# Latest developments and innovations in Coal-To-Liquids

BY SERGE PÉRINEAU
PRESIDENT, WORLD CTL CONFERENCE

The idea of converting coal and biomass into liquid fuels raises multiple expectations among nations and companies' strategists, while those less aware of the technology involved consider it as some kind of new alchemy.

CTL can play a part in solving energy security issues. However, the technologies are known to be complex, uncertainties exist regarding their competitiveness, and environment issues are not always clearly assessed.

The commercial experience of CTL has so far been limited to that of one company, Sasol, in South Africa. However, tremendous research work is being done and demonstration plants have recently commenced production with near-to-commercial capacities. Thanks to the considerable information made available in recent years, the benefits of CTL are now better articulated and the questions raised by the process better answered.

## CTL and other acronyms

CTL generally means the conversion of coal (including lignite) or petroleum coke into liquid fuels.

Biomass is often added to coal. Several projects are referred to 'Coal-&-Biomass-To-Liquids' or 'CBTL', but the simpler expression 'CTL' is often maintained for CBTL projects. In this paper, 'CTL' encompasses both CTL and CBTL. At this point, it is important to mention that BTL (Biomass-to-Liquids) is not in the scope of CBTL. We consider that the models of BTL and CBTL respectively are fundamentally different, mainly due to the capacities of the units, which are significantly smaller for BTL than for CBTL units.

The principle of converting coal to liquid fuels is the same as converting it to other fluid hydrocarbons, mainly natural gas and petrochemicals. The processes consist of transforming molecules contained in coal and adding hydrogen to them. The expression "Coal-To-Fluids", referring to all these types of conversions, is appearing in the industry, reinforced by the fact that the versatility of the processes makes it possible to transform a project initially designed for producing a given fluid to another one for another fluid production.

This paper focuses on CTL, with some references to useful experiences from other CTFs.

## CTL: already a long story

CTL was first carried out at the beginning of the 20th century in Germany, where two technology routes were developed and patented: the 'indirect route' by Franz Fischer and Hans Tropsch and the 'direct route', by Friedrich Bergius.

These processes, applied in Germany, became uncompetitive with the discovery of large and easy-to-produce quantities of crude oil in the 1950s.

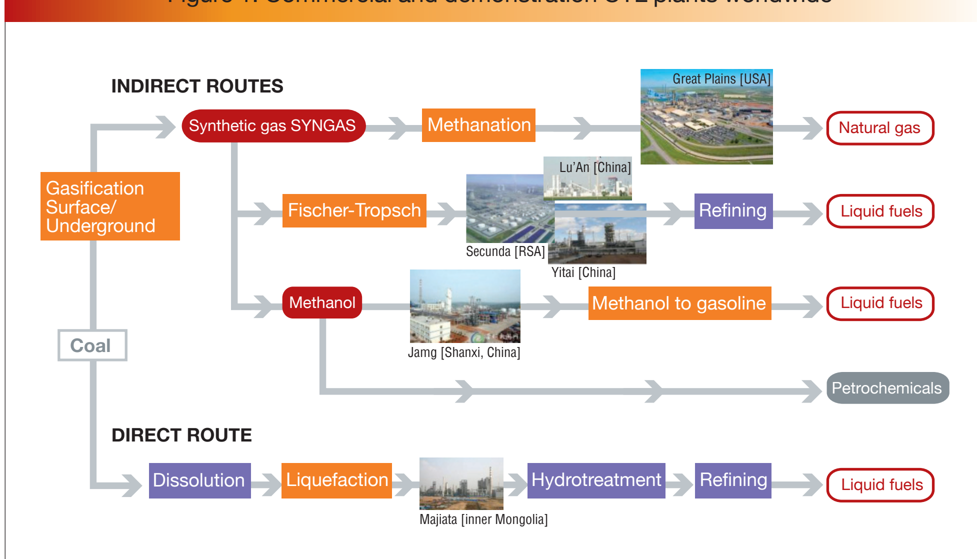
Later in the century, in order to secure its petroleum requirements, South Africa began an ambitious industrial CTL programme which resulted in today's only commercial operations. After the second oil shock, several billion dollars were allocated to research on CTL in the US before a slowdown linked to the decrease of the price of crude oil in the 1990s. Today, CTL and more generally CTF projects are being studied in most countries that are rich in coal. China is by far the most active, with several coal-to-chemicals plants already in operation, four demonstration CTL plants accumulating thousands of hours of tests and several coal-to-gas projects officially approved in recent months.

