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# GREEN INSIGHTS

Newsletter on "Environment Literacy - Eco-labelling and Eco-friendly Products"

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# HYDROGEN

Sponsored by:
**Ministry of Environment, Forest and Climate Change, Government of India**
ENVIS Resource Partner on:
**Environment Literacy - Eco-labelling and Eco-friendly Products**

GREEN INSIGHTS
January - March 2022

# Contents





## Foreword

The environmental damage caused by industrialization and urbanization is evident by climate change such as extreme weather conditions in different parts of the world. Recent IPCC reports also warn against rising global temperatures, which will have an irreversible impact on living organisms. This has given rise to grave concern among world leaders. At COP 26 in Glasgow in 2021, numerous countries committed to reducing their net emissions to zero and reducing their greenhouse gas emissions. Lately, technology advancements and innovations are being made keeping 'Environment' in the center so as to achieve the "Sustainable Development Goals".

Green Hydrogen is now being considered as the most viable option to achieve net zero energy systems. It seems to have a lot of potential in global energy transitions. Today, usage of hydrogen is dominated by industry, namely- oil refining, ammonia production, methanol production and steel production.

Hydrogen based fuel is an attractive and greener option for transportation. In buildings, hydrogen could be blended into existing natural gas networks. In power generation, hydrogen is one of the prime options for storing renewable energy. Green Hydrogen is considered as environmentally friendly, as it has the potential for near-zero greenhouse gas emissions.

This issue of Green Insights sheds light on the current use of Hydrogen, different technologies used in the production of hydrogen and thereby the color coded on the same and Why it can be considered as a strong contender for the replacement of the non-renewable source of energy.

# Hydrogen: An energy carrier

As per IPCC report, human induced warming reached approximately 1°C (likely between 0.8°C and 1.2°C) above pre-industrial levels in 2017, increasing at 0.2°C (likely between 0.1°C and 0.3°C) per decade (high confidence). Globally many regions have experienced warming greater than usual, with higher average warming on land than on sea. This increase in temperature is attributed to the release of greenhouse gas (GHG) emissions such as carbon dioxide, methane, SOx, NOx etc. This rise in temperature brings about the change in the earth's system which results in climate change. The consequences of the climate change can be seen as severe droughts, forest fires, massive floods, melting of polar ice etc. To face this major challenge of climate change, global community has committed to taking action to keep the global temperature rise this century well below 2 degree Celsius, well below pre industrial levels. Many countries around the globe have pledge to net zero carbon dioxide emissions by committing to Sustainable Development Goals. Achieving these goals will need decarbonisation of economies, switching energy systems from fossil fuels to renewables like solar and wind. Energy transmission or shift from non-renewables to renewables in electricity generation could be possible with technological advancement and economic feasibility.

Henry Cavendish discovered the element in 1766

Hydrogen is considered as a strong contender to replace the non-renewables in the energy sector. Hydrogen has been mainly used as feedstock for industrial applications. At the present time, it is introduced as an energy carrier which will help in decarbonizing sectors such as transportation, building and industrial. Countries around the world are developing new hydrogen strategies and policies to promote the use of hydrogen through cost reduction and demand creation. The production of hydrogen has traditionally been carried out by extracting hydrogen from hydrocarbon resources, but in the near future, the use of renewable energy sources and $CO_2$-recovery fossil fuels will enable the reduction of $CO_2$ emissions.

