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Sustainable technologies to fuel the future

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As the world runs out of oil and gas, it urgently needs to find alternative fuel supplies. Teesside University's Professor Maria Olea outlines how her research holds some of the answers.

For the past 10 years I have been working on a number of research projects which technically can be summarised as "advanced catalysis to sustainable technologies". Advanced catalysis means the combination of preparation, experiments and simulations that brings catalytic studies from micro and meso level to macro level or massive commercialisation. Practical examples include the conversion of biomass and municipal solid waste into fuel.

Biomass is an attractive source of renewable energy that will play a major role in future energy generation, says Maria Olea (image courtesy of Shutterstock).

Developing sustainable technologies is a massive agenda, of course. Such innovation is needed to address the big challenges of the 21st century: energy demand, resource allocation, water and pollution. By reducing energy and resources consumption, this will help everyone to protect the environment and to re-use/recycle resources.

Today, 80% of energy usage comes from fossil fuels: petroleum, coal and natural gas. While fossil fuels are still being created by underground heat and pressure, they are being consumed more rapidly than they are being generated. Although there is no consensus for how long these natural resources will last, there is complete agreement that to avoid their complete depletion renewable resources should be used.

Fossil fuels like coal and petroleum still make up 80% of energy usage, but Maria Olea and her team are currently investigating the benefits of syngas and chemical conversion of carbon dioxide as potential sources of energy (image courtesy of Vyacheslav Svetlichnyy via Shutterstock).

Biomass, hydro, wind, solar, geothermal, marine and hydrogen will unquestionably play an important role in the future. Biomass/waste, being a readily available renewable energy source that reduces sulfur dioxide and carbon dioxide emissions, is an extremely attractive option as a fuel for power generation and as a raw material to be converted into transportation fuel.

The School of Science and Engineering at Teeside University focuses on the production of synthetic fuels via thermocatalytic routes, mainly biomass and waste-to-fuel routes. One of the main thermocatalytic routes is pyrolysis, a potential value-added technology for the treatment of biomass/organic waste, with the possibility of producing gases with appreciable fuel value, useful liquid oils and agriculturally applicable biochar.

As chemical engineers, the development of catalysts with high activity and selectivity for sustainable catalytic processes was, and still is, a first priority for our research. As such, we’ve prepared a number of newly-developed technically advanced catalysts which support our over-arching objective of helping to protect the environment and re-using/recycling resources.

Arguably our main research success to date has been in the conversion of biogas (consisting of about 60% methane and 40% carbon dioxide) as produced by anaerobic digestion of municipal wastewater sludge, into syngas (mixture of carbon monoxide and hydrogen). Using nickel-based catalysts in a conversion process known as dry reforming of methane, this proven application converts two major greenhouse gases, methane and carbon dioxide, into synthetic fuel, making it very important from an environmental and economic point of view.

Syngas is already a synthetic fuel as it can be used into a gas engine to produce steam and electricity. However, to comply with the engine's specifications, syngas has to be cleaned. This was the task of our EU-funded Pyrochar project, which was dedicated to the design and development of a process to convert sewage sludge into useful biochar and synthetic gas. A different class of nickel-based catalysts were developed and scaled-up, from mg to kg, for this application. The catalysts were used in the pilot plant unit built by the Pyrochar project consortium and proved to have better performance than existing commercial catalysts used as a benchmark. A related area of our work is the conversion of syngas into long-chain hydrocarbons, substitutes for diesel fuels, through the Fischer-Tropsch catalytic process.

We are also currently investigating the conversion of carbon dioxide into valuable chemicals by polymerisation. The utilisation of carbon dioxide by chemical conversion is a valuable idea which is envisaged to provide answers to two other burning questions of the 21st century, namely around global warming and fossil fuel depletion. Chemical conversion of carbon dioxide into other useful chemicals not only provides a tangible solution to curb the ever increasing amount of greenhouse gases in the earth's atmosphere, it also serves carbon dioxide as a cheap, abundant and natural feed stock.

We are always exploring new opportunities and have found a way to eliminate Volatile Organic Compounds (VOCs) to improve the quality of indoor air, by developing catalysts able to work at room temperature, a promising alternative to minimise energy consumption in catalytic reactions. And, although it is early days, we are currently looking into the conversion of waste oil into biodiesel.

Going forward, our mission is simple: to focus on heterogeneous catalysis in our quest to save the planet for future generations. We plan to develop catalysts for the conversion of pyrolysis oil into valuable chemicals and are also interested in modelling, designing and building microcreactors to intensify the conversion process.

Our ultimate goal is "zero waste, zero emissions" and we are confident that we are not far away from achieving that. Improved catalysts and processes for the cost effective conversion of a wide range of feed-stocks: including biomass, sludge from the wastewater treatment plants, waste plastics, and waste oil; to a tailored range of gas and liquid fuels and chemicals, through mainly synthesis gas (syngas) chemistry have been designed, developed and, most importantly, proven by myself and colleagues.

However, our work does not end in the laboratory. Through our teaching we are able to share our passion for saving the environment. We teach undergraduate and postgraduate students in reaction engineering, environmental and waste minimisation, process improvements, enzyme kinetics, and catalytic processes.

Through this we are able to raise the awareness of the environmental impact of individual day-by-day actions and to challenge students, who are also specialists and managers of the future, to adopt pollution prevention rather than pollution control and to opt for re-use/recycle rather than disposal. It's a long journey, but as the world is running out of oil and gas and urgently needs to find alternative fuel supplies, we all have a responsibility to provide some solutions.

ABOUT THE AUTHOR

Maria Olea is a Professor in Chemical Engineering and Catalysis at Teesside University.