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A Review on Climate Change, Decarbonization and Carbon Capture and Sequestration

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ABSTRACT: Carbon footprint has become an extremely used term in the past few years as climate change has become an apex hierarchical agenda for political and industrial system across the world. Carbon footprint can be further outlined as the magnitude of greenhouse gases produced in our day to day lives which is proportional to the activities that we undertake and pose a threat to the environment. To tackle global climate changes, various methodologies have been utilized by international forums, nations and organizations. In this paper, efforts have been made to understand the impact of carbon emissions and how decarbonization and Carbon Storage and capture amongst various other methods can be done to achieve such outcomes.

KEYWORDS: Carbon footprints, Decarbonisation, INDC (Intended Nationally Determined Contribution), GHG (Green House Gases), Carbon capture and storage.

I. INTRODUCTION

.Greenhouse gases are a group of compounds that are able to trap heat and long wave radiation in the atmosphere keeping the earth's surface warmer than it would be if they were not present. Increase in the amount of GHG in the atmosphere further aggravates the greenhouse effect which is responsible for global warming and climate changes. The term carbon footprint is quite vague in nature. However, the most acceptable of definitions is the measure of greenhouse gases produced by our day to day work which is proportional to the climate change. Is the major factor which is taken into account while calculating carbon footprint. Moreover, global carbon footprint cannot be measured or quantified because of the large amount of data that is required and various sources of CO2 be it natural or man- made. The average global carbon footprint is approximately 4 tons of CO2 eq per year.

Fig.1. World bank 2013 data: Co2 emissions metric tonnes per capita

II. TYPES OF GHGs

Greenhouse gases can be emitted through transport, natural causes, fossil fuel burning and deforestation. Most abundant greenhouse gases based on Global Emissions Report are:

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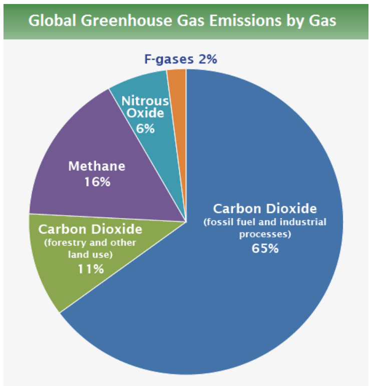

Fig.2. Breakup of GHG emissions

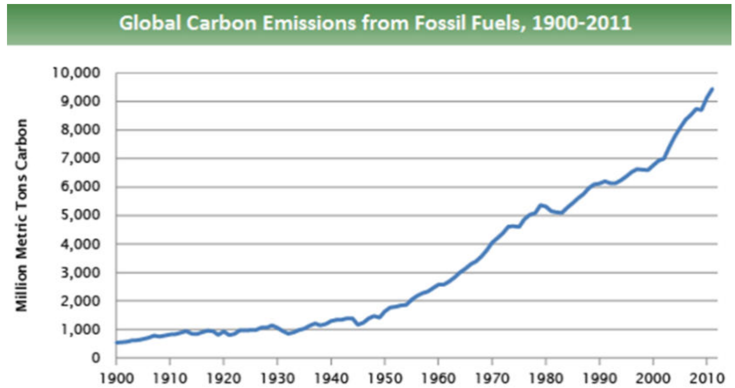

Table.1. Global Carbon emissions (1900-2010)

Carbon Dioxide (CO2): The most dominant form of greenhouse gas in the earth's atmosphere CO2 exists in earth's atmosphere as a trace gas at a concentration about 406.2 ppm as on February 2017, according to Mauna Loa Observatory, Hawaii. Fossil fuels use is considered as the primary source of CO2. CO2 is also emitted from human interference and impacts on land such as deforestation, land clearing, burning of waste products and degradation of soil.

Methane (CH4): It is one of the most potent greenhouse gases as it has 28 times the impact of CO2 emission over a period of 100 years. The main natural sources include the wetlands, oceans and fossil fuel extraction sites. Humans contribute to methane levels by fossil fuels burning, landfills by dumping waste and biomass burning.

Nitrous Oxide (N2O): Agricultural activities, fossil fuels combustion and various industrial processes account for nitrous oxide emissions.

Fluorinated Gases (F-gases): Industrial processes, refrigeration and other departments contribute immensely to the emissions at F-gases which include Hydrofluoro-carbons (HFCs). The use of Chlorofluorocarbons has been discontinued due to its deteriorative effect on ozone layer.

