

The Sustainable Potential of Hydrogen in Agriculture and Allied Sectors

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Summary

Hydrogen is denoted by the chemical symbol 'H' and has an atomic number of 1. It is the lightest element and possesses the characteristics of being colourless, odourless, tasteless, non-toxic, and highly flammable. Depending on its method of production, hydrogen can be categorized as grey, blue, or green hydrogen. Green hydrogen is produced through processes such as Polymer Electrolyte Membrane (PEM) electrolysis, alkaline electrolysis, and gasification of agriculture and municipal waste biomass. Green hydrogen is known for its sustainability, renewability, ability to be stored and transported, and versatility in various applications. In the agricultural sector, hydrogen is utilized for multiple purposes, including the production of fertilizers, alleviating stress in plants, and promoting the growth of beneficial PGPR microbes. It also aids in reducing pre and post-harvest losses. Hydrogen finds applications in various sectors, including industry, aviation, energy, and aerospace. Its versatility and clean nature make it a valuable resource in these fields.

Introduction

- ❖ According to the latest estimates, it is predicted that there will be a 25-30% increase in global energy demand by 2040.
- ❖ In 2015, the global community made a commitment to ensure that the global temperature rise in this century remains well below 2°C above pre-industrial levels.



- ❖ India has pledged to reduce the emission intensity of its economic activity by 33-35% by 2030, compared to the levels in 2005, as part of the Paris Agreement on climate change.
- ❖ An increasing number of countries are making commitments to achieve net-zero carbon dioxide (CO₂) emissions by mid-century, aiming to limit the rise in temperature to 1.5°C. To achieve the comprehensive decarbonization of economies, concerted and wide-ranging action across all economic sectors will be necessary.
- ❖ Hydrogen, which is the most abundant chemical element found in nature, has been utilized as a fuel source for cars, airships, and spaceships since the early 19th century.
- ❖ Hydrogen, represented by the chemical symbol 'H' and atomic number 1, is the lightest element. Under standard conditions, hydrogen exists as a gas consisting of diatomic molecules with the formula H₂. It is a colourless, odourless, tasteless, non-toxic, and highly flammable substance.
- ❖ Although hydrogen is abundantly present on Earth in combination with other elements, such as in water and hydrocarbons, its presence in the atmosphere is minimal, accounting for just 0.00005%.

How Hydrogen is Made

Hydrogen can be produced from various energy sources through a diverse range of production technologies. Each technology yields hydrogen with a different "colour" classification.

- **Grey hydrogen:** It is produced by utilizing a fossil fuel feedstock, with natural gas and coal being the typical sources. Steam Methane Reforming is the process used to convert natural gas into hydrogen, while Gasification is employed to convert coal into hydrogen. Grey hydrogen is considered the most cost-effective option; however, it also has the highest carbon footprint among the different hydrogen production methods.
- **Blue hydrogen:** It is generated through the processes of steam methane reforming and coal gasification. However, in order for hydrogen to be classified as blue hydrogen, carbon capture and sequestration (CCS) must be incorporated into these processes. The addition of CCS makes the production of blue hydrogen slightly more expensive compared to grey hydrogen.

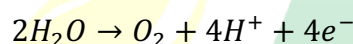
- **Green-** Green hydrogen is produced using renewable sources, earning it the classification of green hydrogen. In this process, renewable electricity is utilized to power an electrolyser, which separates water molecules into oxygen and hydrogen. Currently, green hydrogen is the most expensive option, primarily due to the early stages of technology development and implementation. However, it is anticipated that the costs associated with green hydrogen will significantly decrease in the forthcoming decades.

Industrial-scale electrolysers most commonly employ one of three technologies:

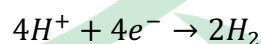
1. Polymer electrolyte membrane electrolysis- In a PEM electrolyser, water at the anode splits to form oxygen and positively charged hydrogen ions.
2. Alkaline electrolysis- It is another method of splitting water into hydrogen and oxygen. At the cathode, water receives additional electrons and splits into hydrogen and hydroxide ions.
3. From Biomass

Polymer Electrolyte Membrane Electrolysis

- ✚ In a PEM electrolyser, water at the anode splits to form oxygen and positively charged hydrogen ions. The anode reaction is:



- ✚ The hydrogen ions then move across the membrane to the negatively charged cathode. The cathode reaction is:

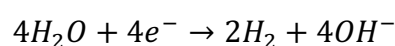


- ✚ PEM Electrolysis also have the benefit of being able to react to high ramp rates and variations that are inherent to renewable electricity by increasing or decreasing hydrogen output.

