CLEAN COAL TECHNOLOGY (CCT) – I

1. Introduction – Coal when burned is the dirtiest of all fossil fuels. A range of technologies are being used and developed to reduce the environmental impact of coal-fired power stations. Thus, clean coal technology (CCT) is the name attributed to coal chemically washed of minerals and impurities, sometimes gasified, burned and the resulting flue gases treated with steam with the purpose of removing sulfur dioxide, and reburned so as to make the carbon dioxide in the flue gas economically recoverable.

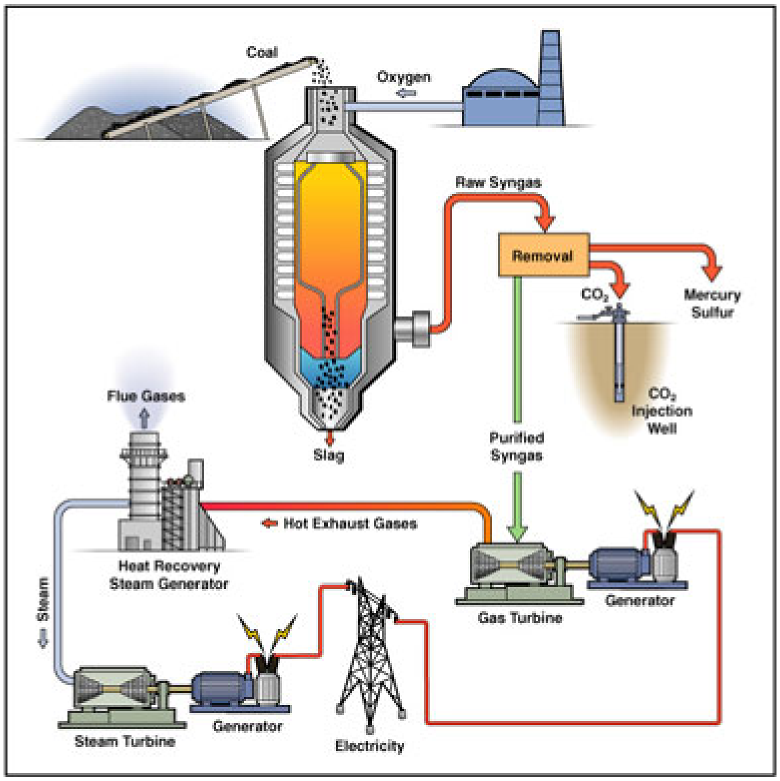
It is a known fact that, the burning of coal, a fossil fuel, is the principal causes of anthropogenic climate change and global warming. In fact, the byproducts of coal combustion are very hazardous to the environment if not properly contained. This is seen to be the technology's largest challenge, both from the practical and public relations perspectives. While it is possible to remove most of the sulfur dioxide (SO2), nitrogen oxides (NOx) and particulate (PM) emissions from the coal-burning process, carbon dioxide (CO2) emissions will be more difficult to address. Therefore, fact regarding the coal remains:

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

(b) Burning coal without adding to global carbon dioxide levels is a major technological challenge which is being addressed.

(c) 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.

(d) 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.



2. 'Clean Coal Technology (CCT)' is the methods to remove pollutants from coal. Carbon dioxide from burning coal is the main focus of attention today, since it is implicated in global warming, and the Kyoto Protocol requires that emissions decline, notwithstanding increasing energy demand.

a. Coal arriving at a power plant contains mineral content that needs to be removed, in order to make it clean, before it is burnt. A number of processes are available to remove unwanted matter and make the coal burn more efficiently.

(i) Coal cleaning by washing - Coal washing involves grinding the coal into smaller pieces and passing it through a process called gravity separation. One technique involves feeding the coal into barrels containing a fluid that has a density which causes the coal to float, while unwanted material sinks and is removed from the fuel mix. The coal is then pulverised and prepared for burning.

(ii) Gasification of coal – The Integrated Gasification Combined Cycle (IGCC) plant is a means of using coal and steam to produce hydrogen and carbon monoxide (CO) which are then burned in a gas turbine with secondary steam turbine (ie combined cycle) to produce electricity.

Coal gasification plants are favoured by some because they are flexible and have high levels of efficiency. The gas can be used to power electricity generators, or it can be used elsewhere, i.e. in transportation or the chemical industry. In Integrated Gasification Combined Cycle (IGCC) systems, coal is not combusted directly but reacts with oxygen and steam to form a “syngas” (primarily hydrogen). After being cleaned, it is burned in a gas turbine to generate electricity and to produce steam to power a steam turbine. Coal gasification plants are seen as a primary component of a zero-emissions system. However, the technology remains unproven on a widespread commercial scale.

