Chapter 12
Hydrogen as the Cornerstone of a Renewable Energy Society

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ABSTRACT

The global transition to renewable energy has positioned green hydrogen as a pivotal element in reshaping energy production, storage and consumption. This chapter explores hydrogen's critical role in creating a renewable energy society, particularly its potential to decarbonize industries, enhance energy security and provide long-term energy storage. Unlike batteries, hydrogen can store excess renewable energy and deliver it during peak demand, offering a versatile solution for grid balancing. Key sectors such as transportation, heavy industry, and residential applications benefit from hydrogen's flexibility, especially where electrification alone is insufficient. Despite its promise, the hydrogen economy faces challenges, including high costs, infrastructure needs and public acceptance. The chapter highlights that while hydrogen is not a standalone solution, its integration with other clean technologies is crucial to achieving a sustainable, carbon-neutral future.

1. INTRODUCTION

An essential component of the shift to a civilization powered by renewable energy is hydrogen. It is a flexible energy source that can be created by water electrolysis and other renewable energy sources like solar, wind, and hydroelectric power. This makes hydrogen an essential element in storing and distributing clean energy Hydrogen produces just water in fuel cells, as opposed to fossil fuels, offering a

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zero-emission substitute for industry, transportation, and power production. Hydrogen was recognized as a distinct matter (element), initially (1713-1810) found by Henry Cavendish, an English Chemist. The aspect is very well known for its unique features. In the periodic table, it is the first element with atomic number Z = 1. Compared to other materials, it is the lightest of all because the hydrogen atom is made of 1 electron and 1 proton, thus the total mass remains very small. Because of its extreme reactivity, it may also be blended with other elements with ease (Juangsa et al., 2021). As we know, a hydrogen molecule contains two atoms and therefore it can be easily combined with other chemicals, to form new compounds in the periodic table. Apart, it is the essential constituent of all living matters present in the universe. When it comes to chemistry, the atoms and molecules of Hydrogen play an influential role and that is the reason why it is cited as an example for rendering several theories. For instance, water also known as H_2O, is an inevitable compound that covers the earth by 3/4th (75%) approximately. H_2O has a 12% weight of Hydrogen that covers the earth's surface in terms of oceans, rivers, lakes, and other bodies of H_2O. Furthermore, it is the element that is more abundant on Earth that is present in compounds. Additionally, there is water in the atmosphere, and planets and animals have a large Hydrogen content due to the water they contain(Lamb & Webb, 2022). Apart from those, a further amount of combined hydrogen is present in plants and creatures in the form of 3 main classes of biological substances proteins, fats, and carbohydrates. It is also a part of the fossil fuels that the sun and other stars have and which are used in nuclear fusion. It is nothing but nuclei of hydrogen that produce Helium and an enormous quantity of energy. This process occurs in the sun provides the all necessary energies required to live on the Earth. Also, it is to be noted that hydrogen is continuously lost from the atmosphere by escaping from the gravity of the earth(Zhu et al., 2023). It is easily replaced by the decay of organic matter, formation of volcanic matter, and photochemical dissociation of water. Hydrogen is an element in the periodic table that is unique in that it does not fall under any particular group. Like Hydrogen, the bonds formed by it known as Hydrogen bonds have unique features for their life-sustaining quality as well as responsible for many biological molecular functions. In the absence of a hydrogen bond, H_2O would not exist as a liquid. The concentration of its ion H+ (in the PH Scale) is used to express the acidity of aqueous solutions. Hydrogen is set as a benchmark or standard for expressing the properties of elements in the modern chemical industry. Valency is one such to be noted(Tarhan & Çil, 2021). Other than valency, the formation of electrochemical series is another one, where hydrogen is assigned arbitrarily to an EMF value of 0 and the EMF values of other elements are expressed related to hydrogen. Metals above Hydrogen in the EMF series will displace it from an acid solution.

Long-term storage and transportation of hydrogen improves the flexibility of renewable energy systems by resolving problems such as the intermittent nature of solar and wind power. Moreover, challenging industries that are challenging to electrify, such as heavy manufacturing, aviation, and shipping, can be decarbonized with green hydrogen. Hydrogen is emerging as a key component for creating a sustainable, renewable energy economy, promoting energy independence, and lowering greenhouse gas emissions as countries and companies strive to achieve carbon neutrality.