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Feature

Economics of Waste-to-Energy, Part II

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Waste-to-energy (WtE) economics are resulting from biogas-fueled fuel cells that can generate multiple revenue streams at MW scale. Part II of this feature looks at other companies keen to demonstrate their technologies in this application.

In Part 1 of this article, we looked at how FuelCell Energy is demonstrating its molten carbonate fuel cell technology operating on biogas from waste operations. Here we look at other companies keen to demonstrate their technologies in this application, such as AFC Energy's alkaline fuel cell technology combined with plasma gasification of waste, and how BMW Manufacturing Co in South Carolina plans to run its fuel cell powered materials handling fleet on hydrogen produced from landfill gas (LFG).

At the opposite end of the operating temperature spectrum from carbonate fuel cells, alkaline fuel cells (AFCs) typically create electricity at 70–100°C (158–212°F). AFC Energy Plc, founded in 2006 and headquartered in Dunsford Park, Surrey, in the UK expects to bring its KORE AFC system online with automated, robotic assembly within the next six months. CEO Ian Williamson says that this latest move towards commercial deployment has been accelerated through a grant from the European Commission's (EC) Seventh Framework Programme.

AFC Energy is leading the EC's €6.1 million ($8.3 million) Power Up project, along with partner Air Products. By-product hydrogen from an existing Air Products industrial gas processing plant in Stade, Germany will fuel the AFC KORE fuel cell system, which is cartridge-based and hot-swappable, and will also produce heat that can be recycled back into processing operations. Williamson says the initial 24-cartridge KORE platform for Power Up is expected to be installed by year's end, with a second unit of the same size going in next year, to ultimately produce 500 kW of electrical output.

The second phase of the EC's Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI), of which Power Up is a part, was launched last July with an EU/industry shared budget of €1.4 billion ($1.8 billion). Ending in 2024, one of the key Phase 2 goals is demonstrating the viability of large-scale hydrogen production from electricity generated through renewable energy sources.

AFC Energy already has two 'Beta' systems in testing and development in Germany since 2009. These are installed at chlor-alkali plants in Bitterfeld, plants owned by Amsterdam-based paint, coatings and specialty chemicals company AkzoNobel. AFC Energy established commercial inroads into the chlorine production industry as part of its WtE market strategy. 'The waste hydrogen generated by this industry in Europe could support about 20% of its total power needs, or over 3000 MW of capacity,' estimates Williamson.

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In addition to low-temperature operation, key benefits of AFC's KORE system include electrical efficiency to 60%, facile electrokinetics at the electrodes during fuel oxidation and oxygen reduction, the use of low-cost recyclable and reusable materials, and scalable manufacturing through modular cartridge assembly. Water and heat management is handled through circulation of the potassium hydroxide (KOH) electrolyte. The KORE system's non-platinum catalysts point to the crux of AFC Energy's value proposition for its customers.

'The ethos of our company is to avoid platinum in the catalyst. We have also borrowed from other industries – such as food and automotive production – to design our manufacturing process to further keep our costs low,' says Williamson. 'Our system is designed to be low cost, recyclable and replaceable every 12 months. That is our long-term strategy, along with being embedded with the customer so that our main focus is to sell them the power, not just the kit [equipment].'

Williamson discusses the formation of AFC Energy's business model. 'Large companies like AkzoNobel and Air Products take significant risks in up-front monies for novel systems such as fuel cells,' he says. 'A comfort level has to be established, and customers have to be given time to see the system proven, which makes business sense.'

'We're changing the way we introduce fuel cells by decreasing the operating risk factors, and then we will be able to share in the success of the system's energy output,' he continues. 'We view this as pushing an already open door, with a business model that adds benefits by combining the value of the engine [power generation equipment, or fuel cells] and the value of the fuel [bioH_2].'

Plasma gasification

AFC Energy's Williamson describes multiple challenges encountered with international WtE applications. 'In terms of managing waste, perspectives are different in different countries,' he explains. 'In the US, waste is managed state by state, whereas in Europe, it is a whole market discussion. Also, for every country, regulations are different. We focused our initial development in the UK, because new technology and changes to waste handling are treated with openness as to their potential.'

This is reflected in the potential for a demonstration project at the New Energy and Technology Park near Billingham, Teesside. Here, Air Products is building a 50 MW advanced gasification plant. Gas turbines will provide primary power; in the longer term, Air Products has stated a desire to see this site as a test bed for fuel cells. AFC Energy hopes to test its KORE system fueled by bioH_2 here. London-based structured solutions provider Waste2Tricity (W2T) identified the project as a good fit for Air Products and AFC Energy, along with plasma gasification technology provider, Alter NRG Corporation in Calgary, Canada. Alter NRG's plasma gasification technology was developed by Westinghouse.

