PROSPECTS FOR COAL TO LIQUIDS TECHNOLOGY UTILISING THAR COAL IN PAKISTAN

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What is Coal

- Coal is combustible, sedimentary, organic rock. Composed primarily of carbon, hydrogen and oxygen formed from vegetate which has been consolidated between rock strata to form coal seams, and altered by the combined effects of microbial action, pressure and heat over a considerable time period.
- With burial, the plant material was subjected to elevated temperatures and pressures, which caused physical and chemical changes in the vegetation, transforming it into coal.
- Initially the peat, the precursor of coal, was converted into lignite or brown coal

What is Coal

- Over many more millions of years, the continuing effects of temperature and pressure produced additional changes in the lignite, progressively increasing its maturity and transforming it into the range known as sub bituminous coals.
- As this process continued, further chemical and physical changes occurred until these coals became hard and more mature, at which point they are classified as bituminous or hard coals.
- Under the right conditions, the progressive increase in the organic maturity continued, ultimately to form anthracite.

RANKS OF COAL

- Low rank coals, such as lignite and sub-bituminous coals, are typically softer materials with a dull, earthy appearance. They are characterized by high moisture levels and a low carbon content, and hence a low energy content.
- Higher rank coals are typically harder and stronger and often have a black vitreous lustre.
- Increasing rank is accompanied by a rise in the carbon and energy contents and a decrease in the moisture content of the coal.

Coal Is:

- **Abundant** – extensive reserves of coal are present in many countries, coal is mined in more than 50 countries.
- **Safe** – coal is stable and hence the safest fossil fuel to transport, store and use.
- **Secure** – abundant reserves mean that coal users are guaranteed security of supply at competitive prices, hence supplies for industrial and domestic use are assured.

PAKISTAN & COAL

- **Pakistan has emerged as one of the leaders in the list of top 20 countries of the world after the discovery of the huge lignite coal resources in Sindh.**
- **Coal – the black gold, is found in all four provinces of Pakistan. The country has massive coal resources.**
- **Pakistan is faced with a serious energy crisis. It is widely known that the present level of energy generation in the country is far short of that which is necessary to sustain the rate of industrial growth and satisfy other growing requirements.**
- **In the energy based society of today, every indigenous source of energy must therefore be tapped and put to optimum use.**

THAR COAL

- Thar is 350 Kilometer away from Pakistan's commercial hub Karachi.
- Total area of coal reserves is around 9000 sq. kilometers.
- Thickness of overburden varies from 114 meter to 203 meters.
- Thickness of coal seams range from 0.2 to 0.3 meters.
- The coal is lignite type.
- Lignite coal is extensively used in the world for power generation and is generally suitable for gasification and liquefaction.

THAR COAL

Approximate quality is:	
Moisture	48%
Ash	9%
Volatile Matter	25%
Sulphur	1%
Fixed Carbon	18%
Heating Value	4480o BTU/lb

THAR COAL

- **The Sulphur content is better than most coals.**
- **Heating value is better than German and Indian Coal.**
- **Water is available in aquafers. Aquafers are generally at 3 levels. First above the coal zone, second in the coal zone and third below the coal zone.**

Coal Utilization

- Electricity Generation
- Steel Industry
- Cement Industry
- Liquid Fuels
- Petrochemicals
- Polygeneration

COAL UTILIZATION – LIQUID FUELS AND PETROCHEMICALS

- Coal is utilized to produce liquid fuels and petrochemicals which provide a substitute for corresponding petroleum products.
- This is done through coal liquefaction process.
- Coal liquefaction processes were developed during the early 20th century. Germany produced liquid fuels during world war 2 to secure their supply.
- South Africa utilized Coal Liquefaction to ensure their fuel supply during the time in the 1960's to overcome supply constraints due to sanctions imposed on them as a result of apartheid.
- The oil crisis in 1970's due to embargo imposed on crude oil supplies, renewed interest in coal liquefaction and lot of research and development was funded by concerned countries to improve the coal liquefaction process.

