RESEARCH ARTICLE

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Various Technology Options of 'Application' of CCS on large Coal-fired Unit - A Rationale

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Abstract

Even though India has made great strides in expanding installed capacity from 1713.0 Megawatt in 1950 to be over 3,79.130 MW in March 2021, renewable energies provide 24.50% with a maximum capacity of over 91,154.0 MW. These contributions do have a high social and environmental effect on the people in rural and remote areas and our commitments to fighting climate change. Alternative energy sources for mega energy production, including such photovoltaic mega power under mission mode, solar thermal and solar panels, green energy techniques, CCTs, i.e., supercritical power plants, Incorporated Gasifying Combined Cycle (IGCC), and fluidization bed combustion (FBC), are important to the achievement of India's Green Power Mission. CCS (Carbon Capture and Sequestration) is a cutting-edge green power technique.

Keywords: Bio-diesel, CCS, CO_2, Coal-fired, Fossil fuel.

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Introduction

GHG reducing emissions in the electricity sector via implementation of co-generation, combined cycle, Green Energy Techniques, and coal beneficiation are some of the Carbon dioxide preventive actions which have already been implemented in the nation. Technology advancements such as extending the life of aging polluted units are predicted to improve the production effectiveness of such units, lowering Emissions of carbon dioxide.

Greenhouse gas emissions in the electrical industry are being reduced via the use of co-generation, combined cycle, Green Energy Techniques, and coal beneficiation, to name a few of the carbon dioxide mitigation measures already in place in the country. Technology developments such as prolonging the life of an aged dirty unit are expected to increase the unit's generating efficiency, cutting carbon dioxide emissions.

The advent of smart power generation systems like Supercritical/Ultra-supercritical power cycles, Integrated Gasification Combined Cycles (IGCC), Fluidized Bed Combustion/Gasification Technologies, and so on, all of which are classified as Clean Coal Technologies (CCTs), would provide a major boost in CO_2 reduction over the long term and sustainably. Apart from Clean Coal Technologies, India now has a gold mine of possibilities for CCT-based Power Development adoption in the next five years.

Energetic and Environmental Safe Green Energy Technologies for Mega Power Production Future Power Sector Initiatives throughout the world will include supercritical and IGCC technologies and renewable energy technology for rural and remote area applications. There would be a strong link between energy planning and environmental preservation in the country's National Power Policy. Fundamental low-carbon energy technologies, renewables, carbon capture and sequestration (CCS), energy farming, and biofuel development need significant investment.

On the other hand, the CCS technique is now in the experimental phase, and India cannot afford to lag behind in this area. While much work is being done in the United States, research alliances and information sharing and transmission may still be required. Novel adsorbents, enhanced process integration of capture equipment, and CO_2 conversion to useful multifunction energies and commodities are all research issues.

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Various Technology Options of 'Application' of CCS on a large Coal-fired Unit – A Rationale

1) CO_2 is widely used.
2) CO_2 Chemical Application
3) Improved Fossil Fuel Recovery is a third option.
4) The Use of Carbon dioxide in Biotechnology

General Use of CO2

- Drinks/Dry ice/Refrigeration (liquid CO_2)/Supercritical food application - Reduce cholesterol / Decaffeinate
- Wastewater neutralization
- Mineralization of desalinated water
- Semi-conductor cleaning
- Welding

Beverages/Dry Ice

Beverages, beer, and alcohol are carbonated using CO_2 gas. Food products, particularly cream, processed meats, and packaged foods, are refrigerated using frozen atmospheric CO_2 in the form of Dry Ice. Furthermore, dry ice is utilized for the specified objectives:

Dry ice particles were utilized instead of sandblasted to eliminate paint off objects. It assists in the reduction of dumping and clean-up costs.

Molded materials that should be retained cool are combined with dry ice. For illustration, in a tumbled drum, dry ice is combined with molded rubber goods to cool it towards the point when the thin flash or rind gets brittle and falls off.

Aluminum rivets are chilled using dry ice. When kept cold using dry ice, they stiffen quickly at ambient temperature yet stay soft.

Neutralization of Waste Water

Alkaline wastewater is generated by a variety of businesses, including iron and steel production, textile and dyeing, paper and pulp production, and power plants. These businesses produce very alkaline wastewater (11.4 pH on average), which should be neutralized before being released or submitted for treatment.

- Carbon dioxide has various advantages against mineral acids as a neutralizing agent:
- Carbon dioxide is not a very poisonous substance, making it safer for employees to handle and requiring no specific safety equipment.
- Although if an overdose happens, Carbon dioxide cannot lower the pH under five due to its intrinsic buffering activity.
- The neutralization process is more ecologically favorable because Carbon dioxide doesn't really form leftover anions like sulfate and chloride, and it is even more environmentally good when recovered Carbon dioxide from flue gases is employed.
- A reduced cost may be attained by replacing the original mineral acid neutralization unit or installing a new Carbon dioxide unit.