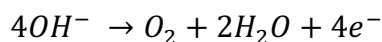
Alkaline Water Electrolysis

- It is another method of splitting water into hydrogen and oxygen. At the cathode, water receives additional electrons and splits into hydrogen and hydroxide ions.

The cathode reaction is:



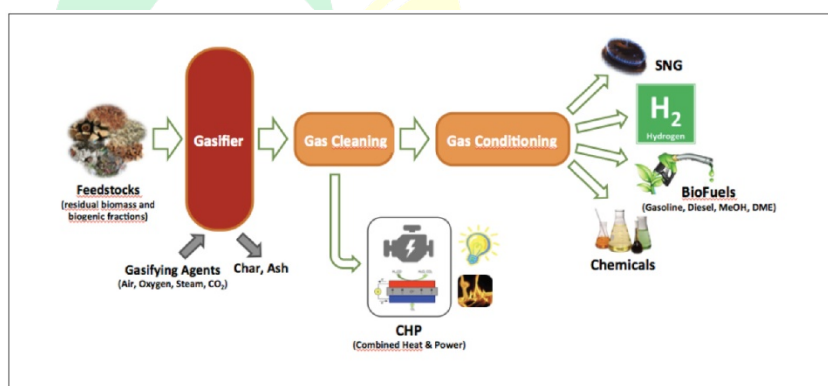
- At the anode, the hydroxide ions are oxidized to oxygen and water, releasing additional electrons. The anode reaction is:



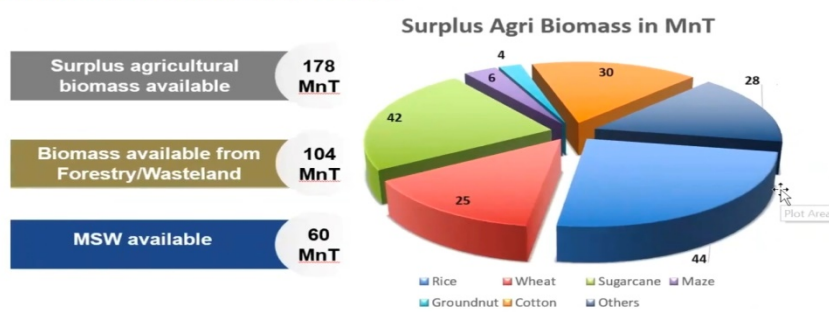
- Alkaline electrolyzers are a mature technology with relatively low costs. However, they do not run efficiently with partial electrical loads and thus must receive stable power. These electrolyzers are ideal for centralized hydrogen production with utilization rates.

Biomass Gasification

- Gasification is a process that converts organic or fossil-based carbonaceous materials at high temperatures. Biomass includes agriculture waste and municipal solid waste.
- The process consists of two steps. In the first step, biomass is converted into syngas – a hydrogen-rich fuel gas mixture – in a novel reactor using oxygen and steam. In the second step, pure hydrogen is generated from syngas using an indigenously developed low-pressure gas separation unit.



BIOMASS AVAILABILITY



Elements	Mass Fraction (%)
Carbon	52.02
Nitrogen	0.12
Sulphur	0.42

Oxygen	41.43
Hydrogen	6.55
Water	11
Molecular weight	27.89 kg kmol ⁻¹

Factor Affecting the Hydrogen Yield from Biomass

1. Biomass type
2. Biomass Particle Size
3. Light intensity
4. Steam to biomass ratio
5. Temperature
6. Catalyst

Advantages of Green Hydrogen

- ✚ **100% Sustainable:** Green hydrogen is considered environmentally friendly as it does not release any polluting gases during its combustion or production processes.
- ✚ **Storable:** Hydrogen possesses excellent storage capabilities, allowing it to be stored for future use and utilized at times beyond its immediate production.
- ✚ **Versatile:** Green hydrogen exhibits versatility as it can be converted into electricity or synthetic gas, making it suitable for various applications, including domestic, commercial, industrial, and mobility purposes.
- ✚ **Transportable:** Hydrogen can be mixed with natural gas in ratios of up to 20% and transported through existing gas pipelines and infrastructure. However, increasing this percentage would necessitate modifications to different elements within the current gas networks to ensure compatibility.

