Syngas Production from Coal

HIGHLIGHTS

■ **PROCESS AND TECHNOLOGY STATUS –** Coal gasification – and virtually all gasification of other carbon-based resources such as biomass or refinery residues - is a versatile conversion technology which adds flexibility to the energy systems. In the gasification reactors, the feedstock is converted into a synthesis gas (syngas), a mixture of H_2, CO and CO_2, which enables the production a variety of downstream energy carriers. A lot of knowledge has been gained from coal gasification worldwide as this so-called town-gas was produced from coal as early as 1792, a high-temperature fluidized-bed gasifier was patented in 1921 by Winkler, and synfuels production from coal was common practice in Germany during World War II. According to the Gasification Technologies Council, in 2007, some 144 gasification plants and 427 gasifiers were in operation worldwide, adding up to an equivalent thermal capacity of 56 GW_{th}, of which coal gasification accounted for approximately 31 GW_{th}.

■ **PERFORMANCE AND COSTS –** Performance and costs of coal gasification plants depend largely on the plant design and the final production objectives. A gasification system that is part of an integrated chemical plant producing methanol, ammonia and electricity differs substantially from a system that only feeds an IGCC plant with carbon capture and storage (CCS). Coal quality is also very important for coal gasification output. The overnight capital cost of coal gasification plants is given per GJ of syngas output and ranges from $13/GJ for bituminous coal to $17.2/GJ for sub-bituminous coal (US$ 2005). Similarly, the syngas production cost decreases with the increase of coal quality and ranges from $15.6/GJ to $19.3/GJ. The production cost is dominated by the investment cost. However, costs may vary significantly depending on the location. Chinese plants may cost 60-65% of the US and European installations. Syngas may be further upgraded to meet specific demands. Co-production of 20% of H_2 using a H_2 separation unit is only slightly more costly than the basic process, resulting in 5% higher capital and 4% higher product costs. The conversion into synthetic natural gas (SNG), i.e. pipeline quality gas, requires additional processes and costs. If the syngas is converted into SNG, the capital cost increases by approximately 25% and the cost of the final product increases by 40%, while the conversion efficiency of the process decreases by some 14 percentage points, reaching about 60%.

■ **POTENTIAL AND BARRIERS –** There is huge potential for coal gasification worldwide, as the technology allows fuel production for many applications such as transport, chemicals, heat and power production. High natural gas prices and limited availability at a regional level are driving factors for investments in coal gasification. Based upon planned projects, the Gasification Technologies Council, a non-profit organization promoting technological advances and surveying the market, expects further market growth to reach a global equivalent thermal capacity of 73 GW_{th} by 2010. Other projections indicate up to 155 GW_{th} by 2014. Most of the growth will materialize in Africa and the Middle East (64%), Asia and Australia (27%), compared with only 9% in Europe and almost no investment in America. Marketable products from new gasification plants include Fischer-Tropsch (F-T) liquids (69%), chemicals (22%) and power (9%). However, because of the need to mitigate GHG emissions and climate change, these market projections appear to be realistic only if CCS technology is made available.

PROCESS AND TECHNOLOGY STATUS – Gasification of coal - and other carbon-based resources such as biomass or oil residues - is a versatile conversion technology that adds flexibility to energy systems. In a gasification reactor the feedstock is transformed into a synthesis gas (syngas), basically a mixture of H_2, CO and CO_2, which opens up to make a variety of downstream energy carriers. The syngas may be used as a fuel in integrated gasification combined cycles (IGCC, see ETSAP TB E01) or as a feedstock for producing H_2 or a synthetic natural gas (SNG). Depending on the CO to H_2 ratio, which can be adjusted using catalysts, the gas can also be used as a feedstock for a number of chemical processes, including Fischer-Tropsch synthesis (see ETSAP TB P06), conversion into CH_4 (methanation), or methanol and ammonia production. The multiple productions of fuels, chemicals and electricity from coal gasification is defined as poly-generation. Coal gasification in IGCC plants holds the potential for easy capture of CO_2 from the syngas and for CO_2 storage in geological formations (CCS).

Gasification takes place under oxygen shortage. Coal is first heated in a closed reaction chamber where it under-goes a pyrolysis process at temperatures above 400°C.

During pyrolysis, hydrogen-rich volatile matter is released, along with tar, phenols, and gaseous hydrocarbons. Char is then gasified, with the release of gases, tar vapours and solid residues. The dominant reaction consists of partial oxidation of char, which produces a syngas with high fractions of H_2 and CO. The process takes place at temperatures between 800°C and 1800°C. Specific operating conditions depend on coal type, properties of the resulting ash, and the gasification technology. The most important variable in a gasification process is the oxidant. It can be either air (with its nitrogen component) or pure

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