HYDROGEN EMISSIONS MEASUREMENT STUDY

A collaborative research initiative of Environmental Defense Fund and partners

Zero and low carbon hydrogen holds great promise as a decarbonization strategy. But to maximize its climate benefits, it is critical that it be produced, managed, and used in a way that minimizes emissions.

Background

Hydrogen has the potential to play a pivotal role in the global energy transition. It could help decarbonize hard-to-electrify sectors, such as fertilizer, steel and cement production, and cut pollution from long-dis-tance transport. Yet, hydrogen is not without its own emissions challenges. It is the smallest molecule in the universe, making it difficult to contain. And while not a direct greenhouse gas, when released into the atmosphere, it indirectly causes warming by extending the lifetime of methane and increasing the amount of tropospheric ozone and stratospheric water vapor. Its warming effects are short lived, but potent: 37 times more powerful than carbon dioxide pound for pound for the first 20 years after its release and 12 times more powerful over 100 years.

Recent studies indicate that if hydrogen emission rates are high, it can severely undermine the intended benefits of hydrogen deployment, particularly over the near term. The international hydrogen community, including the U.S. Department of Energy, EU Joint Undertaking, UK Department for Business Energy & Industrial Strategy, and the International Energy Agency have highlighted the importance of understanding, monitoring, and mitigating hydrogen emissions.

Right now, there is little empirical data to describe thescale of hydrogen emissions from existing operations.Studies over the last 20 years suggest emission rates from less than 1% up to 20% for various components of the value chain, but this range is not based on empirical evidence. Until recently, technologies to measure hydrogen were designed to detect relatively high concentrations (at the parts-per-million to % level), which can pose an immediate safety risk. They do not detect the smaller, but still climate-relevantemissions (at the parts-per-billion level) fast enough to quantify emissions from hydrogen plumes released from various infrastructure.

With the help of new cutting-edge hydrogen measurement technologies, hydrogen emissions from real-world operations across U.S. and Europe are now being quantified for the first time by a small but growing group of scientists and researchers.

The study

Environmental Defense Fund is coordinating a multidisciplinary partnership spanning academic institutions, technology & research innovators, and industry leaders to quantify hydrogen emission rates across the hydrogen value chain. The study leverages innovative sensor technologies, including high-precision analyzers and mobile platforms, coupled with peer-reviewed methodologies to conduct the most comprehensive measurement of hydrogen emissions across today's value chain to date.

This is made possible by dedicated collaboration from industry partners, who are providing access to facilities and critical context on facility operations in real time, allowing researchers to better understand which equipment and processes may release or leak hydrogen. In turn, this will provide facility operators with essential data and insights to make their operations more efficient.

Additionally, partners from leading academic and research institutions created the state-of-the-science measurement technology and methodology that enable useful and relevant data and insights. We are just at the beginning of a hydrogen infrastructure build-out. The knowledge gained from this study – which aims to provide the most comprehensive, publicly available, representative dataset to date – will lay the groundwork for best practices and mitigation strategies to minimize emissions and maximize hydrogen's climate benefits.

Benefits of the hydrogen emissions measurement study

The study will quantify current emissions and improve hydrogen infrastructure development by:

- Establishing a baseline understanding of how much hydrogen is released and from where, thereby laying the foundation for best practices and mitigation strategies.
- Understanding emissions from existing infrastructure to aid new hydrogen projects in the development of infrastructure with high environmental integrity.
- Supporting companies in their efforts to enhance the effectiveness of safety leak repair programs.
- Offering transparency about safety and other local effects.
- Offering insights, backed by high-quality data, to governments and private sector stakeholders whose investments in hydrogen are driven by anticipated climate benefits.
- Saving valuable product by minimizing unintended hydrogen losses.

The detection technology

Aerodyne Research developed an ultra-sensitive hydrogen analyzer capable of measuring hydrogen at a level of sensitivity and speed necessary to quantify climate-relevant emissions. The technology works by first removing all water vapor from sample air, then converting

hydrogen in the air to water vapor and measuring that water vapor with infrared laser direct absorption spectroscopy.

The first field test of the prototype sensor took place in January 2023 at Colorado State University's METEC facility, with researchers from EDF, Cornell University, Aerodyne Research, and CSU. Results are published in the journal Environmental Science & Technology. Controlled-release experiments were carried out, including above- and under-ground releases of pure hydrogen gas and hydrogen/methane blended gas at various flow rates.

The sensor was deployed in a state-of-the-science mobile laboratory to demonstrate that hydrogen emissions can be accurately quantified using measurement techniques and analytics commonly used for other gases. The results of that study show that the hydrogen sensor detects parts-per-billion or higher concentration enhancements downwind of the emission source within seconds. This enables the quantification of site-level hydrogen emission rates at an accuracy comparable to that of other well-studied gases.

The emission quantification approaches

There are two measurement approaches in the study. The first is to measure facility-level emissions, aiming to capture the total emissions of hydrogen from an entire facility. This is done by using the tracer release technique and dispersion modeling method. For tracer release, a known amount of a tracer gas (like N2O) is released at a controlled flow rate at the target facility. Downwind, using the Aerodyne instrument in the mobile laboratory, researchers drive through the plume coming off the facility. Both the hydrogen as well as the tracer gas are measured in the plume. Because we know the flow rate of the tracer gas, we are able to back out the total flow rate of hydrogen from the facility. The second process is the direct component-level measurement, meaning that each potential emission source is measured individually at a facility using a sampling system designed specifically for hydrogen. These are tried and true methods used for methane emissions measurements that have been adjusted for hydrogen's unique properties.

Timing

Following a comprehensive testing phase, field work began in March 2025 and is ongoing through early 2026. All data analyses will be completed and submitted as manuscripts for peer-review journals by mid-2026, making the study results publicly available.

Funding and contributions

The study is fully funded by philanthropic contributions to Environmental Defense Fund. Industry Partners provide necessary staff time to ensure safe facility access and provide operational data to contextualize findings as inkind contributions.

Partners

Leading global not-for-profit: **Environmental Defense Fund**
Academic institutions: **Utrecht University**, **University of Rhode Island, Cornell University**, **West Virginia University**
Technology providers and researchers: **Aerodyne Research**, **TNO, TES**
Industry partners: **Air Liquide**, **Air Products**, **Shell**, **TotalEnergies**

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