Desalinated Water Mineralization

These cannot be utilized directly because desalted or excessively soft waters generated by desalination facilities are unpleasant, caustic, and harmful. To overcome this challenge, re-mineralization is required.

Water reconditioning using salt tablets is among the most complex techniques of purifying desalinated water. Furthermore, Carbon dioxide may be employed as part of an expense post-treatment process that results in stable chemical and re-mineralized waters that meet agricultural demands while also adhering to some of the most current WHO standards.

Contacting Carbon dioxide acidified desalination plants with a bed of local lime is a frequent procedure in the re-mineralization operation. Limestone disintegration gives the water two vital ingredients: bicarbonate alkalinity as well as calcium:

$$CaCO_3 + CO_2 + H_2O = Ca^+ + 2HCO_3.$$

Welding

CO_2 is often used by welding, in which it interacts with many of these metals in the weld zone to oxidize them. It is commonly used as a welding gas in the automobile sector, largely as it's less costly than more inert gases like argon or helium.

CO_2 is sometimes referred to as MAG welding if used for MIG welding, which stands for Metal Active Gas since Carbon dioxide can interact at all these high temperatures. It produces a hotter puddle than completely inert atmospheres, which improves flow properties.

Semi-Conductor Cleaning

Transistors, photovoltaic panels, different types of diodes, and analog and Digital IC's are all examples of semi-conductor technology. Solar PV panels made of semi-conductors transform light energy directly into electricity. Chemical pollutants and particle contaminants on the device surface have long been recognized to have a negative impact on semi-conductor device stability and efficiency. CFCs were formerly widely employed as a cleaning agents, but they've been prohibited owing to their harmful effects on the ozone layer.

Chemical Application of CO2 in production of:

- Urea
- Methanol
- Soda Ash
- DME

Urea Production

Urea is made of synthetic ammonia and CO2 for industrial usage. During the production of ammonia from coal or hydrocarbons, including natural gas and petroleum-derived raw materials, large amounts of CO2 are released. Such Carbon dioxide point sources enhance the direct production of urea. The circumstances under which urea generation occurs and the manner wherein unreacted chemicals are subsequently processed distinguish the different urea processes. The process comprises two primary equilibrium reactions in which the reactants are only partially converted.

The first is an exothermic process in which liquid ammonia reacts with Carbon dioxide to produce ammonia gas (H_2N-$COONH_4$)

$$2\,NH_3 + CO_2 \leftrightarrow H_2N\text{-}COONH_4$$

The second is ammonium carbamate's endothermic breakdown into urea and water:

$$H_2N\text{-}COONH_4 \leftrightarrow (NH_2)2CO + H_2O$$

Methanol Production

Methanol is mostly used in the production of other chemicals. Methanol is transformed to formaldehyde about 40.0% of the time and then into polymers, lumber, paintings, explosive, and permanent press fabrics. Methanol is being used to fuel combustion engines on a temporary scale. Instead of coal, synthesis gas is now most typically made from the CH4 component of natural gas. Industrially, three methods are used. CH4 combines with steam over a nickel catalyst at moderate temperatures of about 850 0C and pressure of 4.0 MPa (40.0 atm) to generate syngas as per the chemical equations:

$$CH_4 + H_2O \rightarrow CO + 3\,H_2$$

This process, known as steam CH4 reforming or SMR, is endothermic, shrinking the amount and pressure of the catalysts utilized due to heat transfer constraints. As shown in the equations below, CH4 may be partially oxidized with molecular O2 to form syngas:

$$2\,CH_4 + O_2 \rightarrow 2\,CO + 4\,H_2$$

It is an exothermic process, as well as the heat released may be utilized to fuel the steam-methane reformation cycle in situ. Auto thermal reforming is the name given to combining the two procedures. The water-gas shift process may modify the Carbon monoxide and hydrogen gas ratio to a certain degree,

$$CO + H_2O \rightarrow CO_2 + H_2$$

Methanol is produced when CO and H2 combine on a secondary catalyst. Cu, ZnO, and Al are the most often utilized catalysts today. This could catalyze the synthesis of CH3OH from CO and H2 with good selectivity at 5.0–10 MPa (50.0–100.0 atm) and 250.0°C:

$$CO + 2\,H_2 \rightarrow CH_3OH$$

Soda Ash

Ashes of Soda (Sodium Carbonate) The solution of sodium of carbonic acid, Na2CO3, is also called as bicarbonate soda, soda crystal, soda ash, or "Soda Carbonate." They are most usually found as a crystallized heptahydrate that quickly effloresces to generate a white powder, the monohydrate, and is widely used as a softener in the home.