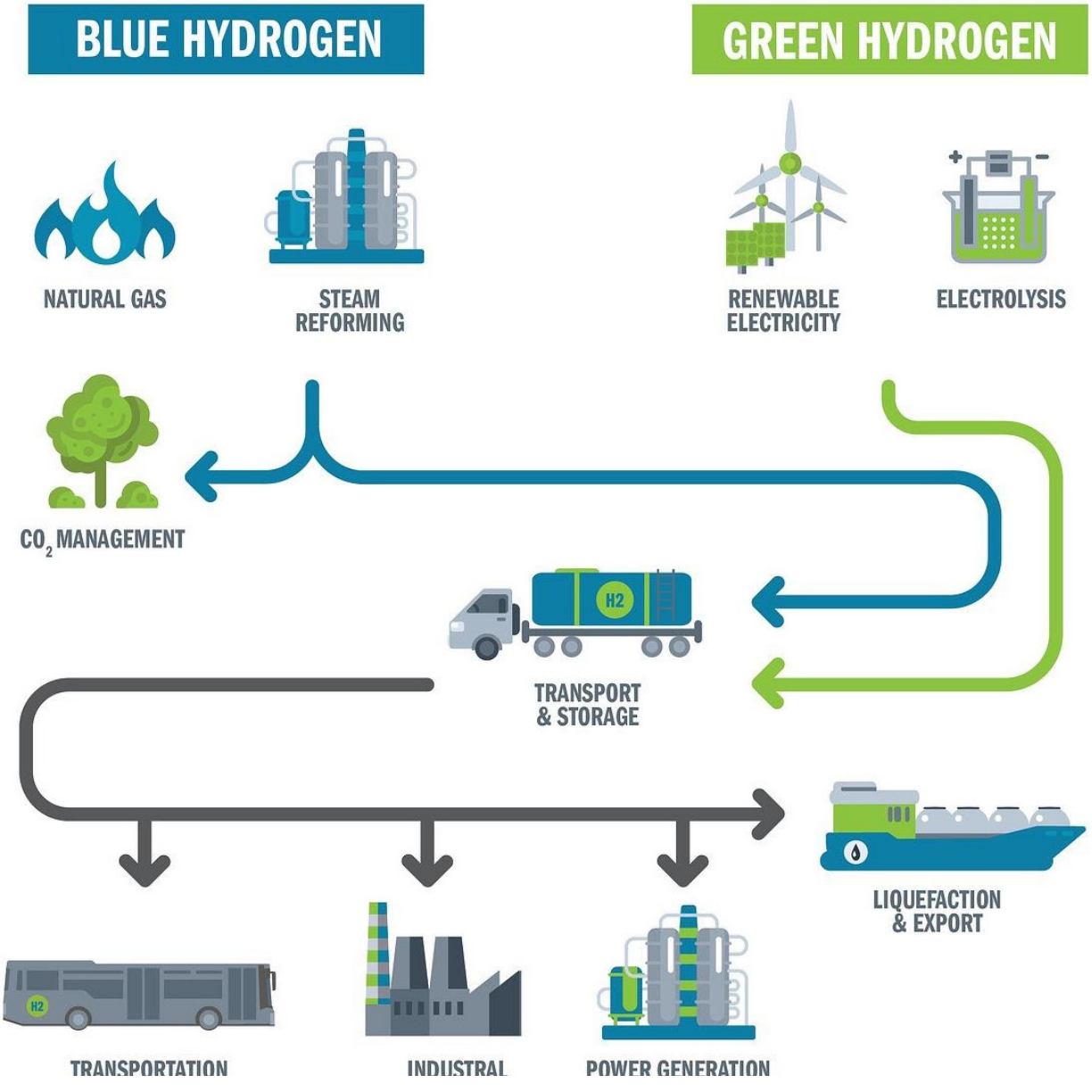
Hydrogen means "Creator (gen) of water (hydro): its combustion releases only water''

**Properties of Hydrogen:**

Hydrogen is number 1 on the periodic table. It has one proton and one electron. Since it has one unpaired electro, it is a free radical. When two hydrogen atom bond together they form a hydrogen molecule. It consists of two protons & two electrons. It is stable and has a neutral charge. Because it does not exist freely in nature, Hydrogen is produced from other sources of energy and hence it is called as an Energy Carrier. At standard temperature and pressure, hydrogen is a non-toxic, non-metallic, odorless, tasteless, colorless, and highly combustible diatomic gas with the molecular formula H2. The combustion of hydrogen does not produce carbon dioxide (CO2), particulate, or sulfur emissions.

**Hydrogen is the most abundant element on earth**

Hydrogen is a clean burning fuel and when combined with oxygen in a fuel cell, it produces heat & electricity with only water vapor as a byproduct. Hydrogen can be made directly from fossil fuels or biomass or by electrolysis (i.e by breaking water molecule).



# Hydrogen Production

Hydrogen can be produced from a wide range of resources like fossil fuel, nuclear energy, biomass and renewable energy sources. This can be done via number of processes. The resulting hydrogen is used as a carrier to provide energy. At the present time, the hydrogen production is mostly based on Steam Reforming of natural gas or coal, which amounts to a total of 95% of overall production.

