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RESEARCH REPORT

Unsettled Issues Concerning the Use of Green Ammonia Fuel in Ground Vehicles

Bart Kolodziejczyk, PhD

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About the Editor

Bart Kolodziejczyk, PhD, is Chief Scientist of Australian mining company Fortescue Metals Group Ltd. Previously, Dr. Kolodziejczyk served as Technology Officer of Singapore-based H2SG Energy Pte Ltd. In his hydrogen-related roles, Dr. Kolodziejczyk developed hydrogen generation technologies and worked with numerous customers throughout the Asia-Pacific region to implement hydrogen solutions in transportation, energy storage, and other industrial applications. He became interested in hydrogen power in 2009 while developing and testing solar and fuel cell inverters for Danfoss Solar Inverters A/S.

Dr. Kolodziejczyk holds a master's degree in Renewable Energy Science with a focus on Fuel Cell Systems and Hydrogen awarded jointly by the University of Iceland and the University of Akureyri, as well as two PhDs in Materials Engineering from Monash University in Australia and Microelectronics from Ecole des Mines de Saint-Etienne in France. He has extensive research experience in electrochemistry, catalysis, fuel cell development, and hydrogen generation. He was a Research Fellow at Carnegie Mellon University, where he explored materials for biosensing and energy applications.

Dr. Kolodziejczyk has advised the United Nations Organisation for Economic Co-operation and Development, G20, and European Commission on science, technology, innovation, and policy and was named one of MIT Technology Review's Innovators Under 35 for developments of new energy materials and catalysis. Most recently, Dr. Kolodziejczyk has received the prestigious Advance Award in the Sustainability category, awarded annually to the brightest change-makers in Australia. He has published extensively, covering electrocatalysis and hydrogen generation and its application, among other energy fields. Dr. Kolodziejczyk is a Fellow of the Royal Society of Arts, a Member of the Royal Society of Chemistry, and a Chartered Environmentalist.

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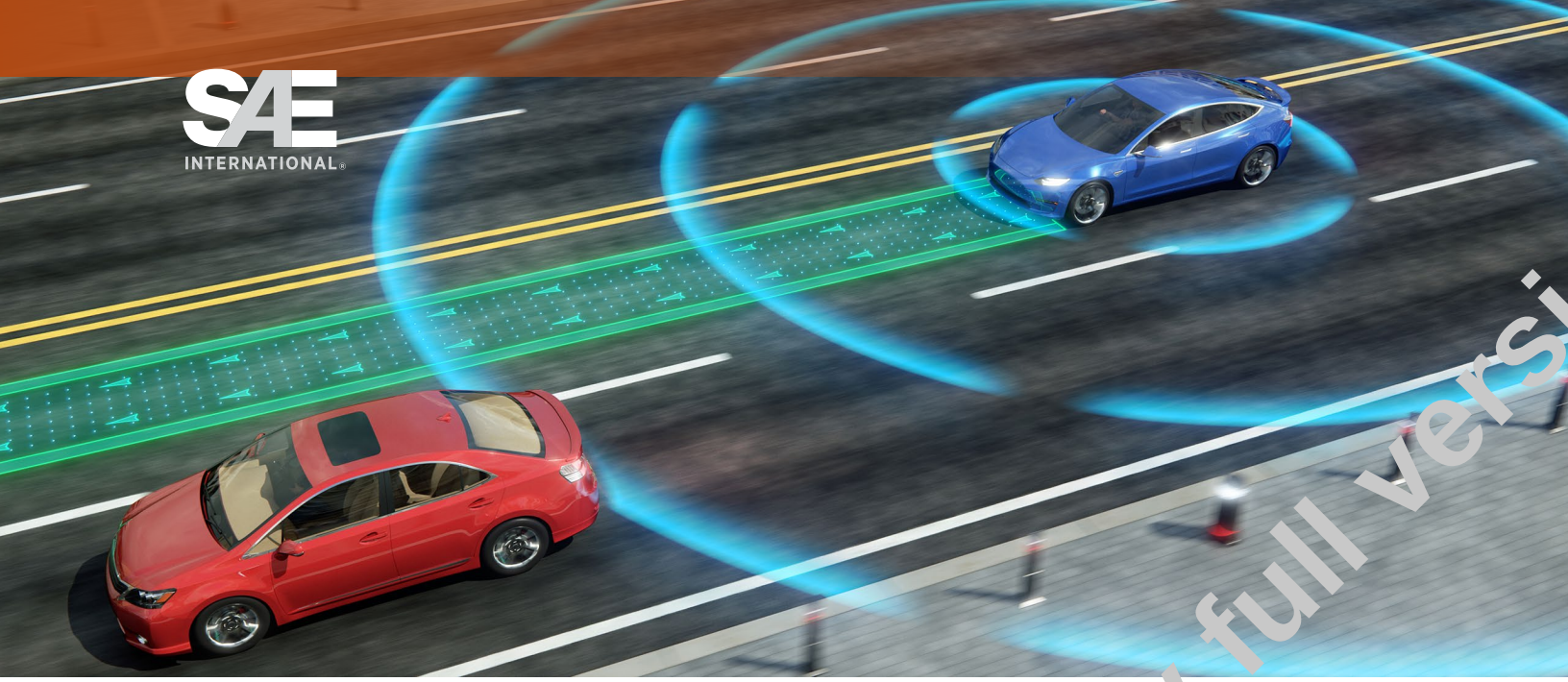