COAL UTILIZATION – LIQUID FUELS AND PETROCHEMICALS

- **The huge crude oil price increases in 2003 renewed the interest in coal liquefaction and many coal liquefaction projects particularly in the USA and China were conceived but few materialized due to big decline in crude oil prices recently.**

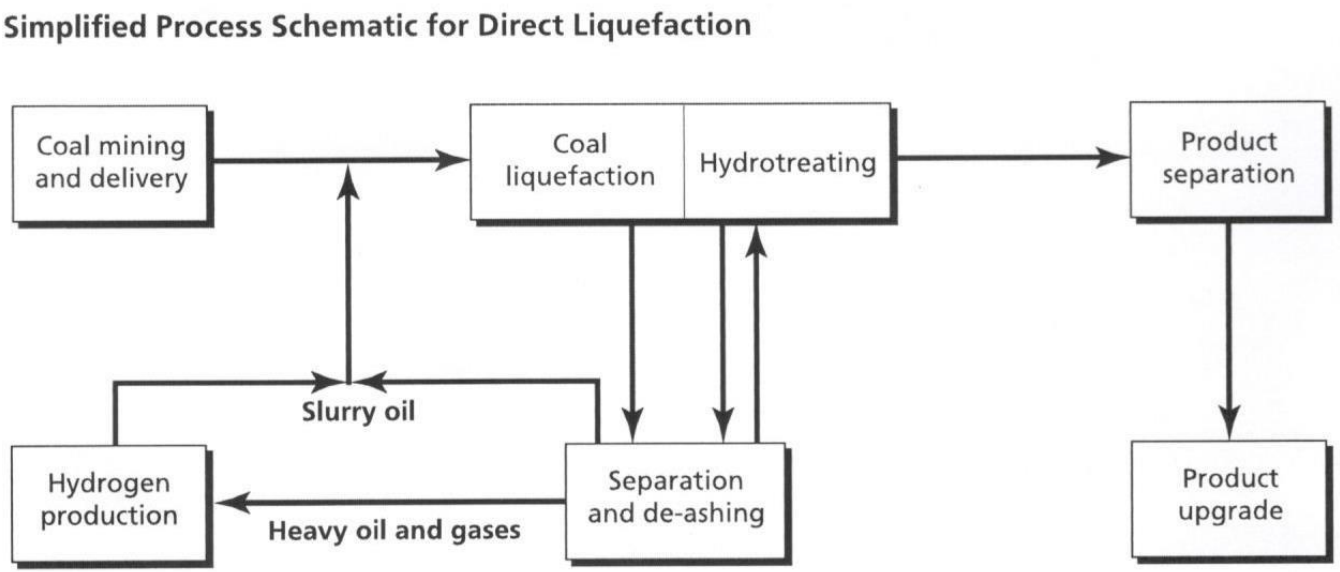
- **Even though recently oil prices have seen a downward spiral which has slowed down the surge in coal liquefaction projects however concerns regarding energy security as a result of oil geo political issues and indirect impact of coal liquefaction on the overall economy of countries with abundant coal reserves has kept interest in coal liquefaction alive.**

COAL LIQUEFACTION TECHNOLOGY

- Coal Liquefaction is a process where coal is converted into liquid products mainly to provide substitutes for corresponding petroleum products and may either be used directly as fuels or converted into petrochemicals and more refined fuels.

- There are two kinds of coal liquefaction technologies
  - Direct cooling liquefaction (DCL)
  - Indirect coal liquefaction (ICL)
  - Hybrid plants may include both direct and indirect coal liquefaction technologies.
- In direct coal liquefaction, pulverized coal is treated at high temperature and pressure with a solvent comprising a process derived recyclable oil slurry. The large coal molecules are broken down into smaller molecules. Generally in DCL's, the H/C ratio is increased by adding gaseous hydrogen to coal slurry and coal derived liquid.

Direct Coal Liquefaction Process



COAL LIQUEFACTION TECHNOLOGY

- The range of partially refined gasoline diesel like products as well as propane and butane can be recovered from the synthetic crude oil by distillation process.
- The range of liquid products produced by DCL depends on:
  - Nature of Coal
  - Solvent
  - Process Conditions
  - Catalyst
  - Reactor Stages
  - Subsequent Refining
- Hydrogen is also needed to reduce Oxygen, Sulphur and Nitrogen present. These are removed as H_2O, H_2S and NH_3.