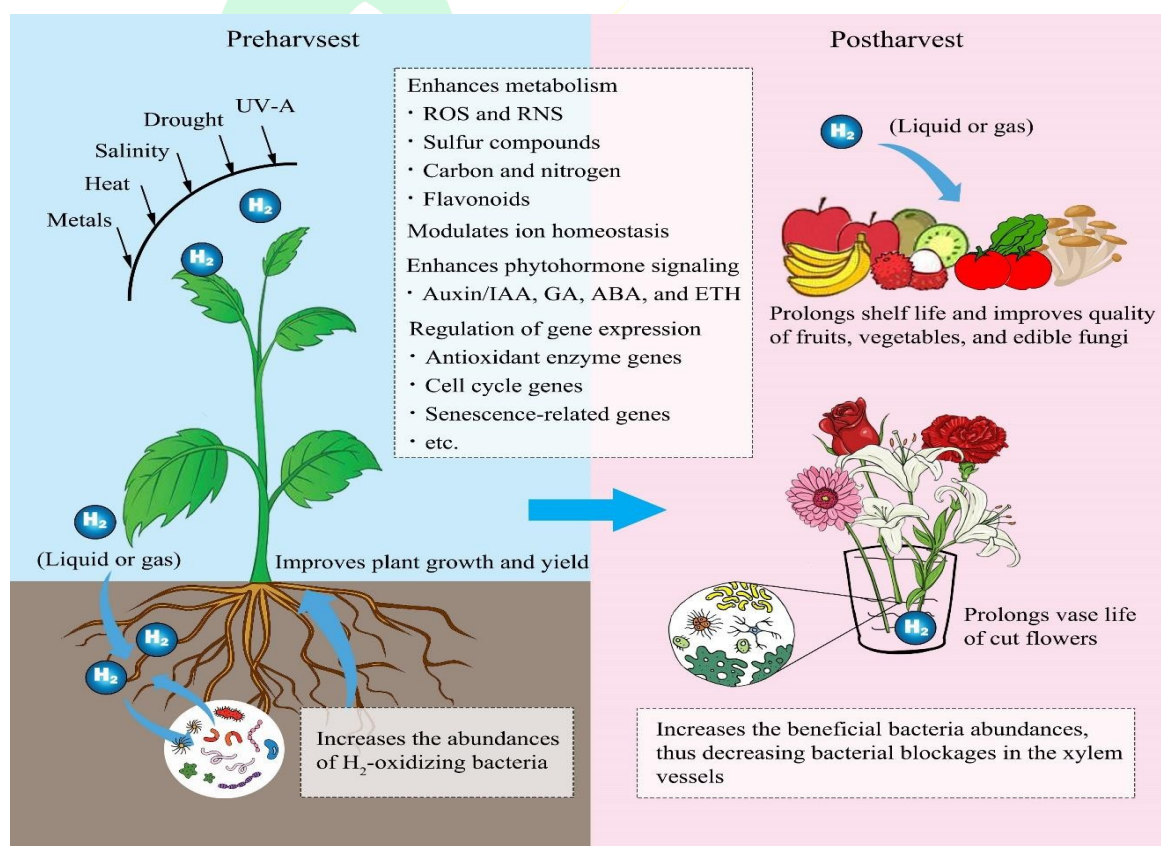
Application of Hydrogen in Agriculture

- ✚ **Ammonia-** Globally, 80% of the 180 million tons of ammonia made each year go towards making fertilizers. Around half of global food production relies on ammonia via the addition of mineral fertilizers. As the world population grows and quality of life increases, ammonia-based fertilizers will be more important than ever to ensure that

everyone has access to the food they need. Ammonia can be directly applied in agricultural settings or converted to other fertilizers such as urea. In direct applications, liquid ammonia is introduced 10 – 20 centimeters below the surface and reacts with water in the soil to produce ammonium ions (NH_4^+).

- ✚ **Seed germination-** Studies show that H_2 can promote the seed germination rate of winter rye and alfalfa. This finding may promote the application of hydrogen in improving the seed germination rate of plants
- ✚ **Regulation of flowering time-** It has been observed that roses and other plants change flowering time after treatment of hydrogen water. It was also found that hydrogen can regulate the expression of plant blossom related plant hormone receptor protein gene. This finding suggests that hydrogen water will have broad application prospects in horticulture.
- ✚ **Improvement of crop stress resistance-** Drought and salinity stresses often result in crop yield reduction and even death. Studies found that hydrogen water can improve the resistance ability of Rice, Arabidopsis and Medicago sativa plants to salinity, drought and other stresses. The crops irrigation or sprinkler irrigation using hydrogen water, will improve the stress resistance of crops, to achieve the purpose of disaster prevention and reduction.
- ✚ **Improvement of crop resistance to disease and pests-** The study has found that hydrogen can regulate the expression of receptor protein genes of many plants' hormone, including some plant hormones associated with disease resistance, such as salicylic acid and jasmonic acid. Irrigation of crops by the use of hydrogen water will likely improve crop resistance to pest and disease leading to substitute for pesticides or reduce the use of pesticides thus it protects environment and improve food security
- ✚ **Improvement of the quality of agricultural products-** Hydrogen water irrigation of crops, such as vegetables and fruits, might make them much more delicious.
- ✚ **Reducing fertilizer use-** H_2 can regulate the effects of plant hormones such as auxin, cytokine. Hydrogen water treatment can promote the growth of the plant. It has been observed that hydrogen water has a significant effect on the growth of mung bean plants. Therefore, in the future, hydrogen water may be attractively used to irrigate crops, promoting plant growth, and reducing the use of chemical fertilizers.

