Hydrogen Energy: Production of Electricity using Fuel Cells and Hydrogen-burning Generators

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Abstract

This project is an exploratory study of the use of hydrogen for sustainable energy systems. The use of hydrogen as a green and sustainable fuel produced from renewable energy sources is one of the solutions being developed for addressing the global warming challenge and moving our energy systems to sustainable platforms without losing the modern comforts of life. While hydrogen has a lower volumetric energy density (kJ/L) than fossil fuels such as coal, diesel, and jet fuel (kerosine), its gravimetric energy density (MJ/kg) is greater. Hydrogen produces electricity in two ways: fuel cells and hydrogen-burning generators.

The primary benefit of hydrogen is that it is generated from water by electrolysis using electricity, and when it is used to generate electricity, water is the only product released. Hydrogen is attractive because it can serve as a mass energy storage medium to bridge the gap between the production and demand of electricity when we depend on renewable energy sources such as wind and solar energy, which are intermittent. Fuel cells and hydrogen-burning generators generate electricity. Fuel cells use hydrogen to be the source of electricity for 1 MW-level loads and to produce electricity in hydrogen-fueled electric cars, delivery vans and semi-trucks.

The project explored hydrogen as a green energy carrier and a large-scale energy storage medium to enable the rapid integration of renewable energy sources into the electric grid. The goal of this project is to explore, learn, and share the knowledge of the potential of hydrogen as a sustainable green fuel.

References

Bains, et al. “Global Hydrogen Review 2023”, *International Energy Agency (IEA)*, December 2023, https://www.iea.org/reports/global-hydrogen-review-2023.

Andrews, et al. “Net Zero Roadmap A Global Pathway to Keep the 1.5˚ C Goal in Reach”, *International Energy Agency (IEA),* 2023*,* https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach.

Blanco, et al. “The Future of Hydrogen”, *International Energy Agency (IEA),* June 2019, https://www.iea.org/reports/the-future-of-hydrogen.

“Sources of Greenhouse Gas Emissions”, *United States Environmental Protection Agency (EPA),* February 23, 2024, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

Methods

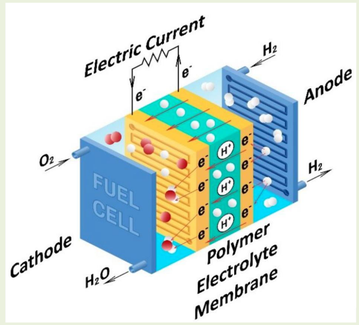
- Talked with experts such as my UROP advisor, Professor Sastry Pamidi, and researchers and graduate students of his group at the Center for Advanced Power Systems.
- I used many publications from the International Energy Agency, the United States Department of Energy, and other research publications. I read the material, discussed it, and asked questions during weekly sessions with my advisor.
- Additional reading material is suggested during the meetings to help crystalize my understanding of the concepts.
- The weekly research group meetings included discussions with my fellow UROP students working on the broad topic of hydrogen as a sustainable energy carrier for many applications. We learned from one another, mediated by my advisor.

Background

If global warming is not addressed, the climate will continue to warm and inevitably cause the planet to be inhabitable for humans. That is why it is crucial that countries continue to incorporate green energy. While there are a lot of contributing factors into the carbon emissions causing harm to this planet, electricity is the focus of this research. In 2021, 25% of greenhouse gas emissions came solely from electricity. In that same year, 60% of the electricity came from fossil fuels (United States Environmental protection Agency, 2024).

The demand for electricity will never go down, which is why it is important to begin incorporating green energy to phase out the use of fossil fuels. The combination of solar, wind, and hydrogen energy will lower carbon emissions. Some renewable energy sources are intermittent, such as solar and wind energy, which is why one source alone will not work to reach the goal of Net Zero carbon emissions. As time goes on, the need for large scale storage will increase for these renewable sources, and hydrogen can be the source that makes this possible.

Currently, up to 20% hydrogen is mixed with natural gas in hydrogen-burning generators to produce electricity. Significant investments are being made by federal and state governments, industry, and R&D institutions to redesign the generators to burn 100% hydrogen (IEA). Over time as hydrogen energy is implemented into our current energy sources, the goal of Net Zero emissions will be reached.



Fuel-cell electricity generator

Source: https://www.mathworks.com/discovery/fuel-cell-model.html

Hydrogen burning electricity generator

Source: https://www.eo-dev.com/products/geh2-the-zero-emission-hydrogen-power-generator

Conclusions

Using green hydrogen as an energy carrier is one of many solutions to the climate crisis. Over time, the investments by the government and private funds will increase access to green hydrogen technologies for everyday use. According to the International Energy Agency’s Global Hydrogen Review for 2023, “...several utilities announced plans to build new gas power plants or to upgrade existing gas power plants to be H2-ready, i.e., able to co-fire a certain share of hydrogen” (IEA 2023, p. 43). In other words, actions are being taken to produce zero or low-emission electricity. With investments and time, hydrogen infrastructure will be ready to fuel transportation systems such as semitrucks, airplanes, and cars.

The switch to hydrogen cannot be immediate. The usage of fossil fuels needs to be scaled down as the use of hydrogen grows. The IEA states, “Running ahead on scaling back fossil fuel investment before clean energy investment ramps up would push up prices and risk price spikes, and this would not necessarily advance secure transitions” (IEA 2023, p.162). The article continues to explain that clean energy investment is urgently needed to begin the switch to sustainable and emissions-free energy. Producing hydrogen fuel cells and hydrogen-burning generators will need investments, political support, and social awareness.

My research shows that the future of energy is “green.” Net zero carbon emissions is possible with the adoption of hydrogen in the energy mix. While there are many contributing factors to using fuel cells and internal combustion engines, one thing remains clear: green hydrogen technologies will save the world.

Acknowledgements

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