IEA CLEAN COAL CENTRE profiles

No 05/01 May 2014

Non-fuel uses of coal

Coal has been historically an important feedstock for the production of chemicals requiring carbon-based raw materials. In the mid-20th century, oil and natural gas gradually displaced coal as the primary source of feedstock for the chemical industry. However, in recent years, the volatility in oil and natural gas prices and security of supply issues have renewed interest in coal as a source for feedstock. Coal comprises 60% of global energy resources. It is a fuel used in many sectors throughout the world. Converting it into viable products can be categorised into three main areas, power production, fuels and chemicals. The most significant uses of coal are in electricity generation, steel production, cement manufacturing and as a liquid fuel. Approximately, 6.6 Bt (or 6.6 Gt) of hard coal and 1 Bt (or 1 Gt) of brown coal were used worldwide in 2012. Since 2000, global coal consumption has grown faster than any other fuel. The five largest coal users are China, USA, India, Russia and Japan, accounting for 76% of total global coal use. For coal utilisation in power generation and fuels visit www.iea-coal.org. The review discusses the general non-fuel uses of coal including replacing crude oil and gas in the production of chemicals. The ways in which coal may be converted to chemicals include carbonisation, gasification followed by conversions of the synthesis gas (syngas) and liquefaction/hydrogenation.

Coal tar is a principal liquid product resulting from the carbonisation of coal, that is, the heating of coal in the absence of air in a coking oven, at temperatures ranging from about 900°C to 1200°C (1650°F to 2200°F). Coal tar, coal tar pitch and coal tar creosote are similar mixtures obtained from the distillation of coal tars. Coals tars are by-products of the carbonisation of coal to produce coke and/or gas. They are complex combinations of poly aromatic hydrocarbons (PAHs), phenols, heterocyclic oxygen, sulphur and nitrogen compounds. Coal tar creosotes are distillation products of coal tar. They consist of aromatic hydrocarbons, anthracite, naphthalene and phenanthrene derivatives. The traditional source of coal chemicals, tars or liquids from by-product coke ovens, has steadily decreased in the last decades and is expected to continue to decline. However, the opportunities are increasing for new applications and markets for coal chemicals.

Coal gasification offers a versatile and clean method of converting coal into not only electricity but also hydrogen and other valuable products. Gasification, which is a thermo-chemical process, breaks down the coal into its basic chemical constituents. In modern gasifiers, coal is typically exposed to steam and carefully controlled amounts of air or oxygen under high temperatures and pressures. Under these conditions, molecules in coal break apart, initiating chemical reactions that typically produce synthesis gas (syngas), hydrogen (H_2), carbon monoxide (CO) and other gaseous compounds. Gasification has been used in the chemical industry since the 1930s. The products from the gasification of coal may be of low-, medium- or high-heat (Btu) content as dictated by the process as well as the ultimate use of the gas. The majority of syngas used worldwide in 2012 from all fuels was for the production of chemicals, liquid fuels and power generation. The majority of planned gasifiers (~40%) are for chemical production and liquid/motor fuels (~29%), power generation (~22%) and gaseous fuels (~9%). Gasification feedstock distribution is coal: 63%, petroleum: 15%, gas: 13%, petcoke: 9% and biomass/waste: <1%. In the case of coal, of the total syngas produced, 49% is used for FT (Fischer-Tropsch) liquids, 32% for chemicals, 11% for power generation and 8% for gaseous fuels. In the case of oil, 63% is used for chemicals, 27% for power production and 10% for gaseous fuels. Petcoke and biomass are gasified mainly for power production. A table containing a list of major coal gasification plants worldwide for the production of chemicals is included in the review.

Concerns over supply security and the price of oil have led to a renewed interest in coal as an alternative, not only for the production of transport fuels, but also for chemicals. Historically, the coal to liquids (CTL) process has been used to convert coal into a substitute for liquid fuels in countries with little or without a secure supply of petroleum, for example South Africa. The review discusses the ***non-fuel uses of coal*** and therefore only briefly presents the use ofliquefied coal as fuel. A number of products can be developed using CTL processes – ultra-clean petroleum and diesel, as well as synthetic waxes, lubricants, chemical feedstocks and alternative liquid fuels such as methanol and dimethyl ether (DME).

