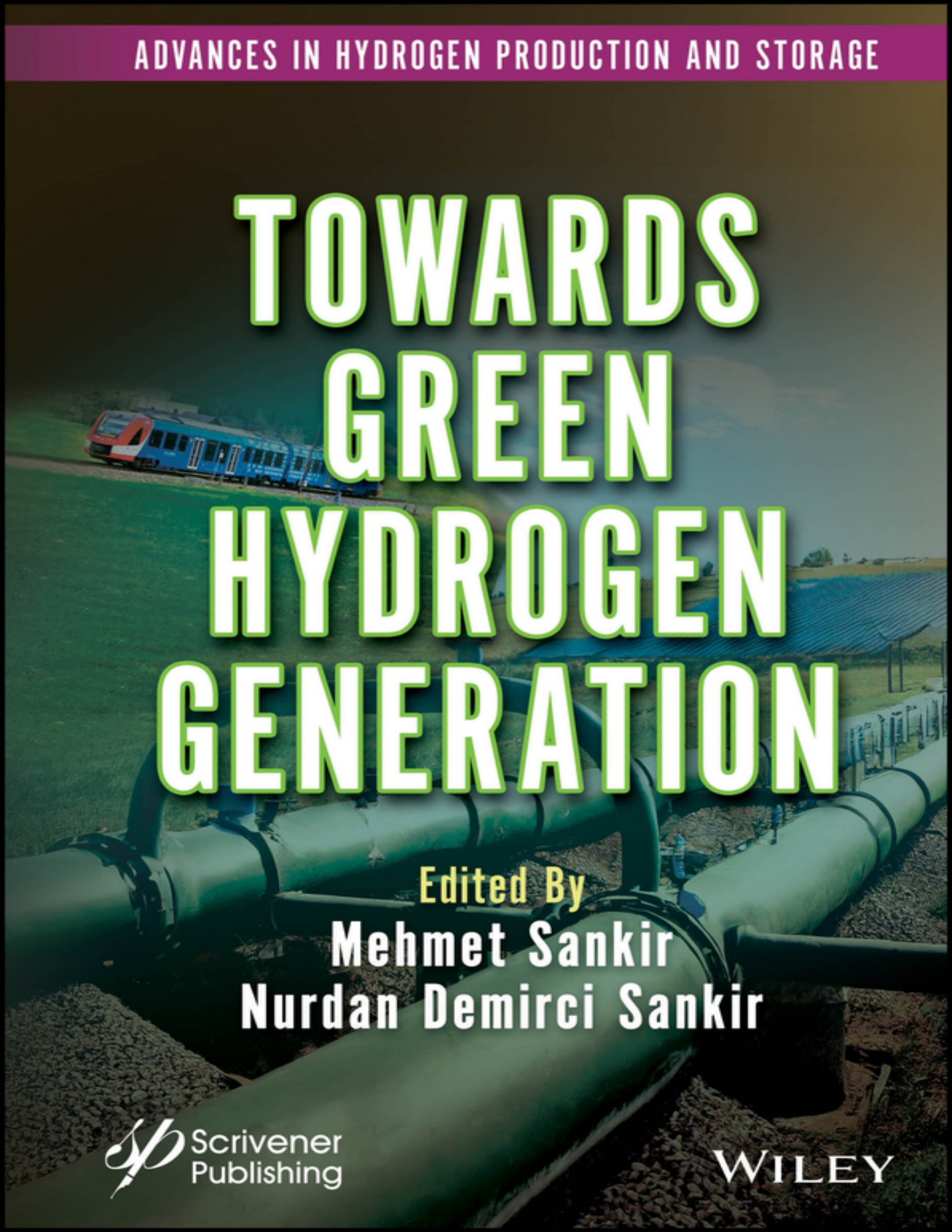
ADVANCES IN HYDROGEN PRODUCTION AND STORAGE

TOWARDS GREEN HYDROGEN GENERATION



Edited By
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Advances in Hydrogen Production and Storage

Series Editors: Mehmet Sankir and Nurdan Demirci Sankir

Scope: Energy is one of the most important issues for humankind. Increasing energy demand, regional limitations, and serious environmental effects of the conventional energy sources provide the urgent need for new, clean, and sustainable energy.

Advances in Hydrogen Production and Storage emphasizes the basics of renewable energy and storage as well as the cutting-edge technologies employed for these applications. The series focuses mainly on hydrogen generation, photoelectrochemical solar cells, fuel cells and flow batteries.

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Towards Green Hydrogen Generation

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Preface

The world is undergoing a new period of upheaval. This process started with the COVID-19 pandemic, and now there is talk of “new” distruptions in many areas. Perhaps the most prominent of these is the emergence of new export items such as hydrogen for countries.

