# Sustainable Energy with New Era Green Hydrogen

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*Abstract*—The escalating global energy demand coupled with growing environmental concerns has necessitated a shift toward sustainable energy sources. As nations aim for net-zero emissions and reduced dependence on fossil fuels, green technologies are revolutionizing energy systems worldwide. Among these technologies, hydrogen energy has emerged as a vital player due to its versatility and potential to support decarbonization efforts. This paper explores sustainable energy, its projected trajectory in the coming decades, and the increasing role of hydrogen as a clean energy vector. The paper further discusses the types of hydrogen, its unique characteristics, and its diverse applications, emphasizing its transformative potential in the transition to a greener future.

In addition to being a zero-emission fuel when used in fuel cells, hydrogen offers the advantage of energy storage, balancing intermittent renewable sources such as solar and wind. The production of green hydrogen, derived from renewable electricity through water electrolysis, is particularly crucial as it aligns directly with global decarbonization targets. This paper also examines the technological, economic, and policy challenges associated with large-scale hydrogen deployment and highlights key advancements driving its adoption. Furthermore, the integration of hydrogen within various sectors-ranging from transportation and power generation to industrial processes and residential heating-demonstrates its multifaceted role in achieving energy sustainability. By focusing on hydrogen's synergies with other green technologies and outlining its contribution to circular economies and smart energy grids, this study underscores hydrogen's central role in shaping a resilient, low-carbon energy future.

*Index Terms*—Sustainable energy, green technology, hydrogen energy, green hydrogen, fuel cells, decarbonization, renewable energy, energy transition, net-zero emissions, smart grids.

#### 1. INTRODUCTION

Global reliance on fossil fuels has led to significant environmental degradation, primarily through greenhouse gas emissions, which contribute to climate change, air pollution, and ecosystem disruption. The burning of coal, oil, and natural gas

continues to be the dominant source of energy worldwide, accounting for a substantial share of carbon dioxide (CO<sub>2</sub>) emissions that accelerate global warming. In response to these challenges, there has been an urgent and growing global push toward the adoption of sustainable and renewable energy systems. Sustainable energy solutions are designed not only to reduce carbon emissions but also to enhance energy efficiency, ensure the long-term availability of resources, and promote environmental stewardship.

The energy landscape is undergoing a profound transformation with the rapid advancement of green technologies such as solar photovoltaics, wind turbines, bioenergy systems, geothermal power, and hydrogen-based solutions. These technologies are playing a crucial role in shaping the "new era" of energy production and consumption, marked by decarbonization, decentralization, and digitalization. In particular, hydrogen energy has emerged as a versatile and efficient energy carrier with wide-ranging applications across various sectors, including transportation, industry, power generation, and residential heating.

Unlike conventional fossil fuels, hydrogen, especially when produced through renewable-powered electrolysis, emits no greenhouse gases at the point of use, making it a key enabler of a low-carbon economy. The versatility of hydrogen allows it to complement other renewable energy sources, providing long-term energy storage solutions and supporting grid stability. As nations and industries strive to achieve ambitious climate targets and transition to net-zero emissions, hydrogen is poised to play a pivotal role in enabling a cleaner, more resilient, and sustainable energy future. [1,2]

## 2. WHAT IS SUSTAINABLE ENERGY?

Sustainable energy refers to energy systems that are environmentally friendly, economically viable, and socially acceptable, ensuring that the energy needs of the present are met without compromising the ability of future generations to meet their own needs. It focuses on minimizing environmental impacts while providing reliable and affordable energy solutions. Sustainable energy is primarily derived from renewable resources, which naturally replenish over short periods and can be continuously harnessed without exhausting the planet's ecosystems.

The transition to sustainable energy is essential in addressing the adverse effects of fossil fuel dependence, such as climate change, air pollution, and resource depletion. By prioritizing sustainable energy, societies can reduce their ecological footprint and work toward a more equitable and stable energy future.