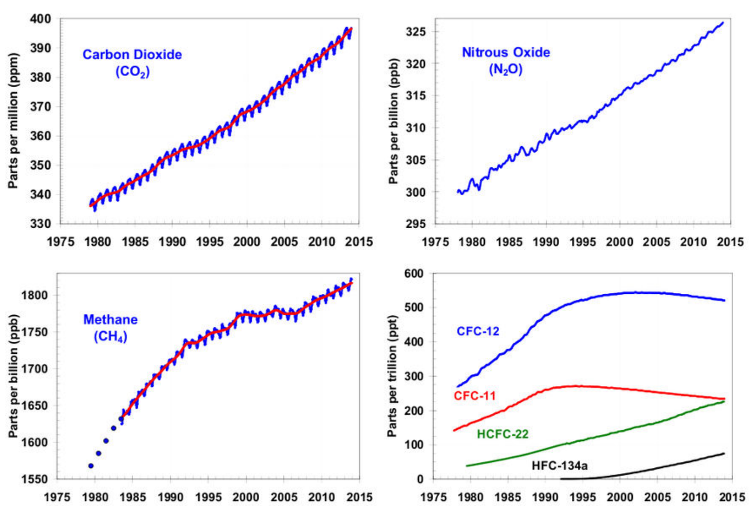

Fig.3. Increasing trends (ppm) in major GHGs

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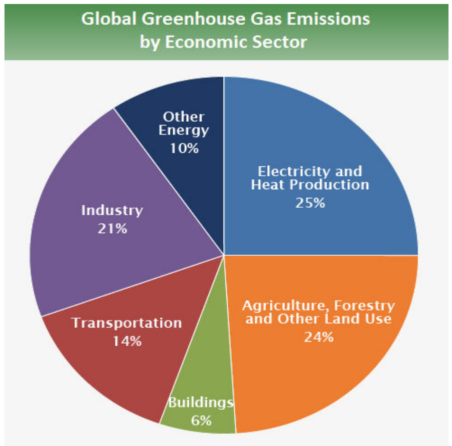
III. GLOBAL EMISSIONS BY ECONOMIC SECTOR



Electricity & Heat Production: These Elements accounts for 1/4th of the total planetary Greenhouse gas emissions. The extensive Combustion of Fossil fuels like Natural Gas, Petroleum, coal etc. in order to generate electricity & thermal energy is substantially the gargantuan source of global greenhouse gas emissions.

Industry: The fundamental emission of Greenhouse gases is due to spontaneous combustion of Fossil fuels in order to generate thermal energy. The subordinate peripheral source for GHG is also due to the wielding of Chemicals, metallurgical, & mineral transformation. The respective sector accounts for about 1/5th of the total global greenhouse gas emissions.

Agriculture & Forestry: The cultivation of plants, livestock rearing and Deforestation accounts for about 1/4th of the total Greenhouse gas emission. Accompanying the magnitude of greenhouse gases absorbed by the ecosystem isolating carbon.

Transportation: The primary combustion of fossil fuels in order to generate enough energy to facilitate transportation through air, land and water. 10% of the entire global emission is fundamentally through the transportation sector.

Buildings & Construction: Approximately 1/10th of the total GHG emissions is due to the thermogenesis of fossil fuels used to isolate heat for cooking & other necessities.

No.	GHGs	GWP (100-year time horizon)	
		SAR*	TAR*
1	Carbon dioxide (CO_2)	1	1
2	Methane (CH_4)	21	23
3	Nitrous oxide (N_2O)	31	296
4	HFCs	140–11,700	120–12,000
5	CFCs	6,500–9,200	5,700–11,900
6	SF	23,900	22,200

*SAR, TAR: Second Assessment Report, Third Assessment Report

Source: *Report on Climate Change and International Security*. Council of European Union, Brussels, 3 March,

Table.2 Global Warming Potential of major GHGs

IV. GLOBAL ACTIONS TAKEN

Climate change negotiations go way back in 1992.The United Nations Framework Convention on Climate Change (UNFCCC), the United Nations body which is responsible for climate is responsible for organizing an international annual