## Energy security

The comparative availability of crude oil, natural gas and coal on a global basis is universally known. Petroleum products' availability is key to the independence and development of countries, linked to needs for transportation and defence where liquid fuels cannot be substituted, at least in the medium term.

While reserves and resources of fossil energy are often discussed on a global basis, their geographical repartition

Figure 1: Commercial and demonstration CTL plants worldwide



holds a strategic importance, as fluid energy (crude oil and natural gas) is generally located far from most consuming regions (notably North America, Asia and Western Europe), while coal and lignite are freely available in most of them.

Opportunities also exist in areas where coal is available but expensive to transport, preventing it from being sold on the international market.

### Several technologies available

Several processes are available to convert coal to liquid fuels, although there are few commercial operations. The processes which today enjoy the most studies and developments can be gathered in (i) the 'indirect route' and (ii) the 'direct route'. They are represented in Figure 1, with pictures illustrating the commercial and 'demonstration' plants, which themselves have capacities between 7,000 and 20,000 bbl/day.

The first route is called 'indirect' because a first step consists in producing an intermediate: synthetic gas or 'Syngas', composed of carbon monoxide and hydrogen. In the second step Syngas is used as a feedstock in four main different processes:

- 'Fischer-Tropsch' synthesis produces liquid fuels: this process has been commercially applied by Sasol for decades; two demonstration plants have been started in China in 2009, by Lu'An and Yitai;
- 'Methanol to Gasoline' process after methanol synthesis: a demonstration plant, using ExxonMobil's MTG process, is being tested by JAMG in China;
- Production of petrochemicals from methanol: several units exist in China;
- 'Methanation', the production of methane or 'Substitute Natural Gas'; Dakota Gas has operated this process for decades in the US.

In the second or 'direct' route, coal is pulverised and mixed in a recycled slurry in which hydrogen is added under pressure. A demonstration plant has been started by Shenhua in China.

Both indirect and direct routes are seen to have respective advantages, in terms of versatility and quality of outputs (naphtha and diesel respectively). Most projects today are based on indirect processes, mainly thanks to the higher level of knowledge accumulated by experience and research so far. The lessons learnt from running demonstration plants will help characterise all tested technologies.

### Sustainable development: two levels of analysis

CTL is a chemical step included within a long energy channel. It is important to assess its environment footprint at two levels, local and global. 'Local' relates to the environmental impact at the place where the material is mined, converted or consumed. 'Global' is linked to greenhouse gas emissions.

### Local footprint

The environmental impact of coal mining is important to manage. Depending on the type of mine and operation conditions, it is controlled by the mining industry and is not within the scope of this paper.

The second step is precisely CTL. CTL presents the same characteristics as chemical and refining operations. The water requirement can be a sticking point. Studies are being made to decrease water needs, but scarce availability can make projects impossible in some areas. The solid wastes generated by CTL processes are the same as the ones produced by power plants and used in the same applications. The treatments of gaseous and liquid effluents are similar to the ones applied in the refining industry and do not raise particular questions.

The third and last step is the consumption or combustion of the fuel. Liquid fuels produced from coal, often referred to as 'synthetic fuels', are significantly cleaner, notably in terms of sulphur, than conventional fuels produced from crude oil. Vehicles using these fuels then generate cleaner emissions, which benefits the quality of air in cities.

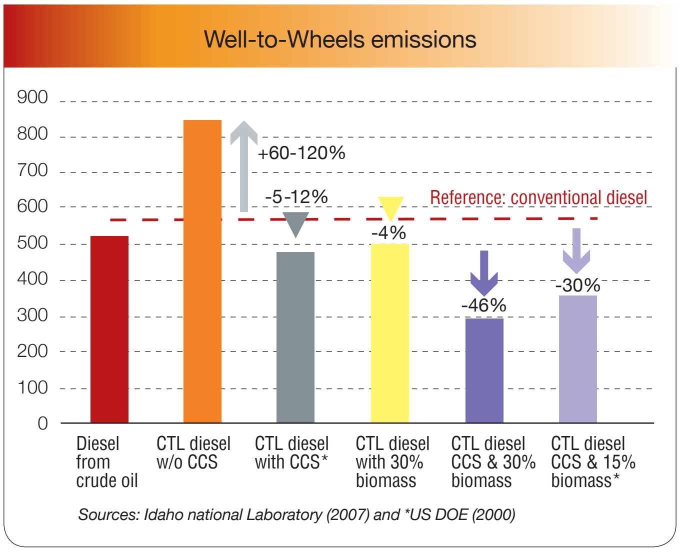
### Global footprint

Global footprint is a major issue for any energy channel. CTL's raw material is coal, the most carbonaceous fossil fuel. This means that, for a given production of energy, $CO_2$ emissions are higher from coal than from other fossil feedstocks such as natural gas or petroleum. In addition, CTL, as an intermediate process between mining and final combustion, requires energy consumption which results in $CO_2$ emissions. $CO_2$ emissions are specifically addressed in CTL projects, most of which include carbon capture and storage (CCS).

