Carbon Dioxide Capture and Storage

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ABSTRACT

Fossil fuel power plants generate significant amounts of CO2 emissions into the atmosphere, which are believed to be the main cause of climate change. Among CO2 mitigation options, carbon capture and storage is considered the only technology that can significantly reduce the emissions of CO2 from fossil fuel combustion sources. There are mainly three technological routes for CO2 capture from power plants: post-combustion, pre-combustion and oxy-fuel combustion. Unfortunately, their application may reduce the net efficiency of a plant by up to 14% points and increase the cost of electricity by 30-70%. In the last few years there has been a growing focus on emissions from post-combustion CO2 capture plants. The main concern has been that plant emissions may result in a buildup of nitrosamines and nitramines in the environment. Nitrosamines and nitramines may be emitted from a CO2 capture plant or may form in the atmosphere as a result of emissions of amines or other degradation products.

Keywords: *Fossil Fuel, Pre-Combustion, Oxy-Fuel Combustion, Post-Combustion, Nitrosamines, etc.*

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1. INTRODUCTION

Carbon Capture and Storage (CCS) is considered an important component of a low-carbon technology portfolio towards mitigating climate change impacts at least cost. CCS comprises a set of technologies that facilitate the capture of carbon dioxide (CO2) emissions at various large point sources and transport of captured CO2 to a geological sequestration site where it is stored indefinitely. There has been some successful application of CCS in the oil and gas industry for enhanced oil recovery, but the integrated largescale deployment of CCS in the power sector is a novel technology proven only at the pilot plant stage. Fossil fuel power plants generate significant amounts of CO2 emissions into the atmosphere, which are believed to be the main cause of climate change. Among CO2 mitigation options, carbon capture and storage is considered the only technology that can significantly reduce the emissions of CO2 from fossil fuel combustion sources. There are mainly three technological routes for CO2 capture from power plants: post-combustion, pre-combustion and oxy-fuel combustion. Unfortunately, their application may reduce the net efficiency of a plant by up to 14% points and increase the cost of electricity by 30-70%. This paper briefly reviews the performance of power plants with carbon capture, and presents current research and development, and demonstration activities on CCS. [1]

2. CO2 EMISSIONS FROM FOSSIL FUEL POWER PLANTS

The amount of CO2 emissions generated from a fossil fuel power plant will mainly depend on the type of fuel used, the type of power generation technology, the size of the plant, and the efficiency. For example, using IPCC default emission factors, a lignite-fired power plant with a capacity of 500 MW, having a thermal efficiency of 40%, would generate approximately 455 tonnes of CO2 per hour (~910 kgCO2/MWh), while the plant with the same capacity and efficiency, but fuelled with bituminous coal would generate 426 tonnes of CO2 per hour (~850 kgCO2/MWh), which is 6.4% less CO2 emitted. If, for example, the efficiency of coal-fired power plants can be increased to 50% (the target for advanced USC-PC plants) it will result in even higher CO2 reduction. The effect of efficiency improvement on the emissions of CO2 from a coal-fired plant. At 50% efficiency, a power plant will emit up to 40% less CO2 than the plant with a thermal efficiency of 30%. It should be noted here that the average global efficiency of coal-fired plants is currently 33%. [2]

3. METHODOLGY

There are many ways in which CO2 emissions can be reduced, such as increasing the efficiency of power plants or by switching from coal to natural gas. However, most scenarios suggest that these steps alone will not achieve the required reductions in CO2 emissions. The capture and storage of CO2 from fossil fuel combustion could play an important part in solving this problem. Widespread use of this technique could be achieved without the need for rapid change in the energy supply infrastructure. In the long-term, the world's energy system may have to be based on non-fossil energy sources. Decarbonising the use of fossil fuels by capture and storage of CO2 would help the transition to a carbon-free energy system in the future. [3]

3.1 POST-COMBUSTION CAPTURE.

CO_2 can be captured from the exhaust of a combustion process by absorbing it in a suitable solvent. This is called post-combustion capture. The absorbed CO_2 is liberated from the solvent and is compressed for transportation and storage. Other methods for separating CO_2 include high pressure membrane filtration, adsorption/desorption processes and cryogenic separation**. [4]**

- Salient features :-
    - At present the most expensive option but commercially available in large size.
    - Can be applied to existing plants.
    - Needs no demo. Optimization of existing options needed. [7]

