



The climate and environmental impacts of ammonia: *Upstream hydrogen emissions*

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Ammonia value chain emissions

PRODUCTION

TRANSFER

END USE

'Blue' method

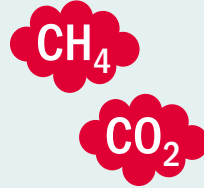
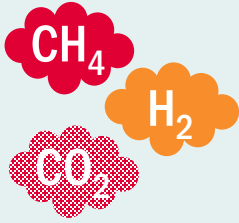
'Green' method

Use fossil energy

Use clean energy

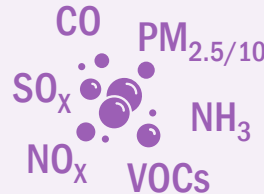
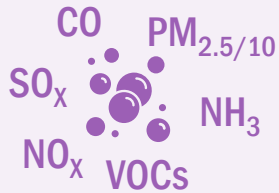
Combustion

CLIMATE



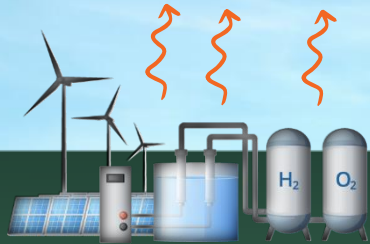
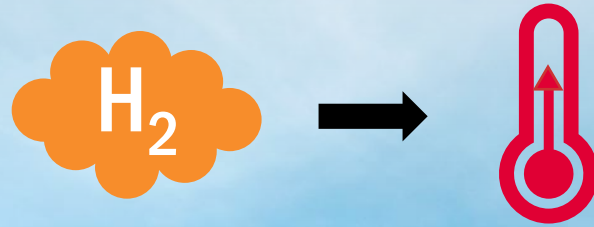
Any NH₃ release/leakage across the value chain also produces N₂O

HEALTH



Hydrogen's warming effects

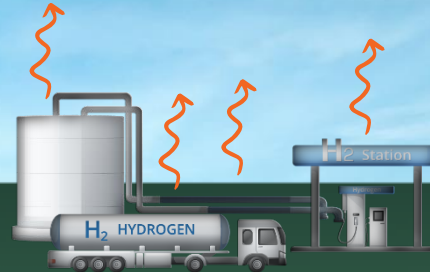
Hydrogen is a leak-prone gas that leads to potent climate warming in the near-term.



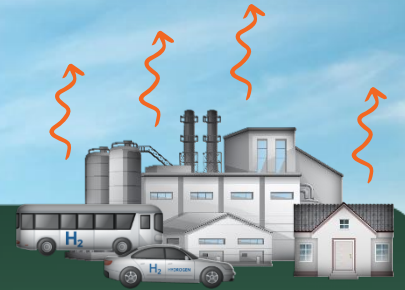
PRODUCTION



COMPRESSION & STORAGE



DISTRIBUTION



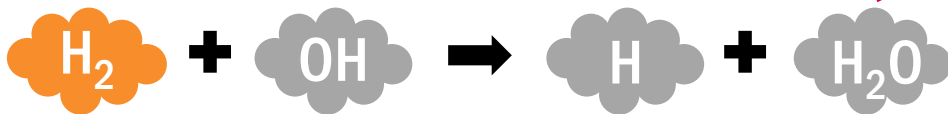
APPLICATION

Hydrogen's warming effects

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

STRATOSPHERE

~ 1/4 of emitted H₂ is oxidized in atmosphere in 1-3 years



High-altitude Water Vapor
increases in the stratosphere.



**SCIENTIFIC
CONSENSUS**

TROPOSPHERE



**AMOUNT
UNKNOWN**



Methane
lasts longer because there is less OH.



