Asian Journal of Convergence in Technology Volume III, Issue II
ISSN No.:2350-1146, I.F-2.71

Carbon Capture, Storage and Utilization Technology By Break Through Solar Cell in India

Miss. Anita V. Kokate
Energy Technology
Department of Technology, Shivaji University, Kolhapur
Kolhapur, India
Anita29_kokate@rediffmail.com

Mr. Mahesh M. Wagh
Energy Technology
Department of Technology, Shivaji University, Kolhapur
Kolhapur, India
waghmahesh2006@gmail.com

***Abstract*— Global warming and climate change concerns have triggered global efforts to reduce the concentration of atmospheric carbon dioxide (CO2). Carbon dioxide capture and storage (CCS) is considered a crucial strategy for meeting CO2 emission reduction targets. This paper reveals, various aspects of CCS including the state of the art technologies for CO2 capture, separation, transport, storage and utilization. As per Greenhouse Development Right (GDR) our projection of different trends of coal-based power plant capacities up to 2050 ranges between 13 and 111 Giga tone (Gt) of CO2 that may be captured from coal-fired power plants to be built by 2050. If very optimistic assumptions about the country's CO2 storage potential are applied, 75 Gt of CO2 could theoretically be stored as a result of matching these sources with suitable sinks. The aim of the present review is to check the feasibility and economics of CCS and CO2 utilization in fuel production by brake through solar cell technology.**

Keywords—component; formatting; Carbon capture and storage (CCS), Carbon capture and utilization (CCU), environmental impacts, Breakthrough solar cell (BSC), photosynthetic solar cell.

I. Introduction

Coal fired power plants, cement/brick factories, oil refineries, natural gas wells, and transportation all emit CO_2 from the burning of fossil fuels. The Indian government is planning to set mandatory caps on CO_2 emissions, causing companies to develop and test methods to mitigate their carbon footprint. One possible way to accomplish this is by Carbon dioxide Capture and Storage. [1]

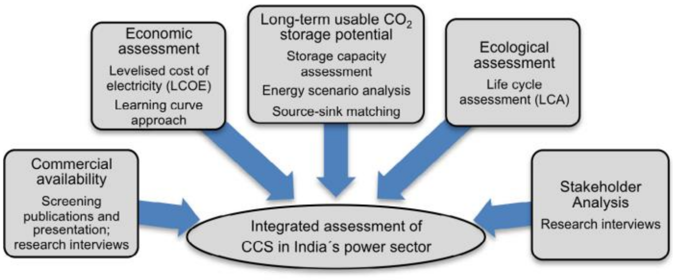
In CCS three technologies are developed such as

1 .Post combustion

2. Pre combustion and

3. Oxy-fuel combustion.

Developing stable homogeneous catalysts for CO_2 reduction to methanol was a challenge. Majority of the catalysts stopped at the formic acid stage. Furthermore, it was needed a catalyst that could reduce carbamates or alkyl ammonium bicarbonates directly to methanol. It has been achieved both with catalyst. With the new catalyst, along with a few additional compounds, the researchers demonstrated that up to 79% of the CO2 captured from the air can be converted into methanol. Initially the methanol is mixed with water, but it can be easily separated out by distillation.



Set of methods used for the integrated assessment

Fig1:-Set of methods used for the integrated assessment [4]

Chemical reactions that convert CO_2 into burnable forms of carbon are called reduction reactions, the opposite of oxidation or combustion. Engineers have been exploring different catalysts to drive CO_2 reduction, but so far such reactions have been inefficient and rely on expensive precious metals such as silver. [3,4,5]

CCS technology plays an important role in providing environmental friendly energy for domestic and industrial applications.

Using specific methods there is a scope for improvement in the efficiency fuel formation process. Main focus of this technology is on a family of nano-structured compounds called transition metal. Dichalcogenides or TMDCs as catalysts, pairing them with an unconventional ionic liquid as the electrolyte inside a two-compartment, three-electrode electrochemical cell. The new catalyst is 1,000 times faster than noble-metal catalysts and about 20 times cheaper.