(iii) Removing pollutants from coal – Burning coal produces a range of pollutants that harm the environment: Sulphur dioxide (acid rain); nitrogen oxides (ground-level ozone) and particulates (affects people’s respiratory systems). There are a number of options to reduce these emissions:

· Sulphur dioxide (SO_2) – Flue gas desulphursation (FGD) systems are used to remove sulphur dioxide. “Wet scrubbers” are the most widespread method and can be up to 99% effective. A mixture of limestone and water is sprayed over the flue gas and this mixture reacts with the SO_2 to form gypsum (a calcium sulphate), which is removed and used in the construction industry.

· Nitrogen oxides (NO_x) – NO_x reduction methods include the use of “low NO_x burners”. These specially designed burners restrict the amount of oxygen available in the hottest part of the combustion chamber where the coal is burned. This minimises the formation of the gas and requires less post-combustion treatment.

· Particulates emissions – Electrostatic precipitators can remove more than 99% of particulates from the flue gas. The system works by creating an electrical field to create a charge on particles which are then attracted by collection plates. Other removal methods include fabric filters and wet particulate scrubbers.

b. Capture & separation of Carbon dioxide - A number of means exist to capture carbon dioxide from gas streams, but they have not yet been optimised for the scale required in coal-burning power plants. The focus has often been on obtaining pure CO_2 for industrial purposes rather than reducing CO_2 levels in power plant emissions. Capture of carbon dioxide from flue gas streams following combustion in air is expensive as the carbon dioxide concentration is only about 14% at best. This treats carbon dioxide like any other pollutant and as flue gases are passed through an amine solution the CO_2 is absorbed. It can later be released by heating the solution. This amine scrubbing process is also used for taking CO_2 out of natural gas. There is an energy cost involved. Captured carbon dioxide gas can be put to good use, even on a commercial basis, for enhanced oil recovery. Injecting carbon dioxide into deep, unmineable coal seams where it is adsorbed to displace methane (effectively: natural gas) is another potential use or disposal strategy.

In relation to clean coal technology, a terminology ‘carbon capture and storage’ (CCS) is being discussed. CCS is nothing but method of capturing the carbon dioxide, preventing the greenhouse gas entering the atmosphere, and storing it deep underground by various ways, such as

(a) CO_2 pumped into disused coal fields displaces methane which can be used as fuel,

(b) CO_2 may be pumped into and stored safely in saline aquifers, or

(c) CO_2 pumped into oil fields helps maintain pressure, making extraction easier.

A range of approaches of CCS have been developed and have proved to be technically feasible. They have yet to be made available on a large-scale commercial basis because of the costs involved.

c. Clean coal technologies are continually developing. Today, efficiencies of 46% can be achieved by implementing the best available technology. With further research into techniques such as Ultra-supercritical combustion, efficiencies above 50% are envisaged in the near future. Work is underway to exploit the opportunities of capturing and storing CO_2, which is an inevitable by-product of the thermal use of all fossil fuels. Coupled with integrated gasification, coal could in this way provide a source of low-carbon hydrogen for fuelling transport without producing local emissions. There will be challenges in bringing these technologies to market, but with the right mix of research investment and market incentives, coal may stake a place in a sustainable and secure energy future.

d. To summarise, burning coal, such as for power generation, gives rise to a variety of wastes which must be controlled or at least accounted for. So-called “clean coal” technologies are a variety of evolving responses to late 20th century environmental concerns, including that of global warming due to carbon dioxide releases to the atmosphere. However, many of the elements have in fact been applied for many years, and they will be only briefly mentioned here:

(i) Coal cleaning by ‘washing’ has been standard practice in developed countries for some time. It reduces emissions of ash and sulfur dioxide when the coal is burned.

(ii) Electrostatic precipitators and fabric filters can remove 99% of the fly ash from the flue gases – these technologies are in widespread use.

(iii) Flue gas desulfurisation reduces the output of sulfur dioxide to the atmosphere by up to 97%, the task depending on the level of sulfur in the coal and the extent of the reduction. It is widely used where needed in developed countries.

(iv) Low-NOx burners allow coal-fired plants to reduce nitrogen oxide emissions by up to 40%. Coupled with re-burning techniques NOx can be reduced 70% and selective catalytic reduction can clean up 90% of NOx emissions.