Each issue of **Profiles** is based on a detailed study undertaken by IEA Clean Coal Centre, the full report of which is available separately. This particular issue of Profiles is based on the report:

Non-fuel uses of coal

Herminé Nalbandian

CCC/236, ISBN 978-92-9029-556-3, 80 pp, May 2014

This report is free to organisations in member countries. £100 to organisations in non-member countries for six months after publication, and free thereafter.

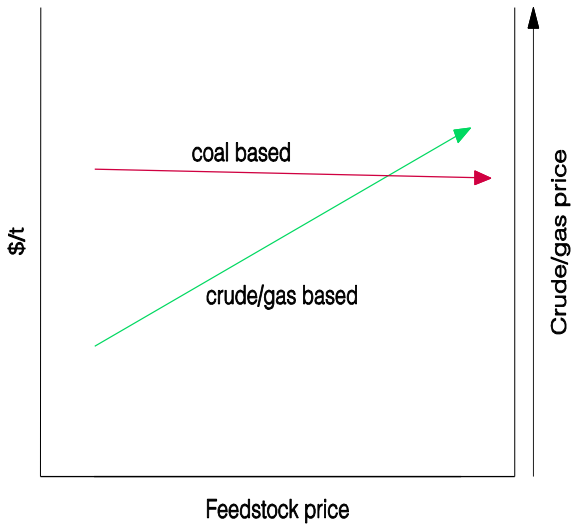
IEA Clean Coal Centre Park House 14 Northfields London SW18 6DD
www.iea-coal.org | +44 (0)20 8877 6280 | email: mail@iea-coal.org

Coal as feedstock for chemical production is driven by a number of factors including:

- rapid increases in energy demand;
- higher oil and gas prices which make the coal routes to chemicals competitive;
- the emergence of new lower cost technologies for the large-scale conversion of coal-to-chemicals;
- the strategic drive of coal rich countries to reduce reliance on imported oil and/or gas; and
- the ability for companies to own coal assets to give a long-term feedstock supply at a predictable price.

Processes for the production of specific chemicals from coal are typically proprietary systems using specialised catalytic technologies, requiring particular process design/operation. Carbon and oxygen are both key elements in organic chemistry. Therefore, there is a wide range of chemicals that may utilise CO_2 as a feedstock for production, including organic acids, alcohols, esters, and sugars. Potential uses of CO_2, based on current markets, could come from acetic acid, which has a current global market of ~6 Mt/y. Acetic acid can be produced by direct catalysis of CO_2 and methane. Examples of chemicals produced from methane are ammonia, carbon black, methanol, chloromethanes and hydrogen cyanide. Many chemicals from coal are being produced, used and developed including formaldehyde, methanol, ammonia/urea, methanol-to-olefins (MTO), mono-ethylene-glycol (MEG) and dimethyl ether (DME), acetic acid, acetylenes such as vinyl chloride monomer (VCM), poly vinyl chloride (PVC), butanediol (BDO), vinyl acetate monomer (VAM), acrylic acid (AA), acrylonitrile (ACN) and naphthalene derivates. Chemicals from coal are boundless, traditional and otherwise, and therefore are **not** all discussed in the review.

The economics of non-fuel uses of coal are reliant on the price spread of the competing fuels and availability of coal, that is, countries with large recoverable reserves of coal and small reserves of oil and gas would have a greater incentive for the production of chemicals from coal. This creates a favourable cost position for chemicals from coals (*see* Figure).



Cost of production comparison between coal and crude/gas *(Nexant, 2010)*

Materials and chemicals from coal are recognised as important, practical and profitable products especially in countries with little or no oil and/or gas resources and therefore are an area of increasing interest and for future coal utilisation research and development.