Key sources of sustainable energy include:

- Solar energy: Captured using photovoltaic (PV) panels or concentrated solar power (CSP) systems, solar energy converts sunlight into electricity or thermal energy. It is one of the most abundant and widely adopted renewable resources globally.
- Wind energy: Utilizes wind turbines to convert the kinetic energy of moving air masses into electrical power. Onshore and offshore wind farms are increasingly contributing to national and regional power grids.
- Hydropower: Generates electricity by harnessing the gravitational force of falling or flowing water, typically through dams, run-of-river systems, or pumped storage facilities.
- Biomass energy: Derived from organic materials such as agricultural residues, forestry by-products, and dedicated energy crops. Biomass can be used for heat, electricity generation, and biofuels.
- Geothermal energy: Extracts heat from beneath the Earth's crust to produce electricity or provide direct heating. Geothermal systems are highly reliable and provide base-load power.

In addition to these, emerging technologies such as ocean energy (tidal and wave power) are being explored to further diversify the renewable energy portfolio.

Benefits of Sustainable Energy

- Reduces greenhouse gas emissions and mitigates climate change: By replacing fossil fuels with clean energy sources, sustainable energy helps to significantly lower CO<sub>2</sub> and other harmful emissions, contributing to global climate goals.
- Diversifies energy supply, enhancing energy security: Relying on a variety of renewable resources reduces dependence on imported fuels and enhances the resilience of national energy systems.
- Promotes economic development and job creation: The renewable energy sector creates millions of jobs worldwide, fostering innovation and stimulating local economies through infrastructure development and manufacturing.
- Decreases air and water pollution, improving public health: Sustainable energy systems minimize pollutants that contribute to respiratory diseases, cardiovascular conditions, and other health issues, resulting in cleaner environments and healthier communities.

Sustainable energy is not only critical for environmental protection but also for building a resilient, inclusive, and economically vibrant global society. [3,4]

Upcoming Status of Sustainable Energy

The renewable energy sector is undergoing a transformative period, marked by rapid technological innovation, robust policy support, and heightened societal awareness regarding the urgent need for climate action. Governments, corporations, and communities are increasingly prioritizing clean energy development as part of their strategies to combat climate change, reduce dependency on fossil fuels, and foster sustainable economic growth. According to the International Renewable Energy Agency (IRENA), renewable energy capacity is projected to grow by more than 50% by 2030, with clean technologies set to dominate global energy investments.

Several key trends are shaping the trajectory of sustainable energy:

- Increased adoption of renewables: Solar and wind power are at the forefront of the global energy transition, thanks to their rapidly declining costs and continuous improvements in efficiency. The levelized cost of electricity (LCOE) for solar photovoltaic and onshore wind has dropped significantly over the past decade, making them highly competitive with traditional fossil fuels. Large-scale wind and solar projects are being developed worldwide, complemented by smaller, community-based and decentralized systems.
- Energy storage solutions: The widespread integration of renewable energy into the grid has created a pressing need for effective energy storage systems to manage the variability of solar and wind generation. Advances in battery technologies-such as lithium-ion, solid-state, and emerging flow batteries-are playing a crucial role in enhancing grid flexibility and reliability. Additionally, hydrogen storage solutions are gaining momentum as а complementary approach, offering long-term and seasonal storage capabilities that can stabilize energy supply.
- Smart grids: The implementation of smart grid technologies is revolutionizing how energy is managed and distributed. Equipped with digital sensors, advanced metering infrastructure, and automation systems, smart grids optimize real-time energy flow, balance supply and demand more efficiently, and facilitate the seamless integration of distributed energy resources. These innovations empower consumers and utilities alike to reduce costs, enhance resilience, and lower emissions.
- Decentralization of energy production: The traditional model of centralized power generation is being reshaped by the rise of distributed energy resources (DERs), such as rooftop solar systems, microgrids, and community wind projects. This decentralization empowers consumers to become "prosumers" who actively participate in energy generation and consumption. Such models improve energy access, reduce transmission losses, and strengthen local energy independence.
- Hydrogen economy: Hydrogen is emerging as a key pillar of the clean energy future, with growing investments in hydrogen production, storage, and

distribution infrastructure. Governments and industries worldwide are recognizing hydrogen's potential to decarbonize hard-to-abate sectors, including heavy transport, steelmaking, and chemical production. For instance, the European Union's "Hydrogen Strategy for a Climate-Neutral Europe" sets an ambitious target to produce 10 million tons of renewable hydrogen by 2030. Similarly, countries like Japan, South Korea, and Australia are actively developing hydrogen supply chains and export hubs to position themselves as leaders in the global hydrogen economy.

