. Zea mays, phaseolus vulgaris and abelmoschus esculentus," Appl.Soil Ecol., vol. 45, pp. 78 - 84, June 2010.
[6] K. S. Lackner, and H. J. Ziock, "From low to no emissions," Mod. Power Syst., vol. 20, pp. 31-32, March 2000.
[7] Goff and K. S. Lackner, "Carbon dioxide sequestering using ultramafic rocks," Environ. Geosci., vol. 5, pp. 89-102, September 1998.
[8] K. S. Lackner, C. H. Wendt, D. P. Butt, E. L. Joyce, and D. H. Sharp, "Carbon dioxide disposal in carbonate minerals," Energy, vol. 20, pp. 1153-1170, March 1995.
[9] X. Y. Shen, A. M. Belcher, P. K. Hansma, G. D. Strucky, and D. E. Morse, "Molecular cloning and characterization of lustring A, a matrix protein from shell and pearl nacre of Haliotis rufescens," Journal of Biological Chemistry, vol. 272, pp. 32472 – 32481, December 1997.
[10] A. Lowenstam, "Minerals formed by organisms," Science, vol. 211, pp. 1126-1131, March 1981.
[11] R. A. Freely, C. L. Sabine, K. Lee, W. Berelson, J. Kleypas, V. J. Fabry, and F. J. Millero, "Impact of anthropenic CO_2 on the $CaCO_3$ system in the oceans," Science, vol. 305, pp. 362-366, July 2004.
[12] A. Kleypas, R. W. Buddemeier, D. Archer, J. P. Gattuso, C. Langdon, and B. N. Opdyke, "Geochemical conswquences of increases atmospheric carbon dioxide on coral reefs," Science, vol. 284, pp. 118-120, April 1999.
[13] Y. Politi, T. Arad, E. Klein, S. Weiner, and L. Addadi, "Sea urchin spine calcite forms via a transient amorpjous calcium carbonate phase," Science, vol. 306, pp. 1161-1164, November 2004.
[14] Li, P. Xiao, D. Xu, and P. A. Webley, "Dual mode roll-up effect in multicomponent non-isothermal adsorption processes with multi-layered bed packing," Chem. Eng. Sci., vol. 66, pp. 1825-1834, May 2011.
[15] R. Li, Y. Ma, M. C. McCarthy, J. Sculley, J. Yu, H. K. Jeong, P. B. Balbuena, and H. C. Zhou, "Carbon dioxide capture-related gas adsorption and separation in metal-organic frameworks," Coord. Chem. Rev., vol. 255, pp. 1791-1823, August 2011.
[16] B. Moghtaderi, "Review of the recent chemical looping process developments for novel energy and fuel applications," Energy Fuels, vol. 26, pp. 15-40, 2012.
[17] B. Acharya, A. Dutta, and P. Basu, "Chemical-looping gasification of biomass for hydrogen-enriched gas production with in-process carbon dioxide capture," Energy Fuels, vol. 23, pp. 5077-5083, September 2009.
[18] W. K. Lewis, and E. R. Gilliland, "Production of pure carbondioxide," United States Patent and Trademark Office, Patent No. 2,665,972, 1954.
[19] Richer, and K. F. Knoche, "Efficiency and costing-second law analysis of processes," ed: Gaggioli, R.A., ACS Symposium Series, Washington D.C., vol. 235, pp. 71-85, 1983.
[20] M. Ishida, D. Zheng, and T. Akehata, "Evaluation of a chemical looping combustion power generation system by graphic exergy analysis," Energy, vol. 12, pp. 147-154, February 1987.
[21] Adanez, A. Abad, F. Garcia-Labiano, P. Gayan, and L.F. de Diego, "Progress in chemical-looping combustion and reforming technologies," Prog. Energy and Combust. Sci., vol. 38, pp. 215-282, April 2012.
[22] T.M.J. Wiedmann, "A definition of carbon footprint dunham," United Kingdom: ISA UK. Research Report 07-01, June 2007.