In December 2022, Japan and Saudi Arabia signed a partnership agreement on carbon capture, carbon economy, clean hydrogen, and ammonia fuels. To meet this agreement, there is a need for economically attractive changes in the production, distribution, storage, and consumption of energy. With these changes, it is possible to create new jobs, increase the number workers in existing jobs, and thus create a large economy. In short, while fulfilling an important function, such as reducing emissions and decarbonizing energy, it is also possible to create a large market with the establishment of a hydrogen ecosystem.

The realization of the 28 countries’ decision to keep global warming at or below two degrees Celsius, as stated in the Paris Climate Agreement, and the achievement of minimizing emissions can only be realized through the establishment of a hydrogen ecosystem. This requires the gradual utilization of carbon-free resources to generate power for everyday life and industry. This is why hydrogen is so important. Therefore, hydrogen technologies come to the fore in the context of achieving net zero emissions. There is virtually no other way to meet the 2053 net zero emissions commitment. Hydrogen is a rare gas in nature and is often found together with natural gas. In summary, while hydrogen is the most abundant element in the known universe, molecular hydrogen is very rare in nature and

needs to be produced—and produced in large quantities, if we are serious about a Green Deal.

This book has been organized into three parts to introduce and discuss these crucial topics. Part I discusses the Green Deal and the current state and challenges encountered in the industrialization of green hydrogen production, as well as related politics. Also, it describes a gradual shift in the approach of hydrogen production technologies from non-renewable to renewable. On the other hand, Part II is devoted to carbon capturing and hydrogen. Biomass mass waste-to-hydrogen conversion and related learning models, life cycle analysis, and metal oxide-based carbon capture technologies are all addressed in this chapter. The last part of the book was designed to present all features of the green hydrogen generation. PEM water electrolysis and other electrolyzers, wind-driven hydrogen production, and bifunctional electrocatalysts-driven hybrid water splitting are introduced and thoroughly discussed.

As a result, despite the uncertainty created by the pandemic, efforts to create social impact on climate change, clean and reliable energy sources, energy-efficient buildings, sustainable and smart mobility, biodiversity and ecosystems, zero pollution, environmentally friendly environments, and a sustainable industry have gained momentum. Therefore, a new geopolitical order is envisaged where energy production, distribution, storage, and sectors that increase carbon footprint are reconfigured. In short, a new economic order in which the carbon footprint will be monitored is desired. As mentioned above, the Green Deal will have a significant impact not only on the European Union countries, but also on all global players that produce, distribute, and dominate the energy market, as well as on stakeholders, such as countries that produce steel, cement, aluminum, and carbon-intensive outputs. This volume covers also these

issues by presenting the relations and opportunities between green hydrogen and related sectors.

In this book, readers will find a multidisciplinary approach that enlightens all the features of green hydrogen in the book. It has been edited for both undergraduate and graduate students, and it will be a valuable reference text in the area of green hydrogen generation and other diverse fields. A wide readership will find this volume quite useful, from professionals in chemistry, physics materials science, chemical engineering, and energy engineering, to those in the fields of economics, political science and international relations.

We are deeply grateful to everyone who helped with this book and greatly appreciate the dedicated support and valuable assistance rendered by Martin Scrivener and the Scrivener Publishing team during its publication.

The Editors

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Part 1
HYDROGEN AND THE GREEN DEAL

1
Decarbonizing the Industry with Green Hydrogen

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Abstract

Perseverance to reduce global greenhouse gas emissions and backward economic and ecological issues of excessive use of carbon-based fuels is more preponderant than any other environmental-related policies. In this respect, hydrogen (H_2) appears to be a revolutionary in decarbonizing the common and energy-intensive industrial applications along with its use in transportation. Nations agree to explore a diverse range of innovations to integrate green H_2 into the common industrial plants. Energy-intensive industrial sectors emitting large amounts of carbon dioxide (CO_2) annually need widespread analysis and investigations to reform the adaptation to carbon-neutral resources. This chapter plunges into these energy-intensive, yet crucial for human needs, applications such as ammonia (NH_3), iron/steel, cement, and oil refining. These sectors can be assisted with green H_2 as an energy source with its high energy density and as a potential carbon-neutral feedstock for the chemical industry.

***Keywords*:** Hydrogen energy, green hydrogen, climate change, hydrogen economy, industrial decarbonizaiton, H_2 strategies

1.1 Introduction

In the gradual transition of the fossil-intensive energy landscape toward a green structure, renewable energy sources (RES) face challenges, particularly in two aspects compared to fossil sources. First, there is an intermittency problem with RES in response to the demand for an uninterrupted energy supply. Despite recent improvements in fields such as storage and smart grid technologies, this issue remains a significant shortcoming. The second challenge is that power generation for hard-to-electrify sectors, which involve processes with very high-temperature combustion, can only be achieved using fossil sources. In this respect, H_2 has

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