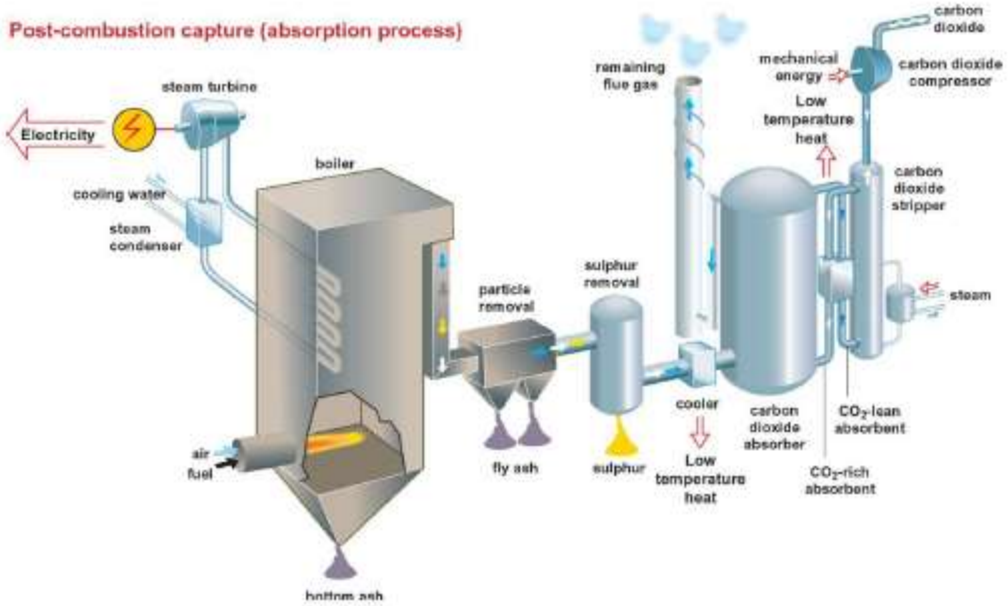

Fig 1. Post-Combustion Capture Process

3.2 PRE-COMBUSTION CAPTURE.

A pre-combustion system involves first converting solid, liquid or gaseous fuel into a mixture of hydrogen and carbon dioxide using one of a number of processes such as ‘gasification’ or ‘reforming’.Reforming of gas is well-established and already used at scale at refineries and chemical plants around the world. Gasification is widely practiced around the world and is similar in some respects to that used for many years to make town gas.The hydrogen produced by these processes may be used, not only to fuel our electricity production, but also in the future to power our cars and heat our homes with near zero emissions.[4]

- Salient features :-
    - The most complicated technology. IGCC demos have not been successful.
      Can be applied to existing plants.
    - Produces hydrogen as integrated intermediate fuel for the power process, from coal or gas.
    - Development need for the gas turbine run on hydrogen – Lab tests + pilot + demo. [7]

