Liquid Fuels Production from Coal & Gas

HIGHLIGHTS

■ **PROCESSES AND TECHNOLOGY STATUS –** The final products of the coal and gas liquefaction process are transport fuels similar to diesel and gasoline, and other liquid chemical products such as methanol and dimethylether (DME). Liquid fuels from coal may be produced using two different approaches, i.e. direct and indirect coal liquefaction (**DCL** and **ICL**), which are at a different stage of development. In both DCL and ICL, the challenge is to increase the hydrogen to carbon (H/C) ratio of the final product, and to produce molecules with an appropriate boiling point at a reasonable overall cost. If (natural) gas is used as a primary feedstock instead of coal, a steam reforming process is used to convert natural gas into a synthetic gas, which is the basis for the production of synthetic liquid fuels. Coal liquefaction was first developed in 1913 in Germany, where high-pressure processes for ammonia and methanol production were applied to gasoline production from coal. In 1925, Fischer and Tropsch developed the FT process to convert syngas into intermediate wax products, which were finally converted into diesel, naphtha and kerosene using a hydro-cracking unit. During the Second World War, Germany produced large amounts of transport fuels via DCL and ICL technologies. Nowadays, the world's largest **Coal-to-Liquids** (**CTL**) production capacity is located in South Africa, based on locally available low-cost coal. Numerous demonstration units have been built elsewhere, but only a few industrial plants are currently under construction. **Gas-to-Liquids** (**GTL**) plants with a capacity of almost 13 Mt are currently in operation in Indonesia, Malaysia, Qatar, Mexico, New Zealand, South Africa and Trinidad. Additional 9 Mt/yr GTL facilities are either under construction in Qatar (Pearl Island) or will be commissioned by 2010.

■ **PERFORMANCE AND COSTS –** Performance and costs of coal liquefaction plants have been reviewed recently, as the result of a new interest in alternative production of transport fuels driven by the 2008 oil price peak. A study on liquefaction of Illinois No. 6 bituminous coal concluded that commercial CTL plants using the US Midwestern bituminous coal offer good economic opportunities. The investment cost of a CTL plant with a production capacity of 50,000 bbl/d of diesel and gasoline is around $ 4.1 billion (US$ 2006). The coal preparation and gasification in the CTL process account for almost 50% of the total investment cost, the rest is the cost of the GTL process. The economic viability of these projects depends heavily on crude oil prices. A crude oil price of $61/bbl (2006 US$) provides a 19.8% rate of return of investment (ROI). Oil prices higher than $37/bbl and $47/bbl provide ROI greater than 10% and 15%, respectively.

■ **POTENTIAL AND BARRIERS –** In principle, GTL potential is huge because synthetic fuels might, in theory, substitute conventional transport fuels and chemical products. In practice, GTL technology is in competition with pipeline gas transportation and liquid natural gas (LNG) technology. It is likely to be chosen only if there is no other economically attractive use for natural gas. Therefore GTL plants are often located where abundant resources of natural gas - including gas associated to oil production - cannot be used for other purposes. CTL also has the potential to produce fuels and chemicals. The technology process however - whether it is DCL or ICL - is rather complex and involves considerable investment costs and risks, including oil price variations, and changes in tax and regulatory regimes, especially those related to health, safety and environmental protection, most notably the mitigation of CO_2 emissions. The CO_2 emissions of the CTL process are as high as the emissions arising from the final consumption of the produced fuels. The application of carbon capture and storage (CCS) technologies could reduce the CO_2 emissions of the CTL process by up to 99%. However, this is only possible with additional costs and significant reduction in the efficiency of the process.

COAL TO LIQUID (CTL) PROCESSES – Coal can be converted into liquid fuels using two different approaches, i.e. the direct and indirect coal liquefaction (**DCL** and **ICL**). In both cases, the challenge is to increase the hydrogen to carbon (H/C) ratio in the final product, and to produce molecules with appropriate boiling points at a reasonable overall cost. The two technologies are at different stages of development. Both processes are illustrated in Figure 1. The final products are transport fuels with properties similar to those of diesel and gasoline, and other liquid chemical products like methanol and dimethylether (DME).

■ **The DCL process** consists of the dissolution of coal in a mixture of solvents. This is followed by thermal cracking, whereby hydrogen is added as a donor solvent. There are two main DCL processes: a) The **single-stage liquefaction process** provides distillates via either a primary reactor or a train of reactors in series, with possibly a hydro-treating reactor to upgrade the primary distillates. The optimal operation temperature for single stage direct liquefaction is around 450°C, and the molar ratio between coal and solvent should be about 2:1; b) The **two-stage liquefaction process** provides distillates via two reactors or two reactor trains in series. The first stage dissolves coal (with/out low - activity catalyst) and the second one provides distillate hydro-treatment in the presence of high-activity catalysts. DCL technology is the most efficient route

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