Unsettled Issues Concerning the Use of Green Ammonia Fuel in Ground Vehicles

Abstract

While hydrogen is emerging as an alternative clean automotive fuel and energy storage medium, there are still numerous challenges that must be addressed. Economy of hydrogen production and deployment is only one, and there are still many technology bottlenecks to be addressed before hydrogen is made a competitive and attractive fuel solution. Storage requires expensive materials, and hydrogen's low energy density makes it challenging to store. Hydrogen compression or liquefaction processes are energy demanding and, to date, performed mainly on a small-scale. There are also several social, behavioral, and educational challenges that need to be addressed before hydrogen can be implemented on an industrial scale. This is why ammonia fuel might be an ultimate clean solution for transportation.

Synthetic ammonia production has been practiced on an industrial scale for nearly a century. Ammonia is one of the most-traded commodities globally and the second most-produced synthetic chemical after sulfuric acid. Traditionally, ammonia has been used in the fertilizer industry to produce nitrogen-based synthetic fertilizers; but, as of late, it is heralded as a potential clean fuel of the future.

Just like hydrogen, ammonia is not another energy carrier. It enables effective hydrogen storage in chemical form by binding hydrogen atoms to atmospheric nitrogen. The energy density of liquid ammonia is superior to energy densities of both compressed gaseous hydrogen and liquefied hydrogen, meaning that more energy can be stored per given volume. In addition, the boiling point of hydrogen is −252.87 °C, whereas ammonia boils at −33.34 °C.

Being one of the most-produced and -traded synthetic chemicals globally, ammonia production, storage, handling, and transportation is generally well explored and widely applied, allowing for economies of scale and cost-competitiveness.

The major unsettled issues of using ammonia as a clean automotive fuel alternative include a lack of regulation and standards for automotive applications, technology readiness, and—predominantly—the fact that traditional ammonia value chains rely on natural gas for both hydrogen feedstocks to generate the ammonia and the energy to facilitate hydrogen and nitrogen conversion into liquid ammonia. Decarbonization of the ammonia value chain is of great international interest. Significant efforts are made to enable and prove the concept of green ammonia generation.

This SAE EDGE Research Report discusses the unsettled aspects of emerging ammonia fuel and its use in automotive applications. In this report, expert contributors share their knowledge and views on current and future prospects for application of ammonia in ground vehicles and provide an overview of technological and regulatory challenges for this new type of clean fuel. Finally, the report concludes with a series of recommendations aimed at enabling this new automotive industry branch. While ammonia as a fuel is still in its infancy, its unique properties render it as a potential and viable candidate for decarbonizing the automotive industry.

NOTE: SAE EDGE Research Reports are intended to identify and illuminate key issues in emerging, but still unsettled, technologies of interest to the mobility industry. The goal of this report is to stimulate discussion and work in the hope of promoting and speeding resolution of identified issues. These reports are not intended to resolve the challenges they identify or close any topic to further scrutiny.

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