CleanEnergyGroup

Green Hydrogen: Costs, Availability, and Risks

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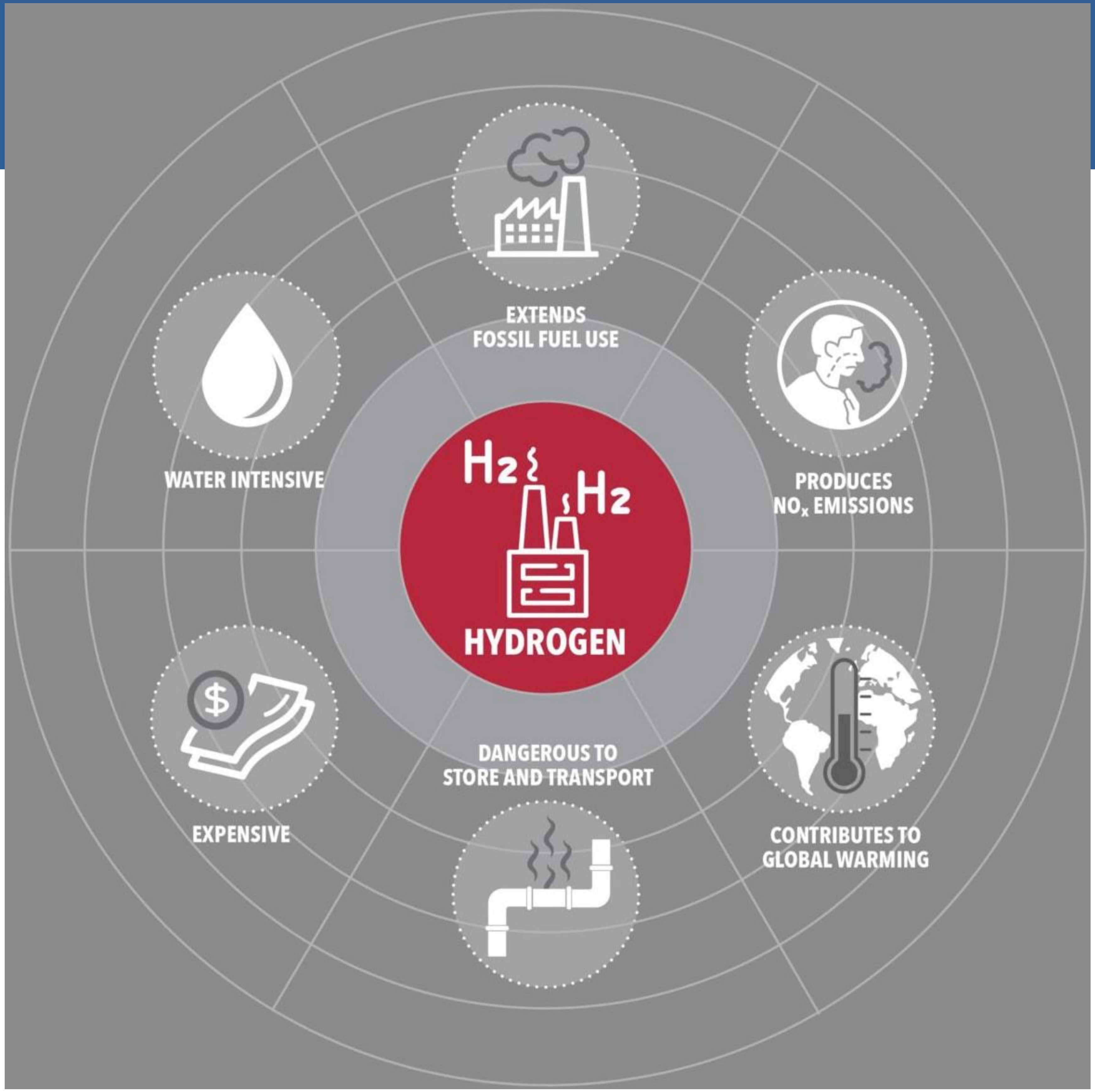
Hydrogen Information & Public Education

Raising awareness of the health and environmental impacts of hydrogen production and use.



