Hydrogen: The Future's Fuel

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Abstract
The exploitation of fossil fuels at a tremendous scale, especially after the industrial revolution in the 18th century, has instigated damage to the environment. The usage of fossil-based fuels results in an excess accumulation of greenhouse gases (GHGs), i.e., mainly CH₄ and CO₂, in the atmosphere. This is the reason for decreased air quality, increased global warming, and disturbed seasonal variations in many world regions. The usage of Hydrogen (H₂) as a fuel is a promising alternative to fossil fuels due to its high calorific value, clean-burning characteristics, and abundance availability from different feedstocks. H₂ can be a game-changer in the fuel industry especially if utilized commercially in transportation sector giving net-zero carbon emission. The recent research is going on the techno-economic feasibility of H₂ production, and recently an Indian Oil & Gas conglomerate Reliance Industries pledged to produce blue H₂ at $1.2-$1.5/Kg. The concept of the H₂ economy is encouraging and supports the pledges of the Paris Agreement. The different H₂ production techniques, along with the corresponding color spectrum, have been discussed in this article. Finally, the prospects and advantages of green H₂ have been discussed over its other color spectrum.

Short Communication
‘Necessity is the mother of invention’ there is no doubt in this proverb by Plato. However, human is greedy, and due to this thirst to achieve bigger, the necessity becomes the sole objective of making profits. The industrial revolution in the 18th century began and was welcomed by different nations of the world, which helped attain a better standard of living. However, the development becomes a curse due to its sustainable nature. So is the case with the over exploitation of fossil fuels. The fossil fuel is formed in millions of years under the earth's crust, whereas it has been exploited over 75% in only two centuries. This tremendous usage of fossil fuels in a brief period resulted in the accumulation of GHGs in the earth's atmosphere.
accumulation of GHGs in the atmosphere at such a pace resulted in the intense change in the climate all over the world. The deterioration in air quality, the rising global temperature, droughts, flooding are some of the visible consequences of present scenarios. The Paris Agreement held in 2015 aimed to control the global temperatures and their devastating consequences, which, however, seems unattainable to date. A promising alternative is needed (i.e., both in terms of techno-economic feasibility and carbon free), which could act as a game-changer in the energy sector, and to control the destructive results caused by the usage of fossil fuels. H₂ usage can help in significant control of air quality if used in transportation sector by reducing the air pollution by 80%. Currently H₂ produced from polymer electrolyte membrane (PEM) electrolyzers cost in the range of ~$5-$6/Kg, which is the most economic price as per the reports of DOE, USA. Further, the Indian Oil and Gas conglomerate Reliance industry pledged to deliver the economic blue H₂ in the market at the rate of $1.2-$1.5/Kg by investing a sum of $4bn in H₂ energy sector. About 87% of total H₂ is produced globally in 2020 which constitute around 1% of world’s energy consumption, which is expected to increase to 4% in 2030 and 13% by 2050, as per the reports of IEA.

The H₂ is one such potential alternative fuel that could replace the fossil fuels from the market in the future. The H₂ has several added benefits over fossil-based fuels, which encourages researchers to commercialize it globally. The H₂ on combustion gives out only water, which makes it clean fuel. Further, it has a high calorific value when compared to fossil-based fuel and an abundance of cheap feedstock in the form of water if economic limitations are resolved. Fossil-based fuels can be utilized for H₂ production via reforming techniques. Also, due to increased emphasis on biodiesel production in the future, its waste bi-product, i.e., glycerol can be used as a rich feedstock for H₂ production, supporting the concept of waste to energy and circular economy. The H₂ produced, however, is of utmost benefit if it is green hydrogen to support sustainable development.

The H₂ spectrum based on the process adopted for its production and the source of energy used has been summarized in Table 1.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Class of H₂ Fuel</th>
<th>Production method</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Green</td>
<td>Electrolysis of water</td>
<td>The process is mainly solar, or wind powered.</td>
</tr>
<tr>
<td>2.</td>
<td>Blue</td>
<td>Splitting natural gas into H₂ and CO₂ via reforming processes</td>
<td>CO₂ produced with H₂ during the reforming process is captured and stored.</td>
</tr>
<tr>
<td>3.</td>
<td>Grey</td>
<td>H₂ is produced via fossil fuels like natural gas by gas reforming processes</td>
<td>CO₂ generated during the process is not captured and is released free into the atmosphere.</td>
</tr>
<tr>
<td>4.</td>
<td>Pink</td>
<td>Electrolysis of water</td>
<td>The process is mainly powered by nuclear energy.</td>
</tr>
<tr>
<td>5.</td>
<td>Turquoise</td>
<td>Pyrolysis of CH₄ is done to produce H₂</td>
<td>The carbon produced is stored in the solid form.</td>
</tr>
<tr>
<td>6.</td>
<td>Black or Brown</td>
<td>Gasification techniques</td>
<td>Black (bituminous) or brown (lignite) coal is used for gasification. This is most damaging to the environment.</td>
</tr>
<tr>
<td>7.</td>
<td>White</td>
<td>Naturally occurring H₂ present underground in geological formations</td>
<td>These H₂ deposits are formed via fracking. Presently they cannot be exploited because of technical limitations.</td>
</tr>
</tbody>
</table>
Around 90% of the world’s H\textsubscript{2} produced is grey in nature and produced from reforming fossil-based fuels.\textsuperscript{18–22} The green H\textsubscript{2} is beneficial for replacing fossil-based fuels and will help eliminate the carbon footprints.\textsuperscript{23,24} Hence, it can be concluded that the various colors of H\textsubscript{2} production will vanish with time, whereas others will shine. Therefore, it may be summarized that the future of the H\textsubscript{2} economy lies in the green, blue, and turquoise H\textsubscript{2}. This is due to the carbon capture scheme and the corresponding clean H\textsubscript{2} production methodology. This predictive analysis is supported by the latest multibillion-dollar projects adopted by different private sectors and governments. The USA, U.K., Arabian Peninsula, Russia, and China are thriving very hard to be the largest stakeholder in the world of the H\textsubscript{2} economy.

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References


