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Waste-to-energy innovations powering a circular economy

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ABSTRACT: The benefits of better food waste management extend to community-building, liveability and poverty reduction in cities. Waste-to-energy (WtE) technologies provide elegant solutions for food waste management with tangible and usable products including energy and fertiliser, and attractive environmental and social benefits. When combined with food security they provide a powerful case for city and rural communities alike. The majority of waste-to-energy facilities in the world are in Europe, Japan, and the US. In developing countries such as African nations, a very limited share of waste is recovered and reused, and only major or capital cities have waste management systems. In a number of these countries the use of waste to generate electricity could have a significant impact. Waste can make a very high contribution to providing electricity to citizens and alleviating energy poverty, especially in countries with little access to electricity and low electricity consumption per capita. For isolated, rural and less wealthy populations, the benefits of an effective circular economy are even more direct than for a Western urban population. The production of biogas from organic waste via anaerobic digestion is one such technology that fits perfectly in a circular economy and engenders the energy independence needed by these communities. This case study presentation gives an overview of the different waste-to-energy technology options that exist, and highlights some key innovations across the globe. A particular focus is novel approaches that have been used in developing countries, and the impacts on food loss and waste, livelihoods and food security.

Keywords: waste-to-energy, biogas, quality-of-life benefits, anaerobic digestion, biofertiliser

My presentation is about waste management and innovations powering a circular economy, and should be a good complement to Steve Lapidge's presentation about recovering nutrients to go back into a circular economy.

As well as recovering nutrients we can also capture energy from organic waste. This talk highlights a particular waste-to-energy technology – anaerobic digestion. I think it is a great example that integrates both nutrient capture and energy capture, and it really embodies what a circular economy is about. First I shall give you a bit of information about waste-to-energy technologies, WtE, or W2E as they are sometimes called.

The term 'waste-to-energy' refers to any waste treatment that creates energy from a waste source, such as mixed waste which could include both inorganic

This is an edited transcript of the presentation, with some of the powerpoint slides shown.

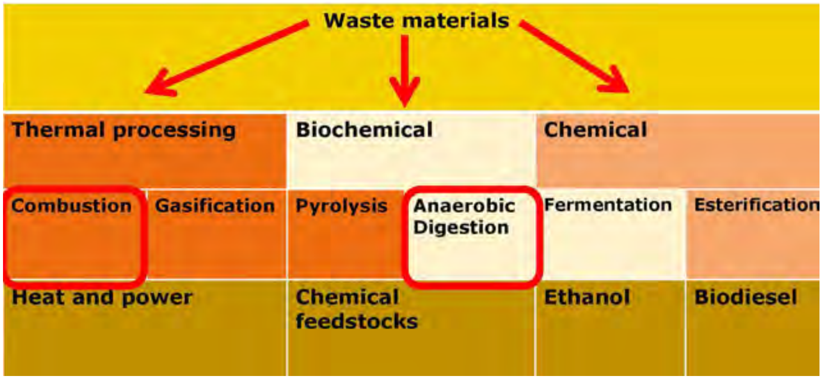

Figure 1. Waste-to-energy (WtE) technologies.

and organic waste. Essentially, through waste-to-energy technologies we are aiming to produce heat and power, chemical feedstocks, ethanol or bio-diesel (Figure 1).

In thermal processing (orange-coloured cells in Figure 1), the most common method of converting municipal solid waste (MSW) to energy is actually combustion, incineration. That method is used primarily with mixed waste input – inorganics or organics. The world leaders in the use of this technology are in Europe where there are about 450 combustion facilities, and Japan (around 100) and the USA (nearly 100).

Gasification and pyrolysis are emerging technologies in 'thermal processing', and they operate in the absence of oxygen, whereas combustion uses oxygen. Both the gasification and pyrolysis technologies are still at pilot scale and demonstration scale, and not in widespread use.

Under 'chemical conversion' (pink-coloured cells in Figure 1), the main techology is esterification. That process will produce bio-diesel, and again it is very much in its pilot stage and not really economically feasible.

The third category is 'bio-chemical conversion', both by anaerobic digestion and by fermentation. The end product of fermentation is ethanol and I am not discussing that here. Anaerobic digestion, however, produces both heat and power, and it also has the benefit of producing large amounts of materials that can be used as a nutrient-rich fertiliser.

Biogas

I shall now focus on biogas and the central issue of food waste, and how we can get more benefits from food waste. Biogas is produced from anaerobic digestion, a naturally occurring process through microbial action in the absence of oxygen. Biogas consists of approximately 60–80% methane, and the remainder is carbon dioxide. The methane can be used to produce electricity, heat and fuel. The material left after anaerobic digestion (the 'digestate') is also very valuable as a rich fertiliser and soil conditioner, which can be used to grow food.

Figure 2. Anaerobic digestion of food waste produces a range of benefits.
Image source: http://www.projectdirt.com/project/14209/#1journal_entry/34491

These products of anaerobic digestion (Figure 2) can support small businesses, organisations and community groups, not only by providing energy but also through soil additives for agriculture. The technology also creates job opportunities which are far more sustainable than those created by some other renewables – say, solar installations and the like.