COAL LIQUEFACTION TECHNOLOGY

- **The principal products from DCL are Naphtha and Middle Distillate. These products contain more aromatic and less paraffins. Significant upgrading is required before the products can be used. These products can be upgraded at DCL plant or exported to a refinery which is generally already equipped with the upgrading units.**

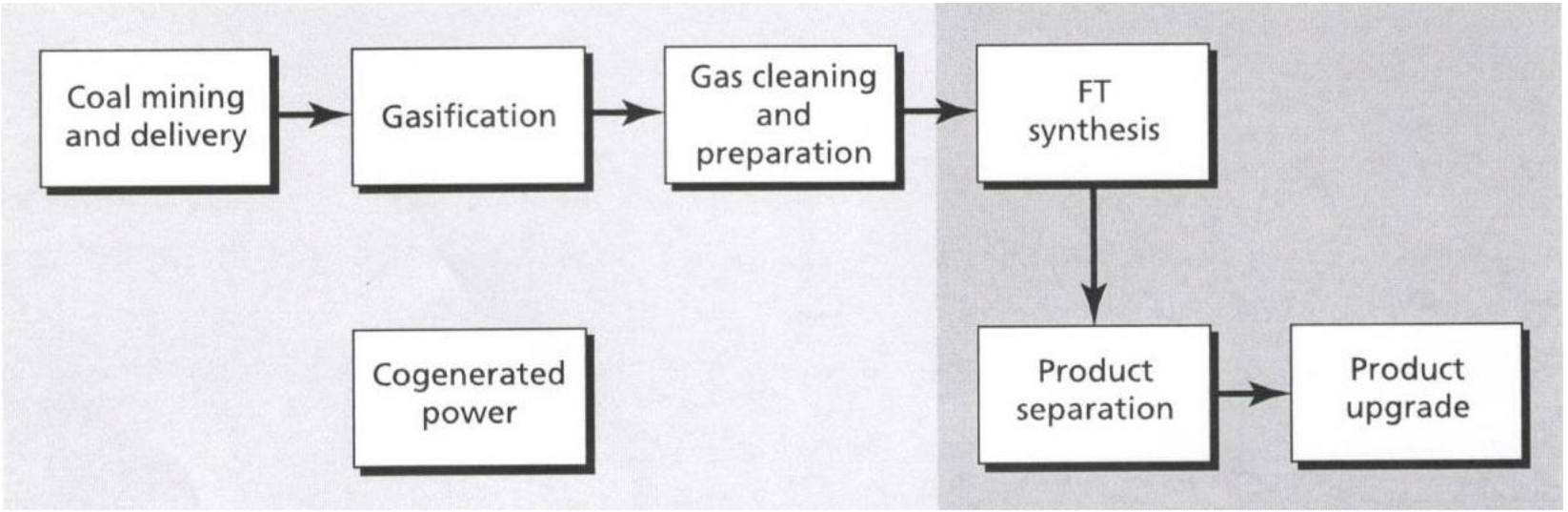
COAL LIQUEFACTION TECHNOLOGY

Indirect Liquefaction

- **ICL is a high temperature, high pressure process which comprises a gasification stage with Syngas clean up followed by either FT or Methanol Synthesis. Oxygen blown gasification of coal produces Syngas consisting mainly of CO and H_2 which can be modified as necessary by using water gas shift reaction to form CO_2 and H_2O, thus increasing the H_2 – CO ratio.**

- **The syngas contains a number of impurities including particulates, Sulphur compounds (H_2S and CO_2) and Nitrogen which are removed in a series of clean up stages**

Indirect Coal Liquefaction Process



COAL LIQUEFACTION TECHNOLOGY

- FT process produces light gases, naphtha, diesel and waxes. It is not possible to avoid generating a broad mix of products. By changing catalysts and operating conditions, the distribution can shifted but not avoided. For example a FT reactor can be run to optimize gasoline and reduce diesel production but this operating regime results in high yield of hydrocarbon gases particularly methane. To avoid methane recent developments in FT fuel production have focused on increasing the fraction of wax which can be cracked to produce useful transportation fuel.

- FT Diesel has a high paraffin content and near zero aromatic content. Its Cetane number is high. The Cetane number is a measure of how readily diesel fuel ignites. FT Diesel has a Cetane number of 70-80 compared to refined Diesel which ranges from 40-55. The higher Cetane number make starting a cold engine easier. It tends to reduce NOx and particulate emissions. These beneficial performance characteristics can be achieve for FT Diesel.

COAL LIQUEFACTION TECHNOLOGY

- Aircraft refueling at Johannesburg International Airport routinely receives a blend of FT derived Jet Fuel and convention Jet Fuel as 50% blending is allowed by International Aviation industry.

- However there are some issues with low aromatic FT Jet Fuel regarding elastomer seals which can cause fuel leak and lower energy density of FT Jet Fuel which could reduce the flight range.

