Tri-Generation Fuel Cells

Opening Doors to Distributed Hydrogen Markets

By Anthony Leo

Industrial gas executives are asking critical questions about hydrogen: Is there an economical way to generate renewable hydrogen closer to the point of use, and reduce distribution costs? And can we then speed adoption of Fuel Cell Electric Vehicles (FCEVs), a potentially sizeable new market opportunity?

Stationary, power-generating fuel cells are helping to address these questions in the form of tri-generation, which produces power, heat, and hydrogen from the same unit of fuel via an electrochemical reaction. Tri-generation fuel cell systems provide affordable and renewable hydrogen for both vehicle fueling and industrial applications, opening doors to distributed hydrogen markets.

How “Tri-Generation” Works

Tri-generation solutions, developed by FuelCell Energy, utilize proprietary fuel cell power plants configured to simultaneously generate three value streams — power, hydrogen, and heat — by reforming hydrogen-rich fuels such as natural gas or renewable biogas. These solutions utilize the same electrochemical process as the company’s power plants, but when configured for tri-generation, generate additional hydrogen beyond the amount needed for normal power production.

Leveraging conventional generation

Tri-generation offers industrial gas companies a means of generating affordable and clean distributed hydrogen that is ideally suited for the emerging FCEV market and many industrial applications, such as users located a far distance from existing industrial gas generation facilities. By supplementing conventional technologies with tri-generation, industrial gas providers can gain access to expanding markets in a manner that controls distribution costs.

Professor Scott Samuelsen, the Director of the National Fuel Cell Research Center (NFCRC) at the University of California, Irvine (UCI), believes that tri-generation systems have enormous potential, due to the many advantages they offer over existing technologies. According to Samuelsen, “Tri-generation is the single most efficient and environmentally sensitive means of transforming natural gas or biogas to hydrogen.”

Samuelsen, who is also Professor of Mechanical, Aerospace, and Environmental Engineering at UCI, highlighted the unique characteristics of tri-generation fuel cells. These include:

- Extremely high efficiency due to their unique operating characteristics;
- Fuel flexibility including clean natural gas for numerous industrial applications; or renewable biogas for transportation — a carbon negative application;
- Near-zero emission of criteria pollutants, and zero water use;
- Clean and affordable hydrogen generation near or at the point of use;
- Readiness for immediate deployment.

Approximately 95 percent of the hydrogen produced today is generated by steam methane reformation of natural gas, which uses energy and water to produce the required steam and is only economical on a large scale. Supplementing reformation with clean, efficient distributed tri-generation can minimize distribution costs while reducing harmful emissions and water consumption.

Electrolysis, another means of production, requires energy to separate hydrogen from water with a low conversion efficiency leading to high power needs in addition to water consumption. Utilizing renewable wind and solar energy in electrolysis can require considerable land and capital. Tri-generation can be a practical alternative for generating affordable, clean hydrogen where space and water consumption are constraints.

Demonstrated Solutions for Hydrogen Markets

“Tri-generation systems are based on FCE’s commercial power plant products. The key to the affordability of the hydrogen from these systems is that it
is produced along with two other value streams: power and heat,” said Chip Bottone, President and Chief Executive Officer, FuelCell Energy, Inc. “When fueled with renewable biogas, these systems produce 100-percent renewable hydrogen at a price that is competitive with gasoline. The system has also been shown to have a negative carbon footprint for use in FCEVs.”

FuelCell Energy provides comprehensive solutions for utility and on-site customers’ energy, environmental and business challenges, including developing large-scale turn-key projects. The company’s installed base of more than 50 sites on three continents has generated more than 4.5 billion kWh of electricity. FuelCell Energy operates and maintains the plants under long-term service agreements, and provides financing options so the end-users of power or hydrogen do not necessarily need to own the generation equipment.

**Transportation:**  
**Speeding FCEV Adoption**

California, a leader for the emerging FCEV market, enacted Senate Bill 1505 which mandates that at least 33.3 percent of hydrogen produced at state-supported stations must come from low-carbon sources, and that 46 percent must come from renewable sources. Growth of a hydrogen fueling infrastructure has been slower than desired, however, impeding adoption.

“FCEVs represent a significant growth opportunity for the renewable hydrogen market,” said Dr. Pere Margalef, Director, Advanced Technology Business Development for FuelCell Energy. FuelCell Energy successfully demonstrated its tri-generation solution during a three-year pilot program at the Orange County Sanitation District facility. Under a US Department of Energy project with support from California Air Resources Board (CARB), South Coast Air Quality Management District, the Orange County Sanitation District (OCSD), and Southern California Gas, FuelCell Energy in collaboration with the NFCRC successfully demonstrated its tri-generation solution during a three-year pilot program, installing its DFC-H2® tri-generation system at an OCSD facility. Configured to operate on renewable biogas produced from wastewater, it reliably generated value streams of renewable hydrogen, electricity and heat (see Figure 1). The hydrogen was supplied to a nearby fueling station operated by Air Products, while the electricity and heat supported the day-to-day operation of the wastewater treatment plant in a self-sustaining cycle.

“The project was a major success,” Samuelsen reported. “It exceeded...
chemical substance in the universe, has tremendous unrealized potential as an energy carrier. Through tri-generation, fuel cells offer an affordable approach to clean hydrogen production at or near the point of use, providing desirable attributes other technologies can’t such as zero water consumption and minimizing or even avoiding distribution challenges. As industry moves toward a vision of hydrogen that is affordable, environmentally responsible and readily available for both vehicles and industry, tri-generation appears to be a promising solution whose time has come.

By converting waste into hydrogen, electricity, and heat while conserving water, tri-generation represents the epitome of sustainability.

Tri-generation offers industrial hydrogen users an affordable, clean on-site distributed alternative to conventional generation, helping reduce operating costs and enhance energy and hydrogen independence, while enhancing sustainability. Potential users include petroleum refiners, pharmaceutical manufacturers, and chemical producers, as well as material handling, metals processing, and glass manufacturing concerns.

FuelCell Energy uses a tri-generation solution at its North American manufacturing facility, where it showcases the advantages of on-site hydrogen generation. The hydrogen it generates serves as an oxidation preventative in fuel cell manufacturing processes, and replaces delivered hydrogen. Simultaneously, the electricity and heat generated by the tri-generation system supports around-the-clock manufacturing and facility heating, and reduces operating costs.

Hydrogen, the most abundant chemical substance in the universe, has tremendous unrealized potential as an energy carrier. Through tri-generation, fuel cells offer an affordable approach to clean hydrogen production at or near the point of use, providing desirable attributes other technologies can’t such as zero water consumption and minimizing or even avoiding distribution challenges. As industry moves toward a vision of hydrogen that is affordable, environmentally responsible and readily available for both vehicles and industry, tri-generation appears to be a promising solution whose time has come.

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