(v) Increased efficiency of plant – up to 45% thermal efficiency now (and 50% expected in future) means that newer plants create less emissions per kWh than older ones.

(vi) Advanced technologies such as Integrated Gasification Combined Cycle (IGCC) and Pressurised Fluidised Bed Combustion (PFBC) will enable higher thermal efficiencies still – up to 50% in the future.

(vii) Ultra-clean coal from new processing technologies which reduce ash below 0.25% and sulfur to very low levels mean that pulverised coal might be fed directly into gas turbines with combined cycle and burned at high thermal efficiency.

(viii) Gasification, including underground gasification in situ, uses steam and oxygen to turn the coal into carbon monoxide and hydrogen.

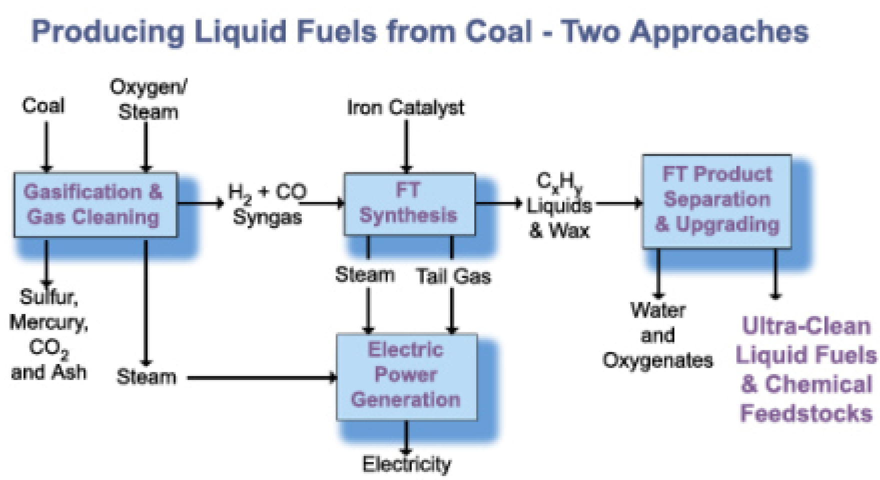
(ix) Sequestration refers to disposal of liquid carbon dioxide, once captured, into deep geological strata.

3. 'FutureGen' project is to design, build and operate a nearly emission-free coal-based electricity and hydrogen.

a. The clean coal technology field is moving very rapidly in the direction of coal gasification with a second stage so as to produce a concentrated and pressurised carbon dioxide stream followed by its separation and geological storage. At present the high cost of carbon capture and storage renders the option uneconomic. But a lot of work is being done by many of the research institutes, to improve the economic viability of this system. Recently department of energy (DOE) of Federal Govt. of the USA has announced 'FutureGen' project to design, build and operate a nearly emission-free coal-based electricity and hydrogen production plant. It will use cutting-edge technologies to generate electricity while capturing and permanently storing carbon dioxide deep beneath the earth. The integration of these technologies is what makes FutureGen unique. Researchers and industry have made great progress advancing technologies for coal gasification, electricity generation, emissions control, carbon dioxide capture and storage, and hydrogen production. But these technologies have yet to be put together and tested at a single plant – an essential step for technical and commercial viability.

Therefore, the FutureGen initiative would have comprised a coal gasification plant with additional water-shift reactor, to produce hydrogen and carbon dioxide. About one million tones of CO2 would then be separated by membrane technology and sequestered geologically. The hydrogen would have been be burned in a power generating plant and in fuel cells. The project was designed to validate the technical feasibility and economic viability of near-zero emission coal-based generation. Construction of FutureGen was due to start in 2009, for operation in 2012.

b. Coal to Liquids (CTL) – Though, technology to extract oil from natural gas or from coal was available since the world war – II; but it was not so much significant until the exorbitant hike in international crude oil prices in last decade. During the World war – II, Germany produced some quantity of oil from coal and there after, South Africa (Sasol) was the major country to produce oil from coal, to meet its energy needs during its isolation under Apartheid. As international crude oil prices fluctuate heavily, the cost of coal to oil conversion is becoming competitive. Now, many countries like China, whose coal production is quite substantial but have less reserve of crude oil, have started producing oil from coal. Recently, India has also started thinking of such conversion of their coal to synthetic oil. This conversion process produces low sulfur diesel fuel but also produces large amounts of greenhouse gases.