The first industrial water electrolyser was developed in 1888

Sustainable way of producing hydrogen from a variety of feedstocks using diverse energy sources offers many possibilities for future. There are 7 key promising technology options for producing hydrogen that falls into the 3 broad categories as under:

1. Thermal Processes
2. Electric Processes
3. Photolytic Processes

**Thermal Processes:**
When the energy stored in coal or biomass is used to release the hydrogen contained in their molecular structure it is called Thermal processes. When heat in combination with closed chemical cycles is used to produce hydrogen from feedstocks such as water is called Thermochemical processes.

The following technologies fall under Thermal Processes:

- Distributed Natural Gas Reforming
- Bio derived Liquids Reforming
- Coal & Biomass Gasification
- Thermochemical Production

**A) Distributed Natural Gas Reforming:**
It is the most viable near term option. Here, the technology uses high temperature steam to reform the methane in natural gas into hydrogen and carbon dioxide.

Steam Reforming Reaction:

$CH_4 + H_2O$ ---- $CO + \boxed{3H_2}$

$CO + H_2O$ ----- $CO_2 + \boxed{H_2}$

Challenge is to scale down the equipment so as to operate cost effectively in a distributed mode at the fuelling stations.

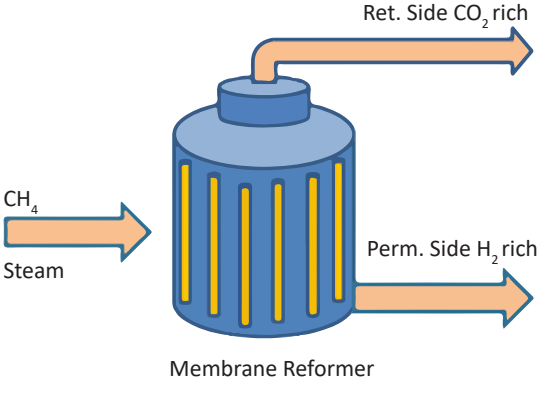



**Image Source:** https://www.sciencedirect.com/science/article/abs/pii/S0360319917346396

**B) Bio-derived liquids reforming:**
Liquids derived from biomass can be reformed into hydrogen using high temperature technologies. Some bio derived liquids offer potential to use lower temperature reforming which would greatly improve system efficiency & decrease reformer cost. Researchers are exploring another reforming technology known as aqueous – phase reforming. A wide variety of feedstocks such as sugars, sugar alcohols like ethanols, bio-oils, less refined sugar streams could be used.

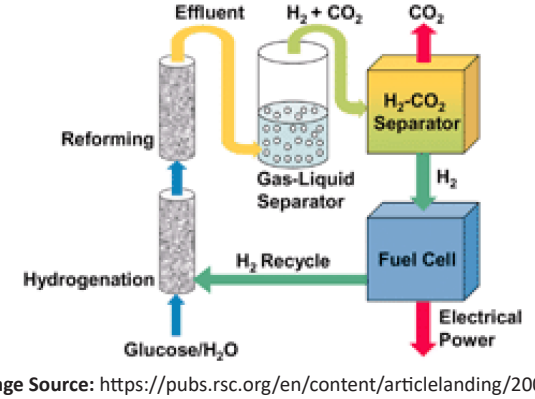



**Image Source:** https://pubs.rsc.org/en/content/articlelanding/2004/cc/b310152e

For near terms, ethanol is the most viable option as it is widely available. In future it could be possible to process biomass directly to hydrogen without first converting it into liquid.

### C) Coal & Biomass Gasification:

The gasification process can break down any carbon based feedstock into its chemical parts. When coal & biomass is subjected to modern gasifiers along with hot steams & controlled amount of air/ oxygen under high temperatures and pressures, chemical reaction happen breaking down the molecules into carbon monoxide & smaller amount of hydrogen along with other gaseous compounds. The CO is then subjected to water gas shift (WGS) to produce hydrogen.

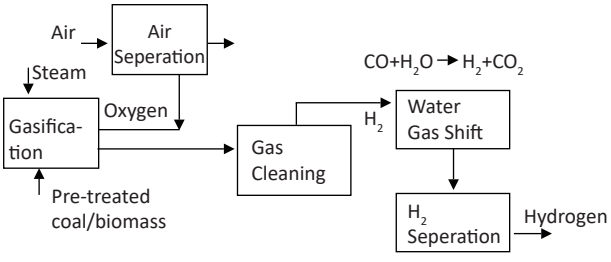



**Image Source:** https://www.energy.gov/eere/articles/hydrogen-clean-flexible-energy-carrier

Coal gasifers which are used commercially to produce power, chemicals & synthetic fuels produce huge amount of carbon dioxide. The challenge is to optimize the system for hydrogen production & develop lower cost methods to capture & store carbon. Cleaner Production through co-gasification of coal & biomass can address both the carbon issues related to coal & cost –supply issues related to biomass.

