Coal to oil, gas and chemicals: Recent challenges and opportunities

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Scope of presentation

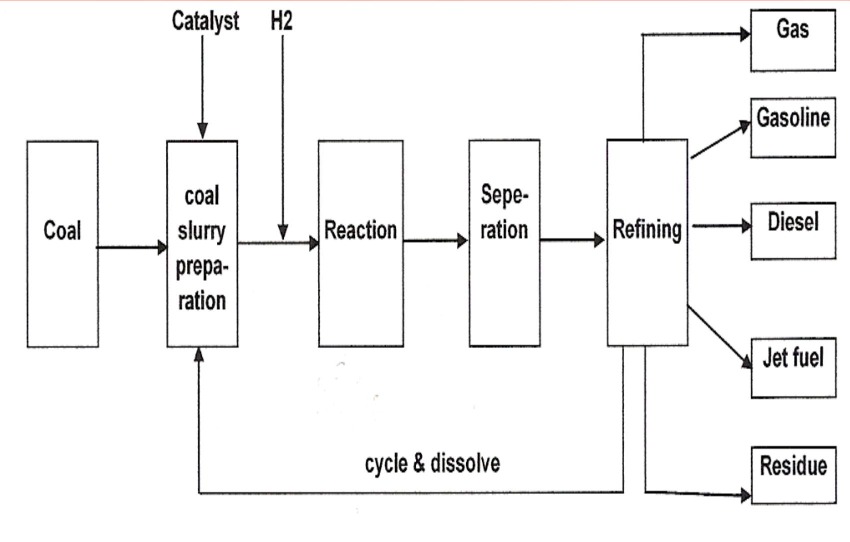
- **Rationale**
  - What is it?
  - How to do it?
- **Global considerations**
  - Countries most likely to be interested
  - Drivers for development
- **Recent developments**
- South Africa, China, Australia, USA, Europe
- **Economic & environmental considerations**
- **Final thoughts**

What is coal conversion in this context?

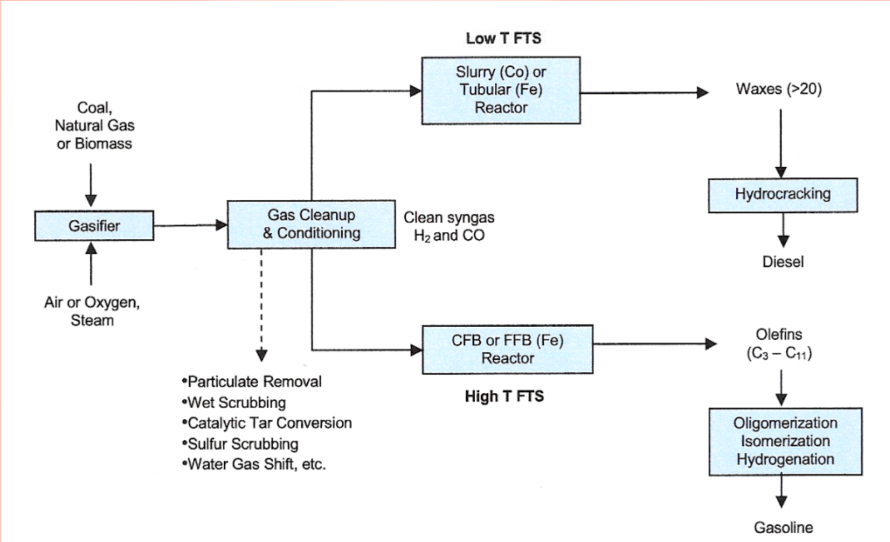
- A solid fossil fuel, such as coal, can be converted into oil, gas or other chemicals. Depending on the process, these initial products can be refined to produce transport fuels, substitute natural gas and a wide of range other products, such as plastics and solvents.

Coal conversion routes and key products

Direct liquefaction process



Fischer Tropsch indirect process



Petrol and diesel, Synthetic natural gas
Olefins, Di-methyl ether, Ethylene glycol

