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Guest Editorial

Future Fuels and Chemicals

Introduction

Today's fuels and chemicals industries have their roots in 20th century investments in fossil fuel extraction and conversion. Highly integrated petrochemical complexes and refineries have evolved to deliver products that have transformed how we feed, clothe, shelter, make healthier and move people across the globe. The environmental impacts of these industries are under ever tighter scrutiny, particularly as we accelerate towards a future with net zero and circularity at the forefront of our thinking.

This *Johnson Matthey Technology Review* issue explores technological advances that may evolve to form the backbone of the future fuels and chemicals industries: technologies which will deliver even greater benefits for human life, while treading lightly on our planet.

Themes in the Transition Towards Net Zero and Circularity

There is no 'silver bullet' as we transition our industries to their future state. Many advocate that they have 'the answer', but the reality is that we must deploy every tool at our disposal today, while continuing to innovate the step-out solutions of tomorrow. The good news is that the fundamentals are in place. Renewable energy costs are falling, we understand the chemical conversions that need to be implemented, and we have the technologies to abate unavoidable greenhouse gas emissions.

New Feedstocks

The chemical industry has always adapted to different feedstocks, driven by price or geopolitical pressures. In recent years shale gas has revolutionised the US chemical industry, whilst China retains a strategic interest in coal. Methane offers significant carbon reduction potential and while it can be readily processed by syngas routes, direct upgrading options continue to be explored. These technologies, applied to renewably derived methane, maintain their relevance in a net zero world.

Bio-derived fuels are already established in transport applications where legislation drives today's investments (1). While some commercial routes to bio-derived chemicals exist, the same driving force for change is not there. However, brand owners of consumer facing products are making strong commitments to sustainability and decarbonisation (2) which may create the market pull for biobased plastics, surfactants and formulating agents. Contaminated plastics, which cannot be easily recycled back to monomers or polymers, as well as municipal solid wastes, are emerging as feedstocks that can be reconstituted into chemical products *via* pyrolysis or gasification.

Carbon dioxide from industrial processes or direct air capture will become an important carbon source in the decades ahead. The direct or indirect addition of renewable energy is needed to move back up the thermodynamic hill. Hydrogen generated by splitting water will be a key enabler, as subsequent conversion *via* syngas into alcohols and hydrocarbons leads into downstream value chains. As well as water electrolysis, electrochemical technologies that reduce carbon dioxide directly are being developed and scaled. These may enable future chemical production at more localised scale.

New Processes

Regardless of feedstock, designing energy and atom efficient processes remains key. 90% of chemical processes today are already catalysed (3), and we can expect this to grow. When developing new processes the mantra of 'right catalyst, right reactor, right process' remains truer than ever. Recent progress by Johnson Matthey and its partners in Low Carbon Hydrogen (4) and FT-CANS^{TM} (5) technologies serve to illustrate this point.

Catalytic processes will continue to evolve to deliver more atom and energy efficient flowsheets. Seamless integration of renewable electricity, decarbonised hydrogen and carbon capture will become the norm for chemical plants of the future. Advances in reactor design and control may revolutionise process operation, and the use of lower density feedstocks may drive some applications towards distributed, intensified modules. More hybrid bio-thermochemical processes are likely to emerge as advances in biotechnology are leveraged. The aim here must be to preserve some of the precious functionality within the biomass feed.

New Products

It is interesting to reflect on whether the portfolio of chemicals that make up the industry toolkit today will change significantly in the years ahead. For example, the challenges of recycling a more divergent range of plastics is likely to incentivise the industry to work mostly with decarbonised variants of what is known, rather than seeking radically new polymers.

Fuel slates will shift as transport becomes increasingly electrified, and hydrogen will take up a role as an energy vector alongside electricity. It will be valued for its ability to store and distribute low carbon energy, as well as being the solution to decarbonisation challenges in heavy transport and industry. Kerosene type fuels derived from biomass, waste or e-fuels will continue to dominate long-haul aviation (6). There is much debate around shipping, with hydrogen, methanol and ammonia vying to be selected as the future fuel of choice (7). While production of these molecules is well established, the scale of investments needed to move these commodity chemicals into the fuels arena will surely drive innovation in these mature processes.

Markets that are likely to see most innovation in product design are those in which chemicals are unavoidably released into the environment, such as pesticides, fertilisers, detergents and water-soluble polymers. Biodegradability in real conditions and the minimisation of eco-toxicity will drive the search for materials with improved environmental functionality.

Conclusion

The transition of the fuels and chemicals industries towards a circular, net zero future will require disruptive transformation in how we innovate and deploy technologies. New ecosystems will evolve as the power generation, agriculture and waste management sectors integrate with the chemicals and fuels sectors to meet the challenge. The transition will not be achieved by technology solutions alone. The right legislative frameworks, incentives and business models must be established to create a level playing field in which all embedded environmental impacts are accounted for. Deployment at scale is also essential to move quickly down the cost curves.

We are at the start of a revolution in our industries, but one at which efficient and effective catalyst technology sits at the heart. Industry's current skills in deploying thermocatalysis will be complemented by advances in bio, electro and possibly photocatalysis. I for one am excited to see what we can collectively achieve over the coming decades as we step up to deliver the solutions needed for a cleaner, healthier world.

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