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GLOBAL EMISSION OF CARBON DIOXIDE CONTROLLED BY GENERATING POWER FROM CARBON DIOXIDE

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ABSTRACT

Even though the carbon dioxide plays an important role in an ecosystem-carbon cycle, agricultural uses, food industry, chemical industry and other product manufacturing, the global carbon dioxide emission is to be reduced in large scale because of its effects-global warming, respiratory problems, ocean acidification, extinction of species and liquid contamination. In this paper, the main field of discussion is about, Carbon dioxide captured from coal fired power plants by using Direct Air Capture (DAC) technology based artificial tree. Converting liquefied carbon dioxide from artificial tree into electricity directly by geothermal heating method. DAC technology based artificial tree used along with photo catalytic coating based Solar Chimney Power Plant (SCPP) for generating electricity. This paper mainly focus on global reduction of carbon dioxide emission by using DAC technology based artificial tree used along with giant photo catalytic reactor based SCPP and geothermal power plant for converting the captured carbon dioxide into useful electricity.

Keywords: Carbon dioxide emission reduction, Direct Air Capture (DAC) Technology-Artificial tree, Solar Chimney Power Plant (SCPP), Photo catalytic reactor, Geothermal.

1. INTRODUCTION

The Earth's atmosphere contains carbon dioxide. This gas acts as a blanket around the planet, capturing some of the suns energy and the human influences also leads to more carbon dioxide emission that the blanket around our planet gets thicker and thicker and the Earth gets hotter every day i.e. greenhouse effect-global warming. Carbon dioxide plays a vital role in carbon cycle(photosynthesis and respiration) and it is also a by-product of combustion; is emitted from volcanoes, hot springs, power plants and geysers; and is freed from carbonate rocks by dissolution.

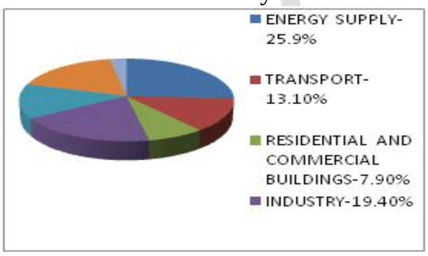


Figure.1-Sources of carbon dioxide emission- *Source:* **Inventory of U.S Greenhouse Gas Emissions and Sinks (2008), EPA**

The main sources of carbon dioxide emission [1] **(Fig.1-Sources of carbon dioxide emission-*Source:* Inventory of U.S Greenhouse Gas Emissions and Sinks (2008), EPA.)** are

1. Huge power stations generating electricity by burning coal, natural gas and oil-- one-third of carbon dioxide production in the industrialized nations.
2. Transportation -- generally 20 to 25 percent in most nations.
3.
4. Home heating, agriculture.
5. Industries like the cement industry[2], which is a very polluting industry because it has to heat up limestone to 1,450 degrees Celsius to turn it into cement, and the chemical process itself produces carbon dioxide. Cement causes about 5 to 10 percent of the global carbon dioxide emissions.

Carbon dioxide is the largest contributor among well-mixed long-lived greenhouse gases, accounting for more than 63% [3]. The coal is the major fuel used in all among the industries which produces more carbon dioxide due to combustion. Hence, carbon dioxide is mainly captured from coal fired power plants by using Post combustion method [4] which is effective among three methods.

Artificial Carbon Dioxide Capture Tree

Plans already exist to use artificial carbon dioxide capture trees just like the artificial solar tree. The idea behind this is to lead air with carbon dioxide through the tubes filled with a solution of **sodium hydroxide (NaOH)** which acts as resin plate for carbon dioxide capture from the ambient air by using DAC(Direct Air Capture) technology which is cheaper and has many advantages than CCS(Carbon Capture and Storage) technology. The carbon dioxide in the air will react with the sodium carbonate solution (Na2CO3=soda) which is regenerated, transported, stored, compressed and converted into liquefied carbon dioxide that reaches the underground rock region and heated to produce steam i.e. geothermal heating method, which runs the turbine and then generator that produces electric power.

