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Carbon Capture and Storage Using Renewable Energy Sources: A Review

To cite this article: S Ragul hari *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **573** 012004

Carbon Capture and Storage Using Renewable Energy Sources: A Review

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Abstract: The world is undergoing a population explosion; urbanization has also taken giant leaps with higher standards of people. It is noted that the supply and the demand for energy have not been in correlation with one another, as around. When the supply of energy is scaled up, there will large amounts of emissions released from the power plants. Therefore, it is important to focus on capturing and storage of harmful greenhouse gas emissions, using renewable energy resources, so that emission mitigation can be made in an efficient and economically feasible way. The pragmatic analysis of solar-assisted post-combustion carbon capture (SPCC) has been reviewed upon, where the energy compensation of a coal-fired plant due to regeneration of absorbent has been scrutinized. It is also been compared with the integration of geothermal energy (GTCC) for carbon capture. In the adsorption process, various techno-economic analysis of Carbon Capture and Storage (CCS) integrating solar-assisted temperature swing adsorption has been reported along with the effect of absorbent material in pressure-temperature swing adsorption for CO2 capture. Assessment of solar-assisted CCS are also been accomplished by adopting pliable thinking on the energy system. Finally, the integration with solar thermal power plant using novel Sodium Carbonate as a solvent is discussed. Thus, several parts of the CCS system have been construed with renewable energy towards the goal of zero-emission power generation, which seems highly impossible, can be harnessed by 2050

Keywords: Carbon capture and storage; Renewable energy; Solar assisted carbon capture; geothermal energy; adsorption.

1. Introduction

Carbon capture and storage (CCS) plays a pivotal role in eliminating emissions from energy extraction and prevent it from entering the atmosphere. CCS includes capture, storage, and transportation. It has many advantages such as ameliorating climate change and boosting the economy. It also provides energy security to the citizens of a country. CCS are of three different types which include the post-combustion capture, oxy-fuel combustion, pre-combustion capture. The post-combustion capture process deals with capturing of carbon dioxide once the reactants are treated to produce the output of heat along with the by-product of flue gases. The oxy-fuel combustion involves capturing carbon dioxide that takes place well inside the combustion chamber by altering the reactants and other parameters involved such as pressure and temperature during the combustion process. In pre-Combustion capture, the capture takes place well before the combustion process[1]. Since the post-combustion process is the one that deals with most parts of the CCS systems, many methods have reported on incorporating renewable sources such as the solar and geothermal process in either solvent regeneration of absorption or pressure-temperature swing adsorption. A literature case study in each of the two processes has been presented in detail along with other corresponding factors relating to maximizing the output efficiency and depreciating the overall existing cost of price of the power plant. Various retreatment activities in the commercialization of the captured carbon have been made by producing sodium bicarbonate, an important component in the food and chemical industry. A generic analysis has been made on negotiating factors in the implementation of SPCC in the power plant by considering data from several geographical locations (raw analysis).

2. Methodology of integrating renewable energy sources in carbon capture

2.1. Absorption

Absorption is considered to be the most commonly used method involving a relatively easy as well as compact mechanism. It is further classified into two types based on the pressure at which the flue gases are dealt with. If the pressure is found to be on the lower side, the flue gases are treated by chemical absorption and if the pressure is higher, then the absorption process was physical [2]. It is reported that the basic differences between these processes depend on the way by which, the solvent is regenerated either physically or chemically. A certain amount of energy is utilized for the regeneration of the solvents. So, it is important to save this energy utilized, that is, the produced thermal energy from the power plant. It is for this reason; renewable energy has been implicated for solvent regeneration owing to its feasibility. Construction of the solar assisted CCS system is set up as shown in Figure 1.