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climate change conference called the Conference of Parties or COP. Intergovernmental Panel on Climate Change (IPCC) submitted 5th assessment report AR5 on anthropogenic global warming coming to a conclusion that greenhouse gases need to be checked and carbon fuel free world economy should be achieved by 21st century. The 20th COP took place in Lima, Peru, from 1 to 12 December 2014, as Kyoto Protocol was expired in 2012 but the meet was not fruitful at all. In 2015, COP 21 was held in Paris, France, from 30 November to 12 December 2015. The conference was highly successful as it was able to negotiate the Paris Agreement, a global agreement on the reduction of climate change. The agreement will come into existence when it is to be joined by at least 55 countries which together represent at least 55 percent of global greenhouse emissions. Many countries signed the agreement in New York, and began adopting it within their own legal systems (through the process of ratification, acceptance, approval, or accession). Till now 134 parties have ratified to the convention out of 194 signatories.

The Paris Agreement's central aim is to prevent a global temperature rise this century and contain it to well below 2 degrees Celsius above the pre-industrial levels and to further the efforts required to limit the temperature increase even further to 1.5 degrees Celsius. Moreover, the agreement aims to strengthen the bond and the ability of participating countries to deal with the harmful effects of climate change. Appropriate financial flows, a new technology framework and an enhanced capacity building framework thus support the action by developing countries and the vulnerable countries, which is also in line with their national objectives. In the long run, agreement calls for zero net anthropogenic greenhouse gas emissions to be reached during the second half of the 21st century.

V. REPORTS

The sustainable level of GHG emission is about less than 2 ton per CO2 equivalent per person per year.

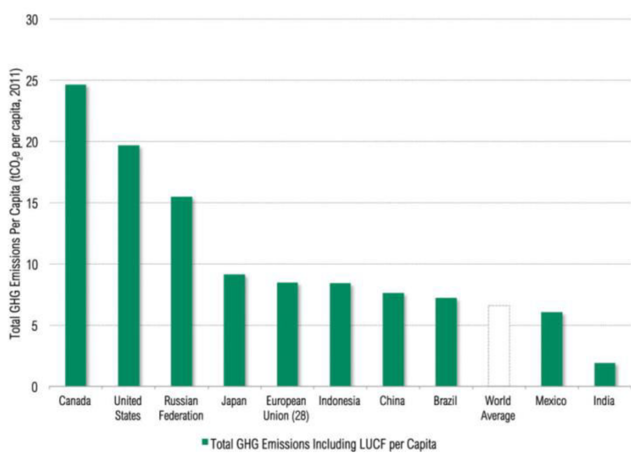

Fig.4. Per Capita Emission of top 10 emitters, 2011

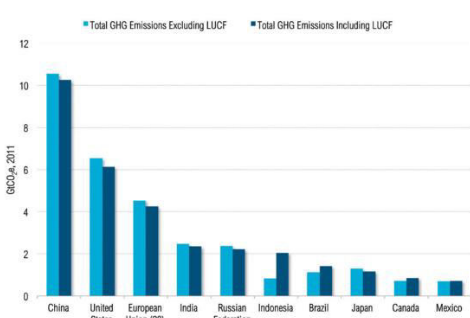

Fig.5. Top 10 Emitters in the World

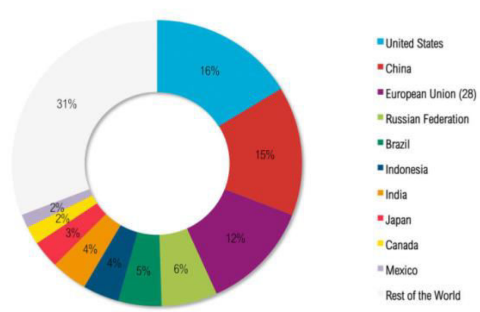

Fig.6. Cumulative GHG Emissions 1990-2011 (% of World Total)

Cumulative Emissions refer to the country's total historic emissions. They are commonly used in order to understand the full responsibility of for the climate change caused by specific countries. About 50% of the emissions were from the following countries:

United States
China
European Union
Russia

VI.REDUCING CARBON FOOTPRINTS

ELECTRICITY: Switch to a renewable electricity supplier or utilize renewable energy in the form of installing appliances such as Solar PV Cells. Buy 5star rated electrical appliances. Switching to energy saving light bulbs, such as LED Bulbs as they have longer operational life and high energy efficiency. Items left on standby can use up to 85% of the energy they would use if they are fully switched on, so it is better to turn them off in order to avoid wasting of energy**.**

WATER SAVING: Heating the amount of water that is required and not wasting it is essential as it can be reflected in both water costs and water heating costs. Try to have a shower instead of a bath, which uses far less energy and water also has carbon footprint, thus using water judiciously is a part of solution.