Among the most common applications of sodium carbonate is in the production of glass. Glass is made when it is joined with sand (SiO_2) and calcium carbonate ($CaCO_3$), heated to extremely high temperatures, and then quickly cooled. Soda-lime glass is the name for this sort of glass. Sodium carbonate is also employed in various applications as a moderately strong base. Numerous technologies, including the Leblanc, Solvay, and others, use Carbon dioxide from the atmosphere to boost the synthesis of soda ash nowadays.

Dimethyl Ether (DME) Production

The chemical molecule dimethyl ether (DME) has the structure CH_3OCH_3. If DME is burned, it creates very little NOx and Carbon Monoxide. Whenever consumed in engines appropriately designed for DME, DME may be a clean fuel.

DME is now manufactured mostly by turning hydrocarbon to synthesis gas, mainly obtained from natural gas (and to a lesser extent, coal gasification) (syngas). The synthesis gas would then be transformed to methanol in the presence of catalysts (typically copper), followed by methanol dehydration in the presence of another catalyst (for illustration, silica-alumina) to produce DME.

Enhanced Fossil Fuel Recovery

i) CO_2 Enhanced Oil Recovery (EOR)
ii) Enhanced Coal Bed Methane (ECBM)

i) CO_2 Enhanced Oil Recovery (EOR)

To varying degrees, three key types of EOR were shown to be financially successful:

1. Thermal recovery includes injecting the heat into the reservoirs, including steam, to determine the viscosity, or thinner, the heavy viscous oil, and enhance its flowability through it. Thermal approaches account for more than 40.0% of EOR generation in the United States, especially in California.
2. Gas injection that employs gases like natural gas, ammonia, or co2 to inflate in a reservoir as well as force more petroleum to a producing wellbore, or even other gasses that dissolve in the oil to lessen viscosity and enhance flow rate. In the US, gas injection contributes for roughly 60% of EOR output.
3. Chemical injection may include the introduction of long-chained compounds called polymers to improve the efficacy of water floods or detergent-like surfactants to assist decrease the surface tension that stops oil droplets from migrating through a reservoir. Chemical approaches account for around 1% of EOR generation in the United States. Each of these methods has indeed been limited by its relatively higher cost and its unpredictable efficacy in certain situations.

- ### *CO_2 Injection Offers Considerable Potential Benefits*

Carbon dioxide (CO_2)-EOR is the EOR technology generating the most significant fresh market interest. Carbon dioxide injections have indeed been effectively employed across the Permian Basin of West Texas and eastern New Mexico and has currently been explored to a limited degree in Kansas, Mississippi, Wyoming, Oklahoma, Colorado, Utah, Montana, Alaska, and Pennsylvania. It was first tested in 1972 in Scurry County, Texas.

Until recently, the majority of Carbon dioxide for EOR came from existing natural reserves. However, in areas where natural reserves are not accessible, new techniques are being developed to manufacture Carbon dioxide for industrial purposes, including natural gas processing, fertilization, alcohol, and hydro-plants. One example at the Dakota Gasification Company's facility in Beulah, North Dakota, which produces Carbon dioxide and transports it to the Weyburn oil field in Saskatchewan, Canada, through a 204-mile pipeline.

ii) Enhanced Coal Bed Methane (ECBM)

Improved coal bed CH_4 recovery, like oil recovery in oil and gas fields, is a technique of extracting more coal-bed CH_4 from the source rock. CO_2 poured into a bituminous coal bed could fill pore space and adsorption onto the carbon in the coal at a rate about double that of CH_4, perhaps leading to improved methane recovery. Such an approach might have been used in combination with carbon capture and sequestration to prevent climate change by sequestering co2 from the atmosphere from the outputs of fossil fuel power plants.

Use of Carbon dioxide in Biotechnology

i) Greenhouses
ii) Biodiesel from microalgae

i) Greenhouses

For several years, the advantages of co2 gas supplementing on greenhouses growing plants and output were well recognized.

Photosynthesis requires the presence of carbon dioxide (CO2), known as carbon assimilation). In green plants, photosynthesis is a biochemical process that converts Carbon dioxide and water into carbohydrates using light energy. During respiration, those carbohydrates are subsequently utilized towards plant development. The differential between both the rates of photosynthesis and respiration is what allows the plant to accumulate dry matter (grow). The goal of all greenhouse farmers is to improve dry-matter contents and maximize crop output at a low cost. Carbon dioxide boosts production by boosting plant growth and vitality. Early blooming, larger fruit yields, decreased bud abortion in roses, enhanced stem strength, and flower size are just a few of the ways CO2 boosts production. Carbon dioxide must be treated as a fertilizer by growers.

ii) Biodiesel from Microalgae

Due to the limited availability of fossil fuels as well as the rising emissions of the greenhouse gases atmospheric co2 as a result of their burning, emphasis has moved to biomass-derived fuel resources. Additional algal strains with strong growth potential, high lipid component levels, and resilience in a variety of environments are being explored.