- Between 20-40% of total product from FT plant would be Naphtha. Upgrading FT Naphtha is more difficult than refinery Naphtha hence it may be preferable to use FT Naphtha as feedstock for Petrochemicals. For upgrading it maybe better to send it to the refinery after Hydro treating. The petrochemical approach may provide better value for FT Naphtha than Gasoline.

COAL LIQUEFACTION TECHNOLOGY

METHANOL PRODUCTION

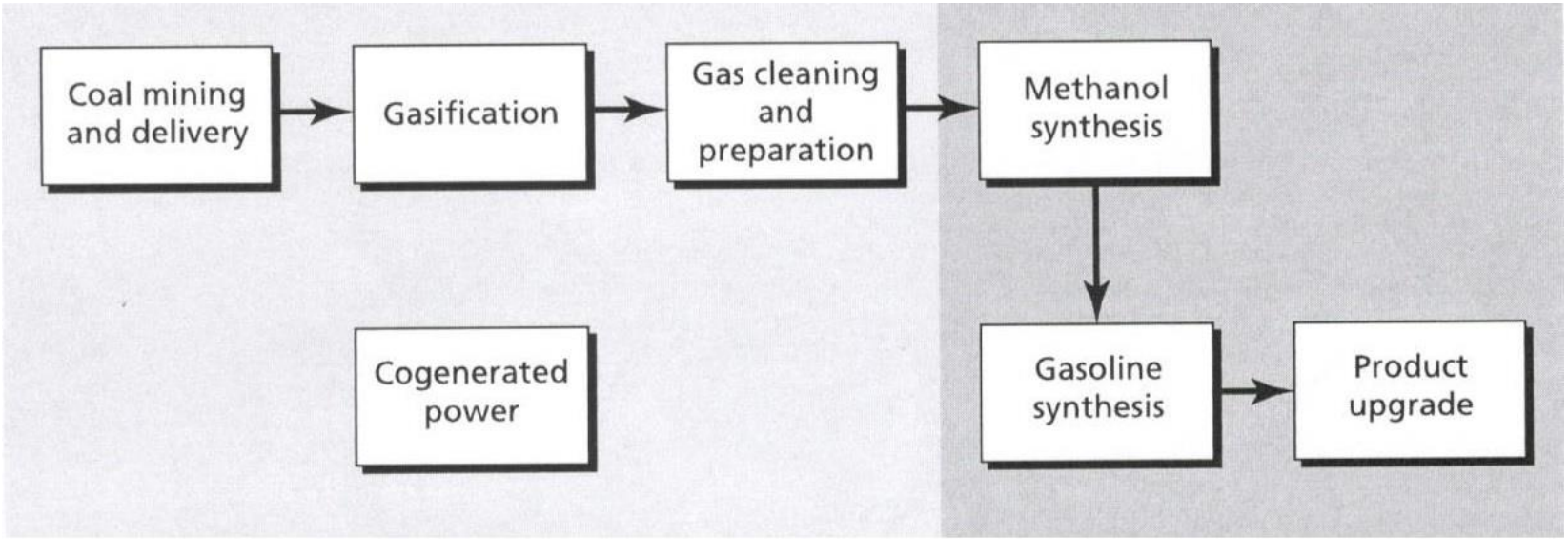
- Methanol is an important chemical product used as a chemical feedstock for production of a range of important industrial chemicals such as Acetic Acid, Formaldehyde, MTBE. Methanol is also directly used as a fuel or fuel supplement. Methanol can also be converted to gasoline via Exxon Mobil MTG Technology and to DME to power Diesel Engine.

- The MTG CTL approach consists of three steps. First coal is gasified to produce Syngas. Then syngas is converted to Methanol through LPMEOH process. Methanol is then converted to Gasoline through MTG technology.
- The synthesis of Methanol takes place at moderate temperature (200-300C) and pressure (750 psi). Gasoline production from Methanol releases a large amount of heat. The heat release is controlled by first dehydrating Methanol to DME. The DME is converted to raw gasoline which is then upgraded to the product are 90% Gasoline and 10% LPG

COAL LIQUEFACTION TECHNOLOGY

- Methanol is also a commodity chemical which is used to produce a large number of consumer and industrial products such as synthetic textiles, plastics, adhesives and pharmaceuticals
- There is an ongoing commercial production of methanol using coal derived synthetic gas in USA. Eastman chemicals company is producing 100,000 gallons per day of Methanol through this process.
- The raw gasoline from MTG reactor is very close to finished gasoline. The finished MTG has zero Sulphur. In addition to gasoline, hydrocarbon gases are also produced which can be sold as LPG or these can be reformed to make additional gasoline.
- Ethylene and propylene have generally been produced with naphtha and ethane as feedstock. So naphtha produced in CTL with some further processes can be utilized for production of ethylene and polyethylene. UOP have come up with Methanol to Olefins (MTO) process to produce ethylene and propylene from methanol.