DRIVING: Anticipate road conditions, adapt and drive smoothly as this saves fuel, reduces accident rates and is also economical. The most efficient speed depends upon the car in question but is typically around 55 – 65mph. Faster speed will greatly increase your fuel consumption Switch the engine off if it is stuck in a traffic jam expected to be there for more than a minute or two. This would help save fuel and reduce emissions.

OFFICE: Use the lights only when it is needed. Install occupancy sensors in the building. Try to print double-sided – or even print multiple pages to a sheet Also try sharing resources such as car-pooling to get to work

EMISSION TRADING: It provides a financial incentive for organizations and corporations to reduce their carbon footprint. Organizations that emit less carbon than their predetermined emission target can also sell their 'excess carbon emissions' thus earning additionally

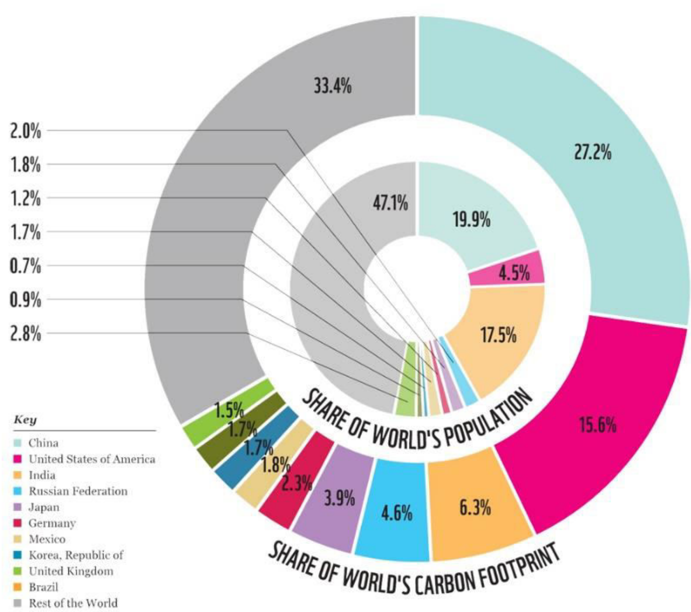

Fig.7. Breakdown of Carbon Footprint

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VI. INDIA's INDC

Intended Nationally Determined Contributions i.e. INDC are the climate action plans submitted by each country ahead of the COP21. They outline how, and by how much, countries are willing to reduce their emissions, and the actions they will undertake to strengthen climate resilience and achieve their targets in stipulated time**.** India is the world's third-largest emitter and is also highly vulnerable to the impacts of climate change. India's INDC has set an ambitious target of installing 175 gigawatts (GW) of renewable power capacity by 2022 by setting a new target to increase its share of non-fossil-based power capacity from 30 percent today to about 40 percent by 2030 (with the help of international support).
India also committed to reduce its emissions intensity per unit GDP by 33 to 35 percent below 2005 by 2030 and thereby creating carbon sink of 2.5 to 3 billion tonnes of carbon dioxide through additional tree cover and planned afforestation.
Clear Signal for Clean Energy Generation: Achieving the target of 40 % non-fossil-based power capacity by 2030 would result in at least 200 GW of cumulative renewable power capacity by 2030. However, India has an ambitious target of achieving 175 GW of power renewable power energy by 2022, mainly 100 GW from the solar department. It is worth pondering that the world's entire installed solar power capacity was about 181 GW, and it would clearly position India as a major renewable power.
Emissions Intensity Target would further increase: India's emissions intensity (CO_2 emissions per unit of GDP) has declined approximately 18 % between the time period 1990 and 2005. India is also committed to reduce it, without any obligations, by another 20-25 percent from 2005 level by 2020. The new INDC target commits India to go further up to 33-35 % from 2005 by 2030.
Increasing Forest Cover: Restoring forest cover aggressively would lead to creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 through additional forest and tree cover. This would cause average annual carbon sequestration to increase by at least 14 percent over the next 15 years relative to the 2008-2013 period, thus playing an important role in the efforts towards climate change.

