HYDROGEN ENERGY SYSTEMS

ADVANCING SUSTAINABLE POWER SOLUTIONS

Edited By
Krishan Arora
Himanshu Sharma
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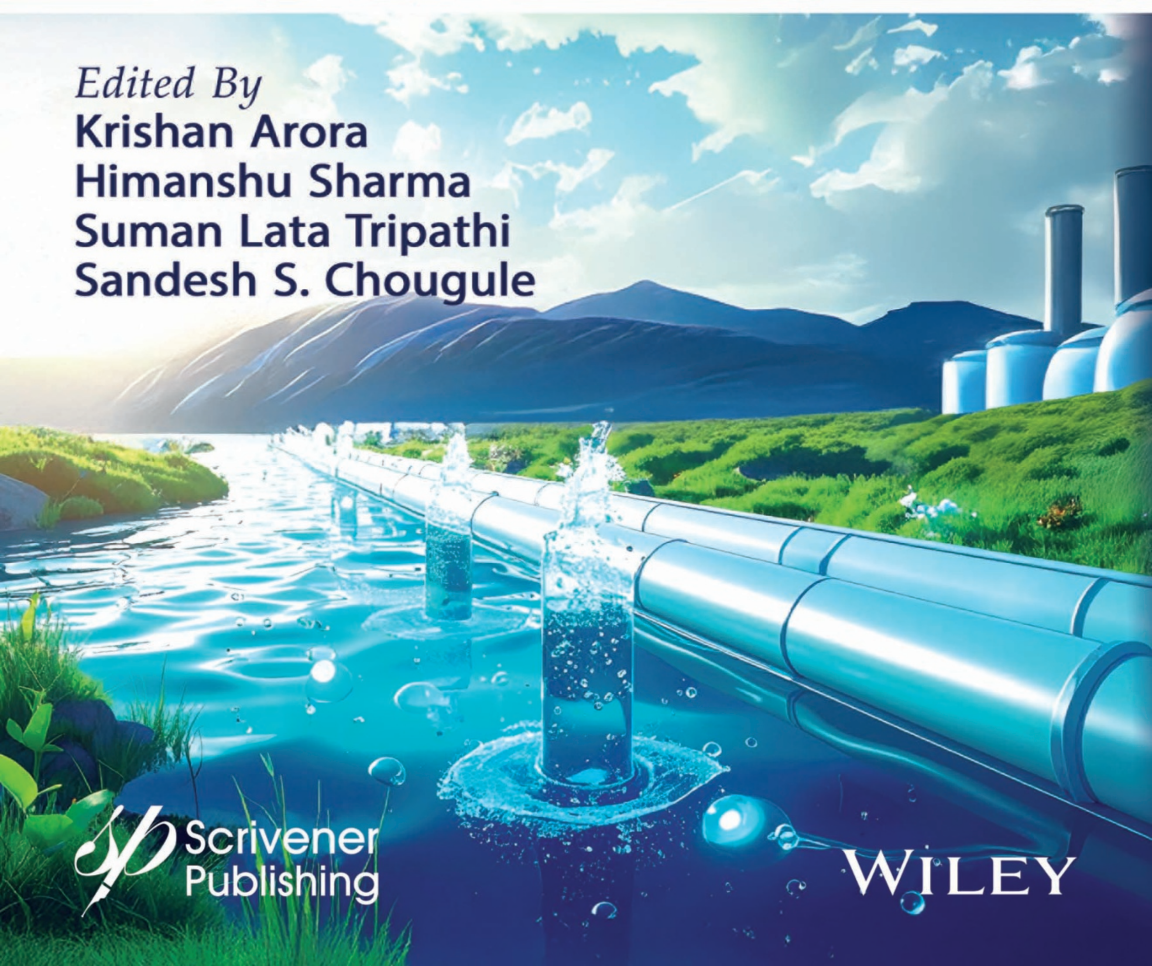
Sandesh S. Chougule



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Preface

The growing global demand for clean and sustainable energy has placed hydrogen at the forefront of next-generation power solutions. As the world transitions from fossil fuels to renewable energy, hydrogen has emerged as a versatile and promising energy carrier with the potential to decarbonize various sectors, including transportation, industry, and power generation. This book, *Hydrogen Energy Systems: Advancing Sustainable Power Solutions*, provides a comprehensive exploration of the fundamental principles, technologies, and applications of hydrogen energy. It is designed to serve as a valuable resource for researchers, engineers, policymakers, and students who are keen to understand the role of hydrogen in the global energy landscape.

