SAE INTERNATIONAL

SAE EDGE™
RESEARCH REPORT

Unsettled Issues Concerning the Economics of Fuel Cells and Electric Ground Vehicles

Bartlomiej Kolodziejczyk, Ph.D.

SAE EDGE™
RESEARCH REPORT

Unsettled Issues Concerning the Economics of Fuel Cells and Electric Ground Vehicles

Bartlomiej Kołodziejczyk, Ph.D.
H2SG Energy Pte Ltd.

EDGE DEVELOPMENT TEAM

Wee-Liat Ong, Ph.D., *Zhejiang University*
Craig Knight, *Horizon Fuel Cell Technologies*
Alena Fargere, Ph.D., *World Energy Council*
James Carton, Ph.D., *Dublin City University*
Anna Trendewicz, Ph.D., *E.ON*
Jose Castro Nieto, Ph.D., *Ad Astra Rocket Company*
Yena Chae, *Korea Gas Safety Corporation*

SAE INTERNATIONAL
Warrendale, Pennsylvania, USA

About the Publisher

SAE International® is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive, and commercial vehicle industries. Our core competencies are lifelong learning and voluntary consensus standards development. Visit sae.org

SAE EDGE™ Research Report Disclaimer

SAE EDGE™ Research Reports focus on topics that are dynamic, in which knowledge is incomplete, and which have yet to be standardized. They represent the collective wisdom of a group of experts and serve as a practical guide to the reader in understanding unsettled subject matter. They are not meant to provide a recommended practice or protocol. The experts have assembled as a community of practitioners to contribute and collectivize their thoughts and points of view; these are not the positions of the institutions or businesses with which they are affiliated, nor is one contributor's perspective advanced over other contributors. SAE EDGE™ Research Reports are the property of SAE International, and SAE alone is responsible for their content.

About This Publication

SAE EDGE™ Research Reports provide state-of-the-art and state-of-industry examinations of the most significant topics in mobility engineering. SAE EDGE™ contributors are experts from research, academia, and industry who have come together to explore and define the most critical advancements, challenges, and future direction in areas such as vehicle automation, unmanned aircraft, cyber security, advanced propulsion, advanced manufacturing, Internet of Things, and connectivity.

Related Resources

SAE MOBILUS® Automated & Connected Knowledge Hub
https://saemobilus.sae.org/automated-connected

SAE Team

Frank Menchaca, Chief Growth Officer
Michael Thompson, Director, Standards, Information and Research Publications
Monica Logueira, Content Acquisition Director
Beth Ellen Dibeler, Product Manager
William Kucinski, Managing Technical Editor

Printed in USA

EPR2020002
ISSN 2640-353
e-ISSN 2640-354
ISBN 978-1-4-01**-4**

To purchase bulk quantities, please contact: SAE Customer Service

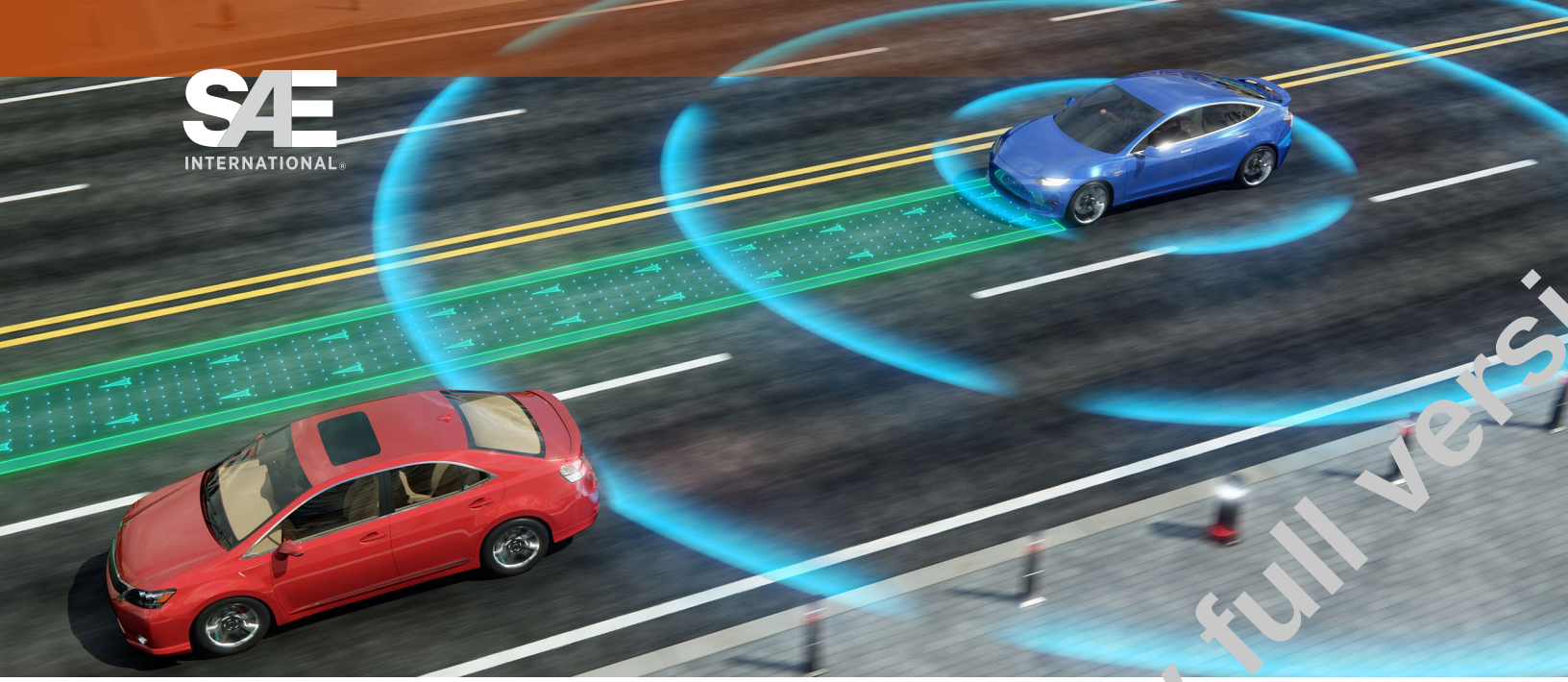
E-mail: CustomerService@sae.org
Phone: 877-606-7323 (*inside USA and Canada*)
+1-724-776-4970 (*outside USA*)
Fax: +1-724-776-0790

