Novel Sorbent to Clean Biogas for Fuel Cell CHP

Improving Desulfurization to Enable Fuel Cell Utilization of Digester Gases

Introduction

With their clean and quiet operation, fuel cells represent a promising means of implementing small-scale distributed power generation. Waste heat from the fuel cell can be harnessed for heating, creating an efficient combined heat and power (CHP) system. If the fuel cell is powered by a renewable source, its use has the potential to reduce greenhouse gas emissions and natural gas consumption.

Derived from agricultural, industrial, and municipal waste streams or from byproducts of industrial processes, opportunity fuels are unconventional fuels that have the potential to become economically viable sources of power generation. One of the most common opportunity fuels, anaerobic digester gas (ADG), is produced from microorganisms' digestion of biomass. Composed mainly of methane (CH_4) and carbon dioxide (CO_2), ADG is similar in composition to natural gas.

Before ADG can successfully be used in fuel cells, the gas must be cleaned of sulfur compounds that could otherwise lead to decreased performance or even system failure. Fuel cell manufacturers set stringent sulfur limits for feed gas, such as a maximum level of 10 parts per billion by volume (ppbv). However, unreformed ADG may have a much higher sulfur content—up to 150,000 ppbv. A significant reduction in ADG sulfur content is required; however, such large reductions cannot be achieved with conventional desulfurization techniques. In particular, existing processes are not effective in removing organic sulfur species, such as dimethyl sulfide, dimethyl disulfide, methanethiol, carbon disulfide, and carbonyl sulfide.

This project developed a new high-capacity, expendable sorbent to remove sulfur compounds from ADG, thereby producing an essentially sulfur-free biogas meeting the cleanliness requirements of fuel cell power plants. This sorbent reduces the operating costs of fuel cells consuming ADG and encourages increased use of opportunity fuels.

Benefits for Our Industry and Our Nation

The desulfurization sorbent developed by this project is an enabling technology that allows small-scale CHP fuel cell systems to operate on biogas.

Commercialization of this technology has the potential to achieve the following benefits:

- A decrease in the net energy intensity of industry by generating power and heat from existing waste streams

Sulfur polishing skid installed at the South Area Transfer Station (SATS) in Sacramento, CA. *Photo credit TDA Research Inc.*

- A reduction in greenhouse emissions due to the venting or flaring of digester gases
- A reduction in solid waste due to the reduction of sorbent used
- A reduced desulfurization cost with extended sorbent replacement cycles and decreased sorbent consumption

Applications in Our Nation's Industry

Improved biogas reforming technology will benefit industries that employ anaerobic digesters, particularly those that feed the generated gas into fuel cells. U.S. Environmental Protection Agency analysis from 2014 estimates that the United States has the potential to produce approximately 650 billion cubic feet of biogas per year. This could provide 41 billion kWh of electricity, which is enough energy to power more than 3 million U.S. homes.

Anaerobic digesters are used by industries that generate organic waste, including the following:

- Wastewater treatment
- Municipal and industrial landfills
- Food processing
- Agricultural operations that generate manure and crop waste, such as dairy farms

Project Description

The project objective was to develop a new, high-capacity, expendable sorbent to remove sulfur species from anaerobic digester gas, thereby providing a nearly sulfur-free biogas that meets the cleanliness requirements of fuel cell power plants. This sorbent bed operates downstream of a bulk desulfurization system as a polishing bed and removes any residual hydrogen sulfide (H_2S) and other organic sulfur species from the biogas. The sorbent is an enabling technology that allows small-scale fuel cell CHP systems to operate on biogas as an alternative to natural gas.

Barriers

- Demonstrating the effectiveness of the sorbent under varying real-world biogas conditions
- Scaling up production of the sorbent to a commercial scale
- Providing demonstration results and economic analysis to convey the advantages of the new sorbent, as compared to existing alternatives

Pathways

TDA Research Inc. (TDA) optimized the key features of the sorbent, such as the concentration of active material and the amount and type of binders used. TDA then increased the batch size of sorbent production over two orders of magnitude to support field demonstrations.

TDA performed successful slipstream field demonstrations at two different sites using relatively small sorbent beds. The team manufactured a large-scale desulfurization system capable of cleaning all of the biogas for a 600-kilowatt fuel cell plant.

A detailed cost analysis was performed to assess the economic viability of the new sorbent technology based on field demonstration results.

Milestones

- Establishing sorbent production capabilities
- Screening sorbent variants to determine the best-performing option
- Testing the sorbent against alternatives in the laboratory
- Testing the sorbent in a slipstream setup at two working digesters
- Building a large-scale prototype sorbent bed

Accomplishments

TDA developed several low-cost, high-capacity expendable sorbents that can remove both the hydrogen sulfide and organic sulfur species in biogas to the low levels required by fuel cell systems. The novel sulfur sorbents developed by TDA were tested in the laboratory as well as at two slipstream field demonstrations. Compared to current commercial sorbents, the developed sorbent reduces the cost by 83% (on a per volume of gas treated basis) when used in a polishing role in the desulfurization process.

Commercialization

This project led to the development of a sorbent that is capable of removing complex sulfur compounds from aerobic digester gas at high efficiency. While positive results were obtained from the slipstream testing, operating data from the prototype demonstration was not obtained due to problems with the anaerobic digester at the host site. Hence, as a follow-up to the project, the plan is to carry out a prototype demonstration at another site and then move forward with a full-scale demonstration with TDA's SulfaTrap™ polishing sorbents.

Both TDA and its project partner FuelCell Energy have successfully commercialized and installed similar technologies in the past. TDA previously developed and commercialized a related sorbent for the desulfurization of natural gas. FuelCell Energy has built numerous fuel cell plants fed by anaerobic digester gas, giving the firm experience in the market and access to operating facilities for demonstrations and testing.

Project Partners

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