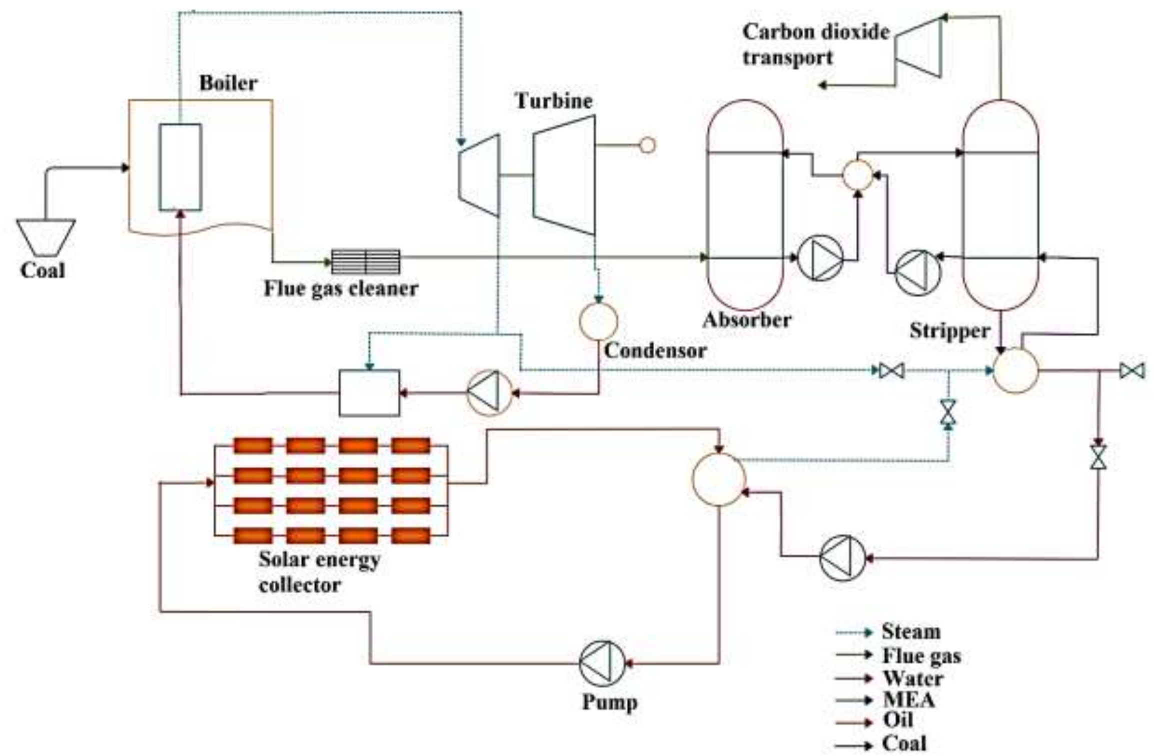

Figure 1 Schematic representation of proposed integration of SPCC in a coal fired power plant

The desorber and absorber is designed to have an internal diameter of 0.15 m. The height was absorber and desorbers were found to 2m and 1.5 m respectively. Parabolic Trough Collectors or Linear Fresnel Reflectors are used as solar collectors for collecting the heat required for solvent regeneration. The area of cross section of these erected solar collectors is 23.5 m^2 [3]. The collectors are placed from north to south in the direction so to facilitate solar radiation efficiently. Due to the fluctuations in solar energy generated throughout the year, an electric heater of capacity 20 W is used as an alternative source to generate heat. Many parameters such as four gas concentrations, the flow rate of heat transfer fluid, the concentration of Mono Ethyl Amine (solvent), the flow rate at which solvent circulated, and temperature of the solvent, absorbed by the cross-flow cooling system were altered and results were inferred. It was reported that performance has been very significantly impacted for carbon capture standalone systems. The solar collector efficiency increased with the rise in solar irradiation, due to which the area of solar collectors required can be reduced. It is discovered that the parabolic trough collector was relatively more efficient in collecting heat for the same amount of area than the linear Fresnel reflector [4]. Though it had this advantage, linear Fresnel was comparatively cheaper and required an easy erection process. Hence both the collectors can equally be preferred. The main observation that was deduced after all analysis is the liquid-to-gas ratio was optimized to 2.5-3 for critical lower energy requirement during this regeneration process [2-4]

2.2. Geothermal

Geothermal energy assisted CCS (also referred to as GTCC) has been developed for the same function of solvent regeneration because solar energy at high temperature zones is not quite feasible. Geothermal energy, owing to its property of its non-intermittence, has been preferred. Meanwhile, current electricity has high investment and also lowers the efficiency of steam extraction[5]. It can be used to replace the extraction of carbon dioxide due to large availability and process too, depends on chemical solvents. The major objective of GTCC is the economic and effective use of geothermal energy. The diagram of this figure has been exemplified as shown in figure 2. This system is integrated with the boiler.