2. METHODS OF CARBON DI OXIDE CAPTURE

DAC Versus Ccs-Carbon Di Oxide Capture Technology

DAC is very similar to CCS [5] technology, in which the alkali component is made to react with weak acidic carbon dioxide that separates neutral gases(N2 and O2) and carbon dioxide is regenerated thus the separated carbon dioxide is used further for transportation and sequestration process and the alkali component is recycled. So, the maintenance cost and installation cost is very high thus absorbs very less carbon dioxide from ambient air with 90% of carbon dioxide concentration. Hence DAC technology is more advantageous than that of CCS technology.

The difference between these two technologies depends upon

1. Initial equipment investment
2. Carbon dioxide capture with sorbents
3. Carbon dioxide release from sorbents
4. Regeneration and recycling of sorbents
5. Sorbent loss
6. Carbon dioxide compression
7. Transportation of pressurized carbon dioxide
8. Geological sequestration
9. Maintenance of infrastructure
10. Environmental impacts etc.,

The main reason behind the drawback of CCS technology is that the recycling of the liquid alkaline sorbent requires more energy because the liquid sorbent bind very strongly with carbon dioxide so that more energy is required for separation which leads to increase in driving cost for CCS method. Besides these the regeneration process is to be under 100º C to 140º C so that maintenance cost is quite high. The flue gas from the power plant or air must contain 90% carbon dioxide concentration so that the capturing of carbon dioxide is efficient. Then the use of liquid sorbents is less resistive and is to replaced frequently for some cycles so that the installation cost is also high (>$200/tonne carbon dioxide). But the cost for compression and sequestration is similar to the DAC technology. But the DAC technology is more advantageous that uses solid sorbent for carbon d oxide capturing which is highly resistive and less corrosive. So that the recycling require less energy and the regeneration is to be under 40º C to 45º C. The inlet air for capturing does not need to have more carbon dioxide concentration. The installation and maintenance cost is low. Operating costs of DAC [6] could thus be reduced comparatively to CSS, as components such as binding materials, are long lived and retain their effectiveness through a larger number of cycles. According to Lackner [7], the immediate small scale implementation of DAC is about $206/tonne carbon di oxide and for widespread mass production it is $30/tonne carbon dioxide.

Overall DAC Technology-Process

The overall DAC process [8] consists of consists of the two main components. They are closed box for carbon di oxide release and regeneration process and dry alkali resin plastic sheet for carbon dioxide capture. There are five steps in this technology (Fig.2-over all DAC process (inspired from)).

1. The air with carbon dioxide is passed through the closed box with resin plate which is exposed for wind flow.
2.
3. Then carbon dioxide sticks to the resin plate until almost all region of the resin sheet reaches acid-base salt state.
4. The device is isolated for pumping out the captured air from regeneration chamber.
5. The resin is made to wet and warmed up to 40ºC to 45ºC and the captured carbon dioxide is released and the resin retains to its base state [9] then it is used under dry condition for capturing carbon dioxide second time and the process continues.

Artificial Tree

The geo-physicist Professor Klaus Lackner has designed a synthetic tree (Fig.3 Artificial tree prototype), a construction that mimics the function of natural trees whereby leaves pull carbon dioxide out of the air as it flows over them. The carbon dioxide removed from the atmosphere in this way, he believes, could be stored deep underground both safely and permanently. When carbon dioxide comes into contact with sodium hydroxide, it is absorbed, producing a liquid solution of sodium carbonate. It is that liquid solution that the professor believes could be piped away, and the time at which the carbon dioxide could be recovered as a concentrated gas in preparation for its final storage. Once trees and other plants have absorbed carbon dioxide, the carbon is retained in their tissues. His vision is to have thousands of artificial trees and estimates that every single one would remove 90,000 tonnes of carbon dioxide a year - the equivalent emissions of 20,000 cars.

The pumped out carbon dioxide is compressed at 70 atmospheric pressure and it is stored in the storage chamber.