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



HYDROGEN VALUE CHAIN

State of the science

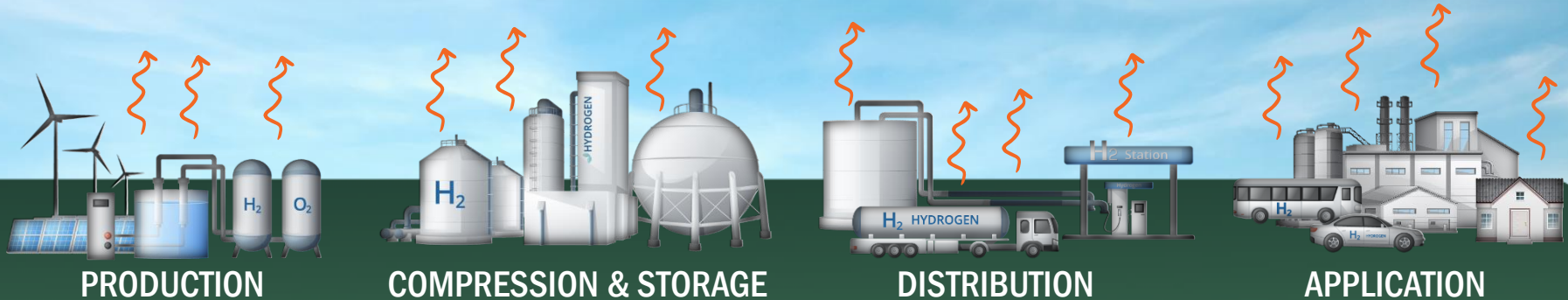
There is consensus on hydrogen's warming effects but emissions rates are unknown.



SCIENTIFIC CONSENSUS

- H₂ chemistry known since the 1970s
- H₂ warming effects studied since the early 2000s
- Recent multi-model assessment concludes H₂ is **37x** more powerful at trapping heat than CO₂ **over 20-year period** and 12x over 100 years (Global Warming Potential)

Sand et al. 2023



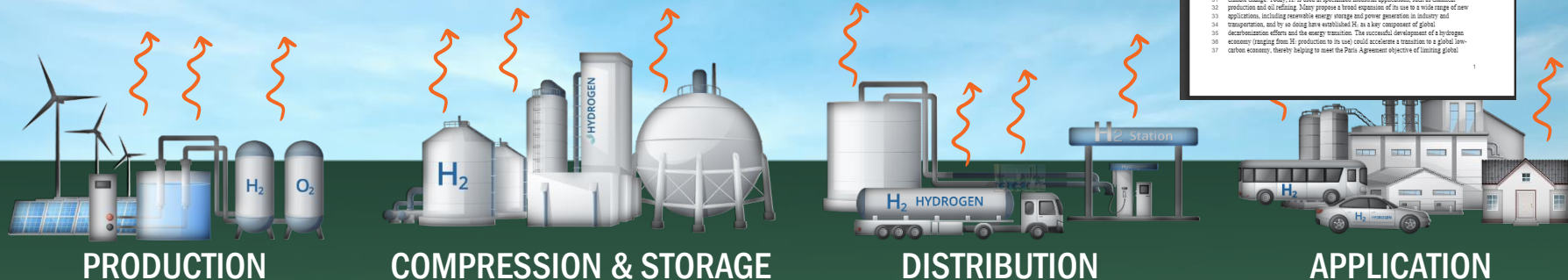
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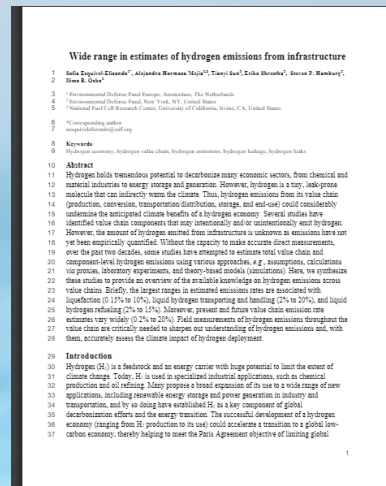
AMOUNT
UNKNOWN



