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A Study of Carbon Dioxide Capture & Storage (CCS) Technology for Coal Based Thermal Power Plants and Utilization of CO_2 to Refineries: Indian Scenario

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Abstract. Clean coal technologies (CCT) reduce the environmental impact of coal energy generation. Today's best available technologies allow efficiency gains of up to 46% for hard coal plants and 43% for lignite plants. The aim of the Clean Coal activity is to raise the efficiency level to above 50% and to reduce emissions. Carbon Capture and Storage (CCS) is one of the key available technologies for cutting CO_2 emissions from fossil fuel-based power generation and CO_2-intensive industries. CO_2 emissions are captured before entering the atmosphere and stored underground. In the transition to a low-carbon economy, the CCS technology is one of the key ways to reduce greenhouse gas emissions. Lowering the cost and energy penalty associated with CO_2 capture from large stationary sources.Improving the understanding of factors affecting CO_2 storage permanence, capacity, and safety in geologic formations and terrestrial ecosystems.Once these objectives are met, new and existing power plants and fuel processing facilities around the world have the potential.

Keywords: Coal Mine improvement methodology, IGCC, CO2 capture plant

1. Introduction

Many countries are dependent on fossil fuels for energy generation, and fossil fuels remain a vast energy resource, widely distributed around the world. Coal in particular is abundant in regions that have large existing or projected energy demand and limited alternative energy options. With an average of two coal-fired power stations being built in the developing world every week, reduction in local pollution and emissions of greenhouse gases (GHGs) from the combustion and processing of fossil fuels will remain one of the world's biggest challenges in the years ahead.

The power sector will remain the main driver of global coal demand between now and 2035 in all three scenarios. Power generation accounts, respectively, for just over 80% and around 75% of the increase in world coal demand in both the Current and New Policies Scenarios.

The IEA analysis of the international coal market shows that "for all the talk about natural gas and renewables, coal unquestionably won the energy race in the first decade of the 21st century."

Between 2000 and 2010 primary coal demand grew by 4.4% per year, which is well above the average of 2.7% for natural gas and 1.1% for oil. In 2010, world coal demand was almost 55% higher than in 2000, which is a bigger increase in both volume and percentage terms than for any other fuel category, including renewables.

India has a long history of commercial coal mining covering nearly 220 years starting from 1774 by M/s Sumner and Heatly of East India Company in the Raniganj Coalfield along the Western bank of river Damodar. However, for about a century the growth of Indian coal mining remained sluggish for want of demand but the introduction of steam locomotives in 1853 gave a fillip to it. Within a short span, production rose to an annual average of 1 million tonne (mt) and India could produce 6.12 mts. per year by 1900 and 18 mts per year by 1920. The production got a sudden boost from the First World War but went through a slump in the early thirties. The production reached a level of 29 mts. by 1942 and 30 mts. by 1946[1].

Commercial primary energy consumption in India has grown by about 700% in the last four decades. The current per capita commercial primary energy consumption in India is about 350 kgoe/year which is well

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below that of developed countries. Driven by the rising population, expanding economy and a quest for improved quality of life, energy usage in India is expected to rise. Considering the limited reserve potentiality of petroleum & natural gas, eco-conservation restriction on hydel project and geo-political perception of nuclear power, coal will continue to occupy centre-stage of India's energy scenario. [2].

In 2006, the total production of the global coal industry stood at 6,142 million tons (MT). Of this, the production of hard coal stood at 5,205 MT and that of brown coal was 937 MT. In 2010, the production of hard coal and brown coal rose to 6,185 MT and 1,042 MT, respectively (source: World Coal Association). The top four coal producing countries are China, USA, Australia and India.

In 2010, coal catered to 29.6% of the global energy needs and almost 42% of the global electricity requirements. Coal is also used for producing heat through combustion. At the current consumption rate, the coal reserves are nominally sufficient to generate electricity for a period of 118 years. According to IEA, share of coal in Asian electricity production will rise from 56% in 2004 to 63% in 2030. Countries such as China, USA, India and South Africa depend primarily on coal for their electricity generation.

Coal will continue to be an expanding, cheap foundation for economic and social development. Backed by its vast and well-distributed resource base, coal has the potential to make a significant contribution to eradicating energy poverty. Coal can be increasingly clean – at a bearable cost in terms of technological sophistication and at little cost in terms of international technology transfer and R&D in CO_2 sequestration. For this to happen, a more pro-active involvement of the coal and power industries is needed in " globalizing" best technical and managerial practices and advocating coal's credentials[3].