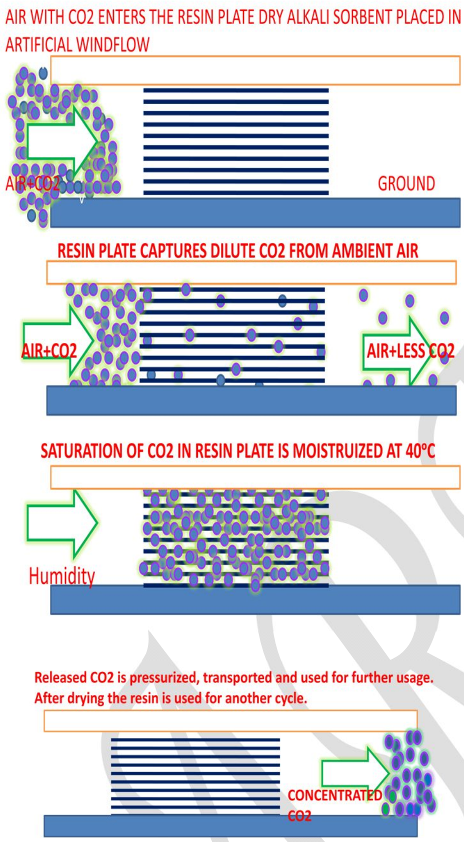


Figure.2 Overall DAC process (Source: Lackner's DAC process)

Figure.3 Artificial tree-PROTOTYPE (Source: Global Research Technologies)

He has estimated that the expected financial cost for the operation and installation of artificial tree. According to Lackner, when the mass production has been reached the individual units of 500 square meter which is able to capture 10 tonnes of carbon d oxide per day that would cost $20,999 each including all equipment and the material costs comparatively to $200,000 with current technology.

Structure And Function Of Artificial Tree

The image of the artificial tree [10] Fig.4 Artificial tree structure (Source: artificial tree for carbon scrubbing by Boston) consists of trunk, stem, branches, leaves and roots. The trunk of the tree will be used as the regeneration chamber to release the captured carbon dioxide and for resin regenerating by equipping it with hydraulic cylinders and engine in order to lift and lower the resin trays outside or inside the chamber for effective carbon capture and regeneration purposes. It is also used for supporting structure for the active part of the device-leaves made of alkali polymeric resin. The tower with its height acts as the stem for the artificial tree which supports the regeneration. The resin trays along with the resin are considered as the branches and leaves of the artificial tree.

The resin plates with carbon dioxide absorbents will cost low in future and available in cheap. Thus the compressor and pump are the costly equipments used in this artificial tree. This artificial tree's function is similar to the action of natural tree thus absorbing carbon dioxide directly from the atmosphere by using solid alkaline absorbents depending mainly on wind to make the mass transport of air across the absorbent. This alkaline absorbent is then regenerated by low temperature process releasing almost pure carbon dioxide and this technology represents similar to the CCS technology but it requires smaller amount of energy. Thus, the carbon dioxide is effectively captured by artificial tree. Then, is converted into electricity by using geothermal heating method.

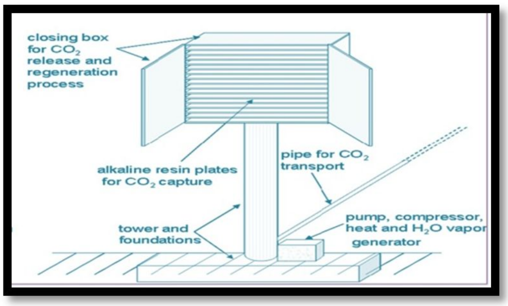


Figure.4 Artificial tree structure (Source: artificial tree for carbon scrubbing by Boston)

3. METHODS OF CONVERSION

Converting Geothermally Heated Carbon Dioxide Into Useful Electricity

The captured carbon dioxide in the pipe is injected in underground of three km in the sedimentary layer whose temperature is 125ºC so that carbon dioxide is in supercritical state i.e. both gaseous and liquid properties Fig.5 carbon dioxide conversion into electricity (Source: http://newscenter.lbl.gov/)