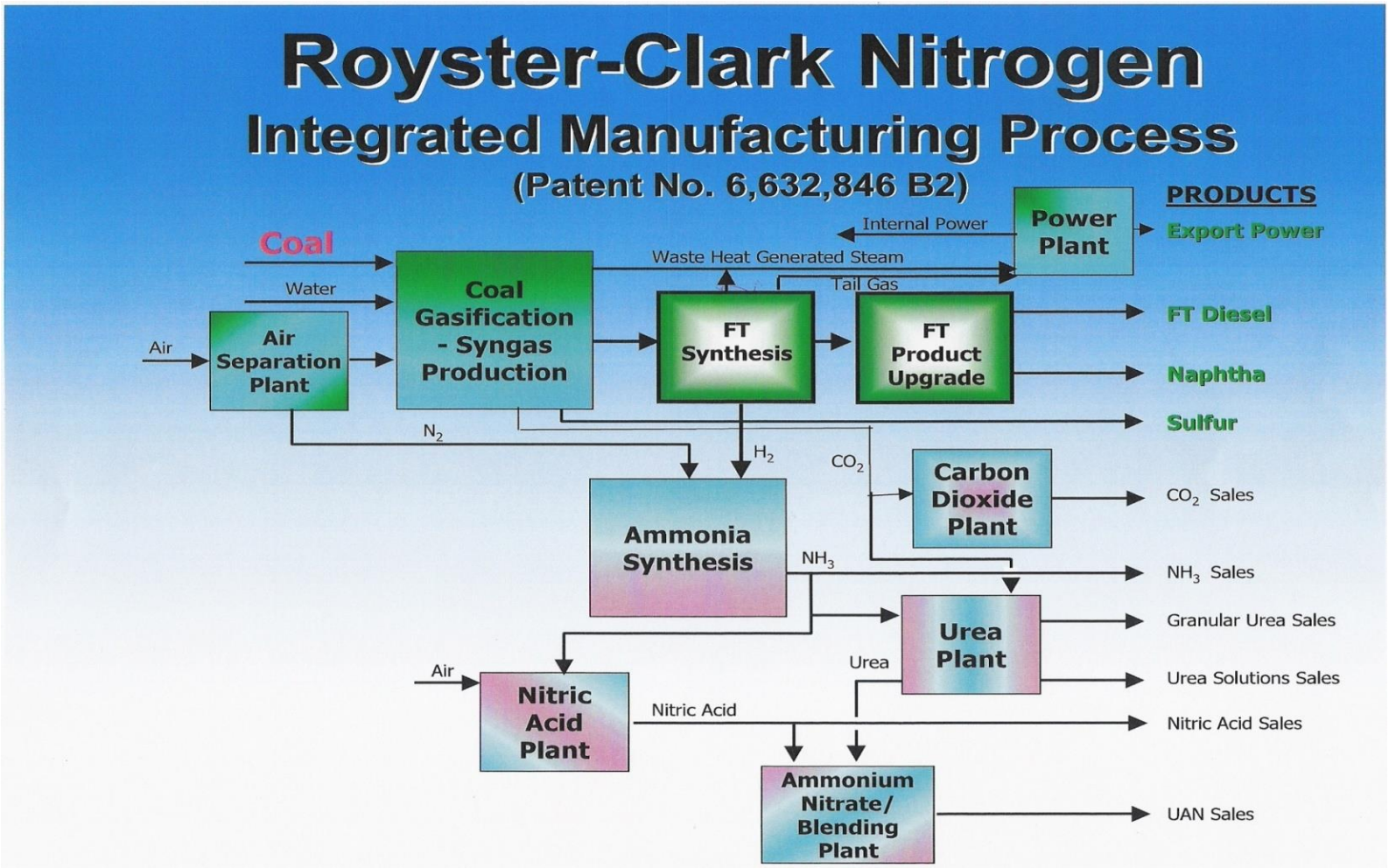
METHANOL TO GASOLINE PROCESS SCHEME



COAL LIQUEFACTION TECHNOLOGY

- **Once the basic petrochemical schemes are in place, a number of consumer and industrial products can be manufactured utilizing ethylene, propylene and methanol which include industrial parts, packaging, fibers, fabrics etc.**