'Plasma gasification already demonstrates very clean syngas with existing proven equipment in non-fuel cell applications,' Williamson points out. 'Of course, there has to be a high-temperature capability for the plasma torch [on the order of 5000°C/9000°F] to create clean syngas, and one can't just bolt a fuel cell onto the back of a gasifier. Within this partnership, we're seeking to match up the most appropriate components for the best conversion of waste to electricity.'

Market growth, company growth

In his 2013 operational review and strategic report for AFC Energy, Williamson comments that '2013 was another year of growth, but could just as easily be described as the company visibly 'growing up.' Some important building blocks have added to our long-term strategy.'

These include the company's participation in three EC-funded projects, and initiation of a technical partnership with the University of Lancaster in the UK to test fuel cells with various hydrogen feedstocks at different impurity levels (including AFC Energy's 'Alkammonia' mixture discussed in FCB, January 2013, p9). System integration has advanced based on operations data collected from the AkzoNobel demonstration units; electrode life has been extended beyond 12 months, and additional patent portfolio development now includes 30 patents.

AFC Energy's international reach continues through multiple WtE projects with Waste2Tricity, particularly in Thailand [FCB, November 2013, p7]. 'AFC and W2T want to focus on early adopters in appropriate geographies,' says Williamson. 'We helped launch W2T to provide project leadership and support to customers globally, to complement our physical equipment in place. In our view, a bankable technology involves giving customers a business model they know and accept; we don't just set up a black box and then we're gone.'

Another promising geography is South Korea. 'We sense a 'demand pull' for fuel cell technology, whereas we had expected to have to 'push' our solutions there,' says Williamson. 'Korea has a thriving chemical industry and is a major producer of hydrogen.'

Last year, AFC Energy opened its first regional sales office in Seoul, working with market access and business development partner Intralink Ltd to establish a steady presence in the region, which offers government subsidies for electricity generated from fuel cells. For its WtE markets in all locations, Williamson concludes, 'We believe if you take the fuel cell to the hydrogen, and not the other way around, you don't have to put safety, technology, and cultural changes in place, and therefore are essentially free to create your own destiny.'

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Technology agnostic

Plasma gasification is just one of the WtE conversion technologies that Waste2Tricity (W2T) has recommended to its customers seeking renewable hydrogen. Others include water electrolysis, steam methane reforming, and anaerobic digestion. Likewise, AFC's KORE system is not the only power option that W2T recommends, as the company is also involved with projects powered by internal combustion engines and turbines. This is because W2T conducts its business as 'technology agnostic'.

Howard White, former executive director of AFC Energy and now a lead consultant to both companies, notes that while W2T is committed to deploying proven technology today, it is investing in the technology of tomorrow. So far these 'tomorrow technologies' will be applied in WtE projects ranging from the 350 000 tonnes of municipal solid waste (MSW) that Air Products' Tees Valley power plants will process into bioH_2, to inroads in Thailand that will build on the success of the Teesside project. In fact, manufacture of AFC's KORE system in Thailand may be in the offing. Such a move could serve to open up the WtE market quickly, and engender similar projects in other Southeast Asian nations.

In the UK, W2T has exclusive deployment rights for AFC Energy alkaline fuel cell technology in WtE applications combined with Alter NRG plasma gasification. The company is working with multiple partners on a concept design study for an advanced WtE plant that could convert 100 000 tonnes per annum of feedstock into electricity. The 13.6 MW plant would demonstrate AFC's KORE system with plasma gasification of waste, with a goal of producing nearly 109 000 MWh of electricity per annum. White estimates that such a system would use only 5000 tonnes of waste-derived feedstock per MW to generate power, a 50% reduction in required feedstock compared to traditional incineration.

White believes the marketplace for electrical energy 'just hasn't understood that this is a game of efficiency of conversion. The game changer will come from whoever can generate the most electricity from the least amount of feedstock.'

'The increased efficiency of fuel cells over turbines could add 30% extra generated electricity which, in the UK mode, would be worth an additional revenue stream of $40 million per year from the sale of electricity and extra subsidies,' he continues. 'The additional capital expenditure/operating expenses (CAPEX/OPEX) is likely to be a small percentage of this revenue stream – less than $10 million (€7.2 million) per annum, by my guess.'