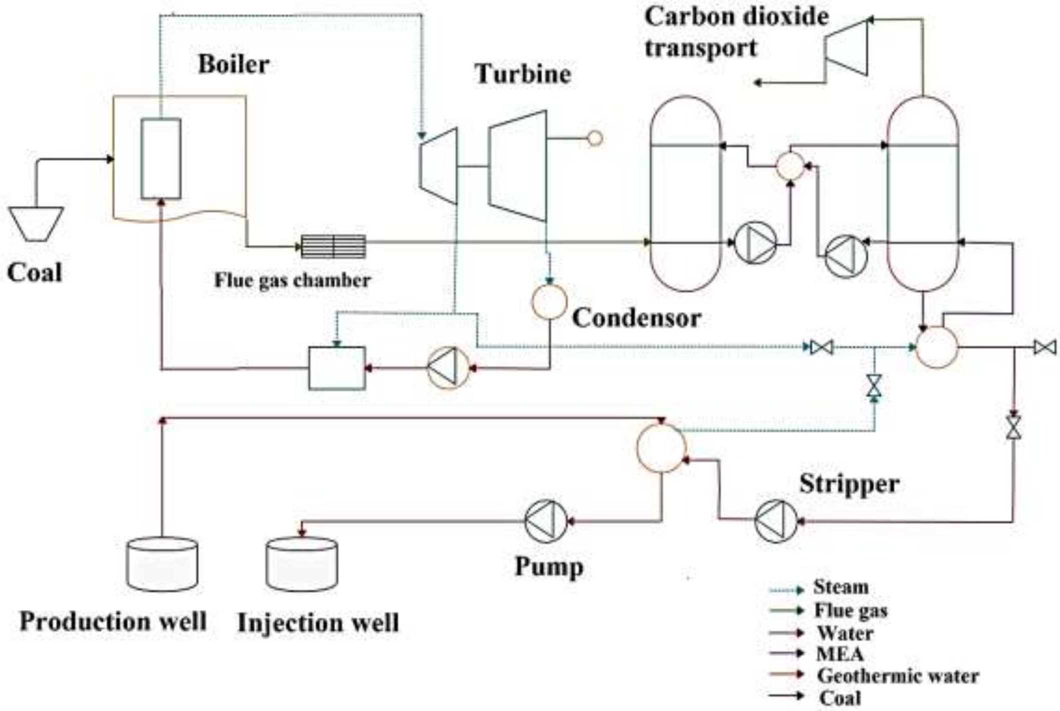

Figure 2 Schematic diagram of the proposed integration of GPCC in a coal-fired power plant

There are 5 main types of geothermal systems- 1. Vapor dominated reservoir 2. Water dominated reservoir 3. Geopressured geothermal reservoir 4. Hot dry rocks 5. Magma system. Water dominated reservoir has been used predominantly since it can hold high temperature ranges. There are two terms related to financial Management: Levelized Cost of Electricity (LCOE) and the Cost of Carbon Avoidance (COA), which is supposed to be minimized as much as possible as they determine the economic conservationism of the power plant. It is also reported that the Thermal Load Factor of SPCC was greater than the corresponding factor of GTCC[6], when storage size is considered as a factor, while the vice-versa took place when the thermal fluid of each system was considered. Other inferences during the comparison were also observed. Solar variations vary according to seasons significantly and monthly calculations were carried out on TLF and Direct Normal Irradiation (DNI), while GTCC depends on the total number and drilling depth of holes which are delved underground for extraction of energy. Further investigations revealed that SPCC is subjected to fluctuations in energy that mostly dwells upon DNI, while GTCC provided constant output all around the year. Factors such as LCOE and COA depends on economic evaluation of the local climatic condition, while TLF depends on the area of solar collector and number of wells dug around GTCC. The schematic representation of GTCC in the coal-fired power plant is shown in Figure 2. Thus, it can be concluded that for the same amount of power saved during solvent regeneration and similar geographical factors, GTCC is found to be on the efficient side, due to lower prices of storage costs [5,6].

2.3 Adsorption

Compared to chemical absorption, adsorption is reported to be a consistent carbon capture method owing to low-cost investments and feasible automated operations [7]. A large amount of adsorbent materials has been synthesized and also have been scrutinized experimentally. All this practical analysis has reported that the adsorption process is said to have consumed less power compared to the chemical absorption process.