II. Literature Review

The purpose of this literature review is to outline in some detail literature relevant to carbon capture technologies.

Abdallah et al. studied the potential for the use of different amines with desalination brines for the simultaneous capture and conversion of CO_2 into solid bicarbonates was evaluated.

The focus of this work was to find the most suitable amine solvent for this proposed process. [1]

Peter et al. justified the carbon dioxide transport system. CCS clusters, where multiple CO_2 emitting sources share CO_2 transport and storage infrastructures, offer cost savings and enable smaller sources to undertake CCS, which are unlikely to be capable of justifying a stand-alone transport and storage system. [2]

Dennis et al. studied, if carbon dioxide storage in oil and gas reservoir the technology used for enhanced oil recovery (EOR)is mature and has been practiced for many years using natural CO2 sources and mostly on-shore. However, the economical feasibility of using captured CO_2 from anthropogenic sources for EOR has not been fully demonstrated yet mostly for offshore storage. The use of un mineable coal beds, eventually recovering methane by Enhanced Coal Bed Methane (ECBM) recovery, can be an option but it will make the coal used for CO_2 storage unavailable even if future mining technology and economical consideration should make it of commercial value. [3] Technologies considered for capturing of CO_2 are post-combustion carbon capture (PCC) and oxygen blast furnace route (OBF). Post-combustion capture for the integrated steel mill was evaluated in an earlier study by Arasto et Al. and Tsupari et Al. Implications of different capture amounts, different solvents for post-combustion capture and process integration levels to the greenhouse gas balance and operation economics are compared to the steel production base case with varying costs of CO_2 emission allowances. Furthermore the effect of reducing the carbon intensity of steel production on the final steel production cost was evaluated. [4,5]

Thomas et al. analyzed the commonalities and differences between CCU and CCS and recommended how one should be distinguished from the other, particularly in environmental policy fields and the public debate. Particularly, they hopes that CCU could represent a promising perspective for contributing to mitigation efforts should not be exaggerated and considerations of CCU in climate politics need to account for the largely varying and technology specific temporary storage times of CO_2 and its specific substitution potential. [11,12]

III. Overview of CCS and CCU Technologies

A. *carbon capture and storage*

This idea of preventing the CO_2 from being released into the atmosphere is called Carbon Capture and Storage (CCS). This is a synthetic version of Carbon Sequestration, the process which takes place in plants and trees naturally during photosynthesis and is powered by sunlight during which they suck Carbon-dioxide from the air and use it to build their roots, shoots, and leaves. As the name suggests, CCS involves two separate processes carbon capture and carbon storage.

IV. Technologies of CCS

Three technologies of CCS are

1. Before the fuel is burnt (pre combustion)
2. After the fuel is burned (post combustion)
3. By burning the fuel in more oxygen and storing all the gases produced as a result (Oxy fuel).

4.1 Pre combustion

In pre combustion, the aim is to remove the carbon from coal fuel before it is burned. The coal is reacted with oxygen (O_2) to make syngas (synthesis gas), a mixture of carbon (CO) monoxide and hydrogen (H_2) gases. The hydrogen can be removed and either burned directly as fuel or compressed and stored for use in fuel-cell cars. Water is added to the carbon monoxide to make carbon dioxide (which is stored) and additional hydrogen, which is added to the hydrogen previously removed. This method is applicable for gasification plant and biomass.[1,3]

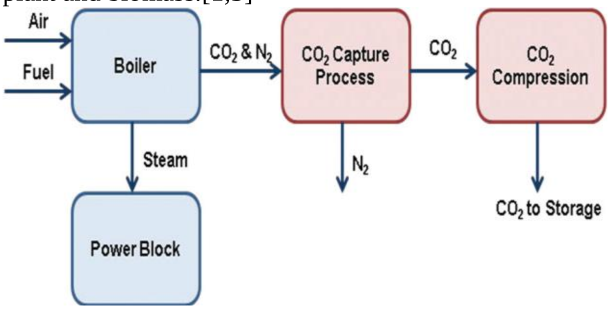


Fig. 1: Pre combustion technology [3]