Climate change is one of the most significant issues facing humanity and the global society needs to deploy immediate countermeasures against the threat posed by global warming. Yet with the current global energy structure, there are no viable energy alternatives to fossil fuels. Thus, CO_2 capture and storage (CCS) is considered as a critical and indispensable countermeasure to reduce the potentially catastrophic environmental impacts associated with this phenomenon. To improve the economic viability of CO_2 capture, power producers will need to help facilitate the practical deployment of CO_2 capture from coal-fired power plants and thus reduce the CO_2 capture cost. Mitsubishi Heavy Industries, Ltd. (MHI) has realized the significant and important role of CO_2 capture technology and is continuing research and development of effective countermeasure technologies against global warming.

According to the "Special Report on Carbon Dioxide Capture and Storage"1 produced by the IPCC (Intergovernmental Panel on Climate Change), CO_2 emissions from fossil fuel cannot effectively be reduced without CCS from stationary sources. Table 1 shows the potential amount of underground Co_2, some 13.5 billion tons of CO_2 per year, about 60% of worldwide emissions, is generated from stationary sources (excluding those sources which produce less than 100,000 tons per year). Some 78% of the CO_2 emission from stationary sources is generated from thermal power generation facilities, and 60% of this figure originates from coal-fired power plants. Coal reserves are widely distributed and source locations are abundant. Furthermore coal is significantly cheaper than oil and natural gas. For these reasons, the quantity of coal consumed for power generation is expected to increase further, conversely with CO_2 emissions.

Large amounts of energy are required for CO_2 capture and storage. The energy required for CO_2 capture and storage is highest for coal-fired power plants, due to the large CO_2 emission per kW of generated power and one of the most important challenge will be to further reduce this additional energy[4].

1.1. Why aren't CO_2 capture and storage projects widely implemented?

As mentioned above, there are a few commercial scale CCS projects currently operating but the widespread global implementation of CCS faces several hurdles.

The CCS projects now underway seek to reduce current CO2 emissions or to reduce future emissions. Most of these projects operate at relatively low cost. Some have been established through the provision of incentives or disincentives, such as the CO2 tax in Norway, the use of recovered CO2 for EOR (Enhanced Oil Recovery) in Weyburn (Canada), and so on.

Table 1 Potential amount of underground CO_2 storage

Storage geological formations	Low CO_2 storage potential ($GtCO_2$)	High CO_2 storage potential ($GtCO_2$)
Oil and gas fields	675*	900*
Coal bed that cannot be excavated	3 - 15	200
Deep saline water aquifer	1000	10^4

Note * If a new oil and gas field is found, this value is expected to increase by 25%.

To implement CO2 capture and storage on a wide scale in the future, two issues must first be resolved.

1.2. 1.2. Burden of cost of CO2 capture and storage

To implement CO2 capture and storage as a countermeasure against global warming, incentive based mechanisms such as CO2 emission trading and funding/subsidy instruments by central government are required.

1.3. 1.3. Improved knowledge of business circumstances

Such as storage potential surveys, further definition and regulatory certainty relating to relevant laws and ordinances, international rules, and social acceptance of CCS.

In the United States, a partnership in seven districts funded with grants from the DOE (Department of Energy) has led to the commencement of CO2-injection experiments at a range of sites. More incentives, such as these, to promote the CO2 capture and storage concept will be necessary in the future. Currently the revenue generating activity of EOR is expected to facilitate some early stage opportunities for CCS in key oil producing regions. Therefore, MHI has deployed a business model strategy focusing on CO2 EOR opportunities. The following items have been identified as key areas of focus to enhance the feasibility of CO2 capture, and MHI is further promoting research and development in these areas.

- Reduced CO_2 capture/compression energy
- Commercialization of CO_2 capture from coal-fired thermal power generation plants
- Economy of scale owing with large-capacity CO_2 capture

2. MHI's CO2 capture technology

2.1. Experiences of MHI

MHI has already delivered four commercial plants to recover CO2 from flue gas in the chemical and fertilizer industries, with another four plants on the drawing board (3 of which are currently under construction). CO2 recovery plants used at urea production facilities with a capacity of 450 tonnes/day, delivered in 2006 at two separate locations in India (Nagarjuna Fertilizers & Chemicals Limited, Kakinada, AP)

2.2. Strategies to reduce CO2 capture energy

MHI began researching and developing CO2 capture technology from the flue gas of power plants in 1990. This was undertaken jointly together with Kansai Electric Power Co., Inc. As a result of this extensive R&D, MHI has developed many proprietary items including; an energy saving absorption solution (KS-1), an energy-saving regeneration system for practical use, and a system for the optimal integration of steam between a power-generation facility and a CO2 capture facility.