INTEGRATED MANUFACTURING PROCESS



COAL LIQUEFACTION TECHNOLOGY

WATER USAGE BY CTL PLANTS

- There are several major requirements for water in a CTL plant.
- Processed water is needed for
  - **Steam fed to the gasifier**
  - **Water for use in liquefaction process**
  - **Wash water for syngas cleaning**
  - **Cooling water to remove heat at different stages, in particular from the FT reactors where highly exothermic reaction is needed for careful temperature control.**
- 5-10 barrels of water is required for each barrel of liquid product.
- Lignite contains high moisture which is recovered can provide a significant proportion of the water needed
- SRI claims that there are developing a process in which by blending some natural gas into the conventional CTL process, they are able to eliminate CTL carbon footprint, slash water consumption by over 70% and more than half its capital cost.

CTL Economics

- CTL plants are capital intensive. Capital cost could be around 100,000 USD/barrel of product.
- CTL being capital intensive, benefits substantially from economies of scale. Most studies on process economics have assumed that a full scale commercial plat would produce 50,000 to 100,000 BPD
- Cost may be reduced as a result on going technological developments and operating experience gained from few existing plants.
- The integrated power and co production of various products may also result in better returns.
- The productive management of CO_2 and Sulphur will also help.
- Underground coal gasification has the potential to reduce capital cost significantly.
- Government support would be important for such large investments, particularly from an energy security point of view and due to uncertainty in oil prices.

CTL Economics

- CTL can provide level of assurance regarding the security of fuels and petro chemicals if price is such that it is deemed worth paying for.
- As with all insurance policies this will always seem unnecessary until it is actually needed and as with all insurance policies under investment or failure to pay the premiums will mean that benefit will not be paid when needed.
- Government support would be important for such large investments, particularly from an energy security point of view and due to uncertainty in oil prices.

CTL Economics

- **The biggest ICL plant is in South Africa. Secunda Complex (Sassol I,II, III) produces 160, 000 bbl/day covering 30% of the country's needs. It contributes US$ 3 Bn to the economy and saves US$ 4 Bn in foreign exchange.**

- **Shenhua group reported that their DCL project in Erdos Mongolia with design fuel production of 1.08 million Tons/ year liquid products including Diesel Oil, LPG and Naphtha had been in continuous operation since 2010.**

COAL Liquefaction – Environmental Issues

- **Although, Coal is now much more clean, efficient and environmentally friendly, the coal industry of today is still working to escape the false image which lingers from the past.**
- **Coal bears the unjustifiable stigma of being a 'dirty', polluting fuel, bringing to mind, pictures of black smoke rising from chimney stacks.**
- **There may once have been reason to feel this way about coal; During early industrialist era, industrial areas were covered in a dark haze although the smoke was often viewed as a symbol of economic progress.**
- **London and other European cities suffered from fogs aggravated by the inefficient combustion of coal in countless domestic hearths.**
- **Today however, this view needs to be left to the history books. Coal can be burnt more cleanly and effectively throughout the world, using constantly improving technologies.**

COAL Liquefaction – Environmental Issues

- **The development of the modern world is based on the availability of industrial energy, electricity and improved modes of transport.**
- **However, in recent decades both industry and the public have recognized the increasing need for the preservation of the environment from some of the potentially detrimental effects of unregulated economic growth.**

PROSPECTS FOR CTL TECHNOLOGY UTILISING THAR COAL IN PAKISTAN

COAL Liquefaction – Environmental Issues

- **Problems arising from emissions were initially alleviated by building tall chimney stacks to improve dispersion**
- **But in parts of world, it became obvious there were more serious problems, from gaseous emissions such as Oxides of Sulphur (SOX).**
- **Much of the blame was attributed to coal and other fossil fuel-burning power stations, which emit SOX and Oxides of Nitrogen (NOX) during combustion.**
- **These gases react chemically with water vapor and other substances in the atmosphere to form acids, which are then deposited in rainfall.**
- **Industry developed access to supplies of lower Sulphur coals, and applied the necessary technology to reduce the emissions of SOX and NOx to meet the relevant standards.**