Bioenergy future

Other fuel cell OEMs and development partners (including governments) involved in the WtE market include Ballard Power Systems, Plug Power, ClearEdge Power, Fuel Cell Technologies, Nedstack Fuel Cell Technology BV, Hydrogenics, and Bloom Energy. Ballard has stacks working in PEMFCs powered by biogas in Singapore, South Korea [FCB, November 2011, p5], Japan, Canada, and the US. Bloom Energy has made headlines with its installation of a 10 MW SOFC at the Maiden, North Carolina data centre for Apple Inc, fueled by directed biogas from landfill gas conversion [FCB, January 2013, p5].

Speaking of government partners, the US Department of Energy has funded fuel cell R&D for at least the past 20 years. The agency formed a Biomass Program in 2002, and its National Renewable Energy Laboratory (NREL) in Golden, Colorado is leading continuing efforts to help establish a domestic bioenergy industry. Through its Fuel Cell Technologies Office and in cooperation with its Bioenergy Technologies Office, DOE has research under way on biomass reformation and gasification, the availability of biomass, and renewable hydrogen as an enabler for biofuel production. As such, DOE-sponsored projects involving fuel cells, biomass, and biofuels have crosscutting agendas.

Case in point: A DOE-supported project with Plug Power seeks to determine if landfill gas (LFG) converted to bioH_2 can successfully compare in performance to commercial hydrogen for running materials handling equipment. At the 371 000 m^2 (4 million sq ft) BMW Manufacturing Co plant in Spartanburg, South Carolina, the automaker has swapped conventional batteries in 275 forklifts and pallet jacks for Plug Power GenDrive systems (which incorporate Ballard PEMFC stacks). BMW also built a refueling system for this equipment to utilise commercial hydrogen supplied by Linde Industrial Gases [FCB, March 2013, p1].

Through the South Carolina Landfill Gas Purification Project, begun in 2011, DOE is helping develop at the BMW site the first-of-its-kind landfill gas (LFG) to hydrogen production plant in the US. BMW views both the battery replacement by hydrogen-powered fuel cells and the potential for LFG-to-H_2 fuel sourcing as integral to its corporate clean production and sustainability goals. South Carolina Research Authority (SCRA) Applied R&D in Charleston provides overall programme management of the three-phase LFG-to-H_2 project. The waste methane comes from the Palmetto Landfill in nearby Wellford, and already supplies a significant portion of BMW's plant electricity.

Russ Keller, SCRA Vice President, tells FCB that the first two phases of the LFG-to-H_2 project encompassed a validating technical feasibility study and business case analysis, plus installation of a clean-up system to remove sulfur and trace contaminants from the methane. One of the challenges encountered was high concentrations of nitrogen in the LFG stream at BMW, on initial delivery of the clean-up skid.

'Our project team engaged the gas separation experts at DOE Argonne National Lab to help address this issue,' says Keller. After retaining a gas separation vendor, fixes involved installation of a number of new components, and changing some of the programming logic within the system control scheme. Purge system elements had to be balanced, and pressure/cycle times and absorbent change-out times refined.

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'We installed our PSA [pressure swing adsorption] equipment solution as the final stage in our gas clean-up process in the late summer of 2013. This new configuration successfully resolved our high nitrogen concentration problem,' Keller explained. 'The first successful test occurred in mid-October 2013. We repeated the process in mid-January 2014, to satisfy ourselves that any seasonal fluctuations in LFG composition could be accommodated within our project equipment configuration. Our hydrogen analysis from the mid-January samples also confirmed purity well within the industry specs for use in fuel cell equipment. Both the October and January hydrogen analyses confirmed purity in excess of 99.9998%. That completed all the requirements for Phase 2 work on the project.'

Phase 3 of this WtE project: actually fueling BMW's materials handling vehicles with bioH_2 from LFG. Keller estimates the start of this phase is four to six weeks away, and will include operational monitoring for six to eight weeks to provide data to help determine if there is any detectable difference in fuel cell performance using LFG-derived hydrogen versus using merchant hydrogen as the fueling source.

Keller expected to report on the progress of this final phase at the DOE 2014 Annual Merit Review and Peer Evaluation Meeting (AMR) for its Hydrogen and Fuel Cells Program in Washington, DC in mid-June. Having that report in hand will assist BMW in making a business case decision regarding scale-up of the LFG-to-H_2 process to accommodate site-wide hydrogen fuel needs. The cost-competitive target for the biogas is ~$5.50 (€4) per kg.

Ultimately, the business case for biomassto-fuel-cell systems is strongest when accessible feedstocks and high electricity prices prevail. As forecast by Pike Research in its Biopower Markets and Technologies report in January 2012, worldwide biomass power generation capacity will grow from 58 GW in 2011 to at least 86 GW by 2021. Just how much of this capacity could emanate from fuel cells running on biogas is as yet unknown, but the technology will assuredly be in the mix — and that's no pile of rubbish.