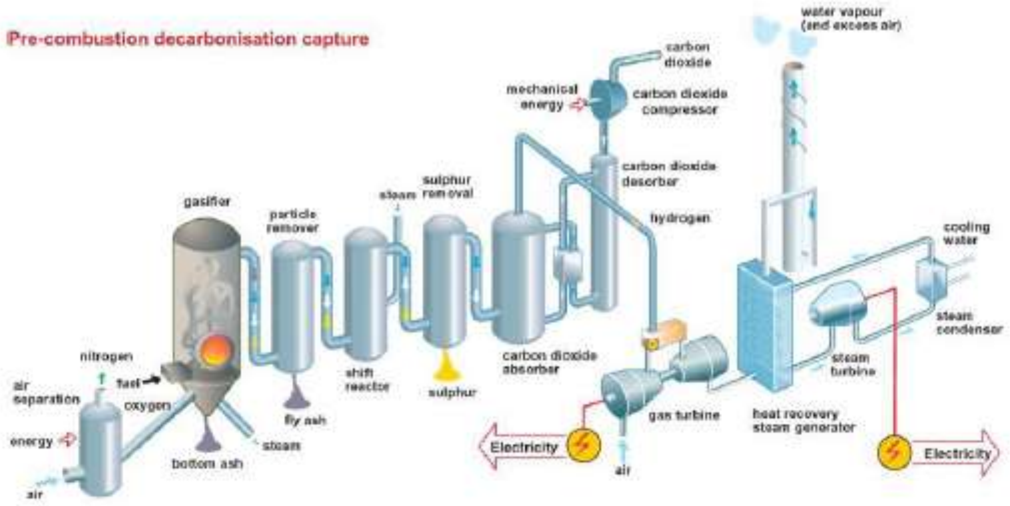

Fig 2. Pre-Combustion Decarbonisation Capture Process

3.3 OXY-COMBUSTION CAPTURE.

In the process of oxy-fuel combustion the oxygen required is separated from air prior to combustion and the fuel is combusted in oxygen diluted with recycled flue-gas rather than by air.This oxygen-rich, nigtrogen-free atmosphere results in final flue-gases consisting mainly of CO2 and H2O (water), so producing a more concentrated CO2 stream for easier purification.[4]

- Salient features :-
  - The most preferred option at present.
  - Technology straight forward and builds on the modern supercritical coal fired boilers.
  - Tests in technical scale positive. Needs pilot plant and demo plant. [7]

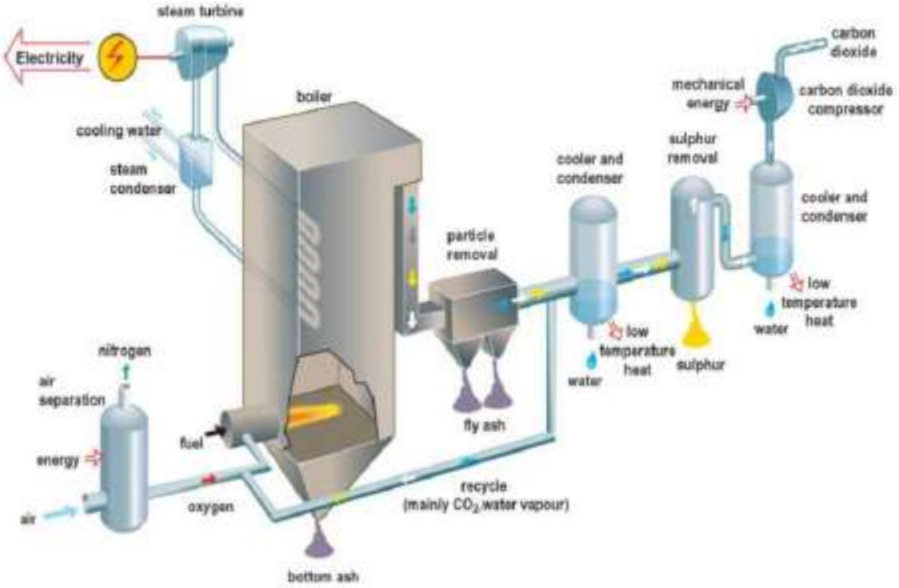

Fig 3. Oxy-fuel Combustion Process

4. TECHNOLOGIES FOR CCS

Technologies for the capture of CO2 are relatively well understood today based on industrial experience in a variety of applications. Similarly, there are no major technical or knowledge barriers to the adoption of pipeline transport, or to the adoption of geological storage of captured CO2. However, the integration of capture, transport and storage in full-scale projects is needed to gain the knowledge and experience required for a more widespread deployment of CCS technologies. R&D is also needed to improve knowledge of emerging concepts and enabling technologies for CO2 capture that have the potential to significantly reduce the costs of capture for new and existing facilities. More specifically, there are knowledge gaps relating to large coal-based and natural gas-based power plants with CO2 capture on the order of several hundred megawatts (or several MtCO2). Demonstration of CO2 capture on this scale is needed to establish the reliability and environmental performance of different types of power systems with capture, to reduce the costs of CCS, and to improve confidence in the cost estimates. In addition, large-scale implementation is needed to obtain better estimates of the costs and performance of CCS in industrial processes, such as the cement and steel industries, that are significant sources of CO2 but have little or no experience with CO2 capture. [5]

