The climate benefit of hydrogen depends on many factors

HOW H_2 IS MADE

HOW H_2 IS MANAGED

- H_2 is a small, **leak-prone** gas that when purged/vented/leaked can cause **potent near-term warming**
- Total H_2 emissions from current systems are **unknown** – the tech isn't yet available (monitoring for safety isn't sufficient)
- Depending on how much H_2 is emitted, anticipated climate benefits can be **severely undercut** in the near-term

HOW H_2 IS USED

Environmental Defense Fund

Hydrogen's warming effects

Hydrogen emissions warm the climate indirectly by increasing amounts of short-lived greenhouse gases.

STRATOSPHERE

~ 1/4 of emitted H_2 is oxidized in atmosphere in 1-3 years

H_2 + OH → H + H_2O

3 → H_2O

High-altitude Water Vapor
increases in the stratosphere.

1 → CH_4

Methane
lasts longer because there is less OH.

2 → O_3

Ground-level Ozone
Increases from chain of reactions triggered by production of H.

communications earth & environment

Sand et al. 2023

ARTICLE

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A multi-model assessment of the Global Warming Potential of hydrogen

Maria Sand[1&], Ragnhild Bieltvedt Skeie[1], Marit Sandstad[1], Srinath Krishnan[1], Gunnar Myhre[1], Hannah Bryant[2], Richard Derwent[3], Didier Hauglustaine[4], Fabien Paulot[5], Michael Prather[6] & David Stevenson[2]

With increasing global interest in molecular hydrogen to replace fossil fuels, more attention is being paid to potential leakages of hydrogen into the atmosphere and its environmental consequences. Hydrogen is not directly a greenhouse gas, but its chemical reactions change the abundances of the greenhouse gases methane, ozone, and stratospheric water vapor, as well as aerosols. Here, we use a model ensemble of five global atmospheric chemistry models to estimate the 100-year time-horizon Global Warming Potential (GWP100) of hydrogen. We estimate a hydrogen GWP100 of 11.6 ± 2.8 (one standard deviation). The uncertainty range covers soil uptake, photochemical production of hydrogen, the lifetimes of hydrogen and methane, and the hydroxyl radical feedback on methane and hydrogen. The hydrogen-induced changes are robust across the different models. It will be important to keep hydrogen leakages at a minimum to accomplish the benefits of switching to a hydrogen economy.