2.3. CO2 capture from coal-fired power plants

MHI has already gained considerable experience in CO2 capture from natural gas-fired boilers. Yet the more urgent challenge today, with the advent of global warming, will be CO2 capture from coal-fired power plants, the largest source of global CO2 emissions. It is expected that CO2 capture systems will be crucial in areas such as Europe and the US.

MHI responded to this challenge in 2000 by constructing and testing a CO2 capture pilot plant with a capacity of 1 tonne/day from coal-fired flue gas at its Hiroshima Research and Development Center.

Furthermore with grant funding (50% of project cost) from the Research Institute of Innovative Technology for the Earth (RITE) and cooperation from the Electric Power Development Co., Ltd., MHI constructed a demonstration plant of 10 tonnes/day at the Matsushima Power Plant of Electric Power Development Co., Ltd. The plant was constructed in 2004 and commenced demonstration testing in 2006. The plant successfully completed stable operation for over 4,000 hours and proved that MHI's CO2 recovery process can be successfully applied to a coal-fired power plant[5] .

2.4. Approach for large capacity CCS implementation

The CO2 recovery plants that MHI has already delivered for the chemical and fertilizer industries range in capacity between 200 - 450 tonnes/day. If CO2 is captured for EOR all the flue gas from the boiler and/or gas turbines of the power plants must be treated. To capture CO2 from a 1000 MW coal-fired power plant, for example, a large-capacity, multi-train CO2 recovery plant of 17,000 tonnes/day will be required.

MHI has already standardized a CO2 recovery plant of 3,000 tonnes/day and completed basic design. Further, MHI is working to realize a large-capacity plant on a scale of 5,000 - 6,000 tonnes/day.

3. Significance

Mitsubishi Heavy Industries, Ltd. Plays a major role in CCS Technology and implemented the project "CO2 recovery plants used at urea production facilities" in Nagarjuna Fertilizers & Chemicals Limited, Kakinada, AP, India. But, still it is need an improvement in CCS technology for CO2 recovery plant and implementation of this CCS technology model in Coal based Power plants like Neyveli Lignite corporation*. The CO2 from the Power plant is captured, stored and this CO2 can be used for Power generation, Oil refineries and Urea production by using our CCS technology model.