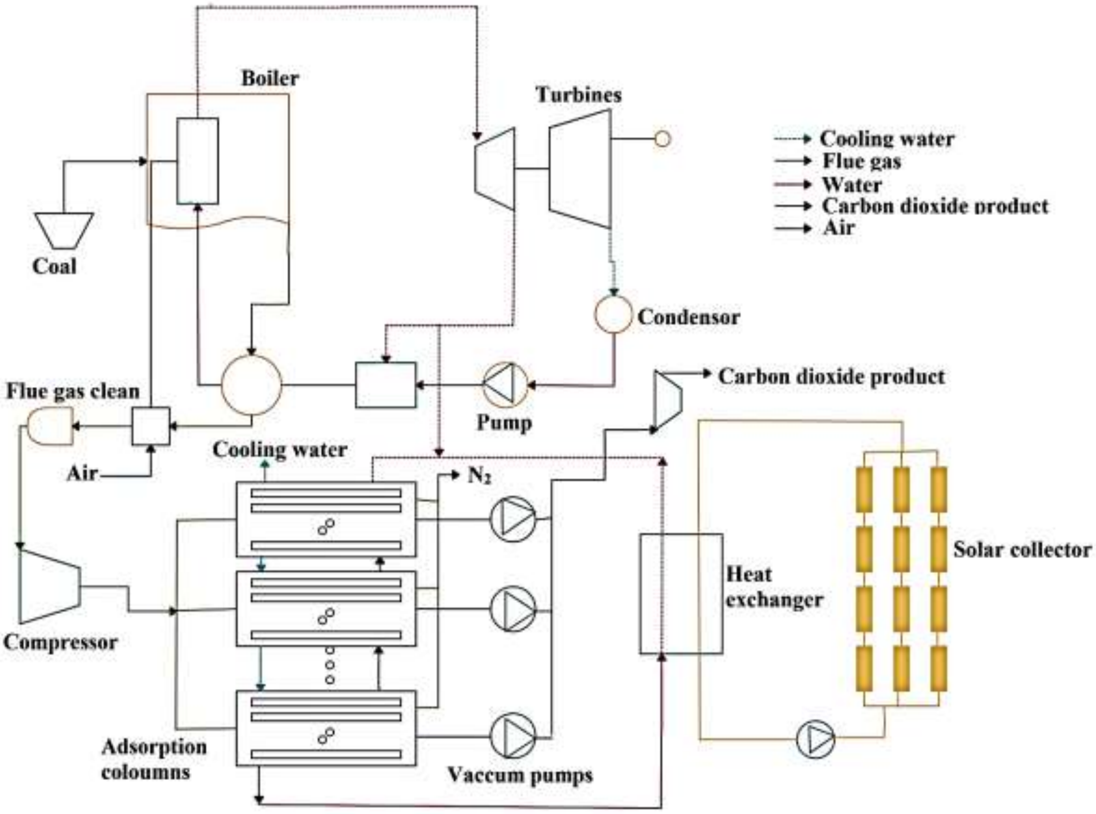

Figure 3 System sketch of integrating solar assisted PTSA into a coal-burning power plant for CO2 capture.

The process involved: A system as shown in Figure 3 is erected. The adsorbent regeneration heat is supplied from solar energy. The heat transfer oil is heated initially to a temperature that is required to facilitate desorption. The heat for this process is collected from the solar collectors. A high boiling point is a requirement when heat transfer fluid is considered to be a working fluid. The adsorbent used in the working bed is considered to be activated charcoal or Zeolite 13[8]. At higher pressure (>0.7 MPa), zeolite is considered while at a lower pressure (<0.1MPa), activated charcoal is preferred over other absorbent materials. The carbon capture takes place as described in the following steps.

1. The pressure of the flue gas is increased from atmospheric pressure using a blower to very pressures (10 bar). The adsorbent material selectively removes the carbon dioxide, leaving out nitrogen-rich effluents to flow out of the system.
2. Carbon dioxide is continuously removed and desorber using a vacuum pump system and the temperature and pressure are equalized to desorption temperature and evacuated pressure respectively, due to which, one can find an increase in temperature and decrease in pressure, which causes desorption of the adsorbed gas. The heat from the solar collector is supplied in this step.
3. Adsorbent bed temperature is reduced by the circulation of cooling water so that the adsorbed amount is kept unchanged.

Further investigations are done on the cost related factors such as LCOE and COA.
The following conclusions were derived from solar-assisted adsorption in the CCS system.

(i) The SPCC absorbent regeneration system can easily improve efficiency and minimized the energy penalty because of the carbon capture system.
(ii) LCOE and COA of this system were found to be lesser than the reference system, expounding to the existing economic advantages [9].
(iii) From various literature sources, it was also noted that the CEI of this system was found to be 100g/KWh which is way larger than the reference system [10].

