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Hydrogen Energy: 101

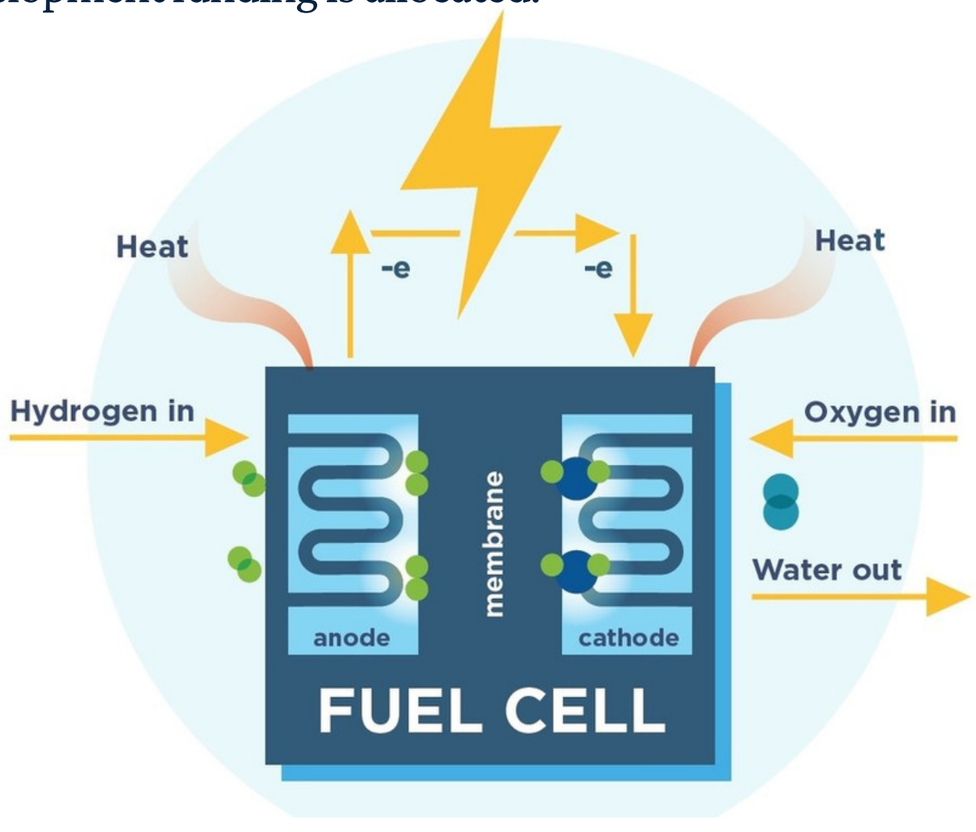
What is Hydrogen Energy?

The pursuit of clean and abundant energy has brought hydrogen to the forefront of the discussion. Hydrogen energy, once only discussed in its potential applicability to vehicles, has grown into a key piece of the United States' future energy mix. The opportunity hydrogen energy presents has prompted the federal government to earmark billions of dollars for the development of hydrogen energy and associated systems within the United States.

Hydrogen is the most abundant element in the universe, composing 75% of all mass [11]. However abundant, it is not easily accessible in its gaseous form as most hydrogen on the planet exists within matter, including water, plants, and other living materials. Though scarce as a gas, hydrogen can be separated from other elements, collected, and then used in fuel cells to generate electricity.

What are Fuel Cells?