NYLPI JUSTICE THROUGH COMMUNITY POWER

EARTHJUSTICE BECAUSE THE EARTH NEEDS A GOOD LAWYER

THE POINT

UPROSE

www.cleanegroup.org/initiatives/hydrogen

Types of Hydrogen Generation – the "Rainbow"

Carbon intensive	Grey Hydrogen	Hydrogen produced from natural gas via a process called steam methane reformation (SMR), without carbon capture. 95% of hydrogen produced today is grey hydrogen.
	Blue Hydrogen	Hydrogen produced from natural gas via SMR, but with carbon capture deployed during the process to capture production-related carbon emissions.
	Turquoise Hydrogen	Hydrogen produced by splitting natural gas into methane, hydrogen, and solid carbon black.
	Gold or Orange Hydrogen	Produced by pumping a mix of CO2 and microbes into depleted oil wells, paired with carbon capture.
Carbon free	Green Hydrogen	Hydrogen produced via a process called electrolysis, in which an electric current is run through water to separate the hydrogen and oxygen molecules. If that electricity comes from renewable energy, the hydrogen is considered green. There are no carbon emissions associated with this process .
	Pink Hydrogen	Hydrogen produced via electrolysis, but the electrolyzer is powered by nuclear energy.
	White Hydrogen	Naturally occurring hydrogen found in underground deposits.

Why Defining Green Hydrogen is Important

- Green hydrogen, blue hydrogen, and more recently, gold/orange hydrogen, are often conflated under the umbrella term "clean hydrogen."
- However, only green hydrogen produced via renewable-powered electrolysis is truly carbon-free.
- This definition is even more important now because of recently released draft guidance by the Treasury for the 45V Clean Hydrogen Production Tax Credit.
- 45V is a tiered incentive based on CO2-equivalent emissions. Carbon-free hydrogen is eligible for a $3.00/kgH2 credit.
- To be eligible for the highest tier of the 45V credit, hydrogen projects must demonstrate:
  - **Temporal matching:** every hour of electrolytic production is matched by an hour of renewable energy production using Energy Attribute Certificates (EACs).
  - **Additionality:** hydrogen production must be powered by new renewable energy resources, built within three years of the hydrogen facility, not existing ones.
  - **Localized production:** renewable energy resources must be located within the same region as the hydrogen production facility.

Availability of Green Hydrogen

- Without 45V, **a green hydrogen production facility is unlikely to be financially viable in the next 10 years,** due to:
- **Efficiency:** Electrolyzers are very inefficient. 65-70% of the renewable energy put into the electrolysis process is lost.
- **Scale:** To minimize start-up and shut-down energy losses, electrolyzers must be run nearly constantly.
- **Supply Chain:** Although efforts are underway to increase the availability of electrolyzers, they remain scarce and expensive.

Table 1: Electrolyzer system investment costs (US dollars per kilowatt)

Present		2030	2050	Source
Alkaline				
700	2017	450	450	Fraunhofer, 2018
500 to 1,400	2019	400 to 850	200 to 700	IEA, 2019
500 to 1,000	2020			IRENA, 2020
540 to 900	2022			OIES, 2022
600 to 1,100	2022			Goldman Sachs, 2022
610	2022	344		DOE, 2022
Proton exchange membrane (PEM)				
1,460	2017	810	510	Fraunhofer, 2018
1,100 to 1,800	2019	650 to 1,800	200 to 900	IEA, 2019
700 to 1,400	2020			IRENA, 2020
667 to 1,450	2022			OIES, 2022
800 to 1,250	2022			Goldman Sachs, 2022
Solid oxide				
1,410	2017	800	500	Fraunhofer, 2018
2,800 to 5,600	2019	800 to 2,800	500 to 1,000	IEA, 2019
-	2020		<300	IRENA, 2020
2,300 to 6,667	2022			OIES, 2022
>1,850	2022			Goldman Sachs, 2022
Anion exchange (alkaline membrane)				
>931	2022			OIES, 2022