2.4 Sodium Bicarbonate production
An alternate and feasible method apart from the storage of the captured carbon is to process it and produce an economically commercial byproduct [11]. The process through which it has been synthesized is depicted in Figure 4. The captured carbon using SPCC and GPCC is treated to produce a commercial product sodium bicarbonate from crushed trona. The process of production of Sodium carbonate and Sodium bicarbonate from crushed trona initiates at the fluidized bed reactor at 220°C and 1 bar using solar thermal power as the source for heating medium. To achieve the temperature requirement, an intermediate temperature parabolic troughs collector is fixed with a storage system of thermal energy, and is appropriate to supply the necessary energy. The crushed trona, before entering the fluidized bed reactor is sent through the heat exchanger, the transfer of heat from Na2CO3 byproduct from the bed reactor to crushed trona occurs was the rise of temperature from 25°C to 127°C occurs. Subsequently, the other heat exchanger manages to exchange heat obtained through the gases and vapor steam outlet from a fluidized bed reactor to the water entering the fluidized bed reactor, where an increase of 205°C is achieved.

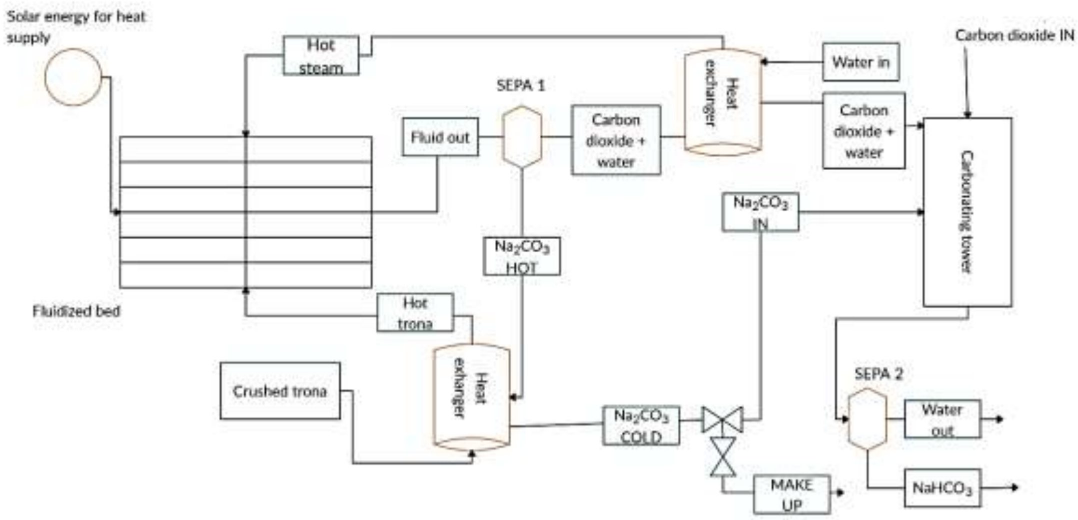

Figure 4 Representation of process involved in sodium bicarbonate method

As the reaction outcome by utilizing the solar thermal energy(power) for heat supply, Sodium carbonate, carbon dioxide, and water is obtained. A part of this outcome is utilized in the carbon dioxide capture (dry carbonate process), the other part is transferred to the carbonating tower for the production of NaHCO3, a continuous flow of pure carbon dioxide from the capturing system and water released from the fluidized bed is utilized [12]. Thus, the production of a marketable product is achieved by consuming the seized CO2 from the SPCC plant enhancing greater value in economic aspects. It is majorly used in the food and chemical industry.

The chemical reactions between crushed trona and sodium bicarbonate are:

$$2(Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O)\ (s) \rightarrow 3Na_2CO_3(s) + CO_2\ (g) + 5H_2O\ (g) \qquad (1)$$
ΔH at 298K = 133.9 kJ/mol

$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$ (2)

3. Economic feasibility

Urbanization has taken giant leaps with higher standards of people enhancing the increase in global warming. The emission of CO_2 tends to major disaster to the natural and environmental resources. As CO_2 is considered to be one of the important greenhouse gas major steps and strategies are framed to control its threat to the environment [13].
The major contribution of CO_2 emission is through the following sectors:

- Transport sector
- Power plant
- Industrial emissions.