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

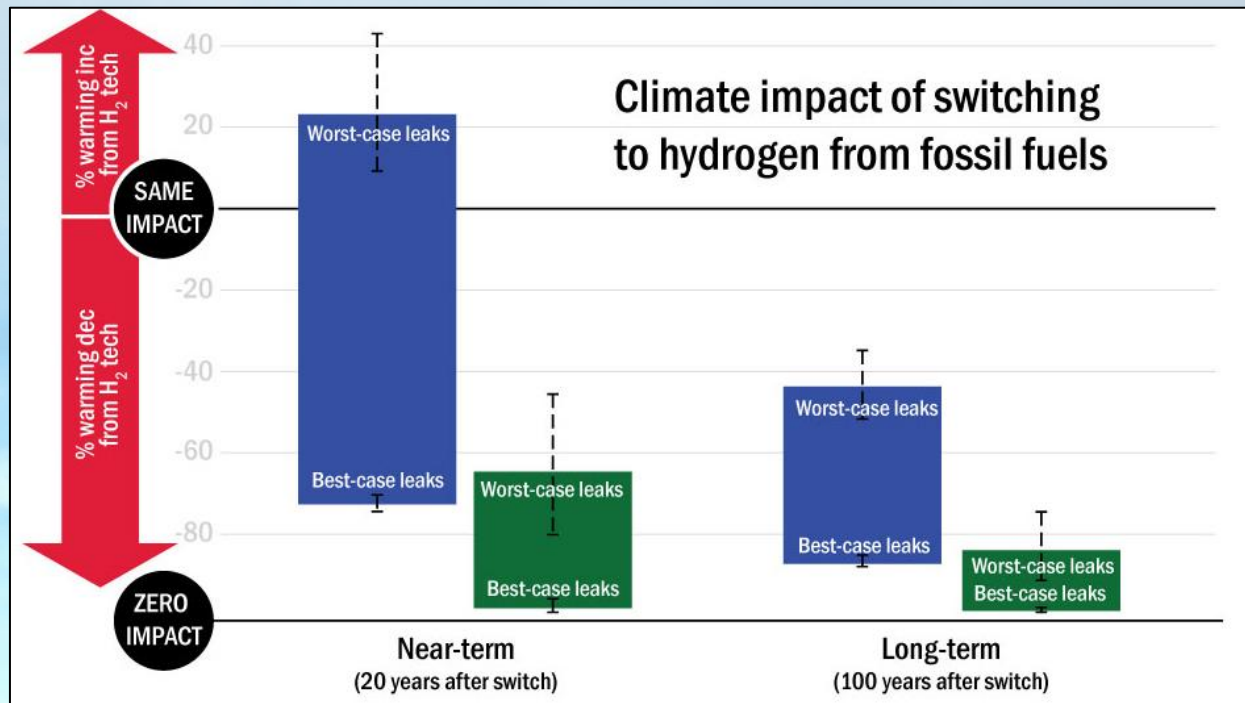
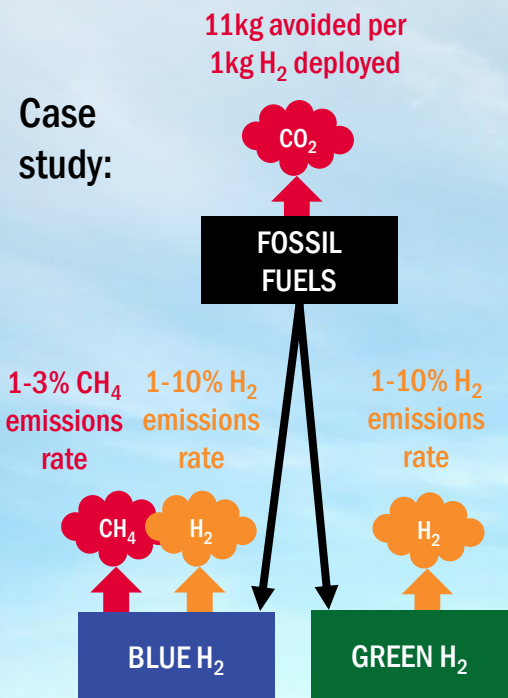


Esquivel-Elizondo et al. 2023



EDF research on the impact of hydrogen systems

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



Why are there no high precision hydrogen emissions data?