4.2 Post combustion:

In post combustion, the aim to remove carbon dioxide from a power station's output after a fuel has been burned. That means waste gases have to be captured and scrubbed clean of their CO_2 before they travel up smokestacks. The scrubbing is done by passing the gases through ammonia, which is then blasted clean with steam, releasing the CO_2 for storage. The $CO_2$is stored in stripper. This method applicable for CO_2conventional coal, oil, and gas-fired power plants.[1,7,12]

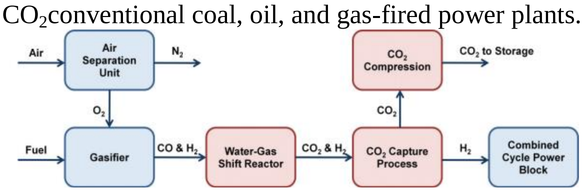


Fig.2: Post combustion [7]

4.3 Oxy fuel (oxy combustion)

CCS would be much easier if power plants produced pure CO_2 as their smokestack waste. Then, instead of laboriously separating out the CO_2 from other waste gases, it could trap the entire output from the smokestacks and store the lot. The trouble is that power plants don't produce pure CO_2: because there is often not enough oxygen for complete combustion they produce other pollutant gases as well. One way to purify the exhaust is to blow extra oxygen into the furnace so the fuel burns completely producing relatively pure steam and CO_2. Once the steam is removed (by cooling and condensing it to make water), the CO_2 can be stored. This method is applicable for hydrocarbons. [6,7]

A. Best technology:

Each of these techniques has its advantages and disadvantages. In theory, post combustion CCS can be applied to any power plant burning any carbon-based fuel, so it could be retrofitted (at a price) to the world's thousands of existing power plants. Pre combustion and oxy fuel both are alter the fuel before it enters the station and are more suitable for newly built plants. Post combustion is the best option for cleaning up the plants. Pre combustion and oxy fuel could help us build cleaner plants in future.

V. Storage of Carbon dioxide

Once capturing of the carbon dioxide takes place, there is the small matter of where to store it. Carbon dioxide is a gas under everyday conditions so it takes up a huge amount of space and it has been producing it in vast quantities too. Stuffing it in a tank somewhere and closing the lid is not really an option: the tank would probably need to be the size of a country. The best option is to turn the carbon dioxide into a liquid (so it takes up a tiny fraction as much room) and then pump it either deep underground or into the deep ocean where it will remain safely for perhaps 1000 years or more.

Storing carbon dioxide under Earth's surface up to 1500 meter is called geo-sequestration or geological storage and uses things like worked out oil fields, aquifers, or other rock formations deep underground. It might sound like hugely impractical science fiction, but oil companies already routinely pump CO_2 into underground rocks to help them flush oil to the surface of declining wells, so it is actually a reasonably well-understood process. Less well understood is the idea of storing CO_2 in the oceans. The CO_2 stored in sea/ocean up to 3000 meter is called ocean storage. The main problem here is that carbon dioxide reacts with water to form acid, so the oceans could become significantly more acidic with potentially devastating consequences for marine ecosystems. But another difficulty is that the CO_2would also eventually return to the atmosphere. A third option is to store CO_2 by reacting it with minerals, though that requires a lot more energy. [1,3]

5.1 Methods of CO_2storage

1.Geological storage
2.Ocean storage

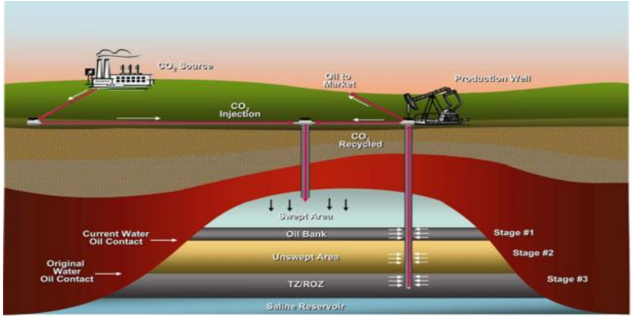


Fig.5: CO_2 storage[13]

VI. Utilization of Carbon dioxide

A. Break through solar cell

Unlike conventional solar cells, which convert sunlight into electricity that must be stored in heavy batteries, the new device essentially does the work of plants, converting atmospheric carbon dioxide into fuel, solving two crucial problems at once. A solar farm of such "artificial leaves" could remove significant amounts of carbon from the atmosphere and produce energy-dense fuel efficiently.