### D) Thermochemical Production:

Solar energy can be used to generate temperatures up to 2000 degree Celsius to trigger the chemical reactions to split water into hydrogen & oxygen. The chemicals that are used can be recycled. The process consumes only water & produces only hydrogen and oxygen. The challenge is the corrosiveness of chemicals at high temperature & economic feasibility.

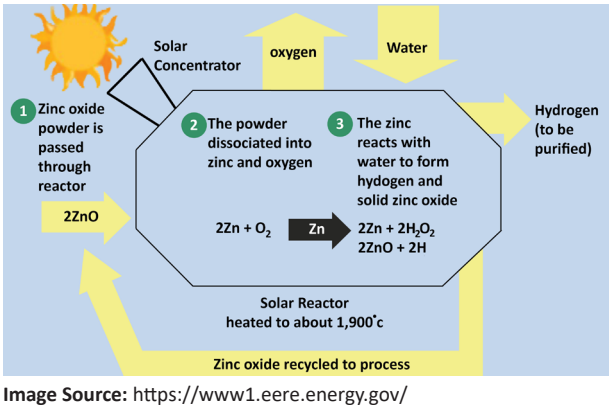



**Image Source:** https://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/h2_tech_roadmap.pdf

As the process is immature and more development & demonstration is needed. The potential materials include refractory metals, reactive metals, super alloys, ceramics, polymers & coatings.

### Electrolytic Process:

Hydrogen produced via electrolysis can resist zero greenhouse gases depending on the source of electricity used.

### A) Water Electrolysis:

Hydrogen is produced by splitting water using electricity. Electrolysis process releases no pollution or toxic byproducts. Low temperature water electrolysis takes up little place and so it can be set up at the onsite fuelling stations in the near term.

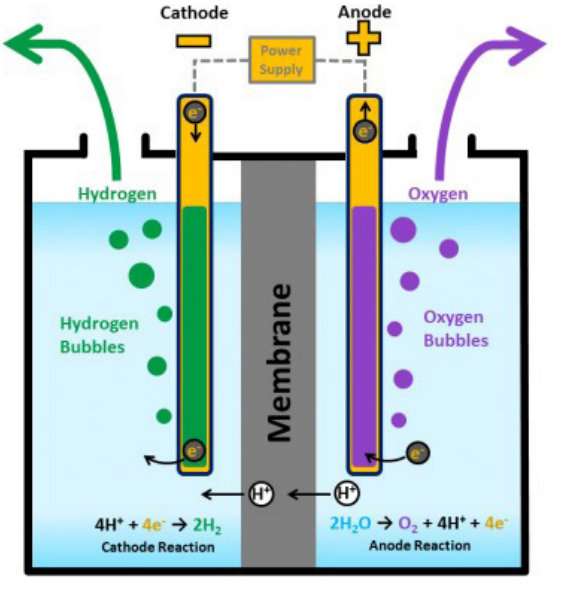



**Image Source:** https://www.pemteco.com/pfsaionmembrane/pem-water-electrolysis.html

The major drawback is the cost of electricity and carbon emission on the energy sources. Electrolysis is less efficient than a direct chemical path. To overcome the challenge, renewable powered (wind/ solar) water electrolysis at central or semi central facilities could be used.

### Photolytic process:

Photolysis, chemical process by which molecules are broken down into smaller units through the absorption of light. Hydrogen can be produced by the following two technologies that use photolytic process.

### A) Photo-electrochemical Hydrogen Production:

Production of Hydrogen using water & sunlight & semiconductor materials. The technology requires materials i.e. highly durable and efficient at photo-

electrochemical hydrogen production. Scientists have identified materials that split water efficiently & others that offer high durability. Research continues to search materials that meet both the criteria such as photo-electrochemical materials or coatings such as nano material coatings, metal doping or various hybrid material.