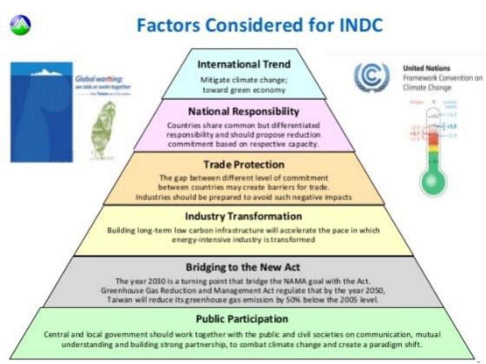

Fig.8. Factors essential for INDC(UNFCC)

VII.DECARBONISATION

The reduction ofgreenhouse gas (GHG) emissions produced as a result of various energy sources including emissions released directly during transport & due to the production of transport, from the production of electricity from major conventional energy resources. The decarbonisarion of the power sector means reducing the carbon intensity that is, the emissions per unit of electricity generated (often measured in grams of CO_2 per kWh). Proper decarbonisation of the power sector can be achieved by increasing the share of low-carbon energy sources, like renewables and nuclear, as well as by capping greenhouse gas emissions from fossil fuel power stations through Carbon Capture and Storage (CCS) devices, A gradual shift from 'dirtier' fossil fuels, like coal (which emits on average 900g CO_2/kWh) to lower emissions fuels like natural gas (which emits about 400 g CO_2/kWh) or renewables utilizing solar or wind energy alongside the functional power plant can also further reduce these emissions.The transport sector plays a major role in carbon emissions and constitutes 23% of energy related CO_2 emissions all over the world and 13% of all greenhouse gas emissions. Some measures that can be taken to help achieve decarbonization are Avoid/Shift/Improve: A mix of policy, technology and behavioral policies to understand and grasp the required knowledge in order to move forward; Modal Shift: shift inclined more towards using

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public transport as a medium for long distances; Commercial Speed and Reliability: Increase in commercial speed further increases the reliability factor and can lead to less energy consumption.

Solar Prospect

	Coverage	Rooftop (MW)	Ground (MW)	Total (MW)
Phase 1	Gujarat & Rajasthan	25	50	75
Phase 2	Nine states	60	660	720
Phase 3	Rest of India	400	3,800	4,200
				~ 5,000 MW

Table.3. Plans for solar deployment for Indian Railways up to 2025. Credit: UNDP

Indian Railways, which carries about 23 million passengers every day has set a target of achieving 5GW of solar by 2025 in partnership with global development organization UNDP. The target is to be realized using vacant Indian Railways land and rooftop spaces. Indian Railways account for more than 2% of India's entire electricity consumption, thus consuming about 2.6 billion litres of diesel annually leading to a huge proportion of CO2 being released into the atmosphere. It already has planned to reach 1GW of solar by 2020.The first 500MW of solar will be placed on rooftops using Central Finance Assistance (CFA) from the Ministry of New and Renewable Energy (MNRE) with the other 500MW set for ground-mount in the vacant lands. Out of them,15 MW of PV has already been deployed.

Global call for decarbonisation is the right message. The low-carbon transformation needs to happen largely by the middle, not the end, of this century in order to fulfill UNFCC, COP21 and other internationally agreed climate goals objectives in the long run.

Transforming energy: The recipe for a low-carbon energy system has three essential ingredients. Achieve radical improvements in energy productivity or the amount of economic output per unit of the energy used by a particular organization. Carbon needs to be taken out of the energy supply. It can be started by replacing coal and gas in the electricity sector with renewable sources and nuclear power, and using new advancements such as carbon capture and storage where feasible. Direct fuel use should be somehow converted and shifted to decarbonised electricity to further the process. For example, by adopting electric cars.

Biggest Challenge: Carbon-free energy supply is clearly difficult to achieve as the world's overall energy system is heavily dependent on fossil fuels such as coal and oil which accounts for about 30% each of total energy supply, and gas for another 20%. Low- or zero-carbon energy sources together account for the remaining 20%. Falling cost of renewable energy sources is an important key. The economies of the future need to be less polluting, less materially intensive and have a holistic approach towards the environment if sustainable growth has to occur.