This momentum indicates that sustainable energy will not only play a central role in mitigating climate change but will also reshape energy markets, create new economic opportunities, and drive innovation in the years ahead.[5]

# 3. WHAT IS HYDROGEN?

Hydrogen is a colorless, odorless, non-toxic, and highly combustible gas, known for being the lightest and most abundant element in the universe. Although it constitutes approximately 75% of the universe's elemental mass, hydrogen rarely exists in its pure molecular form (H<sub>2</sub>) on Earth. Instead, it is typically found in compound forms, such as water (H<sub>2</sub>O) and hydrocarbons like methane (CH<sub>4</sub>). Extracting hydrogen from these compounds requires energyintensive processes, positioning hydrogen as a secondary energy carrier rather than a primary energy source, much like electricity.

As an energy carrier, hydrogen can store and deliver usable energy, making it highly versatile. Once produced, hydrogen can be used in various applications, such as generating electricity in fuel cells, providing heat for industrial processes, and serving as a feedstock in the production of chemicals and synthetic fuels. Its combustion or electrochemical conversion in fuel cells yields only water as a byproduct, making hydrogen an environmentally friendly option when produced sustainably.

## Hydrogen Production Methods

Hydrogen can be produced through several pathways, each with distinct environmental and economic implications:

- Electrolysis: This process uses electricity to split water (H<sub>2</sub>O) into hydrogen and oxygen via an electrolyzer. When powered by renewable energy sources (such as solar or wind), this method produces what is known as "green hydrogen," resulting in no direct carbon emissions.
- Steam Methane Reforming (SMR): The most widely used method for industrial hydrogen production, SMR reacts methane (CH<sub>4</sub>) with steam to produce hydrogen and carbon dioxide (CO<sub>2</sub>) as a byproduct. This process typically results in "grey hydrogen" unless combined with carbon capture and storage (CCS) technologies, which can lower emissions and produce "blue hydrogen."
- Gasification: Biomass or coal is converted into hydrogen, carbon monoxide, and carbon dioxide through high-temperature reactions in a low-oxygen environment. Biomass gasification can contribute to low-carbon hydrogen production, especially when paired with sustainable biomass sources.

Emerging methods such as photoelectrochemical water splitting and methane pyrolysis are also being researched to further enhance hydrogen production efficiency and reduce associated emissions.

## The Role of Hydrogen in Decarbonization

Hydrogen's appeal lies in its potential to decarbonize sectors where direct electrification is technically or economically challenging. In heavy industries such as steel, cement, and chemicals, hydrogen can serve as a clean-burning fuel or feedstock, replacing fossil fuelbased processes. In transportation, hydrogen fuel cells are particularly advantageous for long-haul trucking, shipping, aviation, and railways—applications where battery-electric solutions may be limited by energy density and weight constraints.

Furthermore, hydrogen is being explored for gridscale energy storage and power generation, enabling a reliable balance between supply and demand, especially as variable renewable energy sources expand. Its flexibility and wide applicability across sectors make hydrogen a cornerstone of future lowcarbon energy systems.[12]

## 4. TYPES OF HYDROGEN

Hydrogen is categorized into distinct types based on the production method and the type of energy source used. This classification helps to distinguish between the environmental impacts and sustainability of each hydrogen pathway. Understanding these types is crucial for evaluating hydrogen's role in achieving global decarbonization targets.[6]

Grey Hydrogen

- Production method: Produced primarily through Steam Methane Reforming (SMR) or coal gasification without capturing the resulting carbon dioxide (CO<sub>2</sub>).
- Energy source: Fossil fuels (mainly natural gas or coal).
- Environmental impact: Grey hydrogen is the most widely produced type today but is carbonintensive, responsible for significant CO<sub>2</sub> emissions released directly into the atmosphere.
- Current status: Dominates global hydrogen production but is increasingly viewed as unsustainable due to its high carbon footprint.