Direct conversion

Advantages

Conceptually simple process

Produces high-octane gasoline

More energy efficient than indirect conversion

Products have higher energy density than indirect conversion

Disadvantages

High aromatic content

Low-cetane number diesel

Potential water and air emissions issues

Fuels produced are not a good environmental fit for certain markets

May have higher operating expenses than indirect conversion

Indirect conversion

Advantages

Ultra-clean products

Well suited for CO_2 capture

Well suited for electric power co-production

May have lower operating costs than direct conversion

Disadvantages

Conceptually more complex than direct conversion

Less efficient fuel production than direct

Produces low-octane gasoline

Lower energy density than direct conversion products

Drivers for developing coal conversion technologies

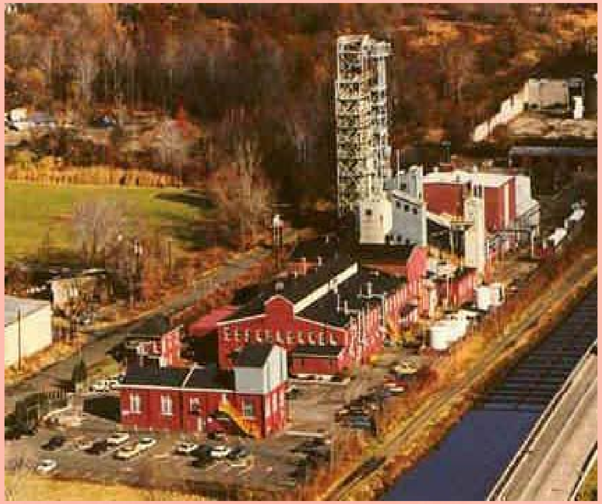
- Security of supply in the provision of liquid fuels and chemicals for countries that have substantial coal reserves.
- Such countries can be characterised as being “oil poor, coal rich”, with increasing vehicle numbers and demand for liquid fuels – as well as increasing imports of crude oil and petroleum products.
- CTL projects and associated coal conversion developments have the potential to create higher paid employment in coalfield areas
- Isolated and low rank/poor quality coal deposits can be utilised in the production of liquid fuels. Use of UCG may also be beneficial in creating added value

Cyclic development of the technology

- Economics dependent on relative prices of oil and coal, and on the level of capital investment
- Commercial interest in CTL has been very variable depending on the price of oil relative to coal
- R,D&D has followed the same trend

Historical direct coal conversion R, D&D

- **Originally developed in Germany in early 1900s**
- **USA spent $3.6 billion on DCL from 1975-2000**
- **EU and Japan also had significant programmes**



Lawrenceville, NJ
3 TPD

Catlettsburg, KY
250 – 600 TPD

Recent international developments

South Africa

South Africa has been the world leader in CTL technologies for several decades – with Sasol having built large-scale plants using indirect coal liquefaction technology at Sasolburg in the 1950s and Secunda in the 1980s.

Sasol current consumes up to 30m tonnes/year of coal, producing up to 150,000 barrels/day of liquid fuels and chemicals.

Sasol's plant at Secunda

The company has been evaluating the construction of a further 80,000 barrels/day liquid fuels plant at Mafutha near Lephalale, South Africa.

China now leading the way for coal conversion developments

- Close to 100 major coal to chemicals plants, using modern gasification technologies for ammonia or methanol production, have been established in several Chinese provinces.
- The most prominent DCTL project, with 1Mt annual product capacity, is being operated by the integrated energy company Shenhua Group
- Other large scale plants, using ICL technologies, have also started operation, with annual capacities of some 160kt.
- Various other very large demonstration units being established for coal conversion to synthetic natural gas (each 4 billion m^3 annual output) and key chemicals such as olefins and DME (up to 3Mt annual capacity).

Shenhua direct coal liquefaction demonstration

Incorporates components from USA, Japan and Germany. Start up at end 2008
Annual output 1 Mt including 621,000t diesel, 321,000t naptha and 70,000t LPG
Some operational difficulties
100,000 t/year CO_2 capture and storage (in aquifer) project underway

Yitai coal to oil facility
(Synfuels China 2010)

Slurry fed gasifier. Start up in 2009
Daily output includes 265 tonnes of light diesel, 51 tonnes of heavy diesel, 148 tonnes of naphtha, and 19 tonnes of LPG

Shanxi Lu'an Coal-To-Liquids Demonstration Plant (Synfuels China 2010)

Fixed bed coal gasification system
Local high sulphur coal . Start-up in 2009
Annual production of 210,000 tonnes of diesel, naphtha and LPG

Australia

•Companies based in Australia has been developing several underground coal gasification projects, which will provide opportunities to test this evolving technology, with small volumes of product gas being used for power generation and/or CTL production.

In October 2008, Linc Energy successfully produced the first hydrocarbon liquids from its Chinchilla demonstration facility in Queensland which introduces underground coal gasification synthesis gas into a Fischer-Tropsch reactor that produces high quality synthetic fuel. Linc Energy is licensing Syntroleum's CTL technology.

Australia (2)

Another prospective project in Australia is the Monash Energy Project . The project envisages a large CTL plant producing up to 60,000 barrels/day of FT diesel as well as associated power generation. Brown coal will be the fuel source – with the reserves located in the Latrobe Valley, approximately 160km to the east of Melbourne, Victoria.

The development of this project [like other large coal-based projects in Australia] will require CCS. The project developers have yet to announce their final plans.