Instead of producing energy in an unsustainable one-way route from fossil fuels to greenhouse gas, now reverse the process and recycle atmospheric carbon into fuel using sunlight. The ability to turn CO_2 into fuel at a cost comparable to a gallon of gasoline would render fossil fuels obsolete.

Reaction of CO_2 in presence of sunlight:-

Chemical reactions that convert CO_2 into burnable forms of carbon are called reduction reactions, the opposite of oxidation or combustion.

CO_2+2H_2+sunlight = CH_4+O_2 [14]

family of nano-structured compounds called transition metal dichalcogenides or TMDCs as catalysts, pairing them with an unconventional ionic liquid as the electrolyte inside a two-compartment, three-electrode electrochemical cell.

The best of several catalysts turned out to be nanoflake tungsten diselenide. This catalyst more able to break carbon dioxide's chemical bonds.

Artificial leaf consists of two silicon triple-junction photovoltaic cells of 18 square centimeters to harvest light; the tungsten diselenide and ionic liquid co-catalyst system on the cathode side; and cobalt oxide in potassium phosphate electrolyte on the anode side. When light of 100 watts per square meter – about the average intensity reaching the Earth's surface – energizes the cell, hydrogen and carbon monoxide gas bubble up from the cathode, while free oxygen and hydrogen ions are produced at the anode.

VII. Economics of CCS technology for India

As per IEA report, it is assumed that a total of 663 GW CCS-based coal-fired power plants will be installed by 2050 in India. As per international energy association report (IEA) economic development and the fulfillment of basic human needs such as education, sanitation, health and communication are critically dependent on the availability of modern energy services. For this reason, improved living standards in India are inherently linked with an increase in energy demand. This rise in energy demand has led to an increase in India's overall CO_2 emissions since the vast majority of the increase in energy demand has, so far, been met by increased use of fossil fuels. Over 70% of India's carbon emissions are associated with the burning of fossil fuels, with a significant proportion of these associated with coal fired power plants. In terms of electricity, India presently has roughly 138GW of installed capacity, where roughly 70% is generated by thermal power plants, 25% by hydro and 5% from other renewable, mostly wind. The reason for this is that only the additional expenditure for CO_2 capture follows the learning curve, the actual thermal power plant is a widely mature and deployed technology. The learning rates are then applied to the capacity additions projected in the coal development pathway for India. Only India's capacity deployment is taken into account because the quality parameters of Indian coal require a highly 4 specialized boiler design, which is not available on the Indian as well as world market.[1]

Table 1. Cost of CCS technology for India in terms of Rupees

CCS system components	Cost range	Remarks
Capture from a coal- or gas-fired power plant	795 – 3000 Rs/TCO_2 net captured	Net costs of captured CO_2, compared to the same plant without capture
Capture from hydrogen and ammonia production or gas processing	325 – 3250 Rs/TCO_2net captured	Applies to high-purity sources requiring simple drying and compression
Capture from other industrial sources	1650-3500 Rs/TCO_2 net captured	Range reflects use of a number of different technologies and fuels
Transportation	65-520 Rs/TCO_2transported	Per 250 km pipeline or shipping for mass flow rates of 5 (high end) to 40 (low end) $MtCO_2$/yr.
Geological storage: monitoring and verification	6.5 – 52 Rs/TCO_2 injected	This covers pre-injection, injection, and post-injection monitoring, and depends on the regulatory

		requirements

VIII. Discussion of Pros and cons of carbon capture and storage

Researchers are either heavily in favor of CCS technology or heavily against. Environmentalists tend to see CCS as a distraction from the need to convert humankind quickly to renewable energy. They argue that investing in carbon capture is a waste of money when it could be putting the same investment to better use perfecting such things as building insulation, solar energy, wind turbines, tidal power and perhaps even nuclear plants. Another drawback of CCS is that this technique uses considerable extra energy (increasing the coal need by as much as 40 percent) and could double the cost of electricity; both are very unwelcome at a time when energy is becoming increasingly expensive and humans are having trouble meeting their energy needs.