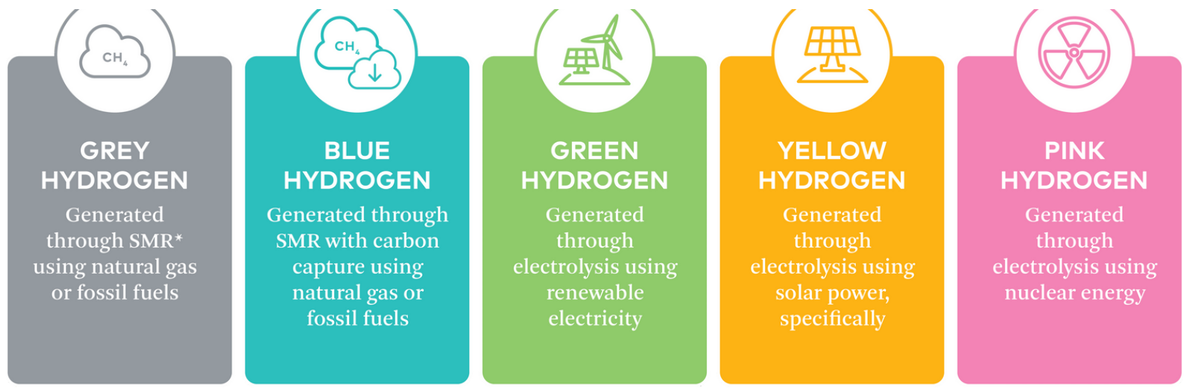
A hydrogen fuel cell is a device that creates electricity through chemical reactions between hydrogen and oxygen. Within a fuel cell, hydrogen and oxygen are mixed in an electrochemical cell, yielding heat, water, and most importantly, energy [10]. Fuel cells have been used in small specialized applications like spacecraft, passenger vehicles, and some electricity generation. The modern vision of hydrogen fuel cells is to be able to generate electricity at the utility scale, which is where much of the research and development funding is allocated.



Source: Fuel Cell & Hydrogen Energy Association

The Many Colors of Hydrogen

Though hydrogen energy creation happens in fuel cells, the sources of that hydrogen can be very different. For that reason, the various sources of hydrogen energy have been color coded, denoting the method in which the hydrogen was harvested for use. The common classifications are as follows:



Source: 3Degrees

Green

Green hydrogen is created using renewable energy sources to produce hydrogen from water using electrolysis. Electrolysis is a process in which hydrogen and oxygen compounds within water are split through an electrochemical reaction in an electrolyser. Hydrogen is collected as a byproduct of the reaction to be used in fuel cells. Green hydrogen also has the added benefit of not producing any carbon dioxide as a byproduct of the process, but is limited by the economics and current scalability [5].

Blue

Blue hydrogen is created using natural gas through the process of steam methane reforming (SMR). With blue hydrogen, methane gas is processed through a steam reformer, which uses a series of chemical reactions to generate hydrogen from chemical reactions between methane and high-temperature steam [7]. However, hydrogen is not the only product of this process, as carbon dioxide is also created as a byproduct which necessitates the use of carbon capture to prevent the carbon dioxide from entering the atmosphere.

Grey

Grey hydrogen uses the same process as blue hydrogen, but does not include a carbon capture component. Because grey hydrogen does not use carbon capture, carbon dioxide created as a byproduct is typically released into the atmosphere.

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Black/Brown

Black and brown hydrogen uses coal as a feedstock to harness hydrogen from within the coal. This process utilizes coal gasification, which is when coal is heated to extremely high temperatures, cooled, and then purified yielding a combination of pure hydrogen and carbon dioxide [6]. Carbon capture can be used in this method, but is not imperative to be considered black or brown hydrogen.

Pink

Pink hydrogen, like green hydrogen, uses water electrolysis to capture hydrogen, but uses nuclear energy, not renewables, as the power source.

Opportunities & Challenges

Hydrogen energy has attracted much attention, and investment, due to its potential as a solution for several challenges faced in the United States today.

Decarbonization

Hydrogen energy could play a significant role in decarbonizing efforts. The ability to separate and store hydrogen in low or non-emissive ways would naturally reduce power generation-borne emissions. [4]. Hydrogen also has the potential to decarbonize previously hard-to-decarbonize industries like the steel and ammonia industries [8].

Energy Security

Diversifying the American energy mix strengthens its security. The addition of hydrogen energy helps reduce the United States' reliance on traditional energy systems like fossil fuels, allowing for those fuels to be exported to other nations [1].