## Blue Hydrogen

- Production method: Similar to grey hydrogen, but the CO<sub>2</sub> generated during SMR or gasification is captured and stored underground using Carbon Capture and Storage (CCS) technologies.
- Energy source: Fossil fuels with CCS.
- Environmental impact: Emits fewer greenhouse gases than grey hydrogen but is still dependent on fossil fuels and the effectiveness of CCS.
- Current status: Seen as a transitional solution in the move toward a hydrogen economy while green hydrogen infrastructure scales up.
- Green Hydrogen
- Production method: Created through water electrolysis powered entirely by renewable electricity (e.g., wind, solar, hydropower).
- Energy source: Renewable energy.
- Environmental impact: Produces zero direct CO<sub>2</sub> emissions, making it the most environmentally friendly and sustainable form of hydrogen.
- Current status: A critical component of future netzero strategies, but current production costs are higher compared to grey and blue hydrogen due

to the price of renewable electricity and electrolyzer technology.

Pink Hydrogen

- Production method: Generated via electrolysis, similar to green hydrogen, but powered by nuclear energy.
- Energy source: Nuclear-generated electricity.
- Environmental impact: Considered low-carbon, as nuclear power emits no direct CO<sub>2</sub>, though it does carry concerns related to nuclear waste and public acceptance.
- Current status: Attracting interest in countries with established nuclear infrastructure as an additional pathway for clean hydrogen.

# Turquoise Hydrogen

- Production method: Produced via methane pyrolysis, a process that splits methane into hydrogen and solid carbon instead of CO<sub>2</sub> gas.
- Energy source: Natural gas.
- Environmental impact: The carbon byproduct is solid rather than gaseous CO<sub>2</sub>, making it potentially easier to manage. If renewable electricity is used to heat the process, its carbon footprint could be further minimized.

# 5. CHARACTERISTICS OF HYDROGEN

Hydrogen's distinct physical and chemical characteristics make it one of the most versatile and promising energy carriers available. These properties contribute to its potential role in decarbonizing various sectors, though they also introduce technical challenges that must be addressed to enable widespread adoption.[7]

High Specific Energy

• Hydrogen boasts an exceptionally high specific energy of approximately 120 megajoules per kilogram (MJ/kg), nearly three times that of gasoline. This makes it an ideal fuel for applications where energy-to-weight ratio is crucial, such as in aerospace, aviation, and heavyduty transport. However, while it has high energy per mass, its energy density per unit volume is relatively low.

# Zero-Carbon Combustion

• When combusted in air or used in hydrogen fuel cells, hydrogen combines with oxygen to produce only water vapor as a byproduct, eliminating direct carbon dioxide emissions. This attribute makes hydrogen a key enabler of net-zero emission targets, especially when used to replace fossil fuels in high-emission sectors like steel production or transportation.

# Non-Toxic and Odorless

• Hydrogen is non-toxic, colorless, and odorless, posing no direct health risks at low concentrations. However, its odorless nature means that leaks are harder to detect without sensors or odorizing agents. Safety precautions are critical due to its high flammability and the wide flammable range (4% to 75% hydrogen in air).

# Low Density

Hydrogen is the lightest element, resulting in a very low energy density by volume. At ambient temperature and pressure, hydrogen gas occupies a large volume, necessitating compression (typically to 350-700 bar), liquefaction (at -253°C), or chemical bonding (e.g., metal hydrides or ammonia) for practical storage and transportation.

# Highly Reactive

• Hydrogen readily forms compounds with many elements, such as oxygen (to form water) or carbon (to form hydrocarbons like methane). This reactivity enables its wide range of industrial uses but also requires careful system design to prevent unwanted reactions or material degradation, especially in pipelines and storage systems. [8,9,10]

# 6. OPPORTUNITIES AND CHALLENGES

While these characteristics make hydrogen suitable for a wide array of applications (from clean transportation and energy storage to industrial processes and chemical production), its widespread adoption is still hindered by several factors:

• Infrastructure Gaps: Existing energy infrastructure, such as pipelines and fueling

stations, often requires retrofitting or replacement to safely handle hydrogen.

- Storage & Transportation Costs: Compressing or liquefying hydrogen is energy-intensive and expensive, contributing to higher overall system costs.
- Safety Concerns: Due to its flammability and invisible flame, hydrogen requires robust leak detection systems, safety protocols, and public awareness.

Despite these hurdles, ongoing research and investment in hydrogen storage technologies, fuel cell innovation, and supply chain development are gradually addressing these limitations. [11-13]

## 7. APPLICATIONS OF HYDROGEN

Hydrogen's versatility as an energy carrier enables it to play a critical role in various sectors, driving decarbonization efforts and enhancing energy security. Its adaptability across transportation, power generation, industry, heating, and even global trade makes it a cornerstone of the emerging low-carbon economy.