**B) Biological Hydrogen Production:**

Hydrogen is produced using sunlight and specialized micro orgainsms such as green alage, cyanobacteria to split water and produce hydrogen as byproduct. The challenge is oxygen produced along with hydrogen accumulate and impede the work of hydrogen evolving enzymes. The other challenge is the absorption of photons at a faster rate by the chlorophyll under bright sunlight. Here 80% energy gets wasted. This technology requires more research.

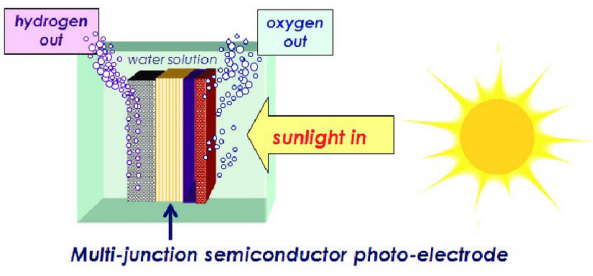



**Image Source:** https://www.researchgate.net/figure/Illustration-of-PEC-solar-hydrogen-production-using-a-semiconductor-photoelectrode_fig1_257712379

**Hydrogen Color Coding**

Hydrogen is color coded based on how it is produced. It could be grey, green, black, brown etc. These naming conventions can vary across countries and with time. Hydrogen on its combustion produces only water, but its creation is carbon intensive.

Green hydrogen has been hailed as a clean energy source for the future as it is `produced in a climate-neutral manner. It is also referred as "Clean Hydrogen". Energy from renewable source (Solar/ Wind) is used to split water into two hydrogen and one oxygen atom through the process called electrolysis. Green hydrogen is perceived as the best viable option as a renewable resource as excess energy can be stored and fed back into the grid when there is high demand. It can be considered as a decarbonizing alternative in industrial, transportation and chemical sectors.

| | | |
|---|---|---|
| | Grey Hydrogen | It is produced from natural gas or methane through the process called "Steam Reforming". Substantial amount of carbon produced is not captured. |
| | Black Hydrogen | It is produced through the steam reforming of Bituminous coal. Substantial amount of carbon produced is not captured. |
| | Brown Hydrogen | It is produced through the steam reforming of lignite coal. Substantial amount of carbon produced is not captured. |
| | Blue Hydrogen | It is also produced through steam reforming. And the carbon generated is captured and stored underground through industrial CCS (Carbon Capture System) |
| | Turquoise Hydrogen | It is produced when natural gas undergoes methane pyrolysis. This process produces carbon black which is easy to store compared to gaseous carbon dioxide. Carbon black has a separate market in itself and provides an additional revenue. This production is at a pilot stage. |
| | Pink Hydrogen | It is produced through the process of electrolysis using nuclear energy (non-renewable resource) as the source of power. |
| | Green Hydrogen | It is produced through the process of electrolysis of water using renewable energy i.e. wind & solar. |

**Hydrogen Application in current use:**

**1. Oil refineries:**

- Hydro-desulfurisation (HDS): Removal of sulphur from Natural Gas and other refined petroleum products such as diesel, kerosene, petrol, jet fuel etc.
- Hydrocracking operations: Cracks the larger molecules of heavier refinery products to smaller ones.

**2. Agriculture:**

Production of Ammonia as fertiliser

**3. Food Industry:**

To convert unsaturated fats to saturated oils & fats. i.e to make hydrogenated vegetable oils such as margarine and butter.

**4. Metalworking:**

Hydrogen is used in multiple applications including metal alloying and iron flash making.

**5. Welding:**

Atomic hydrogen welding (AHW) is a type of arc welding which utilizes a hydrogen environment.

**6. Production of flat glass sheets:**

A mixture of hydrogen and nitrogen is used to prevent oxidation and therefore defects during manufacturing.

**7. Electronics Manufacturing:**

As an efficient reducing and etching agent, hydrogen is used to create semiconductors, LEDs, displays, photovoltaic segments, and other electronics. Manufacturing of silicon chips etc.