The chapters within this book cover key aspects of hydrogen energy systems, including production methods, storage solutions, fuel cell technologies, and integration with renewable energy sources. Additionally, the environmental, economic, and policy dimensions of hydrogen energy are discussed to provide a holistic perspective on its potential and challenges.

Our objective in compiling this book is to bridge the knowledge gap between theoretical research and practical implementation. By presenting the latest advancements in hydrogen energy, we aim to equip readers with the insights necessary to contribute to the development of sustainable and efficient hydrogen-based energy solutions.

We extend our gratitude to the researchers, industry professionals, and institutions that continue to advance the field of hydrogen energy. Their contributions and innovations are paving the way for a cleaner and more sustainable future. We hope this book serves as a valuable guide for all those invested in the evolution of hydrogen energy systems.

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3

Hydrogen Energy in Developing Countries

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Abstract
The demand of hydrogen as a fuel is growing rapidly, and it rises as a versatile energy carrier. Hydrogen can be produced through nonrenewable and renewable sources. Developing countries has fast population growth and steady industrialization, which means that energy demand will grow swiftly in transport, electricity, industry, and cooling. Due to the climate change, fossil fuels are less preferred choice to meet the demand. Importantly, the transportation industry will transition to hydrogen and other green fuels. However, most hydrogen is now produced from fossil fuels, but new technologies can generate the hydrogen through the clean energy. Given the versatility in nature, hydrogen can play a great role in making the developing economies to carbon zero. The present chapter throws the light on the major development of the hydrogen energy in the developing counties with the challenges and opportunities of the associated hydrogen economy.

***Keywords*:** Developing countries, hydrogen, renewable energy, hydrogen energy, hydrogen storage, transportation

3.1 Introduction

There is a significant rise in the different portable battery-operated electronics devices and power-driven consumer appliances in daily life [1]. These devices and appliances need the energy for proper functioning. One of the most notable trends in society is the persistent increase in the need

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for electrical energy [2]. To date, leading sources of energy are the conventional fossil fuels, which include coal, oil, and natural gas [3]. As in 2022, it has been assumed that 60% of the electricity is generated by the fossil fuels only [4]. The harmful impacts caused by the fossil fuels cannot be ignored, which let many devastating impacts (greenhouse gas, severe extreme weather events, increased global temperature, negative impact at the ecosystem, etc.) on the environment [5]. Moreover, these resources have dwindling stocks of energy, and fossil fuels are not evenly distributed across the world map. In response to the mentioned issues, the utilization of renewable energy sources is gradually becoming more widespread [6]. Renewable energy, which is also known as green energy [7], generates energy from natural processes and is continuously replenished. Solar power, wind energy, biomass, geothermal, and hydropower are the major sources of renewable energy [8]. However, for technological or geographic reasons, renewable energy sources fall short of the desired manifestation in human existence. In an effort to find new ways to extract maximum energy from energy resources or to adapt current methods, hydrogen is carrier considered as a good potential energy. This is because of the desire to find new ways or to change existing ways [9].

On earth, hydrogen is the chemical element that is both the lightest (first chemical element in the periodic table) and the most abundant [10]. It is a fuel that produces no emissions or that does not cause any emissions, and it may be easily produced by home sources. Hydrogen, in its capacity as energy carrier, has emerged as promising alternative for energy storage in multiple forms (gaseous, liquid, or together with hydrides of the metal), with renewability, cleanliness, massive distribution, high conversion, higher heating value, high gravimetric energy density, low ignition temperature, zero emissions (no or zero waste produced), high energy conversion efficiencies, and simplicity of transformation to several kinds of energy as seen by the recent trend in innovation in energy storage technology [11–15]. Another benefit of hydrogen is its capacity to be developed on the current natural gas infrastructure for buildings [16].

In this regard, hydrogen is considered as the most environmentally friendly and promising energy source. Originally suggested during the 1970s, first world energy crisis was a hydrogen economy [17]. This long-term approach takes safety and energy independence into account. The interest to use hydrogen as fuel has coined in the last couple of decades under the Energy Policy Act 1992 [18]. Hydrogen has high energy density than gasoline (fossil fuel) and two to three times more efficient [19, 20]. Because of its high level of reactivity, hydrogen almost always results in