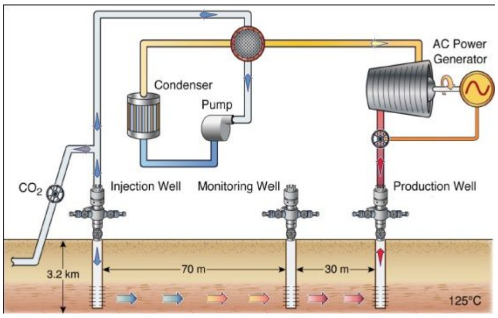
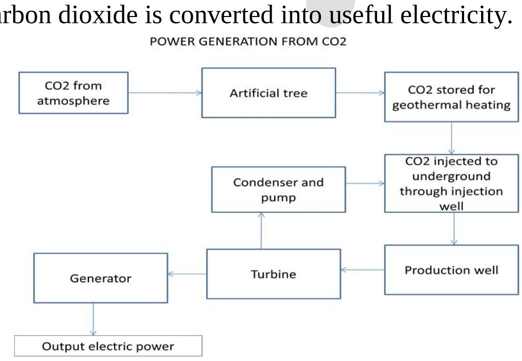


Figure.5 carbon dioxide conversion into Electricity (Source: http://newscenter.lbl.gov/)

The heated carbon dioxide is pulled to the surface and then it is fed to the turbine which converts the heated carbon dioxide's steam in to the useful electricity. This process is made as closed loop by recycling the unusable steam by use of condenser and continuous addition of carbon dioxide to keep the turbine spinning.

The main advantage of this method is that it offsets the cost of geologic carbon storage which is a promising climate change mitigation strategy that involves capturing carbon d oxide from large stationary sources and pumping it into deep underground. This method enables the burning of fossil fuels without releasing the greenhouse gases into the atmosphere. The site's (Southeast Regional Carbon Sequestration Partnership's Cranfield site) three-kilometer deep reservoir has proven to be an ideal site for carbon sequestration by the carbon dioxide injection project since 2009. Much of the infrastructure needed for the test is already in place, including injection and production wells. The output electricity obtained by this method depends on the scale of carbon capture and storage operations and the availability of deep reservoirs that can both heat and store carbon dioxide. The technology also takes advantage of a problem common to conventional geothermal energy. Thus by this technology the carbon dioxide is converted into useful electricity.



Overall Block Diagram

Solar Chimney Power Plant

Solar chimney power plant (SCPP) [11] Fig.6 Solar Chimney Power Plant (SCPP) consists of a circular greenhouse (GH) type collector [12] with a tall chimney at its centre. The captured air inside this GH transparent roof is at several meters above the ground is heated by the sun. The height of the collector increases from the exterior to the centre adjacent to the tower base. Then the hot air passes through the chimney due to buoyancy effect where turbine produces electricity. Thus SCPPs are environmentally friendly compared with existing coal fired power plants and other renewable energy based power generation technologies. The environmental analysis results in, respectively approximately 170 and 70g CARBON DIOXIDE-equivalents/kWh [13] for 5 and 100MW SCPP, as with larger plants the consumption of raw materials and resources decreases. Table 1 shows the typical dimensions of SCPPS for several electricity outputs as calculated by Schlaich [14]. In 2001 Lackner proposed the DAC technology that is coupled with the "convection tower" [15] that could generate electricity and captures carbon dioxide.

Zaslavsky of Technion Institute in Israel has developed the ''energy tower'' [16] which consists of spraying water inside a tall chimney so that the water evaporation cools the hot dry incoming air then it falls down through the tower as it cools and becomes more denser for running the turbine then it drives the generator to produce electricity. The same idea is proposed by Bonnelle [17] and de Ritcher [18]. Then in 2011, US patent by Eisenberger [19] described about the solar heating tower or chimney as solar driven air current source to replace the fans for CCS. The solar chimney power plant is shown in the Fig.6 solar chimney power plant that it consists of chimney, turbine, and collector. In the normal SCPP the inlet air flow is converted into electricity by using collector, turbine and generator.