4. Methodology

COAL MINE IMPROVEMENT METHODOLOGY

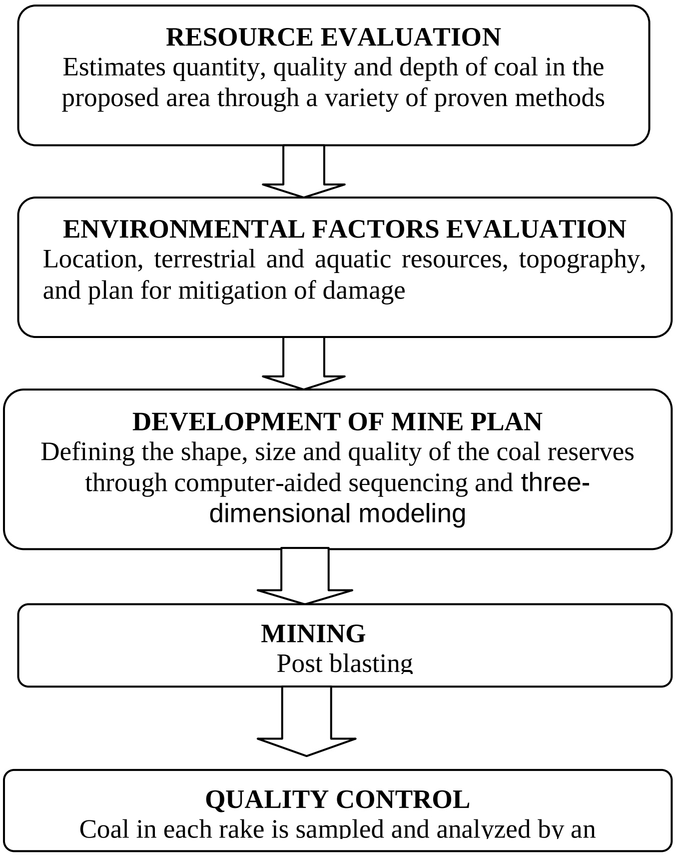

Fig.1 : Coal Mine Improvement Methodology flow diagram

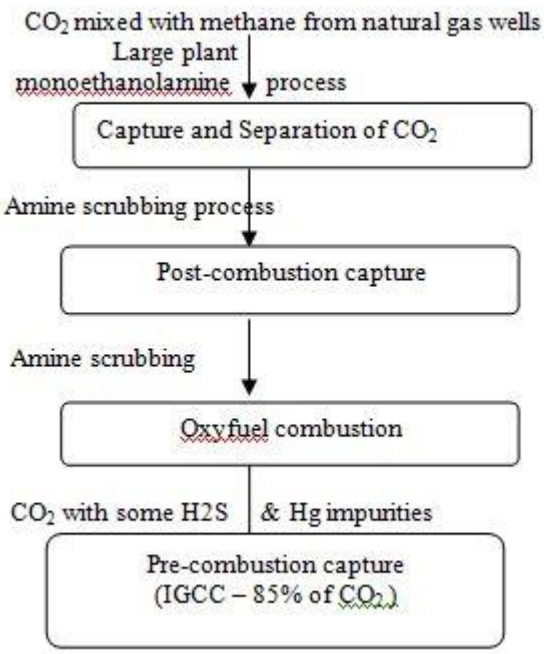

Fig.2 : Post-Burn CO_2 Capture Method

- Coal is a vital fuel in most parts of the world.

- Burning coal without adding to global carbon dioxide levels is a major technological challenge which is being addressed.
- The most promising "clean coal" technology involves using the coal to make hydrogen from water, then burying the resultant carbon dioxide by-product and burning the hydrogen.
- The greatest challenge is bringing the cost of this down sufficiently for "clean coal" to compete with nuclear power on the basis of near-zero emissions for base-load power.

There is typically about a 20% energy penalty involved in "clean coal" processes.

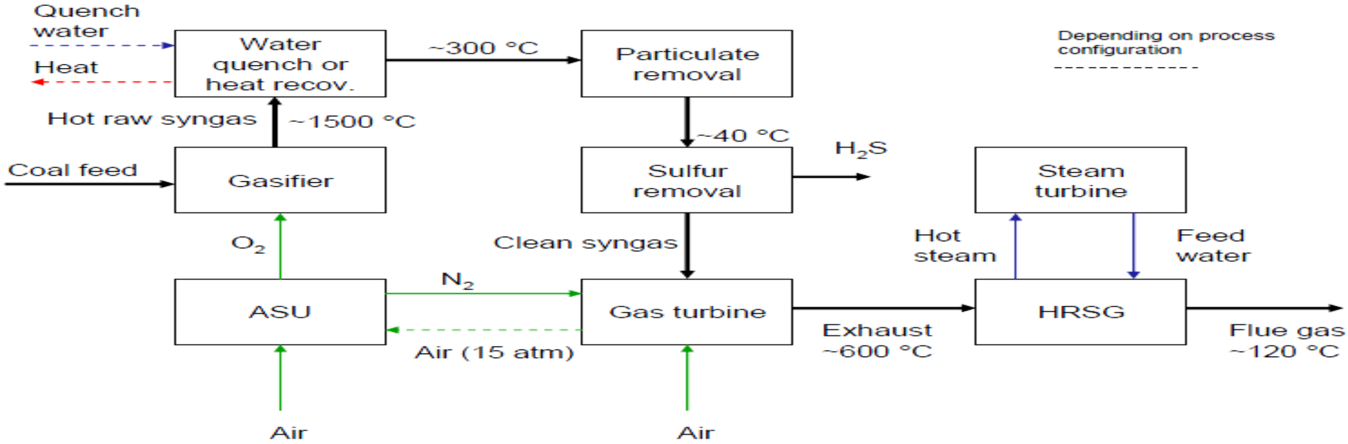

Fig. 3: IGCC Process without CO_2 Capture
IGCC-Integrated Gasification Combined Cycle

