

CARBON CAPTURE AND SEQUESTRATION

K D HARSHARAN*, CHINNAPAGA BABU**

PG SCHOLAR*, ASSISTANT PROFESSOR**

GANDHI ACADEMY OF TECHNICAL EDUCATION

(Approved by A.I.C.T.E, New Delhi Affiliated to JNTUH)

Ramapuram(V), Chilukuru(M), Suryapet District, T.S-508206

ABSTRACT: The Drastic increase of CO₂ emission in the last 30 years is due to the combustion of fossil fuels and it causes a major change in the environment such as global warming. In India, the emission of fossil fuels is developed in the recent years. The alternate energy sources are not sufficient to meet the values of this emission reduction and the framework of climate change demands the emission reduction, the CCS technology can be used as a mitigation tool which evaluates the feasibility for implementation of this technology in India. CCS is a process to capture the carbon dioxide from large sources like fossil fuel station to avoid the entrance of CO₂ in the atmosphere. IPCC accredited this technology and its path for mitigation for the developing countries. In this paper, we present the technologies of CCS with its development and external factors. The main goal of this process is to avoid the release the CO₂ into the atmosphere and also investigates the sequestration and mitigation technologies of carbon.

1. INTRODUCTION The climate variability and changes are one of the evidence for global warming, it increases the average temperature of the globe. It is due to the increase of greenhouse gas in the atmosphere. CO₂ is the main component in greenhouse gas. The processes in industries are the main reason for the emission of CO₂. It is mostly emitted from the burnings of carbonaceous fuels. Greenhouse gas is also emitted by the natural phenomenon like agriculture and live stocks. The mechanism of nature is to absorb the CO₂ to maintain the biosphere balance in the atmosphere. The emission of greenhouse gas is increased when comparing with the initial revolution of the industries. It is due to the usage of fossil fuels, Thermal power generation, Logistics, and transport. Coal is mainly used in the power sector and it consumes 70% of Indian economy. The Economic growth of India is accelerated to add more 600000 MW by 2030 approximately [1]. The emission of CO₂ must be reduced to minimize the global warming. Nuclear energy, hydro energy, fossil fuels, coal power have to produce power in large amount to accommodate the need of power but clean coal technologies and coal combustion in the efficient and clean methods are required to be developed to reduce the emission level of CO₂. Capture and Storage Technologies are used to

reduce the emission of Greenhouse gasses by capturing the CO₂ gas from the viable surface. Carbon capture and sequestration is a physical process which involves in the capturing of CO₂ and its storage. CCS technology is used to reduce the emission of CO₂ in the atmosphere. The integrated system of CCS has the following process, the CO₂ will be captured and separated from the other gasses. Then it will be purified, compressed and transported to the sequestration site. CO₂ will be injected into the geological surface of the reservoir or it will be stored in the ocean. This review is focused to analyze, study and evaluate the importance of CCS technology to reduce the GHG emission to avoid global warming with the implications of economic. The main objective is to research about the Technology of CCS with power sector to understand the feasibility of the technologies. The applicability of the power sector is applied to the demonstration of the requirements to establish the technology. The aim of CCS technology is listed as follows, it enhances the power plant efficiency with the latest technologies to reduce the emission of Carbon dioxide by using the capture technology. CO₂ is captured and it is separated from the gas streams which is emitted from the mixture of combustion gasses. The captured CO₂ will be transported to the underground storage. CO₂ will be stored in underground sedimentary basins, saline aquifers, and coal reservoirs. CO₂ will be stored in the potential areas of the country. Trapping mechanism will be used for the storage process. It is important to ensure the safety of the storage area. The main goal of the CCS technology is to reduce the amount of CO₂ in the environment. CO₂ emitted by the fossil fuels will be stored in secured places for hundreds of years with affordable prices.