Table 1-Typical dimensions and electricity output of different size SCPPs(Source: Schlaich J, Bergermann R, Schiel W, Weinrebe G. Design of commercial solar updraft tower systems)

Capacity	**MW**	**5**	**30**	**100**	200
Tower height	M	550	750	1000	1000
Tower diameter	M	45	70	110	120
Collector diameter	M	1250	2900	4300	7000
Electricity output	GW h yr^-1	14	99	320	680

Thus other thermal power generation technology uses water.

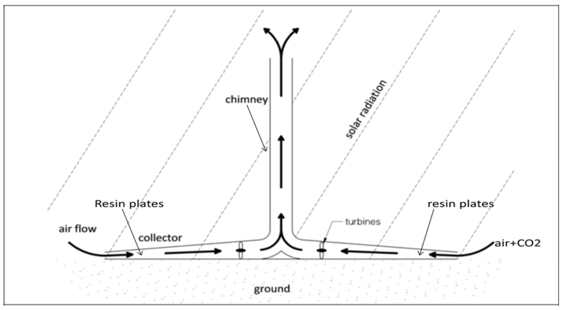


Figure.6 Solar Chimney Power Plant (SCPP)

But, SCPP do not use water for the electricity generation as they do not need any heat sink which is a vital factor in areas with water constraints. Thus for a200 MW with the chimney of 120m diameter and a wind speed of 15ms^-1 [20], the air flow across chimney is about 14.66km^3/day. From this the SCPP acts as giant atmospheric vacuum cleaner.

SCPP along with DAC technology

The SCPP is coupled with the DAC technology to neutralize the carbon content in air. Thus the resin plates Fig.7 SCPP along with DAC system (inspired from lackner's process) used in the inlet of the air flow in SCPP. ithin small area many devices are installed, by varying the position of capture units according to SCPP collector, more carbon dioxide capture per day i.e. 3500tonnes of carbon dioxide per day, quick regeneration process, recycling of heat, for resin regeneration temperature required is 40-45ºC which is obtained from heat recover in carbon dioxide compression, renewable energy usage for carbon dioxide capture leads to overall yield improvement b 25% without emitting new carbon dioxide, more electricity is produced.

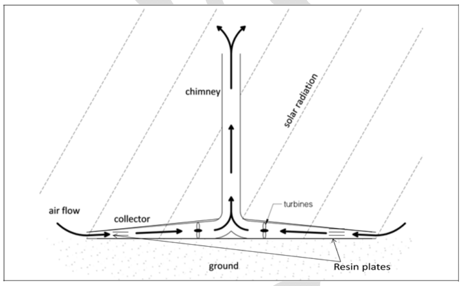


Figure.7 SCPP along with DAC system

4. CONCLUSION

The perspective of SCPPs development is promising, as each solar chimneys power plant of 200 MW could at the same time produce 680GW of renewable electricity per year, which is valuated as an annual saving of 0.9million tons of carbon dioxide emissions for every SCPP [21] and it deliver no intermittent renewable electricity 24 hours a day, 365 days a year, with a delivered power output as constant as possible, but also that can be controlled in order to be increased during peak load and act as a peaking power facility and it drastically reduce the investment costs of Lackner's DAC devices and increase the yields and drastically reducing the operational costs of DAC.

The SCPP associated with DAC and with photo catalysis provides a radical technological breakthrough: producing a carbon dioxide-free renewable energy and at the same time removing the principal green house gas from the atmosphere and enabling production of high density transportation fuels by artificial photosynthesis. As written by Centi [22, 23] this project gives, ''…the possibility to develop ''artificial trees'' able to capture the carbon dioxide and convert it to liquid fuels (hydro carbons, alcohols).

Besides these the carbon dioxide captured from artificial tree through DAC technology is effectively used by converting it into electricity through geothermal heating of carbon d oxide [24]. The output of electric power is generated and it is used for many applications. The system is pollution free and renewable in nature hence it has quite worth in future.

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