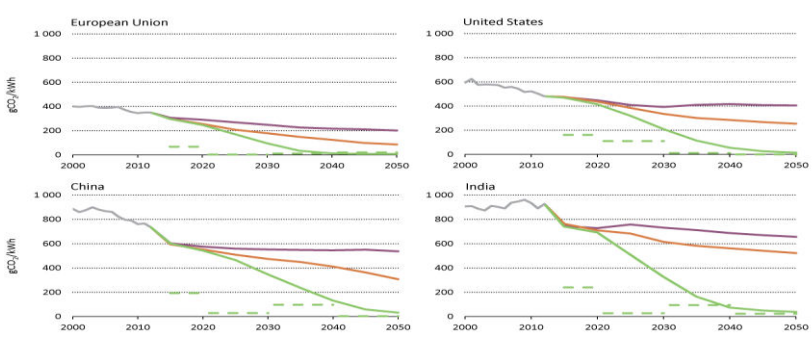

Table.4. Deep decarbonization Pathways Global Power sector fleet average and new-build plants emissions intensity

VII. CARBON CAPTURE AND SEQUESTRATION

Reduction of carbon dioxide in the atmosphere through various steps is carbon sequestration. Carbon dioxide (CO_2) capture and sequestration (CCS) is a set of technologies that has the potential to greatly reduce CO_2 emissions from thermal (using coal) and Gas fired power plants along with many large industrial sources of CO2 emissions.

CCS is a three-step process that includes: CO_2 capture from the power plants or industrial processes, Transport of the captured CO_2 which is compressed to the required size by pipelines. It can also be transported by train, truck, or ship

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depending upon the distance. Underground injection and permanent storage of the captured CO_2 into deep underground rock formations and other cracks. These include the depleted oil and gas fields, deep coal seams, and saline rock formations. Carbon dioxide (CO_2) capture and sequestration (CCS) could play an important role in reducing greenhouse gas emissions, while enabling low-carbon electricity generation from power plants.CO2 sources include thermal and gas based fired power plants, and also ethanol and natural gas processing plants

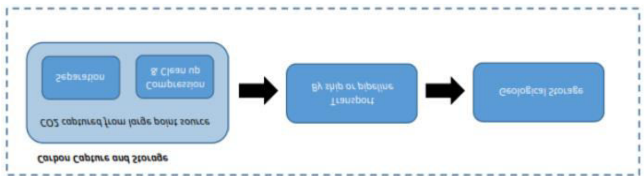

Fig.8. Carbon Capture and Sequestration Flow Diagram

CAPTURE: CO2 capture is done to produce a concentrated stream that can be easily transported to CO2 storage site. It is generally applicable to Power Plants and large industries. These techniques also open pathways for production of low carbon or carbon free electricity and fuels. 3 different configurations of technologies for capture are utilized: Post-Combustion, Pre-Combustion, and Oxyfuel Combustion

POST-COMBUSTION: CO2 can be captured from the exhaust of a combustion process by the process of absorption in a suitable solvent. For example, combustion of a fossil fuel. Here, carbon dioxide is captured from flue gases in a thermal or gas fired power plant. Post combustion capture is the most popular in research because of the fact that existing fossil fuel power plants can be retrofitted properly to include CCS technology and they run effectively.

PRE-COMBUSTION: This method involves first converting the fuel (solid, liquid or gaseous) using various processes such as gasification leading to partial oxidization. The resulting mixture or syngas (CO and H_2) can be converted into CO2 and H2. The CO2 thus formed is removed prior to combustion. H_2 produced as a byproduct can be used as fuel. This method is utilized in new fossil fuel burning power plants, or in some existing plants where there is an option for re-powering.

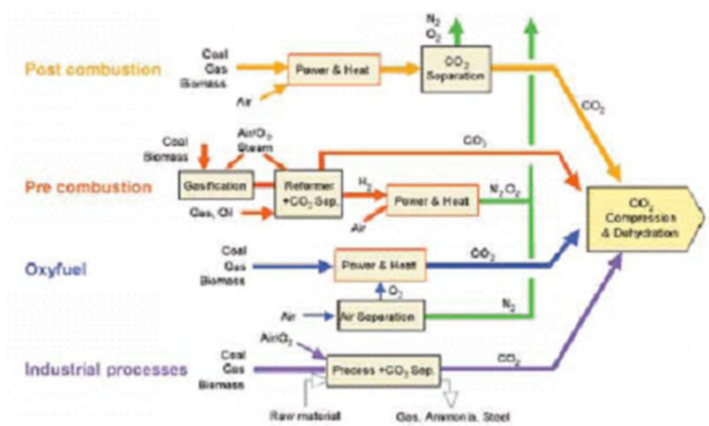

Fig.9. Layout of various type of configurations in a CCS plant.