COAL Liquefaction – Environmental Issues

Coal's technical response to the environmental challenge is ongoing by developing clean coal technologies which are defined as technologies designed to enhance both the efficiency and environmental acceptability of coal extraction, preparation, processing and its products. The core elements of CCT are as follows:

- **Reducing carbon dioxide emissions with the development of carbon capture and storage.**
- **Improving combustion technologies to increase efficiency and to reduce carbon dioxide and other emissions.**
- **Eliminating emissions of pollutants such as particulates, oxides of Sulphur and nitrogen.**

COAL Liquefaction – Environmental Issues

- **Clean Coal Technologies (CCTs) are defined as 'technologies designed to enhance both the efficiency and the environmental acceptability of coal extraction, preparation and use'. These technologies reduce emissions, reduce waste, and increase the amount of energy gained form each ton of coal.**

- **CCT programs are being vigorously pursued by many countries, with many billions of US dollars equivalent being spent annually on developments in utilization techniques.**
- **These technologies will enable coal use to be increasingly efficient and environmentally acceptable as a vital world energy source throughout the next century.**

PROSPECTS FOR CTL TECHNOLOGY UTILISING THAR COAL IN PAKISTAN

COAL Liquefaction – Environmental Issues

- CCTs for the extraction of coal are readily available.
- Improved exploration methods, such as geophysics and seismic techniques. while improving mine planning by reducing geological uncertainties. Improved mining technologies aim to maximize extraction efficiencies while minimizing energy usage.
- Measures to reduce noise and dust level are standard practice, thus minimizing risks to the operators.
- Mining can release methane gas from coal, which can be a potential hazard. Various means to drain the gas are used, and in some cases it is being developed as an energy source.
- Mine plans include provisions to avoid the risk of ground water contamination.

COAL Liquefaction – Environmental Issues

- **CCTs for the preparation of coals can reduce their ash content, and clean them of impurities such as dirt and Sulphur. New technologies are being developed to improve the efficiency and cost of these operations, while improving the quality of any waste water.**

- **CTL fuels are ultra clean, Sulphur free, low in hydro carbons and NOX etc are considerably reduce. Hence, there will be less pollution on roads.**

Coal Liquefaction – Environmental Issues

- **For the entire CTL fuel cycle i.e. From oil well/ coal mines through to production of end products it is estimated that GHG emissions from CTL plant is about twice associated with fuels produced from conventional refining.**
- **To meet the international requirements to reduce global GHG emissions, CTL plants need to manage CO_2 at site through carbon capture and storage (CCS). CO_2 can be used for enhanced oil recovery and other industries.**
- **Due to additional cost associated with CCS, companies will generally require some financial incentives**

Coal Liquefaction – Key Issues

- **Energy security concerns in oil sector are increasing due to supply concerns.**
- **Uncertainty regarding oil prices.**
- **Global concerns regarding environmental issues which need to be addressed.**
- **Financing of capital – intensive CTL projects.**
- **Technology developments and technology transfer.**

COAL LIQUEFACTION – STRATEGICAL CONSIDERATIONS

- **The development of coal based industry utilizing the vast resources of coal which the country possesses from energy security and indirect economic development point of view.**
- **Related technologies are available. Stress needs to be given to encourage further research and development and technology transfer.**
- **Environmental concerns to be addressed with adaptation of mitigation methods with innovative ideas.**
- **Capital Intensive nature of CTL projects and the uncertainties involved require incentives such as loan guarantee, tax holidays, accelerated depreciations etc.**

COAL LIQUEFACTION – RECOMMENDATIONS

- The prospects for CTL industry development in Pakistan look good. However, further studies are required to have enough details and data for decisions to be made.
- Studies to be carried out to establish basic parameters in terms of costs, expected economy performance, risk analysis and the environmental impact analysis along with mitigation requirements.
- Studies should be carried out to look at various options to determine the best options.
- Indirect economy impact on national economy in terms of employment opportunities establishment of service and supply industry etc should also be considered.
- Strategic issues such as security of liquid fuels / petro chemicals should also be included in study.
- If the study shows promise it may be a good idea to start with small demonstration plants to gain early operating and commercial experience.
- Small demonstration plant can later be utilized for research and development.
- Based on the outcome of the studies, strategy, policy and a master plan may be developed for the CTL industry.