2. CCS SCENARIO IN INDIA Nearly 53.7% of electricity is generated through coal which means direct carbon emission to atmosphere. Around 40% of CO₂ emission is for power generation and further emission by the industrial side and transport will be 15% and 32% respectively. Then 11% of carbon released by the residential and commercial sectors [1]–[3]. These overall percentage of carbon dioxide are not flexible to CO₂ Capture and Sequestration. The CCS is well suited for large industry, power plant and stationary sources of carbon dioxide emission due to economic cost and

high capital cost. But the oil refining company, cement production industry and, iron and steel manufacturing combust the fuels and release the carbon. These are all the intensive industries. The cost based on the flue gas cost properties, basically down with high carbon dioxide concentrations and less temperature. The sequestration of CO₂ accumulation in earth is due to unacceptable combustion of fuels such as fossil. Even though the cost invested in fuel acquisition, domestic infrastructure and reserves, the maintenance, and the alternate energy source combustion. The alternate sources are the wind, solar and biomass energy. This CCS technology provides the solution to the dilemma. The solution provided by the carbon emission reduction costs due to the storage of acquired CO₂ and transportation which will increase in helping to control the evaded cost of capture [4]. According to 2007-2008 in India, a particular care had been taken to carbon capture and sequestration field. During the financial year, a various number of researchers sponsored nearly thirty projects depends upon storage or sequestration. CCS technology is one of the interesting processes. By comparing with those years, after 2013 only some researcher's standby in open market. In India, there is no particular CCS policy needs to be expressed. Due to this policy, India lag on R&D dynamic approach. The absence of CCS will cause the cost about 70% increased at 2050 due to the ejection of carbon. In India, CCS is at an initial stage only, because the government does not consider the CCS technology is the key factor for climate and national energy policies [5]. Instead of involving in coordination CCS development process and coordination process, the DST (Department of Science and Technology) started the (ICOSAR) "Indian CO₂ sequestration Applied Research. These CCS projects are always executed in three steps given as absorbing, pre-combustion and post-combustion. The power sector does not yet have demonstration -scale. These levels provide the projects for carbon dioxide capture in 1988 [6]. In India, the four initiating key points are as follows:

- **Capture of pure carbon dioxide streams in Industry** The process is very easy to produce a pure stream of carbon dioxide. The examples are fertilizer and gas industries. The shortage of CO₂ at fertilizer plants in India because of the CO₂ usage produced from the production of ammonia. The excess of Carbon dioxide is also used for the urea manufacture. The waste supply of carbon dioxide replaces the generation of this excess CO₂ [7].

- **EOR (Enhanced Oil Recovery) offshore and onshore** The CO₂ developing plans are already initiated from the offshore sour gas by the Indian government at Gujarat, Hazira. This recovery is done at the onshore site about 70 km far away. Nearly 1200 tons of received carbon dioxide

transportation takes place every day to the oil field. It maintains the pressure and reduces the oil viscosity.

- **CCS technology with power sector and coal**

This process starts with technology generation such as advanced supercritical steam conditions. It includes new power plant design in India, such as UMPP's ("unimpaired performance and less upfront costs").

- **Export CO₂ for foreign EOR activities** The UMPP project design is mainly for imported coal such as Mundra. The project integration formed by the shipping terminals [8].

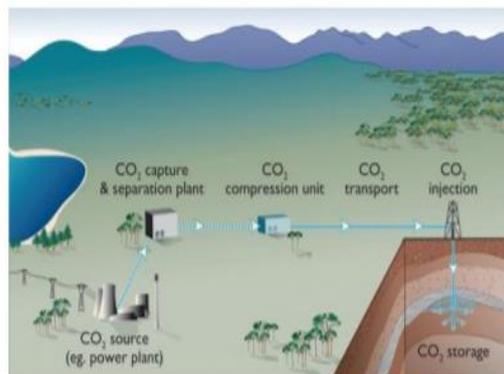


Fig. 2.1 Process flow of geo-sequestration of CO₂ [9]

CCS process has three main steps (as seen in fig. 2.1):

1. Capture of CO₂- CO₂ is captured from the industrial sources, power plants and natural gas as they have high content of CO₂.

2. Transportation- Transportation is the process of transferring the CO₂ to the storage site.

3. Geological storage: In the last step, the transferred CO₂ is saved in geological storage such as in deep saline formations, un-mine-able coal seams, depleted oil/gas fields or gas recovery sites. The combustion processes used to capture the CO₂ gas are in three modes. They are pre-combustion mode, post-combustion mode and oxy-fuel combustion [10].