We weren't looking

- Hydrogen was NOT regarded as a climate pollutant
- It's warming potential had been underestimated
- Concerns were focused on safety risks, thus larger releases

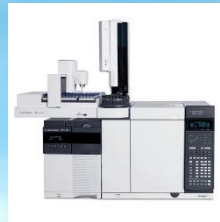
We didn't have the capacity to quantify site-level H₂ emissions



Safety sensors

Response time **a few seconds**

Sensitive at ppm or % level



Research instrument

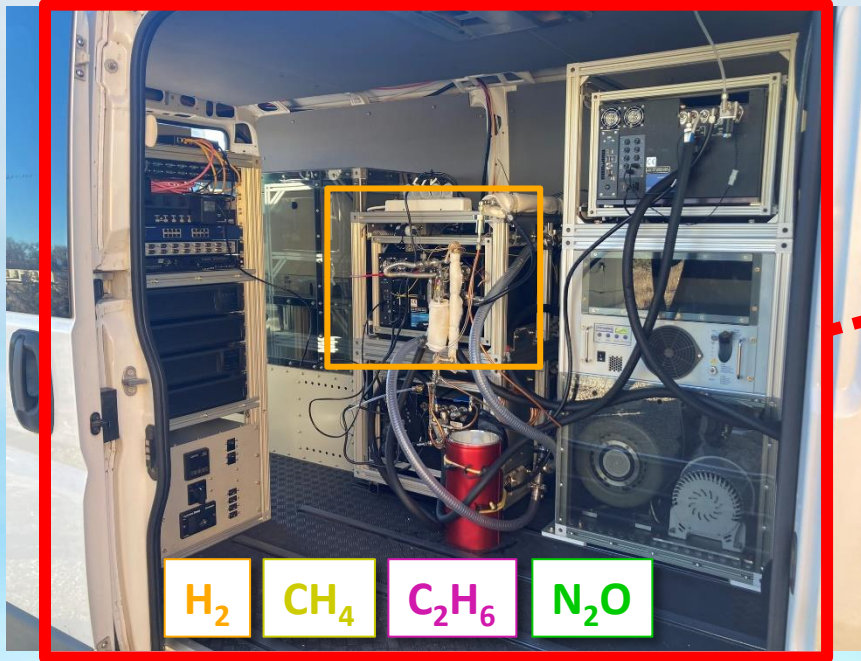
(gas chromatography)

Response time ~1 minute

Sensitive at **ppb level**

New technology for hydrogen emissions measurement

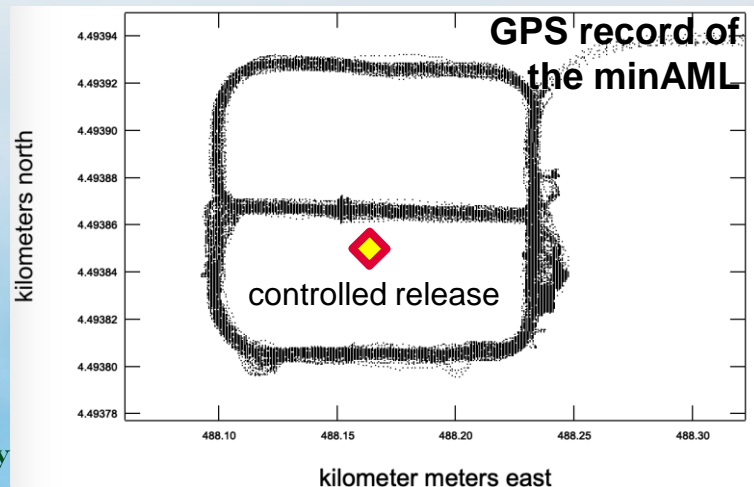
minAML (mini-Aerodyne Mobile Lab)



