COAL AS A RESOURCE – GASIFICATION AND CHEMICALS

A new coal chemical industry has emerged in China that combines coal gasification and liquefaction with the production of commodity chemicals for polymers, fibres, fertiliser and fuel. The strategic basis for the industry is to support China's energy and chemicals security by using indigenous resources. Coal-to-chemicals is now a global scale sector and provides China with a degree of protection from crude oil price fluctuation. The main challenge for the future is that coal-to-chemicals is more carbon intense than petrochemicals; it takes more than three tonnes of coal to make one tonne of product. This is a serious issue given China's intention to reach peak CO_2 emissions by 2030. This target appears at risk as coal-to-chemicals has added substantially to the emissions already produced from cement and steel manufacture and an enhanced coal power sector.

COAL GASIFICATION, CO_2 EMISSION AND DECARBONISATION

The coal gasification industry has successfully produced chemicals and polymers of comparable quality to the petrochemicals industry which remains dominant in China. Using methanol-to-olefins technology for polymer manufacture, the raw syngas product from coal gasification possesses a low H_2/CO ratio, and so the carbon monoxide is reacted with water to form hydrogen and CO_2. For polymers, this means less than one third of the original coal carbon is present in products, with the rest emitted as CO_2. For fertiliser production, involving the conversion of coal to hydrogen and ammonia, much less coal carbon is present in the final urea product. Collectively emissions from coal gasification in China exceed 1.1 $GtCO_2$/y, approaching half that emitted by China's steel and cement sectors.

Carbon capture: Coal gasification plants offer a technically advantaged, lower-cost route to carbon capture and storage (CCS) as a highly concentrated CO_2 stream is obtained prior to methanol production; this is simpler to process than the relatively dilute streams from power, cement and steel reactors. The location of coal gasification plants appears promising for permanent geological sequestration, avoiding construction of excessive infrastructure. Demonstration units are in operation, some assigned to coal-to-chemicals; the overall intent across industry is to remove up to 500 $MtCO_2$/y, ten times the current global capacity of CCS.

Hydrogen: China's renewable energy capacity is developing rapidly, and the cost of solar power is still falling, which supports the deployment of water electrolysis for hydrogen production based on renewable electricity. This raises the prospect of combining coal gasification with electrolytic hydrogen to change syngas composition, providing several benefits. As hydrogen is added, less carbon monoxide and water need to be converted to CO_2 and hydrogen, increasing the proportion of coal carbon incorporated into products. Less coal would be needed per unit of product, lowering handling costs. Ultimately three gasification reactors could be replaced by one. Currently, most of China's hydrogen is obtained from coal and hydrogen is the highest emission product from the industry, so a switch to electrolytic hydrogen is a major industrial event. Hydrogen production using renewable electricity is intermittent, and all manufacturing units would operate beneficially with a constant supply, perhaps solvable by local hydrogen storage. The cost of electrolysis must approach that of coal-to-hydrogen which appears to be increasingly realistic. This hybrid production method would make coal a valuable resource for chemicals with a reduced impact on the climate.

PLASTIC WASTE

The carbon intensity of the industry is one challenge. Plastic waste pollution is another. It is already a highly visible problem, which is worsening with low recycling rates. This is an issue for coal and for petrochemicals, as the dominant producer of plastics. Coal-to-polymers production is unique to China and currently forms less than 20% of polymer production in the country. However, China is expected to produce half of all polymers by 2050. The issue with recycling is that it always means downgrading plastic as the huge range of additives means that fresh plastic cannot be produced. New research may change this in the future, as a low-temperature catalytic process can revert plastic back to a monomer composition making the production of fresh polymers a possibility. The regenerations of plastic is at an early phase of development. If it makes good progress, it could pose an issue for China's chemical industry.

Plastics are durable with lifetimes of centuries in the environment, but are subject to mechanical breakdown forming small particles, termed micro or nanoplastics. These particles are pervasive in the environment, in water supplies, in plants, and in all animals. The health impacts of plastic are unclear, but there are indications that plastics accelerate cardiovascular conditions. The recent finding of plastic in the brain, overcoming the blood-brain barrier, has raised concern leading to calls for extensive research on this subject. Plastics have become central to modern life, and the polymer market is set to increase by up to 50% by 2050, with more than half used in single-use packaging. The use of plastic is likely to come under increasing scrutiny, because of the waste created and the implications of the disquieting health indicators for investors, companies and governments.

RARE EARTH ELEMENTS AND GRAPHITIC CARBONS

Rare earth elements (REEs) are essential to an array of technologies utilising electric motors and batteries. The IEA predicts that demand will rise 7-fold in coming decades as the world transitions from fossil fuels. The issue for OECD countries is that resources are dominated by China. There is an urgency to develop new resources and build independent refining capacity. The connection to coal is the focus of the ICSC. The emphasis has been on extracting REEs from coal wastes and combustion residues, but the discovery of REEs at the Brook coal mine, Wyoming, USA may be groundbreaking. REE concentration is lower than for conventional ores, but they are present in a more easily extractable form. The original intent prior to discovery of REE was to produce carbon products at the minehead, shipping products rather than raw materials. Coal for graphitic compounds has the potential to lower materials costs but the impurities in coal can make that challenging. New approaches combine coal and petrochemical products to achieve suitable properties, for example, mixing pitch and polyacrylonitrile (PAN) carbon fibres to offer strength of PAN and high electrical conductivity of pitch for new applications in energy and carbon storage. Carbon as a resource is still developing but has widespread market potential, especially for inclusion in high-tonnage production.

PROSPECTS

The coal gasification industry in China is at a global scale with the strategic aim achieved for China to possess an alternative source of chemicals using its indigenous feedstock. However, the industry is carbon intensive; expansion is in progress but the momentum has lessened. If future IEA predictions on oil prices are correct, then the economics for coal products will be challenged more by petrochemicals. Gasification is technically advantaged for carbon capture and the industry has the potential to use renewable generation to transform carbon intensity, potentially rivalling petrochemicals. Environmental performance and economics are likely to be more critical factors to future projects than feedstock security.

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Each executive summary is based on a detailed study which is available separately from: www.sustainable-carbon.org. This is a summary of the report: Coal as a resource – gasification and chemicals by Dr Ian Reid, ICSC/335, ISBN 978-92-9029-658–4, 77 pp, January 2025.

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