OXY-FUEL COMBUSTION: In this configuration, the fuel is burned in oxygen instead of air. The oxygen required is separated and is diluted with recycled flue gas and the fuel is combusted in the chamber. This provides an oxygen rich and almost nitrogen free atmosphere which results in an almost pure carbon dioxide stream that can be easily transported to the sequestration site and stored. The technique is very promising, but the initial air separation and water disposal towards a zero-emission cycle step demands a lot of energy.

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TRANSPORT: Once CO2 is captured it must now be shifted or transported to a storage area.CO2 is compressed to about 150 times the atmospheric pressure, making it dense and can now be easily transported and stored efficiently. Thus, it becomes a supercritical fluid. This can be transported by pipelines and ships for longer distances.

STORAGE: Permanent storage can be done in various forms. The gaseous form of storage is done in deep geological formations and depleted gas fields. Solid form is stored by reaction of CO2 with metal oxides thus producing a stable carbonate.

Solid Hydrocarbons

a) Efficiency	:	30%
b) Load Factor	:	70%
c) Emission Factor	:	0.94
d) Fuel Split	:	90%
e) Input Fuel	:	Coal

Gaseous Hydrocarbons

a) Efficiency	:	42%
b) Load Factor	:	70%
c) Emission Factor	:	0.47
d) Fuel Split	:	10%
e) Input Fuel	:	Natural Gas

Table.5,6. Solid and Gaseous Hydrocarbon in a CCS Plant.

VIII. FUTURE OF CCS IN INDIA

Power plant in Tuticorin leads from the front in innovation in this field. Here the captured CO2 from its own boiler is used to make baking soda This is a major advance for carbon capture technology as for decades it has languished and suffered under high costs and lukewarm government support. The technology is attracting interest from around the world. This plant is said to be the first unsubsidized industrial scale example of carbon capture and utilization (CCU) as it has overcome the problem by using a new CO2-stripping chemical. It is considered to be slightly more efficient than the current CCS chemical amine, but it's investors also claim that it needs less energy, is less corrosive, and requires much smaller equipment thus affecting the overall cost as the build cost is much lower than for conventional carbon capture. Baking soda is formed as an end product. It is a base chemical with a wide range of uses including glass manufacturing, sweeteners, detergents and paper products

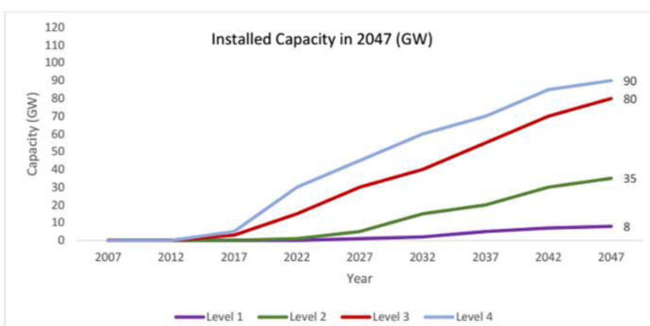

Fig.10. Different levels of Power Capacity

Level 1: There will be no planned generation plants with CCS till 2025 and CCS technology deployment rate will be less. Generation with CCS usage will start to increase from 2025 at a very less pace due to lack of efficient and cheap technology and will increase to 8 GW till 2047. The electricity generated will rise from 0 TWh in 2012 to 42 TWh in 2047.

Level 2: Generation with CCS usage will be deployed at a slow rate. India will follow US projections with a time lag. Generation with CCS will rise from 1 GW in 2022 to 35 GW in 2047. Electricity generation in 2047 will be 185 TWh.

Level 3: India will see a growth in the number of CCS equipped capacity. The absolute growth rate in capture equipped capacity occurs between 2030 and 2040. According to IEA roadmap for CCS technology 2013, India will target generation capacity with CCS of 3 GW till 2022 and will increase to 80 GW till 2047 which will ultimately generate 423 TWh of electricity in 2047.