In Australia

Yesterday I published an article in *The Conversation*, titled 'Australian communities are fighting food waste with circular economies' (McCabe 2016). *The Conversation* is an online magazine in which academics write about research or a topic of interest in language that suits the average non-academic reader. My article describes my observations as related to this conference.

Overseas, the European Council adopted an ambitious circular economy package in December 2015, which includes revised legislative proposals on waste, to stimulate Europe's transition towards a circular economy. In Australia, we do not have anything similar.

Although around 4 million tonnes of food reaches landfill in Australia each year, there is no federal directive on its management. However, I have observed (through pilot plans and various activities) that directives *are* being put forward. They are coming from state and territory governments and from local government and also from communities that are taking it upon themselves to repurpose waste and convert it into energy and by-products such as fertiliser. My article highlights some case studies and projects.

In South Australia, SA Water is using co-digestion in a sewage treatment plant. Most biogas in Australia comes out of sewage treatment plants, but SA Water has commissioned the first co-digestion plant in Australia, and it has been operating for three years. They are using the wastewater treatment plant like a waste management facility and they are bringing in different waste streams to increase the generation and use of the biogas.

In Victoria, in a newly developed study, a team in the Yarra Valley aims to emulate what SA Water has done. Another example, still at the proposal stage, is at Cowra in central New South Wales. The community is coming together, supported by State Government funding and local government funding, to explore a multi-stream waste model. The idea is that the community can gain benefits from both the energy and the fertiliser.

In developing countries

In developing countries, biogas technology is considered to be an excellent tool for improving livelihoods and health. Worldwide, around 16 million households are using small-scale bio-digesters. The process is a boon for developing countries for creating low-cost energy for cooking and lighting in homes. China, India and Nepal have mastered the use of this technology and are employing it as part of development schemes and also investing in it.

As examples of the value of this technology, here are three case studies in Africa. The first one is called Cows to Kilowatts, and it is located at Ibadan in Nigeria. The project centres on the construction of a biogas plant and wastewater treatment facility to run on abattoir wastewater, creating a really cheap source of domestic energy. It also abates pollution and is mitigating the production of greenhouse gases. Figure 3 shows part of the biogas facility at the abattoir. This is a community-driven biogas facility using somewhat sophisticated technology called anaerobic fixed-film technology (AFF). It is providing affordable environmentally-friendly safe cooking gas and organic fertiliser, which benefits the urban poor and provides income to farmers. Traditionally, the main fuel for cooking is kerosene, wood or charcoal. They are expensive and labour-intensive and also a very unclean way of cooking. The value proposition of this project is its impact in improving health and producing a digestate that is useful as fertiliser, thereby reducing the use of chemical fertilisers which cost more and

Figure 3. Cows to Kilowatts project in Ibadan, Nigeria.

Figure 4. Use of kitchen waste in Uganda (RUDMEC 2013).

Figure 5. A biogas rucksack in Ethiopia. Photo: James Jeffrey

pollute the environment. Another benefit of this project is that it will eliminate slaughterhouse-borne diseases that affect public health.

Another example is the kitchen-waste project in Uganda, using up foodscraps that people did not know what to do with (Figure 4). Here again, the project is creating an income – that is a highlight of this project – and the digestate is used as a fertiliser, and is far more nutritious than synthetic fertiliser. It is not only improving yields but also enabling multiple crops per year. The farmers are harvesting and selling surplus produce, which also increases household incomes.

Finally, a biogas project in Ethiopia is boosting incomes there. People can cart away the biogas on their backs (Figure 5). The bag in Figure 5 contains around four-hours-worth of cooking biogas. Imagine how much drudgery would be involved in collecting and carting enough *wood* for four hours of cooking.

Summary of biogas benefits

In summary, biogas is having a really huge impact on the quality of life for these people.

- They have cleaner cooking, and a reduced workload in firewood collecting and fire tending which are women's tasks.
- There is better gender equality, because the women can spend less time on those household matters and more time in other activities such as education.
- Health and sanitation are improved by replacing kerosene, charcoal and wood (which produce a lot of smoke and respiratory diseases) by clean biogas for cooking.
- There are education benefits, because burning biogas provides better light than burning kerosene. Therefore children can spend up to two hours more on study each evening, and their mothers can help them, having more time.
- Food security is also improved through the use of the digestate as productive fertiliser.

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Bernadette McCabe's specific research interest is in energy capture and resource recovery of waste and has attracted over $1.3M in nationally competitive grants and/or research contracts since 2010. She was recently awarded an Advance Queensland Mid-Career Research Fellowship working in partnership with NH Foods Australia, Oakey Beef Exports. She has expertise in the monitoring of wastewater, biogas production and assessment of biosolids as fertiliser replacement. Bernadette collaborates at an international level as National Team Leader representing Australia in the International Energy Agency (IEA) Bioenergy program Task 37: Energy from Biogas. IEA Task 37 is an international working group made up of 15 member countries that exchange global best practice trends in biogas production. Through this role she has established a wide network of national and international research, industry and government contacts.