3. **CO₂ Capture** There are three main sources available for emission of CO₂ gasses. They are from power plants, natural gas, and industrial gas. The most important CO₂ gas emission takes place in power plants. This CCS technology is used to reduce the CO₂ emissions. The pre-combustion technique is used to collect the gas from the coal combustion streams and deposit it geographically. So, this method is used to protect the gas to enter into the atmosphere.

- 3.1. Carbon transportation Transport the connection between the carbon captured and storage sites. This uses the pipeline process to transfer the carbon. Transport the connection between the carbon captured and storage sites. This uses the pipeline process to transfer the carbon. For transferring gas long distance, this pipeline technique is used. Liquid, gas and solid are the three states of carbon

transformation available. The liquid and gaseous carbon are transported by using the commercial scale transport like pipelines, ships, and tanks. The use of ships in transferring gas is the most usable method. There are four types of ships that are used for this transportation. These four types of ships are used to transport the liquefied carbon from the large type of sources such as ammonia plants. The ships then transfer these liquefied carbons to the coastal distribution terminals [11]–[13].

3.2. Carbon Sequestration This stage is the critical stage in this technology. The emissions of the carbon in the atmosphere are protected by this stage. In this sequestration stage, the captured carbon is stored in the geological site. Based on the economic point of view, the famous sites for storing the carbon is un-mineable coal seams, deep saline formations, enhanced oil or gas recovery (EOR or EGR) and depleted oil/gas fields. There are many techniques that are used for storing the carbon into the storage reservoirs [14].

3.3. Potential sources of GHG emissions According to the ministry of power, India, there are five division available in India: Western, Eastern, Northern, Southern and North-Eastern. Coal is found in India in the central regions, eastern, and southern region. Lignite is found in big hydro-power and the southern region. But, for more power generation the lignite required to develop in the north-eastern and northern region. Efficient technologies are used in the growth of the power generation. At this time, there is also a need to maintain the GHG emission to protect the environment [10]. The power sector is one of the largest sources for emission of GHG. In the power sector, the fossil fuel-fired power plants are supplied the base load electricity. This is the major part that affects the environment by GHG emissions. There are some solutions to reduce the emission of GHG as listed below [15],

- Waste reduction and timely maintenance are efficient way to increase the efficiency of power plants.
- Recycling the old power plants and application of new technologies.
- Change the base load generation using the fossil fuel power plants to power plants as renewable energy.
- Should use CCS technology for upcoming power plants.

4. CCS TECHNOLOGIES

4.1. Oxyfuel combustion

This technology is used to remove the fuel in the air with oxygen. The air in atmosphere contains 78.08% nitrogen, 20.95% oxygen and the remaining percentage of air contains gasses like Helium Xenon, Neon etc. (inert gases). In this technology, the fuel is added to the existing atmospheric air for combustion. Inert gases in the

atmospheric air do not reach the high temperature then the combustion is incomplete. But instead of air if oxygen is used in the process, a higher temperature can be attained. The process of Oxy-Fuel Combustion technique therefore is burning the fuel with pure oxygen. This process acts in the air as primary oxidant air [16]. The process flow of plant is shown in fig. 4.1 the process shows oxy-fuel cement plant, which runs on the oxyfuel technology, where the amount of CO₂ was raised in a rotary kiln by combusting oxygen and fuel to get high concentration of CO₂ flue gas which was sent to CO₂ purification unit.

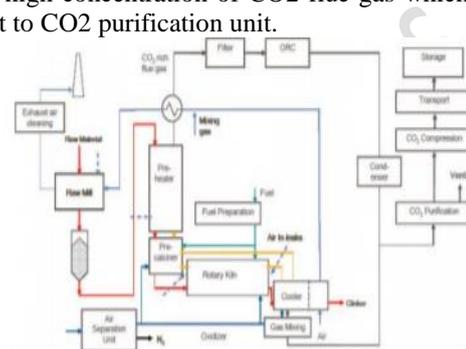


Fig. 4.1 Oxy-fuel cement plant configuration [15]