Level 4: Upgradation of technology and reduction in capital requirement will result in deployment of more generation plants with CCS technology. Construction of India's own demonstration scale facilities will begin and more ambitious CCS projects will be considered. India will target generation capacity with CCS of 5 GW till 2022 and will increase to 90 GW till 2047. The electricity generated would be 476 TWh in 2047.

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IX. DISCUSSION AND WAY FORWARD

Fossil fuels will tend to occupy a major portion of India's energy until 2047. As long as fossil fuels and other carbon intensive industries remain dominant, Carbon capture and storage (CCS) (or carbon capture and sequestration) are essential in order to reduce carbon footprint of the existing Power sector which is directly proportional to the dependency over the fossil fuels. Also, Migration to 2°C or below is possible but requires early action to keep it cost effective. 60–80% share of Planetary primary energy will need to be a result from low-carbon options by 2050. The Power sector will need to be almost entirely decarbonized by mid-century (low carbon shares of 3/4th of the total. Acquiring an entire decarbonisation magnitude of the Power sector shall require a complete codex of technologies. It will be required to achieve negative emissions later in the decade and fossil fuel will have to be phased out as an entirety without CCS will need to be completely phased out by 2050.

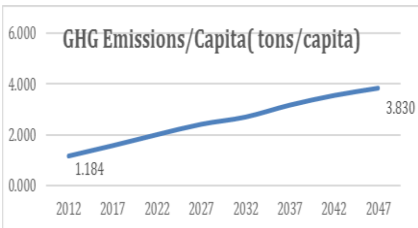

Fig.11. India's projected GHG Emission per capita.

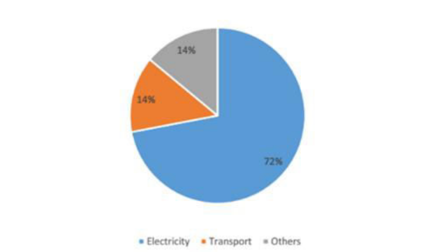

Fig.12. Energy breakup of CO2 emission in India

It is projected that developing economies will have a 75% share of the global increase in the carbon emissions from the period to 2030.Delays or removal of general technologies makes the requisite levels of migration harder to achieve and more expensive. There are various regions where there are significant variations between models used and the comparisons between variable reports are therefore hurdled. Variations between models include differences in socio economic relations, therefore, technology constraints are formed. There is a potential large variation in efficiency and cost of mitigation policies between different countries within the same regional block. Even though introduced in some projects, energy efficiency improvements are highlighted as an individual case excluding the details in technology, costs and deployments in the same way that can be found for the supply side changes. For achieving climate targets low energy intensity on the demand side is important enough to bring more focus on it within the pathway descriptions. The decarbonisation of the Power Sector is defined by the reduction of Carbon emission on an extremely large scale through other renewable sources. A spontaneous decarbonisation of the power sector can be acquired through increasing the allocation of low-carbon energy sources, like hydro, wind and nuclear, as well as by capping greenhouse gas emissions from fossil fuel power stations through Carbon Capture and Storage (CCS) devices, once the technology becomes available. A shift from 'dirtier' fossil fuels, like coal, to lower emissions fuels, like natural gas or renewables, can also help to reduce power plant emissions.

X. CONCLUSION

This paper highlights the various factors that have led to the climate change globally, also the various steps taken for reducing carbon footprint. Global warming is the result of increase in the earth's average surface temperature due to greenhouse gases like carbon dioxide and methane. Apart from CO2 some other gases like methane, N2O etc. also contribute in rise of temperature, reduction of snow cover and rise in water level. Various global actions like going way back to 1992 the UNFCCC calling an international annual climate change conference called as Conference of Parties(COP). In 2015, COP 21 took place in Paris, France from 30 November to 12 December 2015. It was a highly successful conference as it was able to negotiate Paris Agreement, a major step in reduction of climate change. Also, to tackle climate change it requires aggressive and prompt action. One such action taken is CCS (Carbon Capture and Storage). CCS has a valuable role to play in the climate mitigation portfolio, alongside other solutions. Extensive research has shown that this can be done safely and effectively, with the right regulatory oversight. Government have a pivotal role to play in enabling CCS deployment through complementary policies that include limits and a price on carbon emissions, incentives for early development etc. India has put forward a well-balanced climate plan that alongside its renewable energy goals will generate transformational changes. These actions are also being proposed alongside an aggressive development agenda.

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