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Feature article

Down and 'dirty'

In this first installment of a two-part article, Vicki P. McConnell, *Fuel Cell Bulletin* contributor, looks at scavenging waste for energy, with a view of the practicalities of bioH_2 for fuel cells.

FUEL CELL manufacturers worldwide have been examining waste-to-energy applications (WtE, also referred to as EfW, energy from waste, and more specifically hydrogen from waste) since the early 1990s. During that time, proton-exchange membrane (PEMFC), alkaline (AFC), molten carbonate and direct carbonate (MCFC/DFC), solid oxide (SOFC), and phosphoric acid fuel cells (PAFC) have been demonstrated. Recently, promising WtE economics are resulting from biogas-fueled fuel cells that can generate multiple revenue streams at MW scale.

Compared to the hydrocarbon-based 'dirty' fuel options (such as flaring methane and burning coal), WtE conversion of biohydrogen (bioH_2) for use in fuel cells offers the cleanest electrical power available. In many cases, fuel cell WtE installations can produce combined heat and power (CHP) onsite along with excess electricity, hydrogen, and carbon dioxide (CO_2) that can be sold back to the grid and other customers.

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Cenex, Millbrook partner with Charge-Master to power EVs at LCV 2014
http://ow.ly/2MrqU1

NEC Energy Solutions to install energy storage system in California
http://ow.ly/2MQqop

Heliocentris company signs deal for fuel cell backup power at Chinese banks
http://ow.ly/2Mdanb

"An enormous amount of solid waste is dumped in landfills, such as the Palmetto Landfill in South Carolina which produces waste methane gas that can be utilized to create bioH_2 for use in fuel cells. Photo credit: BMW Manufacturing Co via SCRA.

Gills Onions in Oxnard, California, has been operating at 600kw molten carbonate fuel cell system supplied by FuelCell Energy since 2009. It runs on biogas from the fermented onion juice. Photo credit: FuelCell Energy.

Granted, there may still be a 'dirty' connotation associated with various non-hydrocarbon feedstocks, based on their unique origins in the organic waste realm. From hog farms in China to dairies in Minnesota (think manure management), food and manufacturing waste in Japan, forestry dross in Pennsylvania, to agricultural silage (such as grasses and molasses), potato peel, onion skins, pond scum (algae), chicken litter, and sewage sludge, this stuff can be mighty stinky. Yet there's no garbage, in the fact that such solid waste material (some 11.2 billion tonnes per annum collected worldwide) can be converted into biomass – and from that, renewable bioH_2 as a reliable fuel resource for powering fuel cells.

Beyond solid waste, existing landfills, wastewater treatment plants (WWTPs), and chemical and manufacturing plants currently emit by-product hydrogen directly or as a component of waste methane gas. Although regulated, by-product methane is often flared (burnt off), making it an unused asset and creating pollutants such as nitrous oxides. The **US Department of Energy** (DoE) reports that, if captured, annual domestic methane emissions from these facilities could provide an estimated 12.9 million tonnes per annum as a biofuel source and, in turn, generate around 8.3 million kg of bioH_2 per day.

Furthermore, the 40 000 anaerobic digesters already operating in the US industrial sector could provide 300 million m^3 (10.8 trillion cubic feet) of bioH_2 and another 200 million m^3 (7 trillion cubic feet) of bioH_2 from landfill gas. [Anaerobic digestion occurs in oxygen-free, sealed reactors where micro-organisms break down biomass.] An estimated 15% – or 216 000 tonnes per annum – of excess hydrogen produced annually from chlor-alkali manufacturing is flared. At a 50% conversion rate to fuel cell-grade hydrogen, this biogas resource could produce 420 MW of electricity.

Complex value proposition

Fuel cell technology and biogas resources have the potential to create real energy gains as an alternative to the entrenched 'burn and bury' practices of waste handling. But scavenging renewable hydrogen from biomass and waste gas is no easy feat. Capital costs remain high, and this makes customers risk-averse.

FCB asked those interviewed here to help formulate the essence of the WtE value proposition for bioH_2-fueled fuel cells. Their consensus can be stated as: achieving the highest calorific energy value, lowest emissions, and multiple revenue streams from waste-derived fuel at the most competitive price, using the least amount of feedstock.

So far, fuel cell OEMs and early adopters have found government funding incentives extremely helpful, such as investment tax credits and sustainability programme grants. These first-mover companies must also innovate creative business models, strategic partnerships, and sufficient true grit to navigate the divergent international regulatory and operating cultures required to manifest the green value in WtE applications.

Fuel cells for energy

FuelCell Energy (FCE), headquartered in Danbury, Connecticut, has demonstrated the highest number of WtE installations to date, with its high-temperature, carbonate-based Direct Fuel Cell® (DFC®) technology. The company has DFC units in operation in Germany, Japan, Canada, South Korea, and at 15 sites in the US.

"Our first biogas plant began operation in early 2004 in King County, Washington,' said Kurt Goddard, vice president of investor relations. 'This 1 MW demonstration system was meant to show that megawatt-scale fuel cell equipment can operate well with renewable fuel. Our biogas installations now operating are producing about 130 million kWh of renewable and pollutant-free power annually, adequate to power about 12 000 US homes."

Most of these DFC systems operate at 538°C (1000°F), and utilise biogas produced onsite by anaerobic digesters coupled with appropriate gas clean-up equipment. In several projects, the purified digester gas is injected into