Cogeneration is a productive way of achieving near zero emission [14], It can be defined as the continuous production of power/energy for the utilization in the industry with a good efficiency from a single energy source.
The electrical and cogeneration efficiency can be calculated using formulas (3) and (4) respectively.

$$\textbf{Electrical efficiency} = \frac{\text{electrical output [kW]}}{\text{fuel input [kW]}} \quad (3)$$

$$\textbf{Cogeneration efficiency} = \frac{\text{useful thermal[kW]+electrical output[kW]}}{\text{fuel input[kW]}} \quad (4)$$

Governments of several countries have appointed various body to work on carbon dioxide capture technology. They have the main objective of analyzing the factors and limitations concerning the financial, ecological and risks associated with the process [15]. To enhance the economic feasibility different factors are involved like:

3.1. Subsidies
As the initial cost of setup overtakes the entire cost of solar and carbon capture technologies, a subside that helps in the reduction of initial costs would have a significant impact on the expenditure for carbon capturing.

3.2. Carbon Tax
In the motive of reducing emissions a penalty known as carbon tax is filed upon CO_2 emitters enhancing lower amount of emission. Generally, two ways of implementing carbon tax is followed, primary method is fixing a threshold limit for emission and a compulsory tax amount payment for overtaking the threshold limit, the other method is by implementing a cap-and trade system, where government sets up the total emission [16].

3.3. Discount Rates
Deployment expenditure of these technology can be reduced by providing discount rates accordingly, increase in the scale of discount rates proportionally decrease the capital required for deployment of these technologies. Thus, the rate of discount should be greater than the rate of interest and dependent on aspects like the termination of a particular technology and threats due to policies and cost of electricity.

The viability of Solar Assisted Post Carbon Capture for each application is analyzed with respect to the values of LCOE, COA and the NB. LCOE is a method used to compare the cost of generating electricity using various technologies and it is the total up-to-date value of the electricity costs (per MWh) depending on the several costs (investment, process, petroleum etc.) of the power project. Though, there is a limitation in LCOE, as the factor of carbon emission in the application of different technology and the environmental impact due to the post application cannot be determined [17]. It is calculated using the formula (5). The COA is a technique similar to that of LCOE but evaluates the project costs depending on the amount of CO_2 avoided, is calculated using the formula (4). Therefore, COA is a most efficient method in calculating the feasibility of power projects where CO_2 reduction is a predominant factor [18] – [19].

$$\mathrm{LCOE} = \frac{\sum_{y=1}^{n} \frac{\mathrm{Iy+My+Fy+Cy-Ry}}{(1+r)^{\wedge}y}}{\sum_{y=1}^{n} \frac{\mathrm{Ey,solar}}{(1+r)^{\wedge}y}} \quad (5)$$

$$COA = \frac{\sum_{y=1}^{n} \frac{Iy+My+Fy+Cy-Ry}{(1+r)^{\wedge}y}}{\sum_{y=1}^{n} \frac{COy}{(1+r)^{\wedge}y}} \quad (6)$$

All the factors explained are calculated for each renewable technology. The terms which are mentioned above is calculated using (7), (8), (9), (10), (11), (12) and (13)

$$\mathbf{I_y = \sum_{m=1}^{p}((i_m - sub_m) * fi_{m,y})\ ;\ \ sub_m = i_m * sub_{\%}} \quad (7)$$

sub_m – overall subsidy amount
$sub_{\%}$ - fraction of the amount for project from subsidies.

$$\mathbf{M_y = \sum_{m=1}^{p}(\ O_{fixed} + O_{var}) + Z_y} \quad (8)$$

O_{fixed}, O_{var} - static & flexible costs for operations
Z_y - annual sequestration cost

$$\mathbf{F_y = \frac{Pcoal * Ey,coal * \alpha}{\eta th-e,coal}} \quad (9)$$

P_{coal} - energy specific cost of coal
$\eta_{th\_e,\ coal}$ -efficiency to convert thermal to electrical in coal based powerplant
α - unit energy conversion factor
$E_{y,\ coal}$ - gross load of the power plant (coal)

$$\mathbf{E_{y;\ solar} = \int_{t=1}^{t=n}(Y(t) + S(t)) * \eta\ th - e} \quad (9)$$

$$\mathbf{S(t) = S(t\text{-}1) - D(t) + Y(t)} \quad (10)$$

$$\mathbf{C_y = E_{y,\ coal} * (1\text{-}\ CR) * CEI_{coal,\ CSS}} \quad (11)$$

$$\mathbf{R_y = REC * E_{y,\ solar}} \quad (12)$$

Y(t) – output of useful heat from parabolic trough collectors
S(t) – At a time t, the amount of stored thermal energy in the medium
$\eta_{th\ \_e}$ - thermal to electricity conversion efficiency
D(t) – At a time t, the reboiler' s demand of thermal energy

$$\mathbf{Y(t) = \eta_{opt} * G(t) * IAM(t) - a_1 * T_i\text{-}T_a(t))\text{-}a_2 * (T_i\text{-}T_a(t))^2} \quad (13)$$