4.2. Pre-combustion

Pre-combustion is the process to obtain the fossil fuel without carbon. This process is done before the combustion process is completed. First, the coal is oxidized in steam. Then the coal is mixed with the air. This mixture forms the synthesis gas at high temperature. This gas is also referred as 'syngas' and it is the mixture of carbon mono-oxide, hydrogen, CO₂ and a smaller amount of methane. This process is called as gasification. The next level is water-gas shift reaction. In this level, the carbon monoxide and the water are converted to hydrogen H₂ and carbon dioxide (CO₂). In this mixture, the range of the CO₂ is 15-50%. After this pre-combustion method, the CO₂ is captured, transfers and then sequestered, the fig. 4.2 shows the process of pre-combustion explain the process steps. As compared to the postcombustion method, pre-combustion is used to remove dilute CO₂ at low pressure. At high pressure, this combustion removes rich CO₂ gas before the hydrogen is combusted on the water-gas shift reaction. Pre-combustion is the more efficient technique at the time of availability of more concentrated CO₂. But, more expensive for the base gasification process [9], [15].

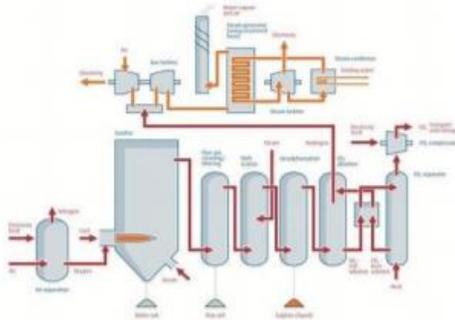


Fig. 4.2 Pre-combustion process [17]

5. RESEARCH IN POST-COMBUSTION CAPTURE PROCESS

The research in post-combustion can be divided into two types. Short time research and long-term research. Short term research focuses on the development of existing technologies. It is important to minimize the requirement of heat and temperature. The improvement of solvents can be divided into three types.

- Concentration of solvents
- Corrosion and degradation of solvents
- Alternative for MEA The solution of MEA for the absorption of acid gas contains 30 wt% of MEA. To reduce the cost of plant operation and circulation, the concentration and capacity of amine can be increased. Solvent degradation increases the cost of the material, waste disposal and creates a demand for capturing of CO₂. There have been many research conducted to find a superior solvent of MEA as alternative to MEA.

6. BARRIERS TO IMPLEMENT CCS The adoption of CCS barriers are divided into three categories.

They are,

- Financial barriers
- Technical barriers
- Institutional barrier
- Other barriers

The Financial barriers are involving the high capital cost and high energy penalty. The Institutional barriers do not meet the overall development goals. It involves the non-productive expenditure which does not contribute to sustainable development. The Technical barriers are commercially demonstrating the high point sources of CO₂. It is used to capture technologies, but it is not standard for high point sources. It identifies the sinks and its capacities. The technical barriers have some permanence issues and the issues are seismically active in many parts of India. It establishes the EGR/EOR and ECBM in India. The technical barriers are used to determine the potential and cost for the depleted gas and oil. It also optimizes matching and mapping of the sinks and their sources [20]. The other barriers include,

- Financial
- Regulatory

- Storage
- Acceptance

The Storage is used to identify the leakages and their carbon accounting. The regulatory is used to provide the EC establishment and it used to allow the CCS for the European trading.

CONCLUSION:

The contribution of Indian government in the accumulation of CO₂ and other GHG's from the atmosphere due to the improper fossil fuel combustion with significant amount of fuel procurement with its maintenance is appreciable. The combined infrastructure and domestic reserves are based on the energy sources like wind, solar energy and biomass are needed to be promoted at first level along with integration of CCS with coal fired plants. The clean coal technologies and CCS are the prime media which can be useful to achieve the carbon target and implement the de-carbonization manufacturing processes. The CCS has completed the CO₂ emission reduction in the power sector and it measures the energy efficiency. The CO₂ emissions are projected to reach the more than 55% of the global aggregate in India. The CCS uses the three technologies such as pre-combustion capture, post combustion capture and oxy-fuel combustion capture, among which pre-combustion and postcombustion capture are the most viable options in regards to India due to their flexibility and retrofitting capability with existing fossil fuel fired plants. The technology holds one major barrier of energy penalty which can also be reduced by integrating solar thermal power generation system with post combustion process.

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