CCS and other process features will impact the carbon footprint of a CTL plant. However, more than the carbon footprint of the sole plant, it is important to compare the global CTL energy channel to others, from the extraction of primary energy (mining or oil extraction) to final consumption, for example, for a vehicle.

This is done in analyses "from the well to the wheels": the total greenhouse gases generated are then analysed: primary feedstock extraction, transportation of this feedstock to transformation place, conversion/refining, transportation of finished fuel and final combustion.

Published results generally show that total greenhouse gas emissions for liquid fuels produced from coal in CTL plants equipped with CCS are up to 10 per cent lower than conventional fuels produced from crude oil. This compares to an increase of 60-120 per cent if CCS is not applied. The addition of biomass to coal brings significant progress, especially if combined with CCS: the carbon footprint is then




reduced by almost 50 per cent in the case of the addition of 30 per cent biomass.

CCS is often seen as a technology that is only possible in the longer term, mainly due to the cost of its 'capture' element, which consists of separating $CO_2$ from large flows of nitrogen, and accounts for 80-90 per cent of total CCS costs. CTL offers a precious advantage in this field: $CO_2$ emitted by CTL processes is free of nitrogen, which generates an 80-90 per cent saving in CCS costs. The cost of CCS is then clearly bearable. This is why it is already applied at the Great Plains plant (USA), where natural gas is produced from lignite and $CO_2$ is exported for enhanced oil recovery.

## Economics

CTL is recognised as a capital-intensive industry, with capital expenditures expressed in billions of dollars. Reported investment costs are between US$80,000 and US$120,000 per daily barrel installed.

Competitiveness is commonly expressed in the price of crude oil equivalent. Given the level of capital expenditure, the calculation of this equivalent price is contingent upon the method through which the cost of capital is taken into account. Crude oil price equivalent will also depend on the price of coal, power (bought or sold by the plant), manpower and other classical parameters in the industry. As a result, figures should be considered with the utmost care. We can say however that reported prices of crude oil equivalent are between US$60 and US$90/bbl.

The return on capital engaged in CTL projects will predominantly depend on the price of crude oil and the cost of construction associated with the cost of capital. The cost of construction and the cost of capital are known when a project is decided. However, the volatility of the price of crude oil over the coming decades remains, with consequences for the financing of CTL projects.

## Developments

Most coal-rich countries and mining companies host research centres and conduct techology improvement programmes in CTL. Subjects include the optimisation of classical processes described earlier. Many start-ups, often linked with research centres, contribute to this dynamics, with innovative projects in new areas such as underground coal gasification, CTL+algae or Nuclear+CTL systems.

The industry monitors the results communicated by Shenhua, Yitai, Lu'An and JAMG on the operation of their demonstration plants, which are accumulating thousands hours of experience. In the medium term, the USA and China have presented forecasts for the development of CTL, which should represent more than 600,000bbl/day by 2020. Shenhua, the world leader in coal, plans to produce 440,000bbl/day by that year, with the goal of distributing its production under a self-owned station network.

## Conclusion

As coal is freely available in most energy-consuming regions, CTL will remain driven by energy security concerns. Greenhouse gas emissions are a key environmental issue. Technology improvements, CCS and the addition of biomass are the best allies of CTL. They open up opportunities for mitigating the carbon footprint in a more efficient way than conventional liquid fuels. Technologies are available. Today, there are few commercial plants in operation but demonstration units are being operated at close-to-commercial scale.

CTL is capital-intensive. Once the cost of construction and financing is known, project profitability will be subject to the volatility of crude oil prices and the cost of coal. With 2008 energy prices, CTL is highly competitive. Research is being actively developed in CTL. This development and the lessons from demonstration plants in China will pave the way for the short-term development of this industry.

International co-operation has played a key role in the progress made in technology, environment footprint improvement and competitiveness of CTL. Partnerships are now being created regarding financing projects. By providing up to date information on innovation to participants and offering them the best opportunities for meeting other members of the community, the World CTL Conference (www.world-ctl.com) has acted as the catalyst for international co-operations, such as in Beijing on 13-16th April 2010 and next year in Paris in February 2011. ❑