## Transportation

Hydrogen is increasingly used to decarbonize modes of transport that are difficult to electrify using batteries alone due to weight and range limitations:

- Fuel Cell Electric Vehicles (FCEVs): These vehicles use hydrogen fuel cells to generate electricity onboard, emitting only water vapor as a byproduct. FCEVs are being deployed in light-duty passenger cars, commercial trucks, and public buses.
- Heavy-duty transport: Hydrogen is well-suited for long-haul trucks, trains, ferries, and ships, where battery-electric solutions may be less viable due to energy density and refueling time constraints.
- Aviation: Aircraft manufacturers are actively developing hydrogen-powered planes and exploring the use of synthetic fuels derived from green hydrogen to reduce aviation's carbon footprint.

## Power Generation

Hydrogen offers flexible solutions for the decarbonization of electricity generation and grid stability:

- Hydrogen-fueled turbines: Hydrogen can be combusted in modified gas turbines to generate electricity with significantly lower emissions than fossil gas.
- Energy storage: Excess renewable electricity from wind or solar can be converted into hydrogen via electrolysis (Power-to-Hydrogen), stored, and later converted back into electricity (Power-to-Hydrogen-to-Power), providing seasonal and long-term energy storage for grid balancing.

## **Industrial Processes**

Industry is one of the largest consumers of hydrogen today, with expanding opportunities in the transition to cleaner production methods:

- Ammonia production: Hydrogen is a critical input in the Haber-Bosch process for ammonia synthesis, essential for global fertilizer production.
- Refining & petrochemicals: Used to remove impurities (hydrodesulfurization) and as a feedstock for various chemicals.
- Steel manufacturing: Hydrogen is emerging as a key enabler of "green steel" by replacing carbonintensive coke in the direct reduction of iron ore, significantly cutting CO<sub>2</sub> emissions in the steel industry.

## Residential and Commercial Heating

Hydrogen is being piloted as a cleaner alternative for heating buildings:

- Hydrogen blending: In several countries (e.g., the UK and the Netherlands), hydrogen is being blended (up to 20%) with natural gas in existing gas networks to reduce carbon emissions in heating systems.
- 100% hydrogen heating: Future visions include dedicated hydrogen pipelines supplying hydrogen for use in hydrogen boilers, cookers, and combined heat and power (CHP) systems.

Aerospace and Defense

Due to its high specific energy, hydrogen is indispensable in space exploration and military applications:

- Rocket propulsion: Liquid hydrogen, combined with liquid oxygen, serves as rocket fuel in launch vehicles, offering high thrust and performance.
- Military use: Hydrogen fuel cells are also explored for silent, efficient power generation in remote defence operations or submarines.

## Exportable Energy Vector

Hydrogen can serve as a globally traded energy commodity:

- Hydrogen exports: Countries rich in renewable resources (e.g., Australia, Chile, Saudi Arabia) are investing in green hydrogen production for export markets, supplying hydrogen in compressed, liquefied, or converted forms (e.g., ammonia or synthetic fuels).
- Hydrogen carriers: Hydrogen can be converted into derivatives such as ammonia, methanol, or liquid organic hydrogen carriers (LOHCs) for easier transportation across long distances. [15,16,17]

## 8. CONCLUSION

- The transition to sustainable energy is no longer a distant objective but an urgent necessity as the world confronts the dual crises of climate change and resource depletion. Advances in green technologies, including solar, wind, smart grids, and energy storage, are reshaping the global energy landscape, fostering a cleaner, more resilient, and decentralized energy system. Central to this shift is hydrogen, which has emerged as a versatile and indispensable energy carrier.
- Hydrogen's ability to decarbonize sectors that are traditionally difficult to electrify—such as heavy industry, long-distance transport, and aviation—positions it as a vital component of a net-zero future. Among the various forms of hydrogen, green hydrogen stands out as the most sustainable option, offering a zero-emission pathway aligned with global climate goals. The growth of hydrogen infrastructure, including electrolysis capacity, storage facilities, and international

supply chains, will be instrumental in scaling up production and distribution.