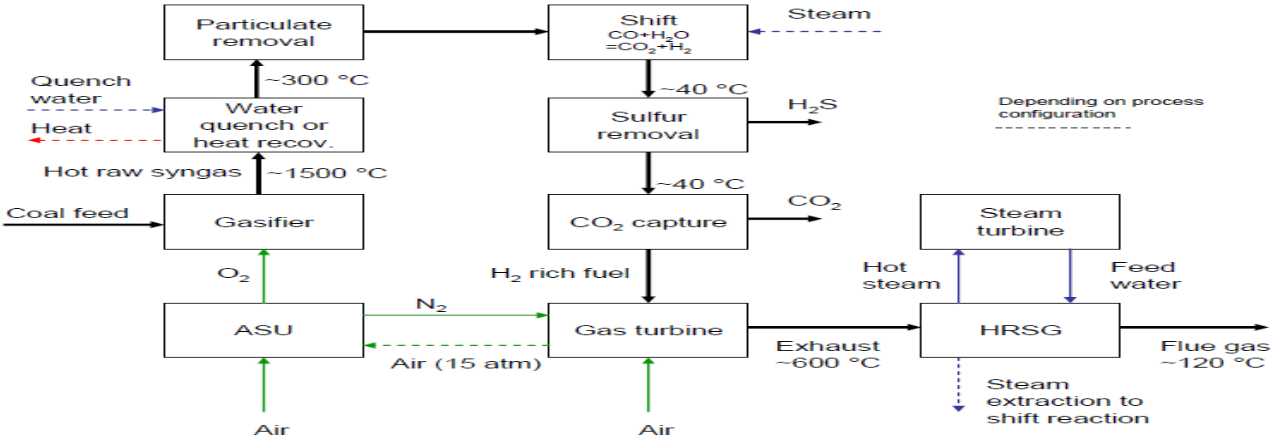

Fig. 4: IGCC Process with CO_2 Capture

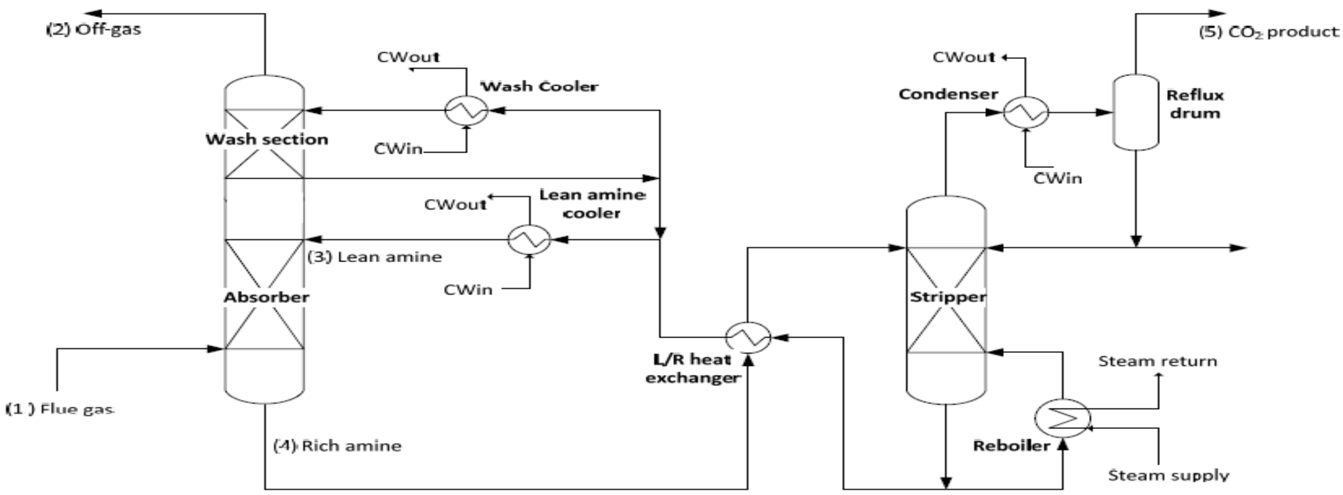

Fig. 5: Simplified process flow diagram of the CO_2 Capture Plant

5. Conclusion

It is not possible, with the global energy structure, to rely significantly on non-fossil fuels for energy in the foreseeable future. Thus, countermeasures for the current and future fossil fuel power generation fleet, against global warming are required urgently throughout the world. CO2 capture and storage systems are therefore indispensable. To promote widespread, viable CO2 capture and storage in the power generation industry, operators will need to reduce the energy required for CO2 capture, develop economically viable commercial technologies to capture CO2 emitted by coal-fired power plants, and aim to further reduce the CO2 capture cost. MHI continues its efforts on a range of research and development initiatives technologies to meet these needs and develop countermeasures against global warming, to ultimately ensure humanity has a sustainable future.

6. Future Scope

1. CCS technology has the potential to provide what may be called "zero emissions" - in reality, extremely low emissions of the conventional coal pollutants, and as low-as-engineered carbon dioxide emissions.
2. This has come about as a result of the realisation that efficiency improvements, together with the use of natural gas and renewables such as wind will not provide the deep cuts in greenhouse gas emissions necessary to meet future national targets.
3. It had an ambitious project to develop and demonstrate the technology and have commercial designs for plants available by 2013.

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