

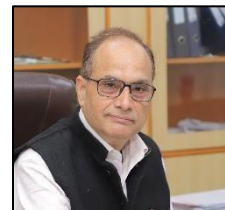
**Hydrogen as a Catalyst for Sustainability: Decoding the Value Chain****Prof. K.K. Pant,**

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The escalating global demand for energy, propelled by rapid economic expansion and population growth, has intensified dependence on fossil fuels, resulting in heightened greenhouse gas emissions and accelerated resource depletion. This pressing scenario underscores the urgent need to transition from conventional energy systems to renewable energy alternatives. Hydrogen (H<sub>2</sub>) has emerged as a clean energy fuel to facilitate a shift towards a lower carbon economy. Unlike carbon-based synthetic fuels, H<sub>2</sub> offers the potential for a carbon-neutral or even carbon-negative lifecycle when produced from renewable energy sources. This review provides a comprehensive and systematic analysis of the hydrogen economy, detailing its value chain from production to practical application and elucidating its potential to support decreasing carbon footprint.

Herein, we discuss a variety of hydrogen production methodologies, including established techniques such as steam methane reforming and innovative approaches such as electrocatalysis, photocatalysis, biomass conversion, and non-thermal plasma-enhanced dry reforming of methane. Further, it discusses the key concept and governing parameters and emphasises its vital role in decarbonising key sectors. In addition, the review also examines hydrogen storage and transport technologies, including high-pressure compression, cryogenic liquefaction, and chemical carriers such as liquid organic hydrogen carriers (LOHCs) and metal hydrides, evaluating their technical feasibility and scalability. Furthermore, the study explores the applications of hydrogen in industrial processes, transportation, and power generation, highlighting its potential to substitute carbon-intensive energy sources. Finally, this review delineates key research and development priorities, underscoring the necessity for interdisciplinary efforts to establish H<sub>2</sub> as a foundational element of a sustainable, low-carbon energy system.

**Keywords:** Hydrogen, Generation, Storage, Utilization