https://www.sae.org/publications/edge-research-reports

About the Series Editor

Bart Kolodziejczyk, Ph.D., is Chief Technology Officer of the Singapore-based H2SG Energy Pte. Ltd.; in his role, Kolodziejczyk develops hydrogen generation technologies and works with a number of customers throughout the Asia-Pacific region to implement hydrogen solutions in transportation, energy storage, and other industrial applications. Kolodziejczyk became interested in hydrogen power in 2009 while developing and testing solar and fuel cell inverters for Danfoss Solar Inverters A/S. Kolodziejczyk holds a master's degree in Renewable Energy Science with focus on Fuel Cell Systems and Hydrogen, awarded jointly by the University of Iceland and the University of Akureyri, as well as two Ph.Ds. in Materials Engineering from Monash University in Australia and Microelectronics from Ecole des Mines de Saint-Etienne in France. Kolodziejczyk 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. Kolodziejczyk has advised the United Nations, OECD, 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 catalysts. Kolodziejczyk has published extensively, covering electrocatalysis, hydrogen generation, and its application, among other energy fields. Kolodziejczyk is a Fellow of the Royal Society of Arts, Member of the Royal Society of Chemistry, and Chartered Environmentalist.

contents



Unsettled Issues Concerning the Economics of Fuel Cells and Electric Ground Vehicles

Abstract

Lately, the idea of using hydrogen in automotive applications is gaining significant momentum. However, the concept of using clean hydrogen fuel generated from water via electrolysis is nothing new. Previously - because of numerous challenges - hydrogen has never managed to become a mainstream industrial or automotive fuel. A decade ago, an attempt to introduce hydrogen for mobility failed miserably and for good reasons. Back then, the fuel cell technology, which efficiently converts hydrogen and atmospheric oxygen into electricity, was not as advanced as it is today. In addition, the fuel cell prototypes were bulky and expensive.

After the first failed wave of hydrogen-based economy implementation followed by another 10 years of development, hydrogen is back, and it seems that this time it is here to stay. The decade of research allowed for improvements in materials, components, and performance of entire fuel cell systems. In addition, new manufacturing tools and techniques have been developed to reduce system costs. Today's fuel cell systems use a fraction of platinum catalyst compared to fuel cells 10 years ago, yet their performance is superior. A number of new fuel cell electric vehicles (FCEVs) have emerged, and hydrogen refueling infrastructure is being built globally. However, even today due to lack of economies of scale and demand, hydrogen generation and fuel cells are still costly and cannot compete with fossil fuel-based solutions. While hydrogen can be a viable tool in combating climate change and air pollution, today hydrogen hardly makes a business case. Many of these hydrogen infrastructure developments are fueled by government subsidies and fear of carbon tax.

This SAE EDGE™ Research Report discusses the unsettled economic aspects of hydrogen and fuel cell applications in the automotive industry. Based on the input of expert contributors, detailed economic evaluations are made in terms of fuel cell systems, FCEVs, and hydrogen refueling infrastructure. This report also evaluates a number of sources and forecasts potential market growth and expansion. Based on techno-economic evaluations performed in this report, it becomes clear that the economy of scale is essential in reducing the technology costs. There is also a clear role that governments must play to enable and facilitate the transition by providing incentives and subsidies. It is also believed that carbon tax will be a viable tool in enabling the cost-competitiveness of the hydrogen economy. Finally, the report concludes with a series of recommendations aimed at government and industry stakeholders to consider in order to facilitate a smooth transition from fossil fuel-based to hydrogen-based mobility.

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

BARTLOMIEJ KOLODZIEJCZYK, Ph.D.
H2SG Energy Pte Ltd.

Edge Development Team

Wee-Liat Ong, Ph.D., *Zhejiang University*
Craig Knight, *Horizon Fuel Cell Technologies*
Alena Fargere, Ph.D., *World Energy Council*
James Carton, Ph.D., *Dublin City University*
Anna Trendewicz, Ph.D., *E.ON*
Jose Castro Nieto, Ph.D., *Ad Astra Rocket Company*
Yena Chae, *Korea Gas Safety Corporation*

ISSN 2640-3536