- ✚ **Beneficial effect on Soil and soil microorganism-** Naturally H_2 can typically be produced as a byproduct of N_2 fixation by nitrogen-fixing microbes and is consumed by the soil H_2 -oxidizing bacteria. Various H_2 -oxidizing bacteria are also known PGPR (plant-growth promoting rhizobacteria). The metabolism of H_2 by H_2 -oxidizing bacteria was responsible for the variation in the microbial community structure of the soil. H_2 can increase CO_2 fixation in soil, thus promoting soil carbon deposition, which may be associated with bacterial Rubisco activity of the soil. In addition, it has been observed to increase the contents of soil enzymes (including dehydrogenase, catalase, urease, and invertase) in H_2 -treated soil. Thereby, H_2 may improve soil fertility.



Indirect Use of Green Hydrogen in Agriculture

- ✓ Avoid climate change.
- ✓ Ensure sustainable agriculture.
- ✓ Reduce cost of production.
- ✓ Reduce cost of transportation.
- ✓ Reduce agricultural and municipal waste.

Direct Use of Green Hydrogen in Industrial and Allied Sectors

- ✚ **Clean Transportation-** One of the most promising applications of hydrogen is in transportation. Hydrogen fuel cells power electric vehicles, offering a cleaner and more efficient alternative to internal combustion engines. These fuel cells generate electricity by combining hydrogen and oxygen, producing only water vapor as a byproduct. With zero tailpipe emissions and the ability to refuel quickly, hydrogen-powered vehicles have the potential to revolutionize the automotive industry and reduce our carbon footprint.
- ✚ **Energy Storage-** Renewable energy sources like solar and wind power are intermittent in nature, making energy storage crucial for their effective utilization. Hydrogen can store excess energy produced during peak generation periods and release it when demand is high. This allows for a more stable and reliable grid system. Hydrogen energy storage can bridge the gap between energy supply and demand, ensuring a smooth integration of renewable energy sources into the existing power infrastructure.
- ✚ **Refining-** Oil and gas refineries use 33% of the hydrogen produced each year to remove sulfur from their products via hydro sulphurisation. Removal of sulfur increases the quality of the diesel and subsequent petrol products that these facilities produce. Any hydrocarbon containing sulfur can undergo a hydrodesulphurization reaction.
- ✚ **Methanol-** Production of methanol consumes 11% of the hydrogen that is produced each year. To produce methanol, a mixture of carbon monoxide and hydrogen called syngas is introduced into a reactor. Currently methanol is mostly used to make alternative fuels and olefins.
- ✚ **Power Generation-** Hydrogen can be utilized to generate electricity in power plants. By combining hydrogen with oxygen in a fuel cell, electricity is produced without the release of greenhouse gases. This offers a cleaner alternative to traditional power generation methods that rely on fossil fuels. Hydrogen-powered stationary fuel cells can provide electricity for homes, offices, and even remote areas where grid connectivity is a challenge.
- ✚ **Residential Heating and Cooking-** Hydrogen can be used as a clean and efficient fuel for residential heating and cooking applications. Hydrogen-powered boilers and stoves produce only water vapor when burned, eliminating harmful emissions such as carbon



monoxide and particulate matter. The use of hydrogen in homes can significantly improve indoor air quality and reduce the environmental impact associated with traditional fossil fuel-based heating systems.

- ✚ **Aerospace and Space Exploration-** The aerospace industry is also exploring hydrogen as a fuel source. Hydrogen-powered aircraft offer the potential for cleaner and quieter flights, reducing both carbon emissions and noise pollution. Moreover, hydrogen fuel cells can provide a reliable and long-lasting power source for space exploration missions, where weight and efficiency are critical factors.

Conclusion

Hydrogen's versatility and clean energy characteristics make it an invaluable resource for a sustainable future. From powering vehicles and industrial processes to providing electricity and heating solutions, hydrogen offers a myriad of applications to agriculture and allied sectors. As we strive to transition towards a low-carbon economy, harnessing the potential of hydrogen will be crucial. Continued research, development, and investment in hydrogen technologies will pave the way for a greener and more sustainable future, benefiting both our planet and future generations.

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