The factors LCOE & COA are useful in equating the advantages of various technologies which possess constant output of electricity, the factor that renewable technologies can produce electricity only at particular times of the day couldn't be exactly equated using the same metric. As COA is a linear function of LCOE, when focused to incentives they both shows similar trends [20] – [22]. After considering several factors and geographical conditions all over the world the incentives and efficiencies are favorable to the SPCC than CCS by working out with the above equations. Solar thermal energy is the only technically & economically attainable renewable energy technology which can deliver reliable, dispatchable power and is an adequate resource [23]. Thus, the solar assisted carbon capture can be achieved by using the generated amount of solar energy which is a feasible measure enhancing almost near zero carbon emission. Though, the current price of electricity and primary capital cost of a solar thermal power plant is relatively high and thus as an alternative, Small scale solar thermal energy in energy mix is valued. It would encourage the powerplant owners to adopt renewable energy thereby achieving their targets meanwhile achieving reduction of CO_2 emission.

4. Conclusions

The idea behind the study is to provide with a basic strive of stressing the fact that the application of SPCC and GPCC in a power plant would enhance in obtaining improved power output thereby reducing CO2 emission, Adsorption has also been discussed owing to the fact that this technology will be in the mere future. The main motive of zero additional carbon emission SPCC is achieved by including the fact that it is high on demand and an abundant available source comparatively with other renewable or traditional energy resources. Depending on the data considered from several areas the final statement on the techno – economical aspects is that the cost of electricity produced at the power plant as a result of Solar assisted post carbon capture arrangement is higher than the cost of electricity of a power plant without solar input. In order for the solar energy addition to be practically applicable and economically feasible, incentives such as carbon tax, discount rates and subsidies are required. Based on the country's policy on solar and carbon capture technologies, specific cost rate the feasibility of SPCC arrangement may be varied. Thus, the thirteenth sustainable development goal formulated by the United Nations of having zero emission fuels by the year 2050 can be only be fulfilled using renewable energy resources.

Table 1: Abbreviations

Symbols	Terms
y	year
M_y	Cost for operation and maintenance
n	Time (per annual)
F_y	Fuel cost
I_y	capital cost
C_y	cost of carbon emissions
R_y	Annual specific revenue made from RECs
E_y	Annual specific electricity ejected
R	Factor of discount
CO_y	Annual specific carbon dioxide eliminated

References

[1] https://www.theguardian.com/environment/2011/mar/18/carbon-capture-storage-technologies

[2] Mohammad Saghafifar, Samuel Gabra ,"A critical overview of solar assisted carbon capture systems: Is solar always the solution?" International Journal of Greenhouse Gas Control Vol.(9), (2020). Article in Press.
DOI:10.1016/j.ijggc.2019.102852.

[3] Dia Milani, Scott Nelson, Minh Tri Luu, Mehdi Aghaei Meybodi, Ali Abbas, "Tailored solar field and solvent storage for direct solvent regeneration: A novel approach to solarise carbon capture technology" Applied Thermal Engineering "Vol. 17. (2020)
DOI:10.1016/j.applthermaleng.2020.115119.

[4] Marwan Mokhtar, Muhammad Tauha Ali, Rajab Khalilpour, Ali Abbas, Sgouris Sgouridis, " Solar-assisted Post-combustion Carbon Capture feasibility study", Applied Energy Vol.9, (2012), pp. 668-676.

[5] Fu Wang, Shuai Deng, Jun Zhao, Jiapei Zhao, Jinyue Yan, "Integrating geothermal into coal-fired power plant with carbon capture: A comparative study with solar energy", Energy Conversion and Management Volume 148, (2017),pp. 569-582

[6] Fu Wang, Shuai Deng, Jun Zhao, Junyao Wang, Jinyue Yan, " Performance and economic assessments of integrating geothermal energy into coal-fired power plant with CO2 capture", Energy Volume 119, (2017), pp. 278-287.