Source: Center on Global Energy Policy

Cost Considerations

- **Electrolysis Inputs:** Running a 1 GW hydrogen capable combined cycle plant on 75% percent hydrogen (as outlined in the Nov 2023 Resource Generation Plan Update), would require approximately 1,591.3 MW of **new** renewable generation. It would require approximately 1,127,699 gallons of water **per day**.[1]
- **Transportation:** Hydrogen is an extremely difficult fuel to transport safely. If run through steel pipelines, it will cause cracks via a process called embrittlement. All hydrogen pipelines also need additional compressor stations compared to natural gas pipelines. Due to these considerations, hydrogen pipelines can cost up to 68 percent more than natural gas pipelines to build. Existing natural gas pipelines cannot safely transport high blends of hydrogen.
- **Hydrogen-Capable Turbine:** 1 GW OCAPS 2x1 hydrogen capable combined cycle turbine proposed at Entergy project in Orange County – hydrogen component is estimated at $91 million. The PUC also stated in January 2023 that Entergy did not meet the burden of proof for demonstrating the reliability or affordability of hydrogen co-firing.

[1] Estimates are based on a GE 7HA.02 hydrogen capable combined cycle turbine configured as a 2x1 combined cycle, assuming 6,549 annual operating hours at a 75% hydrogen, 25% natural gas fuel mix, using GE's Hydrogen and CO2 Emissions Calculator

Green Hydrogen and Decarbonization

- **Leakage:** Hydrogen is a small molecule that is extremely prone to leakage; in fact, equipment sensitive enough to capture hydrogen leaks at lower levels does not currently exist.
- **Indirect Global Warming:** Once hydrogen is leaked into the atmosphere, it prolongs the lifetime of methane in the atmosphere, thus contributing to significant short-term warming. In the first 20 years of its atmospheric lifetime, hydrogen produces 35x the climate warming impacts of CO_2.
- **Blending and Emissions:** Due to its propensity for leakage and indirect global warming impact, one analysis by Argonne National Lab found that combusting a 30 percent blend of hydrogen with natural gas would only yield a modest 6 percent decrease in lifecycle greenhouse gas emissions. This was in part because transporting a 30 percent blend of hydrogen could **double** leakage from transmission lines. This leakage rate only increases as the percentage of hydrogen increases.

Additional Drawbacks

- **Increased Emissions:** When combusted, hydrogen produces 6x as much of the harmful air pollutant nitrogen oxide (NOx) as methane. While hydrogen capable turbines can mitigate these emissions better than existing natural gas turbines, the NOx emissions remain at best at the same levels as that of a newer natural gas plant. We know that nearby communities already face adverse health impacts from NOx emissions at these levels.
- **Winter Reliability:** A hydrogen capable turbine is essentially a new fossil gas plant. These plants are exceptionally vulnerable to climate risk, particularly from severe weather events. This was demonstrated by the rolling blackouts caused by cascading power failures during Winter Storm Uri in 2021. In addition, **there is currently no data on how electrolyzers perform during severe weather conditions, including winter storms.** This past Tuesday during Winter Storm Heather, solar deployed 1.5 GW and batteries deployed 1.2 GW of energy to the Texas grid.
- **Water Scarcity:** Electrolysis requires approximately 1 ton of purified water per ton of hydrogen produced; coupled with climate induced droughts, the introduction of a new source of high-water demand in the Austin area could deplete existing water tables and lead to water scarcity.

Consider a "Least-Regret" Framework

- Hydrogen should only be considered a potentially viable option if:
  - There are no other low-cost decarbonization strategies available;
  - There are no electric technologies being developed that could take advantage of zero-emission technology directly;
  - The logistics and costs of infrastructure for hydrogen transportation and storage can be contained;
  - Technologies for using hydrogen fuel in the sector are or will be available; and
  - Transitioning to hydrogen could measurably reduce air pollution.
- Least regret uses of green hydrogen could include high-heat industrial uses, maritime shipping, and aviation.

Further Reading and Resources

- Hydrogen's Global Warming Impacts
- Blue and Green Hydrogen Production: Potential Harms & Global Warming Impacts
- Hydrogen Areas of Concern
- Safety of Hydrogen Transportation by Gas Pipelines
- Reclaiming Hydrogen for a Renewable Future

Thank you! For additional questions, please email:

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