First field testing at METEC, CSU

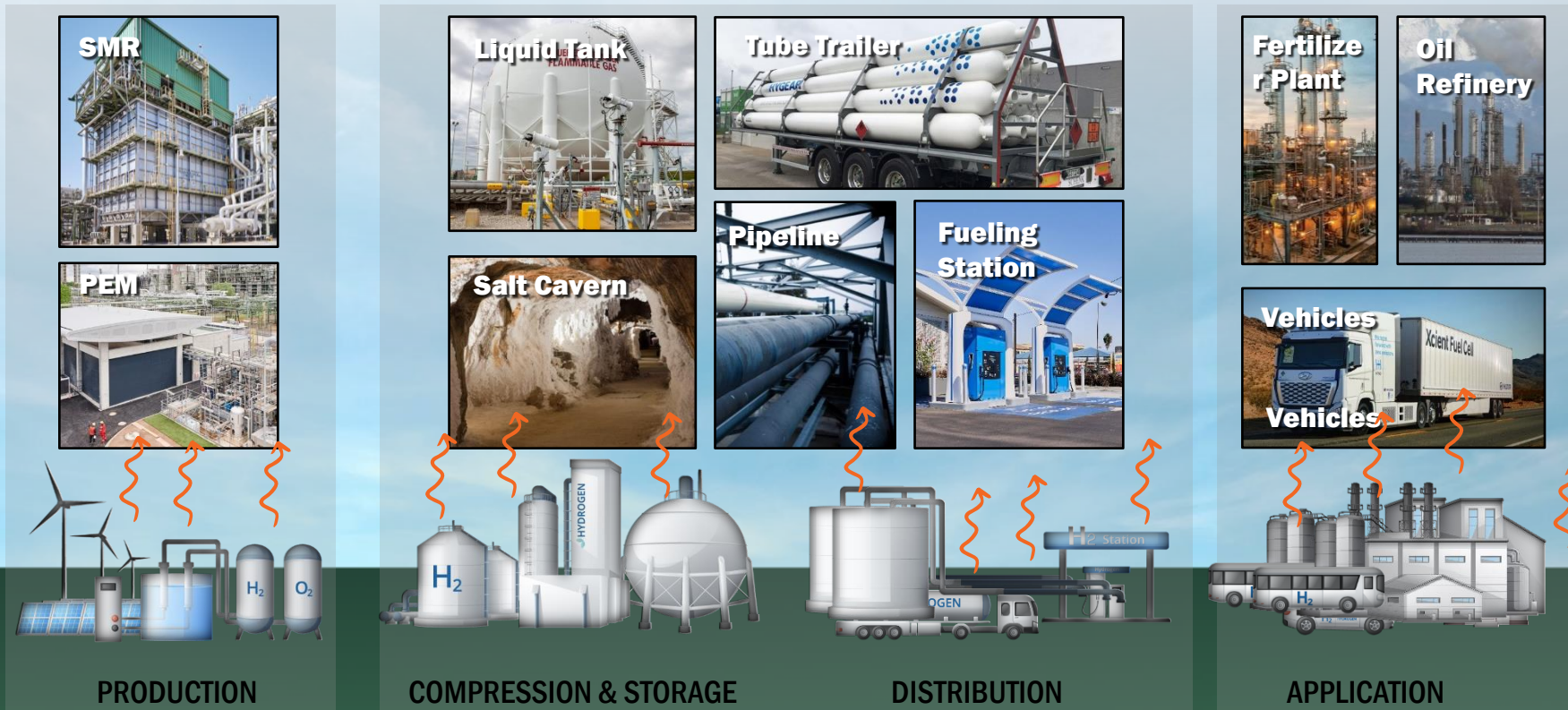


Colorado State University



EDF hydrogen measurement campaign

Plans underway to measure hydrogen emissions from infrastructure with new sensor technology.



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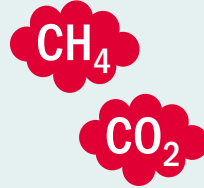
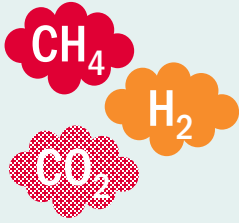
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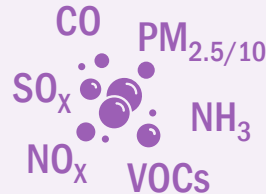
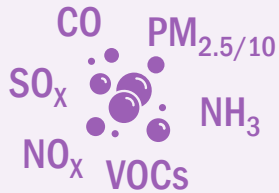
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Thank you!