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_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_x, SO_x, and hydrocarbon pollutants. In this study, SOFCs were investigated for operation on AD-derived biogas at WWTPs. Initially, different H_2 dilutions were tested (N_2, Ar and CO_2 as diluent gases, and H_2O) to examine the performance of tubular SOFCs. When inert gases were employed as diluents, a decrease in cell performance was observed, however, when CO_2 was used the decrease in performance was higher as it promoted the reverse water-gas shift (WGS) reaction, reducing the H_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_2 partial pressure in the reformate resulting from higher H2O formation. The reduction in GHG emissions was estimated to be 2,400 tonnes CO_2, 60 kg CH_4 and 18 kg N_2O. Testing was then conducted using a simulated biogas reformate mixture (66.7% H_2, 16.1% CO, 16.5% CO2 and 0.7% N_2, humidified to 2.3 or 20 mol% H_2O) 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_2 when additional H_2O was provided. It was concluded that WWTP AD-derived biogas, when cleaned effectively to remove H_2S, Si compounds, halides and other contaminants, could be reformed to provide a clean, renewable fuel for SOFCs.

Keywords

biogas, renewable, solid oxide fuel cell, wastewater treatment