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Life Cycle Assessment of Liquid Alkaline Electrolyzers Comparing Environmental Performance across Various Design, Operation, and End-of-Life Scenarios

Journal
ECS Meeting Abstracts, MA2024-02(28)

ISSN
2151-2043

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Publication Date
2024-11-22

DOI
10.1149/ma2024-02282207mtgabs

Life cycle assessment of liquid alkaline electrolyzers comparing environmental performance across various design, operation, and end-of-life scenarios

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Abstract

Alkaline water electrolysis (ALK) is a demonstrated technology, used for over 100 years primarily for ammonia production, and later advanced for oxygen production for nuclear submarine applications. With a new focus on the expansion of renewably-powered hydrogen production, ALK systems hold great promise for commercialization. Recent research may further drive down costs by addressing challenges related to electrodes, electrolytes, bubble formation, and impact of operation patterns. However, literature studies on ALK often lack a comprehensive model that can capture the impact of such innovations and deployment nuances on overall greenhouse gas emissions and environmental impacts. For example, an analysis of the effect of hourly or sub-hourly operation of ALK based on electricity generation profiles on required heat management, shutoffs, hydrogen leakage, safety, and cell degradation are lacking. Additionally, details on the manufacturing of critical components of the ALK cell stack are missing, although material contributions by weight are available. Materials at their end-of-life may have unique requirements for recycling or disposal, and these factors are also not well understood.

Herein, we present an overview of life cycle assessments (LCA) of ALK, as well as novel modeling of environmental impacts associated with ALK supply chains in the United States. Details and impacts of component manufacturing is included, along with the uncertainties of the raw materials production. We will then present our dynamic ALK model that includes cell voltage degradation, effects of the input power load on the electrolyzer temperature, purity, and associated hydrogen leakage at the electrolyzer facility itself. Finally, we present findings on plausible recycling and landfilling of the raw materials. We use the NREL United States Life Cycle Inventory database supplemented by Ecoinvent in the OpenLCA platform to evaluate embodied emissions. We compare the environmental performance for different scenarios of stack design (baseline versus advanced based on reduced diaphragm thickness and improved catalyst material), operation (low versus high pressure and scales such as 50 versus 500 ton/day), end-of-life cases (landfilling versus combination of landfilling and recycling). Finally, we make a comparison of these different scenarios to identify environmental impact hotspots along the life cycle of a liquid alkaline electrolyzer and guide future research on cell stack development.