[7] Ruikai Zhao, Li Zhao, Shengping Wang, Shuai Deng, Zhixin Yu, "Solar-assisted pressure-temperature swing adsorption for CO2 capture: Effect of adsorbent materials", Solar Energy Materials and Solar Cells Vol. (2018), pp. 494-504

[8] Farihahusnah Hussin, Mohamed Kheireddine Aroua, "Recent trends in the development of adsorption technologies for carbon dioxide capture: A brief literature and patent reviews (2014–2018)", Journal of Cleaner Production Vol.253, (2020)

[9] Ruikai Zhao, Longcheng Liu, Li Zhao,Shuai Deng, Hailong Li, "Techno-economic analysis of carbon capture from a coal-fired power plant integrating solar-assisted pressure-temperature swing adsorption (PTSA)", Journal of Cleaner Production Vol.214, (2019), pp. 440-451

[10] Rached Ben-Mansour, Ahmed Abuelyamen, Naef A. A. Qasem, "Thermal design and management towards high capacity CO2 adsorption systems", Energy Conversion and Management, Vol. 212, (2020).

[11] Francesco Nocito, Angela Dibenedetto, "Atmospheric CO_2 mitigation technologies: carbon capture utilization and storage" Current Opinion in Green and Sustainable Chemistry Vol.21 (2020), pp. 34-43.

[12] D. Bonaventura, R. Chacartegui, J. M. Valverde, J. A. Becerra, V. Verda, " Carbon capture and utilization for sodium bicarbonate production assisted by solar thermal power", Energy Conversion and Management, Vol. 149, (2017), pp.860-874

[13] Abdul Qadir, Marwan Mokhtar, Rajab Khalilpour, Dia Milani, Ali Abbas, "Potential for solar-assisted post-combustion carbon capture in Australia", Applied Energy, Vol. 11, (2013), pp.175-185

[14] Junyao Wang, Jun Zhao, Yongzhen Wang, Shuai Deng, Kaixiang Li, "Application potential of solar-assisted post-combustion carbon capture and storage (CCS) in China: A life cycle approach" , Journal of Cleaner Production, Vol. 154, (2017). pp. 541-552

[15] Fu Wang, Jun Zhao, Hao Li, Hailong Li, Jinyue Yan, " Experimental Study of Solar Assisted Post combustion Carbon Capture ", Energy Procedia, Vol. 7, (2015), pp. 2246-2252.

[16] Pérez Sánchez Jordán, Aguillón Martínez Javier Eduardo, Mazur Czerwiec Zdzislaw, Zavala Guzmán Alan Martín, Díaz Guillén Mario Román "Techno-economic analysis of solar-assisted post-combustion carbon capture to a pilot cogeneration system in Mexico", Energy Vol. 167, (2019), pp. 1107-1119.

[17] Junyao Wang, Jun Zhao, Shuai Deng, Taiwei Sun, Yaofeng Xu, "Integrated assessment for solar-assisted carbon capture and storage power plant by adopting resilience thinking on energy system",. Journal of Cleaner Production Volume 208, 20 January 2019, Pages 1009-1021

[18] Abdul Qadir, Lucy Carter, Tony Wood, Ali Abbas, "Economic and policy evaluation of SPCC (solar-assisted post-combustion carbon capture in Australia", Energy, Volume 93(11), (2015), pp. 294-308

[19] Abdul Qadir, Manish Sharma, Forough Parvareh, Rajab Khalilpour, Ali Abbas, "Flexible dynamic operation of solar-integrated power plant with solvent based post- combustion carbon capture (PCC) process", Energy Conversion and Management, Vol. 9, (2015) pp. 7-19

[20] Minh Ha-Duong, Hoang Anh Nguyen-Trinh, "Two scenarios for carbon capture and storage in Vietnam", Energy Policy Vol. 1, (2017), pp. 559-569.

[21] Abdul Qadir, Norhuda Abdul Manaf, Ali Abbas, "Analysis of the integration of a steel plant in Australia with a carbon capture system powered by renewable energy and NG-CHP", Journal of Cleaner Production, Vol. 168 , (2017), pp. 97-104

[22] Junyao Wang, Taiwei Sun, Shuai Deng, Kaixiang Li, Yongzhen Wang, "A resilience analysis on energy system: a preliminary case study for solar-assisted CCS" Energy Procedia, Vol. 14, (2017), pp. 3220-3225.

[23] Enkhbayar Shagdar, Bachirou Guene Lougou, Yong Shuai, Junaid Anees, Heping Tan, "Performance analysis and techno-economic evaluation of 300 MW solar-assisted power generation system in the whole operation conditions", Applied Energy,Vol. 264, (2020).