Biodiesel from Microalgae - Methodology

Solvent Extraction Method

The solvent extraction process extracts nearly all of the oils, leaving just 0.50 percent to 0.70 percent of the raw resources with excess oil. Any low-oil-content substance may be extracted using the solvents extraction algorithm. It could also be used to make pre-pressed oil cake from material with high oil yield. Solvent extraction is now the most preferred technique of extracting fats and oils due to the high amount of residual oil. Green algae is taken from such an open pond, and hexane was used as a solvent.

Experimental Setup

The algae came from a pond that was accessible to the public. Exposed to the environment dries it out. The algae were pulverized following drying. In the thimble of the Soxhlet extractor, a 50 g specimen of dehydrated algae was inserted. The thimble comprises dense filtrate that is put into the Soxhlet extractor's chamber. The extract solvent is put in a flask with the Soxhlet extractor. A condenser is included with the Soxhlet.

The solvent is brought to a state of reflux. The solvent hexane condenses into vapors, which go up a distilling arm and through the chamber containing the solid thimble. Thanks to the condenser, any solvent vapor that starts to cool flows down into the chamber containing the solid substance. Warm solvent progressively fills the compartment housing the solid substance. In the heated hexane, some of the desired chemicals will disintegrate. Whenever the Soxhlet chamber is nearly filled, the siphon side arm mechanically empties the chamber, sending hexane out to the distillation apparatus. This process was repeated for a different amount of time each time. A fraction of the oil is dissolved in hexane throughout every cycle. The necessary oil was concentrated in the distillation flask after several such cycles. Hexane is dissolved upon extracting it, revealing the isolated chemical. The algae's insoluble component stays in the thimble. This time, the identical protocol was conducted, except the open pond algae remained 75.0 percent damp rather than completely dry. The identical procedure was followed, except this time, the open pond algae were 50.0% damp rather than completely dry.

Oil Expeller Method

The approach we used during the RGPV/ RKDF pilot trial, which is outlined below, is fundamentally distinct from solvent extraction. It is a mechanical process whereby we pressed the algae using an expeller. Screw expeller, mechanical pressing (by piston), and osmotic shock are all comparable ways. The osmotic pressure is abruptly lowered in the osmosis shocks technique. We finished our research on the screw expeller. In a single operation, the raw ingredients are pressed under tremendous pressure. Algae oils may be recovered to the tune of 75% using expeller pressing. The alga was taken from a pond that has been available to the public. Exposure to the environment dries it out. Because as materials are crushed in an expeller pressing, friction heats it up; in extreme situations, the temperature might reach 121 degrees Fahrenheit. We employed a screw-type expeller, which crushes oilseeds throughout a caged barrel-like chamber. With one end of the expeller press, algae enter, and products exited, and on the other side, products exit. The algae are long strands of green algae that looked resembled fiber. The algae didn't merely migrate into the screws at first. For simple passage through into the cage barrel, its surfaces would have to be wetted with water. The oil seeps via tiny gaps that prevent some other elements from passing across. Then, the almost-cake-like crushed algae were removed from the machine. Expeller pressing generates heat between 140 and 210 degrees Fahrenheit. The very last trace of oil in algae could not be removed by expeller treatment. The cake made had a substantial quantity of oil remaining in it. The cake that was created was in big quantities. Because the amount of solvent needed would've been significantly larger, this was not submitted to solvent extraction.

Protein, carbohydrate, lipids, and nucleotides are found in variable proportions throughout all algae, with amounts varying depending on the kind of algae. According to its total bulk, certain kinds of algae contain up to 40.0% fatty acids. The fatty acid is the component that can then be removed and transformed into biofuels. Because Carbon dioxide is a frequent industry contaminant, algae may help reduce atmospheric CO_2 concentration by eating Carbon dioxide wastes through industrial sites like power plants. Because microalgae are perhaps the most compelling main source of biomass, it was highly probable to be among the most significant alternative power sites in the form of biodiesel.

Algae can transform CO_2 from the atmosphere into biomass, which may then be treated downstream to generate biofuels, manure, and other valuable goods. Algae need co2 from the atmosphere, moisture, as well as sunshine to develop photosynthetically. Microalgae thrive in aqueous systems that provide for even better accessibility to Pure Water, Carbon dioxide, and certain other minerals, explaining why they have the potential to produce additional oils/ unit area than presently utilized crops. Furthermore, algae's high oil content might be a viable source for biodiesel generation.

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