- While hydrogen technologies face notable challenges, such as high production costs, energyintensive storage methods, and limited refuelling infrastructure, ongoing research, innovation, and economies of scale are expected to drive down costs and improve efficiency over time. Furthermore, coordinated policy frameworks, including carbon pricing, subsidies, and regulatory support, will be crucial to accelerating market adoption and fostering investment in hydrogen projects.
- In the broader context of sustainable energy, hydrogen is more than just a fuel; it is a transformative enabler of systemic change. Its integration with renewable energy systems enhances grid flexibility and energy security, while its role in industrial processes and international energy trade strengthens global decarbonization efforts.
- As the world moves forward in the pursuit of carbon neutrality and climate resilience, hydrogen will undoubtedly play a pivotal role in building an energy system that is clean, secure, and sustainable for generations to come.

# REFERENCES

- International Energy Agency (IEA). (2021).
  Global Hydrogen Review 2021. Retrieved from: https://www.iea.org/reports/global-hydrogenreview-2021
- [2] Intergovernmental Panel on Climate Change (IPCC). (2018). Global Warming of 1.5°C -Summary for Policymakers. Retrieved from: https://www.ipcc.ch/sr15/
- [3] International Renewable Energy Agency (IRENA). (2023). World Energy Transitions Outlook 2023. Retrieved from: https://www.irena.org/publications/2023/Mar/W orld-Energy-Transitions-Outlook-2023
- [4] European Commission. (2020). A Hydrogen Strategy for a Climate-Neutral Europe. Retrieved from:

https://ec.europa.eu/energy/sites/ener/files/hydro gen\_strategy.pdf

- [5] Ibrahim Dincer, Muhammed Iberia Aydin, New paradigms in sustainable energy systems with hydrogen, Energy Conversion and Management, Volume 283,2023,116950, ISSN0196-8904, https://doi.org/10.1016/j.enconman.2023.116950
- [6] Reda, B., Elzamar, A.A., AlFazzani, S. et al. green hydrogen as a source of renewable energy: a step towards sustainability, an overview. Environ Dev Sustain (2024). https://doi.org/10.1007/s10668-024-04892-z
- [7] Dunn, S. (2002). Hydrogen Futures: Toward a Sustainable Energy System. Island Press.
- [8] Momirlan, M., & Veziroglu, T. N. (2005). The properties of hydrogen as fuel tomorrow in sustainable energy system for a cleaner planet. International Journal of Hydrogen Energy, 30(7), 795-802.
- [9] Rifkin, J. (2002). The Hydrogen Economy: The Creation of the Worldwide Energy Web and the Redistribution of Power on Earth. TarcherPerigee.
- [10] U.S. Department of Energy (DOE). (2021). Hydrogen Program Plan. Retrieved from: https://www.hydrogen.energy.gov/pdfs/hydrogen -program-plan-2020.pdf
- [11]Bossel, U. (2006). Does a Hydrogen Economy Make Sense? Proceedings of the IEEE, 94(10), 1826-1837.
- [12] Shell. (2021). Decarbonising Hard-to-Abate Sectors with Hydrogen. Retrieved from: https://www.shell.com/energy-and-innovation /the-energy-future/ hydrogen /\_jcr\_ content /root/main/section/simple/image.img.0.pdf
- [13] International Energy Agency (IEA). (2023). Net Zero by 2050: A Roadmap for the Global Energy Sector. Retrieved from: (Handbookstyle).
- [14] Jude A. Okolie, Biswa R. Patra, Alivia Mukherjee, Sonil Nanda, Ajay K. Dalai, Janusz A. Kozinski, Futuristic applications of hydrogen in energy, biorefining, aerospace, pharmaceuticals and metallurgy, International Journal of Hydrogen Energy,
- [15] Volume 46, Issue 13, 2021, Pages 8885-8905, ISSN 0360-3199, https://doi.org/10.1016 /j.ijhydene.2021.01.014.
- [16] Ramachandran, Ram, and Raghu K. Menon. "An overview of industrial uses of hydrogen." International journal of hydrogen energy 23.7 (1998): 593-598.

[17] Liu, Wenguo, et al. "The production and application of hydrogen in steel industry." International Journal of Hydrogen Energy 46.17 (2021): 10548-10569.