GREEN HYDROGEN COALITION

Environmental Defense Fund

# UNDERSTANDING THE CLIMATE IMPACTS OF HYDROGEN EMISSIONS

## Maximizing the Climate Benefits of Renewable Hydrogen by Applying Best Practices for Hydrogen Emissions Mitigation

**Renewable hydrogen** ($RH_2$), produced from renewable feedstocks, can replace fossil fuels to help decarbonize some of the heaviest polluting and hardest-to-electrify sectors, such as industrial processes and maritime shipping. However, recent research underscores the risk of hydrogen emissions—the hydrogen molecules that we release into the atmosphere—in warming the climate.

**Bottom line:** The climate benefits from a well-regulated, clean, and renewable hydrogen economy outweigh the warming impact of hydrogen emissions, but we can maximize the benefits by minimizing hydrogen emissions.

Research from the Environmental Defense Fund and others[1,2,3,4] shows strong climate benefits when using $RH_2$ made from renewable electricity and water in place of fossil fuels, but those benefits vary depending on how much hydrogen ($H_2$) is emitted into the atmosphere (see Figure 1).

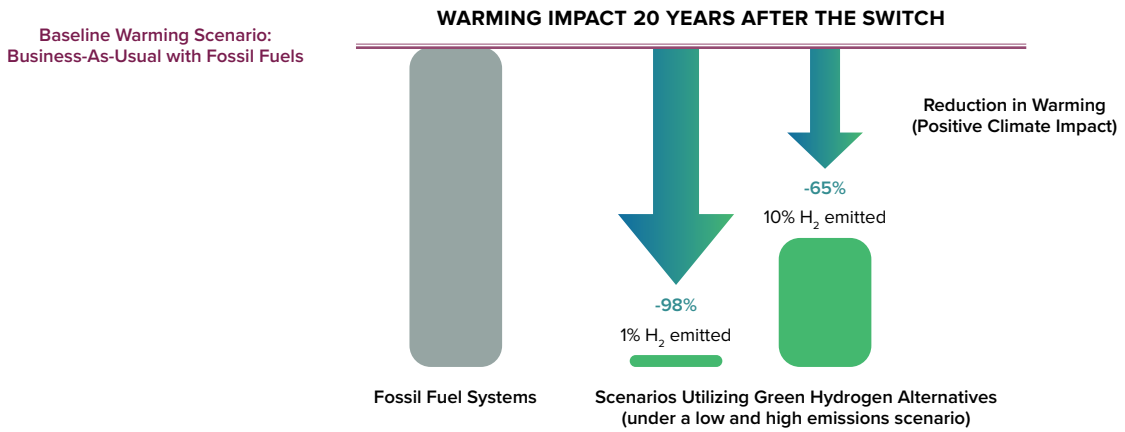


**Figure 1:** Relative warming impact in the near-term from replacing fossil fuel technologies with renewable electrolytic hydrogen alternatives for a generic case (long-term climate benefit is generally larger). The renewable electricity source is assumed to have zero emissions.

*Source*: Ocko and Hamburg, 2022.

## WHAT ARE THE WARMING EFFECTS OF $H_2$ EMISSIONS?

When emitted into the atmosphere, $H_2$ can impact the climate through indirect warming because its chemical breakdown increases the amounts of short-lived greenhouse gases, such as methane, ozone, and water vapor (see Figure 2).[5,6]


**1** Hauglustaine, D., Paulot, F., Collins, W., Derwent, R., Sand, M., and Boucher, O.: Climate benefit of a future hydrogen economy, Commun Earth Environ, 3, 295, 2022, https://doi.org/10.1038/s43247-022-00626-z.
**2** Warwick, N. J., Archibald, A. T., Griffiths, P. T., Keeble, J., O'Connor, F. M., Pyle, J. A., and Shine, K. P.: Atmospheric composition and climate impacts of a future hydrogen economy, Atmos. Chem. Phys., 23, 13451–13467, 2023, https://doi.org/10.5194/acp-23-13451-2023.
**3** Ocko, I. B. and Hamburg, S. P.: Climate consequences of hydrogen emissions, Atmos. Chem. Phys., 22, 9349–9368, 2022, https://doi.org/10.5194/acp-22-9349-2022.
**4** Tianyi Sun et al., "Climate Impacts of Hydrogen and Methane Emissions Can Considerably Reduce the Climate Benefits Across Key Hydrogen Use Cases and Time Scales," Environmental Science & Technology 58, no. 12 (February 21, 2024): 5299–5309, https://doi.org/10.1021/acs.est.3c09030.
**5** Paulot, F., Paynter, D., Naik, V., Malyshev, S., Menzel, R., and Horowitz, L. W.: Global modeling of hydrogen using GFDL-AM4.1: Sensitivity of soil removal and radiative forcing, Int. J. Hydrogen Energ., 46, 13446–13460, 2021, https://doi.org/10.1016/j.ijhydene.2021.01.088.
**6** Sand, M., Skeie, R.B., Sandstad, M. et al. A multi-model assessment of the Global Warming Potential of hydrogen. Commun Earth Environ 4, 203, 2023, https://doi.org/10.1038/s43247-023-00857-8.

