A/Prof Mike Manefield and Dr Sabrina Beckmann have demonstrated a five- to tenfold increase in gas production from a coal seam at the historic Lithgow State Coal Mine in New South Wales

# HOT-WIRING BIOGAS PRODUCTION

**Biogas (methane) production is an increasingly significant statistic on global energy markets, derived both from renewable resources such as food waste, animal waste and crops, and from fossil fuel resources such as coal and oil shale.**

Biogas is produced by microorganisms called methanogenic archaea. They take substrates from the fermentation of organic matter, such as acetate or hydrogen, and produce methane as a metabolic exhaust product. Methane is an efficient fuel for powering transport and generating electricity, with credentials superior to those of coal in terms of greenhouse gas emissions and other air pollutants (sulfides). Since 2010, associate professor Mike Manefield and research associate Dr Sabrina Beckmann at the University of New South Wales have been looking for ways to accelerate this process and increase the biogas yield per unit mass of feedstock.

Initially funded through an ARC Linkage Project grant with New South Wales–based Biogas Energy Ltd as an industry partner, Manefield and Beckmann's research led to the discovery of a simple synthetic chemical amendment to biogas-producing microbial cultures that both accelerated gas production and increased yield. This was not an incremental improvement, but a massive leap forward, the likes of which has not been seen for more than half a century. The discovery not only sheds light on fundamental aspects of methane production by microbes, but is also a game changer for the global biogas industry.

The work was originally focused on enhancing natural methane production from coal seams. While there are legitimate, but resolvable, environmental concerns

regarding coal seam gas extraction, the comparison to coal mining is stark. When coal is mined, the methane incumbent in the seam is released into the atmosphere. It's a potent greenhouse gas and we release it without extracting energy from it; it's profligate waste.

Manefield equates coal mining with lying under a barrique with the tap open, while coal seam gas extraction is seen as sipping at a mature red from the Barossa Valley. The former is an environmental disaster on a planetary scale. The latter is a legitimate play into the future, not just in the transition to hydro-electric, wind, solar, geothermal and tidal energy-harvesting technologies. Gas extraction from coal seams and oil shale is the pace at which we should be consuming fossil fuels. This is the approach required to make these ancient resources last for tens of thousands of years.

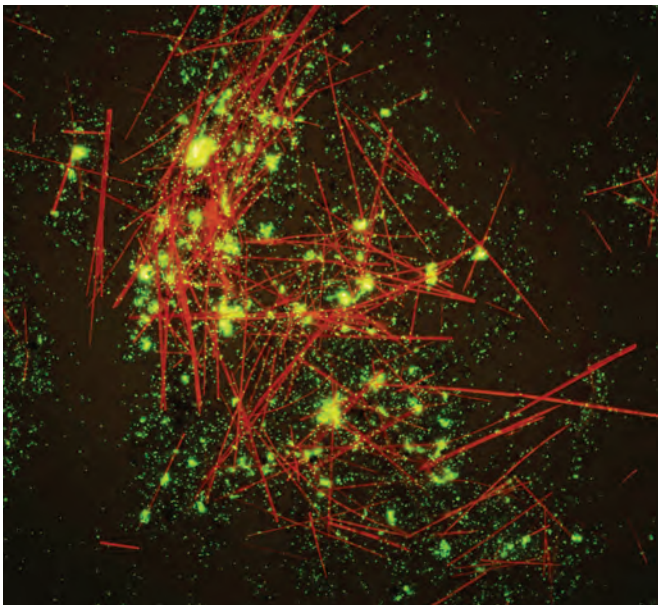
But the discovery by Manefield and Beckmann is equally applicable to gas extraction from renewable resources that have traditionally not been exploited. Food and agricultural waste, for example, mostly ends up in landfill where it is digested, and the methane produced is ultimately released into the atmosphere without exploitation. Manefield's team has shown that application of their chemical amendment can increase methane production from food waste tenfold. That's like turning one dollar's worth of gas into $10 of gas.

So, what is this seemingly magical amendment? During the course of the research, Manefield started to view communities of different species of microbes as an electrical circuit board, with electron transfer reactions (equating to electrical current) as the foundation of their energy harvesting. Manefield then realised that if the electrical network could be short-circuited, it should be possible to channel electrons towards the methane producers. The chemical amendment does just this, but through an entirely unexpected mechanism.

The chemical known as 'neutral red' is a synthetic compound invented more than a century ago and used variously as a textile dye, and more recently in bespoke applications as a histological stain and pH indicator.

It has been around for a long time, and is well known for its ability to pick up electrons from one source and deliver them elsewhere. Such compounds are referred to as 'electron shuttles'. They catalyse electron transfer; they are not consumed. The fact that neutral red has a crystalline form was unknown until Manefield and Beckmann discovered the fact, and that the crystalline form acts like an electron sponge that vends electrons exclusively to methane-producing microbes.

Never content to leave a discovery in the ivory towers of university laboratories, Manefield has pushed hard to conduct field trials of the newly developed technology. Since 2013, trials have been conducted at the historically significant Lithgow State Coal Mine in the Western Coal Fields of New South Wales, with resounding success. A teaspoon of neutral red was added to wells drilled for purpose 80 metres below ground into a three-metre-thick coal seam. Within a week, neutral red had taken on its crystalline form in the coal seam–associated groundwater, and over the course of a year, increased methane yield five- to tenfold.



Enhanced biogas production using neutral red crystals (red) in association with microorganisms (green) and coal particles (black) under fluorescence microscopy (Image courtesy Dr Sabrina Beckmann)

The discovery is protected by an Australian patent filed by University of New South Wales's NewSouth Innovations and financed by Biogas Energy Ltd, and was recently published in the esteemed Royal Society of Chemistry journal *Energy & Environmental Science*. It was picked up by science journalists internationally, and has generated a flood of interest from professionals in the global biogas industry seeking improved returns on their infrastructure investments as government subsidies are wound back.

While there are important technological advances to be made in translating this discovery to biogas reactors treating renewable feedstocks, it is clear that the discovery will have a major impact on biogas production in the future. Ongoing research and commercialisation activities are funded through an Australia-India Strategic Research Fund grant with industry partners Biogas Energy, Santos and the Indian-state-owned Oil and Natural Gas Corporation.

**Mike Manefield will be speaking at the 17th International Biotechnology Symposium 2016 (IBS 2016).**