Feasibility of Fuel Cells for Biogas Energy Conversion on Dairy Farms

Introduction

Fuel cells that can run on the biogas produced by the anaerobic digestion of dairy manure are not economically feasible at present; however, as fuel cell costs decline, they are projected to become affordable by approximately 2010. Fuel cells are more efficient than diesel engine generators at converting biogas to electricity (40-50% vs. 10-30%). They also generate more heat. If the heat is recovered for use on the farm, fuel cell efficiencies could be as high as 80-90%, making them potentially more profitable than diesel engine generators. Finally, fuel cells are quieter, and emit far fewer greenhouse gases. Biogas must be scrubbed of hydrogen sulfide (H_2S) before it can be used by fuel cells.

What are Fuel Cells?

Fuel cells are like electric batteries and convert chemical energy into electricity without combustion. There are three sections in a typical fuel cell system: (1) a fuel pre-treatment and processing section (a reformer), (2) the fuel cell stack, and (3) a DC to AC power electrical conditioning and controller section (an inverter). Fuel cells operate with hydrogen. High temperature systems can run on biogas, liquid fuels, and gaseous hydrocarbons that are first “reformed” into hydrogen. Of the commercially available high-temperature fuel cells, molten carbonate fuel cells (MCFC) are most tolerant of the carbon dioxide (CO_2) and sulfur contaminants found in biogas. These fuel cells can convert all the biogas from a 1,000-cow dairy into 250 kW of electricity or greater, which is more than enough for on-farm use.

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May 2005

Excess generated power can be sold to the grid. High-temperature steam may also be recovered from a MCFC and piped around the farm to appliances such as heat exchangers, milk chillers (absorption cooling) and hot water heaters. By switching all heating fuel applications to utilize the high temperature heat from a fuel cell, there is also potential to eliminate propane and other heating fuel costs.

Advantages of Using Fuel Cells

A conventional diesel engine generator set is only 10-30% efficient in converting biogas to electricity. Fuel cells, on the other hand, are 40-50% efficient in converting biogas to electrical energy, and 80-90% efficient for cogeneration if heat (> 400°C) is recovered and utilized for heating and cooling on the farm. Fuel cells are less noisy than diesel engine generators and produce far less emissions (> 90% reduction in greenhouse gases and particulates, exceeding EPA and state requirements). Carbon dioxide emissions are approximately the same from diesel generators and MCFCs.

Biogas Must be Cleaned

Biogas is similar to natural gas and suitable for operating fuel cells because of its rich methane content. Biogas also differs from natural gas, containing 30-45% CO_2, moisture, and up to 2,000-4,000 ppm H_2S. Hydrogen sulfide is the chief contaminant that makes biogas use problematic, because it is corrosive in engines and poisonous to fuel cell catalysts. In addition to the high sensitivity of fuel cell catalysts, there are also crucial downstream system components that cannot tolerate sulfur compounds and corrosive gases without frequent maintenance. Thus using biogas in fuel cell systems requires more extensive and expensive purification. Mature gas cleaning technologies exist in the fuel industry for scrubbing H_2S, CO_2 and moisture to meet fuel purity requirements for fuel cells.

Economic Feasibility

To see how a fuel cell would fit economically on a New York dairy farm, physical system and cost data were collected from AA Dairy in Candor, New York (Scott and Minott, 2003). AA Dairy has a plug-flow anaerobic digester, and has been producing biogas since 1998. Data on income, capital costs, operating and maintenance costs, and replacement costs were taken from the New York Dairy Farm Business Summary (1990-2002). This information was used to construct baseline income and costs for a 1,000-cow dairy with a 250-kW MCFC.

A net present value analysis showed that the fuel cell system was not feasible under year-2000 economic conditions. A sensitivity analysis was done to see which variables improved the economic feasibility. The fuel cell was only feasible in the scenarios with declining capital costs and/or increased selling price of electricity. By reducing fuel cell capital cost by 75%, the payback period was reduced to seven years. If the farm could sell electricity to the grid at the purchase price it paid in 2000 ($0.09/kWh), the payback period was reduced to nine years. If both of these changes were made, the payback period fell to three years, with a life cycle benefit of $1,375,204 and a 22% increase in net farm income.

Clearly, the primary obstacle facing the adoption of fuel cells on 1,000-cow dairy farms is the high capital cost. Based on a 2001 survey of leading stationary fuel cell manufacturers, the installed cost of fuel cells is expected to fall from an average of $4,500/kW in 2002 to about $1,000/kW by 2010. This price drop is associated with an expected increase in sales, subsequent adoption of mass production, and discounts for large orders. Dairy farmers will need to wait until the price comes down before considering the fuel cell for their operations.

Further Information

Cowpower: Fuel cell feasibility for energy conversion on the dairy farm.
http://www.bee.cornell.edu/sustain/fuelcell/
Accessed 21 February 2005

Scott, N. R. and S. Minott. 2003. Feasibility of fuel cells for energy conversion on the dairy farm: Final report 6243-1 to NYSERDA. Ithaca, NY: Cornell University. (Accesible on the Cowpower website above.) Copies may be requested from NYSERDA at 17 Columbia Circle, Albany, NY 12203.

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Acknowledgements

The research for this fact sheet was supported in part by funds provided by the New York State Energy Research and Development Authority, under agreement 7536, “Transferring Technology from NYSERDA Agricultural Innovation Manure Projects”. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of NYSERDA or the State of New York, and reflect the best professional judgment of the author based on information available as of the publication date.