**8. Medical:**

Hydrogen is used to create hydrogen peroxide ($H_2O_2$). Recently, hydrogen gas has also been studied as a therapeutic gas for a number of different disease

**9. Coolant:**

Hydrogen is already used for cooling power plant generators

**10. Space Exploration:**

Liquid Hydrogen used as a rocket fuel by National Aeronautics and Space Administration (NASA)

**11. Production of Cyclohexane**

(Intermediate in Plastic production)

**12. Production of Methanol**

(Intermediate in production of Pharmaceuticals)

**13. Searching Gas:**

Hydrogen is used in many manufacturing plants to check for leaks, since its environmental impact is less than that of the CClF3-based gases

**14. Reducing Agent:**

Hydrogen is the key element involved in redox reactions. It is used in the manufacture of plate glass, for instance, to prevent the formation of stannous oxide (SnO) in the float bath.

**15. Gas Chromatography:**

Hydrogen is one of the gases which can be used as carrier phase in gas chromatography, used to separate volatile substances.

# Green Hydrogen: An alternative renewable future


The modern world economy is highly dependent on oil price shocks. Oil demand is always on its zenith as almost all of the industrial sectors and transportation sectors run on oil. The technological advances till now have been made based on the consumption of fossil fuels. Mankind has ferociously used fossil fuels to satisfy various needs that now it is on the brink of elimination. Use of non-renewables have a great impact on the climate as it releases greenhouse gases thus creating air pollution and climate change. It is time to change to renewable resources and cease the dependency on the conventional sources.

Many innovations and efforts have been made in technological advances to shift the paradigm on environment friendly resources and ways. Now a days the buzz word is **"Green Hydrogen"**.

Hydrogen is considered as the topmost Global Green Agenda, as it can be used as a fuel, a carrier and a store of energy which is carbon free. It is cleaner than coal, diesel and heavy fuel oil and could be used as a substitute for natural gas.

In November 2021, COP 26 in Glasgow, many countries round the globe have committed themselves in making a drastic reduction in greenhouse emissions. India made 5 commitments such as achieve Net Zero by 2070, and by 2030, take cumulative non fossil fuel generation capacity to 500 GW, meet 50 percent of energy needs from renewable energy, reduce the energy intensity of the economy by 45 percent, and reduce carbon emissions by 1 billion tons.

On August 15, 2021, India's Prime Minister Narendra Modi announced a **"National Hydrogen Mission to make India a Global Hub for Green Hydrogen Production and Export", boost "energy self-reliance" and "inspire" "Clean Energy Transition all over the world" through Green Growth" and "Green Jobs"**. India has become the **18th country** to release a comprehensive green hydrogen policy.


**Image Source:** https://finshots.in/archive/understanding-indias-green-hydrogen-policy/

The policy envisaging a tangible strategy for developing a green hydrogen economy sets in motion the process of decarbonisation of 'hard to abate' sectors such as steel, cement industries, and long-haul transportation. The policy offers a bouquet of incentives to green hydrogen producers for RE power procurement:

- Waiver of interstate transmission system (ISTS) charges for 25 years for projects commissioned before June 30, 2025

- Access to renewable energy through State utilities with 30 days of banking facility (mechanism to store and withdraw surplus renewable power)
- Priority access to connectivity with the ISTS network.
- Purchase of RE from power exchanges, and expedited access to open access mechanism.
- Distribution utilities directed to procure and supply RE power to hydrogen and ammonia producers at nominal wheeling charges.
- Green hydrogen producers can avail land in solar parks across states for establishing their production units. They would also be allowed to establish bunkers near ports for use by the maritime sector and export.
- To streamline the procurement process and ensure competitive pricing, the Ministry of New and Renewable Energy (MNRE) has been directed to consolidate demand from various sectors, and procure green hydrogen through the competitive bidding route

Although efforts are being made to streamline Green Hydrogen in our daily lives. Currently there are some barriers to uptake Green Hydrogen such as High Production Costs. Green Hydrogen produced by an average VRE plants is 2-3 times more expensive than Grey Hydrogen.

Vehicles with fuel cells and Hydrogen tanks are 1.5-2 times costlier than their fossil fuel counterparts. Even today, synthetic fuel used for aviation is much more costly than the fossil fuel jet fuel. Till date most of the used is from where it is produced. The natural gas infrastructure could be repurposed for hydrogen. There is a lack of value recognition that needs to be immediately addressed. There is no Green Hydrogen market or no valuation for lower Greenhouse gas emissions. Bulk consumers of hydrogen from the industrial sectors are unlikely to transition to low carbon alternatives because of higher associated costs and no incentives or valuation for reduced emissions.