The Fischer-Tropsch process is well known for conversion of coal to oil. It is a catalyzed chemical reaction in which carbon monoxide (CO) and hydrogen (H2) are converted into liquid hydrocarbons of various forms. Typical catalysts used are based on iron and cobalt. The principal purpose of this process is to produce a synthetic petroleum substitute, typically from coal, natural gas or biomass.

There is another process called Karrick process for conversion of coal to synthetic oil. It is a low temperature carbonization (LTC) of coal, shale, lignite or any carbonaceous materials. These are heated at 360 degree Celsius to 749 degree Celsius, in the absence of air to distill out oil and gas. Recently, China has announced high volume commercial coal liquefaction production by this method.

Fischer-Tropsch (F-T) technology converts coal, natural gas, and low-value refinery products into a high-value, comparatively cleaner burning fuel. The resultant fuel is colorless, odorless, and low in toxicity. In addition, it is virtually interchangeable with conventional diesel fuels and can be blended with diesel at any ratio with little to no modification. Currently, several oil companies are researching large-scale production of Fischer- Tropsch fuels.

For the past 50 years, Fischer-Tropsch fuels have powered all of South Africa's vehicles—from buses to trucks to taxicabs. The fuel is primarily supplied by Sasol, a world leader in Fischer-Tropsch technologies. Sasol's South African facility produces more than 150,000 barrels of high quality fuel from domestic low-grade coal daily.

The Fischer-Tropsch process is a catalyzed chemical reaction in which carbon monoxide and hydrogen are converted into liquid hydrocarbons of various forms. Typical catalysts used are based on iron and cobalt. Synthesis gas, a mixture of hydrogen and carbon monoxide, is reacted in the presence of an iron or cobalt catalyst; much heat is evolved, and such products as methane, synthetic gasoline and waxes, and alcohols are made, with water or carbon dioxide produced as a byproduct. The catalyst is usually supported on carbon or silicon dioxide to optimize its activity. An important source of the hydrogen-carbon monoxide gas mixture (known as water gas) is obtained by the gasification of coal (manufacturing process of water gas involves treating white-hot hard coal or coke with a blast of steam; carbon monoxide and hydrogen are formed). Thus, gasification is the first step of coal liquefication or production of Fischer-Tropsch fuels from biomass such as corn stover (corn stalks), wood or switch grass. The feed gas is produced in a gasifire by heating the gas to a temperature greater than 700oC. By carefully controlling the oxygen content the hydrocarbons in the feedstock are broken down to carbon monoxide and hydrogen. The temperature, pressure and catalyst determine whether a light or heavy syncrude is produced.

The principal purpose of this process is to produce a synthetic petroleum substitute, typically from coal, natural gas or biomass, for use as synthetic lubrication oil or as synthetic fuel.

There are mainly two types of F-T reactors. The vertical fixed tube type has the catalyst in tubes that are cooled externally by pressurized boiling water. For a large plant, several reactors in parallel may be used presenting energy savings. The other process uses a slurry reactor in which pre-heated synthesis gas (Syngas) is fed to the bottom of the reactor and distributed into the slurry consisting of liquid wax and catalyst particles. As the gas bubbles upwards through the slurry, it is diffused and converted into more wax by the F-T reaction. The heat generated is removed through the reactor's cooling coils where steam is generated for use in the process.

The resulting organic compounds are a synthetic form of petroleum, analogous to a crude oil, and can be converted into many petroleum products including diesel and gasoline. Alternatively hydrogen can be recovered by further processing, resulting in only carbon dioxide and hydrogen with no hydrocarbons in the product stream. The primary interest at the present time is to produce low sulfur diesel fuel. Production of diesel fuel requires little processing from the F-T crude, has low sulfur and aromatic content, high cetane number and it burns exceptionally clean in a diesel engine.

Based on available research, there are no significant differences in Fischer- Tropsch fuel's performance versus petro-diesel fuels. In fact, the higher cetane number of Fischer-Tropsch diesel fuel might result in improved combustion; the cetane number is a primary measure of diesel fuel quality. In addition, many alternative fuels require major changes in vehicle engines, but Fischer-Tropsch fuels require no engine modifications. Fischer-Tropsch fuels, however, are slightly less energy dense than petrodiesel, which might result in lower fuel economy and power. Further investigations of fuel compatibility issues need to take place, as well.

Source : http://saferenvironment.wordpress.com/2008/11/17/clean-coal-technology-cct-%E2%80%93-to-mitigate-global-warming-and-climate-change-for-cleaner-and-safer-environment/