USA

- Until recently, activity in the USA centred around the development of several direct coal-to-liquids pilot plant projects. However, over the last two years several larger-scale coal liquefaction/polygeneration projects have been announced based on indirect coal conversion.
- Major projects, involving feasibility studies, design stage work, include:

  DKRW Advanced Fuels

  Rentech

  Headwaters

  WMPI

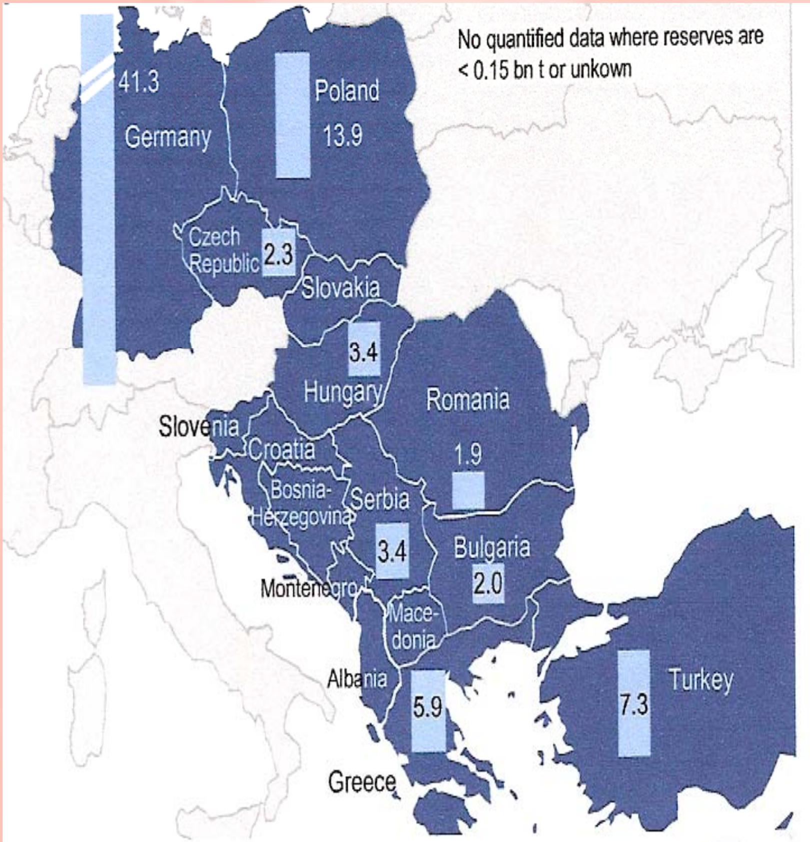
  AIDEA

  Diversified Energy

  Synfuel Inc.
- The projects have capacities ranging from 20,000 to 80,000 barrels/day.

CTL potential in Europe

Large, commercially proven lignite reserves but very limited oil and gas reserves in central and eastern Europe. As such, many countries are possible candidates to establish coal liquefaction given the expectation of an economically-favourable crude oil price.



Economic overview

- CTL will be expensive to build and expensive to run.
- Economies of scale important ((80,000 bbl/day)
- Capital cost US$ 5-6 billion
- Annual operating costs of US$ 250 million.
- 28000t/day of bituminous coal or double that if lignite
- Production cost per bbl will rise by US$5/bbl if CCS is added.
- Vulnerability to oil and coal price fluctuations
- Coal to chemicals vulnerable to imported products produced from low cost gas
- Commercial considerations include decision on scale and product mix (e.g. chemicals, power, CO2), coal cost and security, products off-take agreements, and financing mechanisms.

Environmental considerations

- **Indirect impacts**-It takes about 4t of coal to produce 1t of synthetic oil so more coal will be needed and, if CCS is introduced, even more again.
- **Direct impacts** - Needs up to 10 t of water to produce 1t of synthetic oil, which may well introduce constraints in terms of where plants might be sited. There are also local emissions, effluents and residues from a CTL plant to be considered.
- **High carbon intensity concerns** unless CCS is included, although NETL suggests that environmental footprint could be less than oil with CCS at comparatively modest cost.

Further challenges

- For those countries that wish to take forward coal conversion, more RD&D is required over the next decade to improve CTL plant design, efficiency and operational characteristics. Process intensification could ensure significant improvements in plant efficiency and also the economic utilisation of smaller, stranded coal deposits. Links with UCG may prove very attractive.

- Improvements in catalyst utilisation (particularly the use of nano-catalysts) will help reduce the costs of producing CTL fuels. This is important as some catalysts are based on high cost materials such as cobalt and molybdenum.

- In many countries that have an interest in coal conversion, there is a serious shortage of engineers and specialists who would be needed to build and operate new facilities.

Final thoughts

- Coal based liquid and gaseous fuels will have to compete with other energy sources in the coming decades – not just traditional crude oil, but also biofuels, natural gas and non-traditional hydrocarbon fuels.
- The future development of coal conversion technologies will depend on the process plants being able to produce products that are competitive in the transportation fuel and chemicals markets - and also being able to meet increasingly strict environmental operating standards.
- Strong government support must be a key element in the future development of such projects.