Currently a niche technology, Green Hydrogen needs to get into the mainstream. For which, there should be round the clock generation of Green Hydrogen. There should be flexibility on hydrogen conversion to energy carriers and have a decarbonized power system. Green Hydrogen corridors should be developed which should connect the regions generating low cost renewable energy with demand centers. This can be done through long term signals such as net zero emissions. Short term policies should close the investment and operational gaps. These include R7D funding, risk mitigation policies and co-funding.

**Source:**


1. https://www.moneycontrol.com/news/opinion/green-hydrogen-policy-a-giant-leap-for-indias-climate-aspirations-8148491.html
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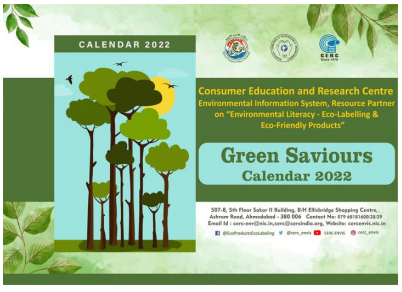
Cover page photo source:
https://www.azocleantech.com/article.aspx?ArticleID=1443

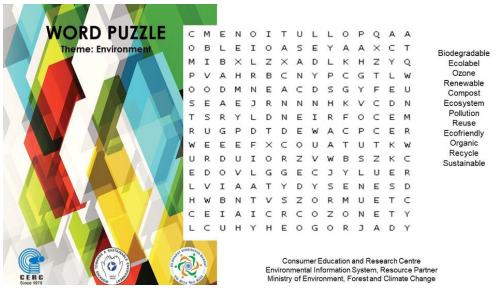
Back page photo source:
https://www.eqmagpro.com/cabinet-nod-sought-for-setting-green-hydrogen-purchase-obligation-for-refineries-fertiliser-plants-r-k-singh-eq-mag-pro/

# Events (January-March 2022)

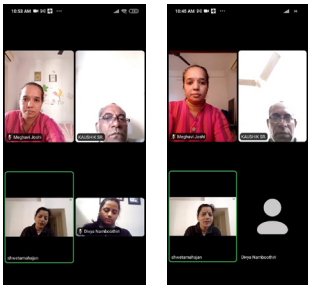



E-Calendar 2022 on 'Green Saviours'

**Link:** http://cercenvis.nic.in/PDF/Calendar2022.pdf



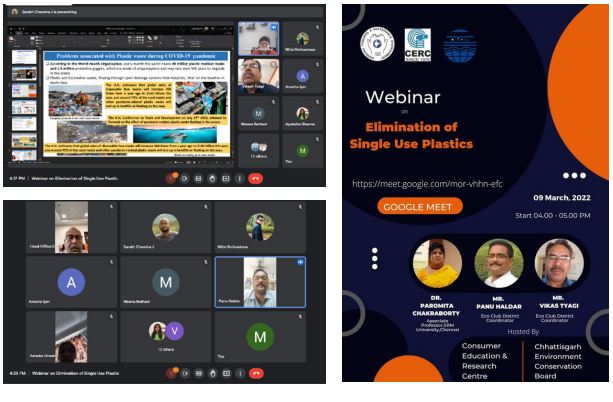

Word Puzzle Challenge on the theme of Environment under Ek Bharat Shreshtha Bharat Programme



Online session on Domestic Energy usage, Conservation and Energy saving, Introduction to home energy audit

Inaugural Ceremony of GSDP Certificate Course on 'Laboratory Technicians for Energy Efficiency, Star Labeling and other Electrical Testing for Environmental Criteria'

Inaugural Ceremony of GSDP Certificate Course on 'Laboratory Assistant for Eco friendly Food Testing Laboratory'




Webinar on Elimination of Single use Plastics under Ek Bharat Shreshtha Bharat Programme


Posters on various environmental themes


The Environmental Information System acronymed as ENVIS was implemented by the Ministry of Environment & Forests by end of 6th Five Year Plan as a Plan Scheme for environmental information collection,collation, storage, retrieval and dissemination to policy planners, decision makers, scientists and environmentalists, researchers, academicians and other stakeholders. The Ministry of Environment and Forests has identified Consumer Education and Research Centre (CERC), Ahmedabad, as one of the Resource Partners to collect and disseminate information on "Environment Literacy - Eco-labelling and Eco-friendly Products". The main objective of this ENVIS Resource Partner is to disseminate information on Eco products, International, and National Eco labeling programmes.

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