Use of Wastewater Treatment Plant Biogas for the Operation of Solid Oxide Fuel Cells (SOFCs)

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Abstract

SOFCs have been shown to perform well on light hydrocarbon fuels and the use of biogas derived from the anaerobic digestion (AD) of municipal wastewater treatment plant (WWTP) sludges would provide an opportunity for the CH\textsubscript{4} produced in AD to be used as a renewable fuel. Greenhouse gas (GHG) emissions would also be reduced, as the use of biogas would decrease the need for flaring. In addition, SOFCs produce lower emissions of NO\textsubscript{x}, SO\textsubscript{x}, and hydrocarbon pollutants. In this study, SOFCs were investigated for operation on AD-derived biogas at WWTPs. Initially, different H\textsubscript{2} dilutions were tested (N\textsubscript{2}, Ar and CO\textsubscript{2} as diluent gases, and H\textsubscript{2}O) to examine the performance of tubular SOFCs. When inert gases were employed as diluents, a decrease in cell performance was observed, however, when CO\textsubscript{2} was used the decrease in performance was higher as it promoted the reverse water-gas shift (WGS) reaction, reducing the H\textsubscript{2} partial pressure in the gas mixture. A model was developed to predict system efficiency and GHG emissions. A higher electrical system efficiency was noted for a steam:carbon ratio of 2 compared to 1 due to the increased H\textsubscript{2} partial pressure in the reformate resulting from higher H\textsubscript{2}O formation. The reduction in GHG emissions was estimated to be 2,400 tonnes CO\textsubscript{2}, 60 kg CH\textsubscript{4} and 18 kg N\textsubscript{2}O. Testing was then conducted using a simulated biogas reformate mixture (66.7% H\textsubscript{2}, 16.1% CO, 16.5% CO\textsubscript{2} and 0.7% N\textsubscript{2}, humidified to 2.3 or 20 mol% H\textsubscript{2}O) developed from an average biogas composition for North America, determined through a survey of biogas composition for urban areas with populations over 150,000 in the United States and 50,000 in Canada. The reformate at the higher humidification level yielded a better performance because the WGS reaction produced more H\textsubscript{2} when additional H\textsubscript{2}O was provided. It was concluded that WWTP AD-derived biogas, when cleaned effectively to remove H\textsubscript{2}S, Si compounds, halides and other contaminants, could be reformd to provide a clean, renewable fuel for SOFCs.

Keywords

biogas, renewable, solid oxide fuel cell, wastewater treatment