5. COST OF CCS

The future cost of capturing, transporting and storing CO2 depends on which capture technologies are used, how they are applied, how far costs fall as a result of RD&D (innovation) and market uptake (learning-by-doing), and fuel prices. Since applying capture requires more energy use and leads to production of more CO2, the cost per tonne of CO2 emission mitigation is higher than the per tonne cost of capturing and storing CO2. The gap between the two narrows as capture energy efficiency increases. At this stage, the total cost of CCS could range from 50 to 100 USD per tonne of CO2. This could drop significantly in future. In most cases, using CCS would cost 25-50 USD per tonne of CO2 by 2030, compared to the same process without. Certain early opportunities exist with substantially lower cost, but their potential is limited. The cost for CCS can be split into cost of capture, transportation and storage. Current estimates for large-scale capture systems (including CO2 pressurization, excluding transportation and storage) are 25-50 USD per tonne of CO2 but are expected to improve as the technology is developed and deployed. If future efficiency gains are taken into account, costs could fall to 10-25 USD/t CO2 for coal-fired plants and to 25-30 USD/t CO2 for gas-fired plants over the next 25 years. With CO2 transportation, pipeline costs depend strongly on the volumes being transported and, to a lesser extent, on the distances involved. [6]

Large-scale pipeline transportation costs range from 1-5 USD/t CO2 per 100 km. If CO2 is shipped over long distances rather than transported in pipelines, the cost falls to around 15-25 USD/t CO2 for a distance of 5,000 km. The cost of CO2 storage depends on the site, its location and method of injection chosen. In general, at around 1-2 USD per tonne of CO2, storage costs are marginal compared to capture and transportation costs. Revenues from using CO2 to enhance oil production (EOR) could be substantial (up to 55 USD/t CO2), and enable the cost of CCS to be offset. However, such potential is highly site specific and would not apply to most CCS projects. Longer-term costs for monitoring and verification of storage sites are of secondary importance. Using CCS with new coal- and gas-fired power plants would increase electricity production costs by 2-3 US cents/kWh. By 2030, CCS cost could fall to 1-2 US cents per kWh (including capture, transportation and storage). [8]

6. SOCIAL BENEFITS

Carbon Capture and Storage (CCS) is a vital tool in the global fight against climate change. With its important application to the capture and storage of carbon dioxide emissions from power stations, CCS has a crucial role to play in tackling greenhouse gas emissions whilst maintaining security of supply. The International Energy Agency (IEA) has estimated that to halve global emissions by 2050 (widely believed to be required to limit the temperature rise to 2ºC), CCS will need to contribute one fifth of the required emissions reductions, both in the power sector as well as the industrial sector. In addition, the IEA have found that attempting to halve global emissions by 2050 without CCS, would increase costs by more than 70% per year. To meet global 2050 goals, the IEA has projected that we will need 100 CCS projects around the world by 2020 and more than 3000 by 2050. This is a significant scale-up from current ambitions. There are very major benefits arising from the deployment of CCS in addition to climate mitigation.There are also significant social benefits from the deployment of CCS. The supply chain for CCS will create a large variety of jobs for those communities living near a capture plant, pipeline or storage facility. Jobs will be required in core engineering and manufacturing sectors, as well as pipeline design, management and operation and a host of skills related to CO2 storage, including exploration and site characterisation, injection well construction and management. Many energy intensive manufacturing industries will in future be seen to be unsustainable without CCS. So the application of CCS will protect jobs and prosperity related to these industries. Developing networks of CCS pipeline networks will enable local prosperity through the longevity of regional industries. [9]

7. CONCLUSION

The main remaining issues concerning CO2 capture plant emissions are a lack of detailed emission data and atmospheric dispersion modelling. It would seem advisable for the first full scale capture plants to have detailed emission monitoring programs. There also remains some uncertainty concerning the environmental fate of nitrosamines and nitramines. Nitramines in particular have never been tracked as environment pollutants and their effects on humans are relatively poorly studied. Further work is required to draw confident conclusions on the extent of nitramine formation, accumulation in the environment and potential for exposure to humans. On the other hand, several non-public financing factors were studied and found to be statistically significant determinants of CCS project success, providing motivation for policymakers to explore alternative supportive mechanisms if aiming to encourage the development and deployment of CCS. Overall, the results from this analysis call for a more nuanced role of government activity in the deployment of CCS given that non-commercial storage of CO2 and public funding are negatively linked to project success while other non-public funding factors are found to be positively linked to project success. From an investor’s perspective, high-cost, low-risk options for technology investment are likely to be favourable relative to slightly lower cost, but higher-risk investments. Storage site identification and liability as well as financial issues account for the underlying risk related to CCS. Our results provide an argument for a critical review of existing funding policy and possibly a re-think of public ownership of non-commercial storage sites. [10]

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