Where opponents see coal as a problem a filthy polluting fuel that should be left underground at all costs supporters prefer to call it "clean coal" and see it as a part of the solution. Their argument is that the world is hugely dependent on a giant fleet of aging power plants that will continue to be operational for decades to come. According to this view, if humans must make dramatic cuts in their carbon emissions while old power plants are still running, and before other technologies can be rolled out, back-fitting CCS could be a vital way of cutting the India's overall emissions when it matters most. CCS is still a relatively untried technology and the argument is unlikely to be settled one way or the other until more work has been done to demonstrate its real costs and benefits.[1,11,12]

IX. Conclusion

The above work analyzes the life cycle environmental impacts of various CCS and CCU options for the capture, storage and/or utilization of CO_2 emitted by power plants and other industrial sources. The main CO_2 capture options are post- and pre-conversion capture and oxy-fuel combustion. Post conversion capture via chemical absorption using monoethanolamine (MEA) is the most mature and widely used technique, especially in the power generation sector. In breakthrough technology, a family of nano-structured compounds called transition metal Dichalcogenides or TMDCs as catalysts, pairing them with an unconventional ionic liquid as the electrolyte inside a two-compartment, three-electrode electrochemical cell. The new catalyst is 1,000 times faster than noble-metal catalysts and about 20 times cheaper. From that technology methane extraction is possible.

References

1. Rosa M. Cue´ llar-Franca, Adisa Azapagic, "Carbon capture, storage and utilization technologies: A critical analysis and comparison of their life cycle environmental impacts", Journal of CO2 Utilization.9, (2015),pp 82–102

2. Abdallah Dindi, Dang Viet Quang, Nabil El Hadri, Aravind Rayer, Abdurahim Abdulkadir, And Mohammad R. M. Abu-Zahra, "Potential for the Simultaneous Capture and Utilization of CO2 Using Desalination Reject Brine: Amine Solvent Selection and Evaluation", Energy Procedia 63, pp7947 – 7953, (2014)

3. StephenComello, Stefan Reichelstein, "Incentives for early adoption of carbon capture technology",Journal of Energy Policy, 74, (2014), pp 579–588.

4. Carbon capture technology program plan, january 2013

5. David Barnes, Bill Harrison, G. Michael Grammer, Jason Asmus, "CO2/EOR and Geological Carbon Storage Resource Potential in the Niagaran Pinnacle Reef Trend, Lower Michigan, USA", Energy Procedia 37,(2013), pp 6786 – 6799

6. IEA, "CO2 Emission from fuel combustion hightlights," International Energy Agency, France, 2012.

7. A. A. Olajire, "CO2 Capture and Separation Technologies for End-of-Pipe Applications – A Review.," Energy, vol. 35,(2010), pp. 2610 – 2628

8. M. Ahmed, W. Shayya, D. Hoey and J. Al-Handaly, "Brine disposal from reverse osmosis desalination plants in Oman and United Arab Emirates," Desalination, vol. 133,(2001) pp. 135-147.

9. D. A. Mohamed and A. M. M. Mohamed, "Environmental Impacts of Seawater Desalination: Arabian Gulf Region Study," International Journal of Environment and Sustainability, vol. 1,(2012), no. 3, p. 2-37.

10. J. M. Arnal, M. Sancho, I. Iborra, J. Gozálvez, A. Santafé and J. Lora, "Concentration of brines from RO desalination plants by natural evaporation,," Desalination, vol. 182,(2005) pp. 435-439.

12. Mohammad R. M. Abu-Zahra1, , Zeina Abbas, Prachi Singh, Paul Feron, "Carbon Dioxide Post-Combustion Capture: Solvent Technologies Overview, Status and Future Directions".

13.http://www.ipcc.ch/pdf/specialreports/srccs/srccs_wholereport.pdf

14. Non conventional energy resources by G.D. rai.