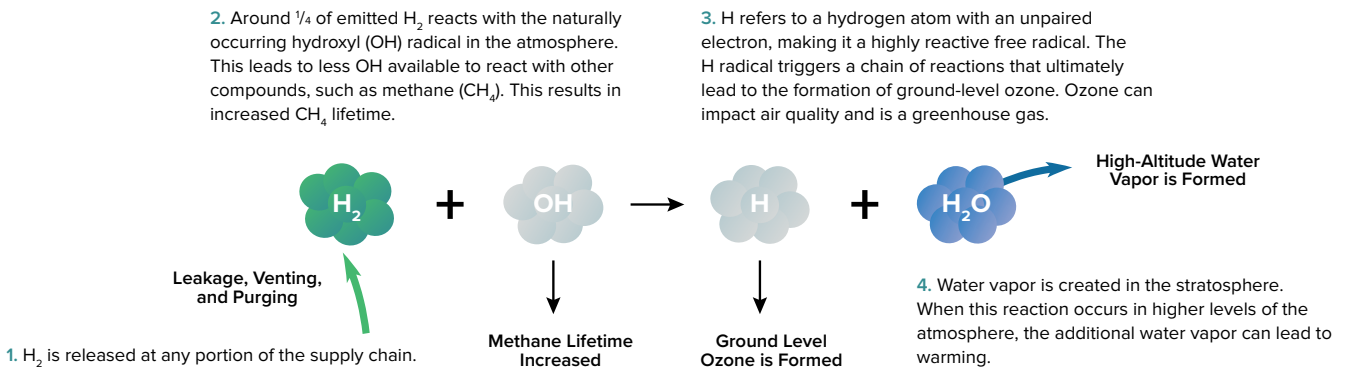


**Figure 2.** Effects of hydrogen oxidation on atmospheric greenhouse gas concentrations and warming.

*Source*: Adapted from Ocko and Hamburg, 2022

## HOW AND WHY DO $H_2$ EMISSIONS OCCUR IN EXISTING SYSTEMS?

$H_2$ is the smallest molecule in existence, making it especially difficult to contain. $H_2$ emissions can occur across the value chain through unintentional releases, such as leakage and residual $H_2$ in exhaust systems, and intentional releases, such as venting and purging. To date, there is no empirical data on how much $H_2$ is emitted in total from existing systems, much less from the $H_2$ infrastructure that many envision.[7]

Current emissions monitoring and standards only exist for safety purposes. Therefore, $H_2$ sensors are designed to detect and minimize large emissions that could cause hydrogen to accumulate to dangerous levels, while smaller emissions that still matter to the climate are overlooked. The good news is that the technologies capable of measuring facility-level emissions—small or large—are becoming available, and real-world data will not be far behind.

## HARNESSING BEST PRACTICES AND INNOVATION TO MINIMIZE $H_2$ EMISSIONS

Innovation to go beyond safety issues and minimize emissions of $H_2$ that also affect the climate is on the horizon. In 2023, a first-of-its-kind real-time $H_2$ sensor that can measure site-level emissions with parts-per-billion sensitivity was built and tested.[8] Researchers will be using this sensor to conduct field measurements of $H_2$ systems in 2025. The resulting data will provide:

- **Understanding of real-world $H_2$ emission rates across different infrastructure types**
- **Insights into best practices for operational excellence to minimize emissions**
- **Strong data deliverables to engage a variety of stakeholders**

In September 2024, the U.S. Department of Energy announced $18 million for nine projects to accelerate innovation that supports the detection and quantification of hydrogen emissions throughout the supply chain.[9] In the meantime, actions can already be taken today to prevent and mitigate $H_2$ emissions through best practices.

It is paramount to further **fund**, **study**, and **avoid** potential negative impacts from **hydrogen emissions**. Any efforts to minimize or prevent hydrogen emissions and advance best practices only amplify the **climate benefits** of **renewable hydrogen**.

**7** Esquivel-Elizondo, S. Mejia, A. et al. "Wide range in estimates of hydrogen emissions from infrastructure," Environmental Defense Fund, National Fuel Cell Research Center, 2023, https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2023.1207208/full.
**8** Hamburg, S. Sun, T. "As Climate Concerns About Hydrogen Energy Grow, New Tech Unveiled at CERAWeek Delivers Unprecedented Results Measuring Leaks, Other Emissions," Environmental Defense Fund, 2023, https://www.edf.org/media/climate-concerns-about-hydrogen-energy-grow-new-tech-unveiled-ceraweek-delivers-unprecedented.
**9** "U.S. Department of Energy Announces $18 Million to Advance Research in Hydrogen Detection Systems," Energy.gov, September 13, 2024, https://www.energy.gov/eere/fuelcells/articles/us-department-energy-announces-18-million-advance-research-hydrogen.

**LEARN MORE ABOUT $H_2$ EMISSIONS GET INVOLVED TODAY!**

GREEN HYDROGEN COALITION



Founded in 2019, the Green Hydrogen Coalition (GHC) is a 501(c)(3) educational nonprofit that is focused on the role of green hydrogen to accelerate a clean and just energy transition. As California works towards carbon neutrality by 2045, $GH_2$ will be a critical tool to achieve economy-wide decarbonization alongside other clean energy technologies. The GHC works to advance education, policies, and practices to achieve progress for $GH_2$. For more information, visit **ghcoalition.org**