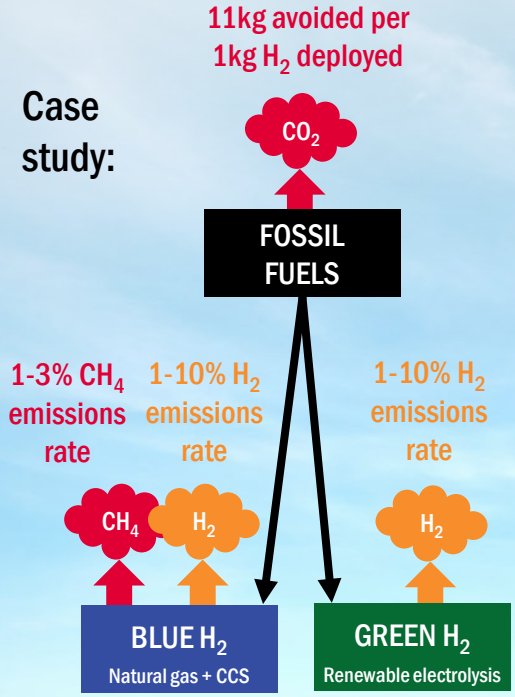
GWP20: 37.3 ± 15.1

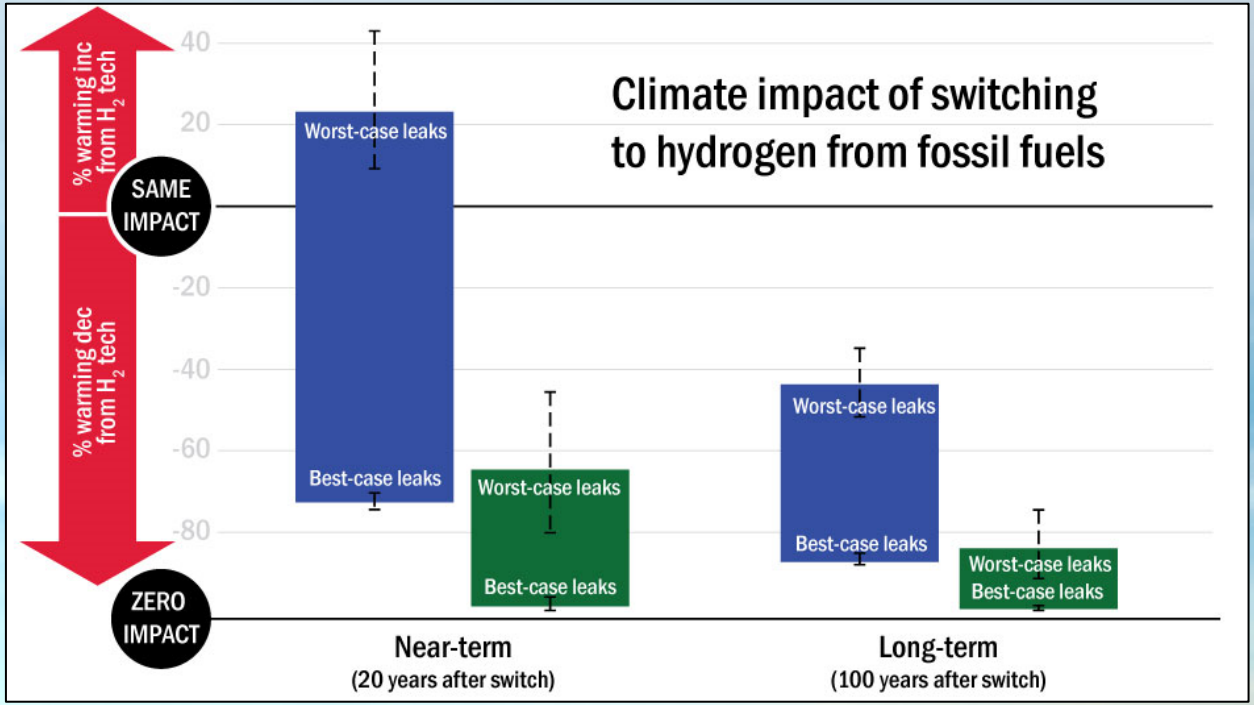
GWP100: 11.6 ± 2.8

Source: Paulot et al. 2021

Climate impact of hydrogen emissions

Climate benefit of switching to hydrogen from fossil fuels depends on emissions and time.





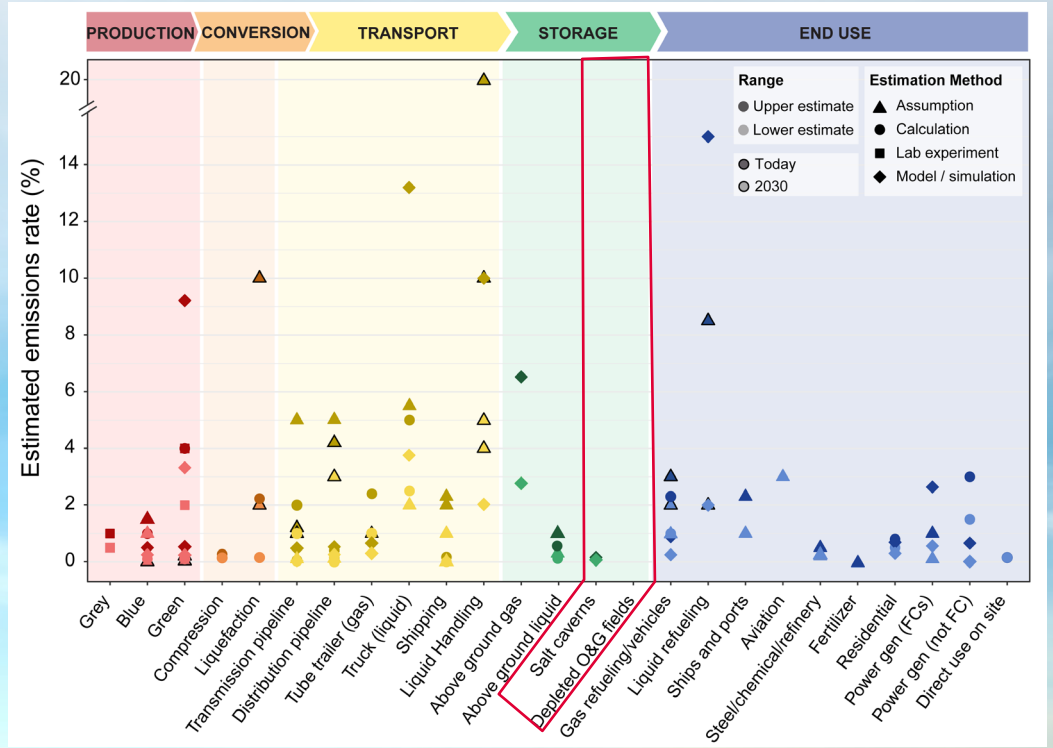
Source: Ocko and Hamburg 2022

More research needed in emissions quantification

Emissions estimates have wide range but there are no empirical measurements in the field.

AMOUNT UNKNOWN

- Tiniest molecule in existence
- Intentionally & unintentionally emitted
- No empirical data from facilities
- Emissions estimates range from **<1%** to **20%**
- Measurements require new sensor technologies



Sources: Esquivel-Elizondo et al. 2023