Environmental

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Challenges

Hydrogen faces several challenges that need to be mitigated for its successful uptake into the American energy system. Primarily, the issues of economics and scalability are key inhibitors. More specifically, production costs associated with hydrogen are still too high to make it economically feasible. However, an analysis conducted by the International Energy Agency (IEA) predicts that falling costs of renewable energy will also bring down the cost of producing hydrogen by 30 percent by 2030 [3]. For hydrogen to be scalable to a national level, major development of related infrastructure, ancillary systems, and regulations must occur.

Relevant Policies

The federal government has recently made significant investments in hydrogen energy. The Bipartisan Infrastructure Law and the Inflation Reduction Act lay out funding opportunities and tax credits related to clean hydrogen's development. The two pieces of legislation earmark funds for specific aspects of hydrogen energy development and include the following:

- $1.5 billion for research and development of electrolysis systems,
- $8 billion for the Regional Clean Hydrogen Hubs program, which seeks to create between six and ten regional hydrogen hubs (H2Hubs) in the United States,
- Tax credits for clean hydrogen production, and
- Approximately $300 billion in loans were made available for clean hydrogen projects. [2]

Other policies directing hydrogen energy's development include:

- Department of Energy's National Clean Hydrogen Strategy & Roadmap,
- Energy Independence and Security Act of 2007,
- Energy Policy Act of 2005, and
- Energy Policy Act of 1992

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Works Cited

[1] Alternative fuels data center: Hydrogen benefits and considerations. (n.d.). U.S. Department of Energy. https://afdc.energy.gov/fuels/hydrogen_benefits.html

[2] The economics of demand-side support for the Department of Energy's clean hydrogen hubs | CEA | the white house [Press release]. (2023, June 5). The White House. https://www.whitehouse.gov/cea/written-materials/2023/07/05/the-economics-of-demand-side-support-for-the-department-of-energys-clean-hydrogen-hubs/#:~:text=Meanwhile,%20the%20Bipartisan%20Infrastructure%20Law,storage,%20and%20end-use

[3] The future of hydrogen. (2020). International Energy Agency. https://www.iea.org/reports/the-future-of-hydrogen

[4] Hydrogen. (n.d.). International Renewable Energy Agency. https://www.irena.org/Energy-Transition/Technology/Hydrogen

[5]The hydrogen colour spectrum. (2023, February 23). National Grid Group. https://www.nationalgrid.com/stories/energy-explained/hydrogen-colour-spectrum

[6] Hydrogen production. (2016, April 1). U.S. Department of Energy. https://www.energy.gov/eere/fuelcells/articles/hydrogen-production-fact-sheet

[7] Hydrogen production: Natural gas reforming. (n.d.). Energy.gov. https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

[8] Kurrer, C. (2020). The potential of hydrogen for decarbonising steel production (PE 641.552). European Union. https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/641552/EPRS_BRI(2020)641552_EN.pdf

[9] Regional clean hydrogen hubs. (n.d.). U.S. Department of Energy. https://www.energy.gov/oced/regional-clean-hydrogen-hubs

[10] Use of hydrogen. (2023, June 23). U.S. Energy Information Administration. https://www.eia.gov/energyexplained/hydrogen/use-of-hydrogen.php

[11] What is hydrogen? (2023, February 23). National Grid Group. https://www.nationalgrid.com/stories/energy-explained/what-is-hydrogen

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Fuel Cell & Hydrogen Energy Basics [Image]. (n.d.). Fuel Cell & Hydrogen Energy Association. https://www.fchea.org/h2-day-2019-events-activities/2019/8/1/fuel-cell-amp-hydrogen-energy-basics

Navigating the complex world of hydrogen fuel in the transportation market [Image]. (n.d.). 3Degrees. https://3degreesinc.com/resources/hydrogen-production-exploring-various-methods-climate-impact/