ADVANCES IN NON-ENERGY PRODUCTS FROM COAL

The global drive to net zero carbon is leading to fundamental changes in the way fossil fuels are used and regarded. New industries are emerging that would have been unthinkable only a few years ago. Vehicles with internal combustion engines will soon be banned in many countries as there is a global shift towards renewable power and electrification of energy. What do these momentous changes mean for the future for coal? The demand for coal as a fuel supply is set to fall and so it is a resource that will be both plentiful and inexpensive, increasing its potential as an attractive feedstock. For instance, coal contains fragments of nanomaterials that are increasingly seen as the future of materials science. Every electric motor and battery require components that can be obtained from coal. Increasingly there is a shift in perspective towards coal as a feedstock, to supply our new industries, whether in sustainable agriculture, addressing shortages in critical elements, or as a source of transformative carbon-rich materials. Coal's growth prospects are as a feedstock rather than a fuel.

COAL TO CHEMICALS

Although the extraction of tar for chemicals and carbon products remains important, coal gasification to chemicals is attracting most investment; large-scale construction in China added 150 new facilities between 2018 and 2020, and a further 220 plants are planned by 2023. China's chemical sector required 250 Mt of coal in 2019, a figure set to rise substantially with new manufacturing capacity. Recently other countries have indicated investment in coal gasification to fuels and fertiliser; these include Indonesia, India and through the Belt and Road Initiative, Pakistan and various African countries.

However, the coal to chemicals sector faces several challenges. First, the economic basis of the industry relies on competitiveness with oil and gas petrochemicals, and the long-term predictions are for subdued oil prices of less than $60 per barrel. Second, the polymer industry is likely to undergo structural change due to concerns about plastic waste; it may lead to alternative formulations or localised production to maximise reuse. Finally, the carbon intensity of coal chemicals is more than three times that of oil and gas equivalents. CO_2 emissions from the chemicals sector threaten to undermine China's international commitments to reduce greenhouse gases.

PITCH CARBON FIBRE

Pitch carbon fibre derived from coal is the most promising low-cost route to fibre enabling its deployment in transport and construction. Carbon fibre (CF) has largely replaced fuselage metals in aeroplane manufacture due to the cost-benefit of higher strength/reduced weight. The transition to electric cars is hampered by the weight of battery arrays, and one way to offset that is to reduce vehicle weight. The benefit of CF to vehicles in terms of greenhouse gas savings is modest compared to that of aircraft but then there are to be over 60 million produced each year. Fibre offers additional benefits including chemical inertness and thermal conductivity that may extend battery life.

The construction industry faces ever rising demand for raw materials leading to over exploitation of resources, while cement production is associated with the greatest industrial CO_2 emissions. CF products are emerging that can be tailored for lightweight insulation materials or structural components; these

offer advantages of chemical inertness and superior properties, materials that can be derived from a plentiful coal resource.

NANOCARBONS (GRAPHENE)

Of the nanomaterials, there is most interest in graphene, a novel, planar form of carbon with revolutionary properties. Remarkable uses for graphene include as a memristor, a new 'state-of-the-art' computer resistive memory chip, and as a contact lens coating that can allow the wearer to see beyond the visible spectrum. Concrene, a new graphene modified concrete, exhibits enhanced chemical bonding and heralds new commodity uses for nanomaterials. The presence of graphene reduces the amount of concrete required to achieve design strength, and has potential to lower the greenhouse gas profile of the construction industry.

This is good news but how is it relevant to coal? There are now at least four coal-based routes to graphene; chemical and molten salt techniques are demonstrated for production of quantum dots; in electronics, an electrochemical method can form A4-sized graphene sheets; and most recently a flash joule heating method has formed graphene. The latter may be the most easily scaled method to produce graphene for commodity products.

LIGNITE IN AGRICULTURE

The use of lignite in agriculture, either partially oxidised or in its raw state, can counter deterioration of soil quality amid a rising demand for food. Lignite humate fertiliser demand may be boosted by concern over the impact of conventional fertilisers based on urea, itself a major product of coal gasification. Lignite products avoid the environmental hazards of urea, with agriculture one of the few emerging large-scale uses for low quality coal.

RARE EARTH ELEMENTS

Minerals present in coal offer an alternative resource of rare earth elements (REE) that are crucial to the new renewable energy, aerospace, and electric transport industries. The supply of REE is essentially a monopoly, and this has led to deep concerns over security of supply for lanthanides, which are set to experience a surge in demand. A new pilot for the extraction of REE from coal wastes, has exceeded targeted REE purity levels, and measures such as x-ray sorting, aim to reduce the impact of the lower concentration of REE in coal compared to REE ores. Novel techniques offer non-chemical routes from coal to REE reducing waste management, and REE recovery has a role in the restoration of old mine workings.

PROSPECTS

Much of the coal industry is at a crossroads termed the 'coal transition', dominated by coal power plant closures, but it also includes making products from coal that are essential to 21st century industries. The emergence of a large-scale coal to chemicals sector is a remarkable achievement although it faces significant environmental challenges. Coal, with its high carbon content, is potentially a superior feedstock for certain carbon products set to revolutionise materials science. The move away from electricity generation will suppress coal prices offering an advantage to those manufacturers utilising coal and enable widespread applications to commodity products.

Each executive summary is based on a detailed study which is available separately from www.iea-coal.org. This is a summary of the report: Advances in non-energy products from coal by Dr Ian Reid, CCC/311, ISBN 978-92-9029-634-8, 90 pp, June 2021.