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May 2nd, 2025

## Context

Hydrogen emissions are indirectly associated with climate impacts, such as:

- Prolonged lifetime of methane (CH<sub>4</sub>)
- Formation of ozone (O<sub>3</sub>) and
- Stratospheric water vapor (H<sub>2</sub>O).

Besides direct leakage to the atmosphere, incomplete combustion of fossil (oil, coal, gas) and biofuels (wood, ethanol, biogas) is key source of emissions.

## Methods

Current work adopts the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model framework, which takes into account activity level (fuel consumption) by sector, emission factors and the application of control strategies for emissions abatement (Amann et al, 2011).



We adopt historical fuel consumption from the International Energy Agency along with GAINS model's assumptions. Hydrogen emission factors are derived from carbon monoxide (CO) emission factors by a conversion ratio estimated from literature (Paulot et al, 2023). Control strategies represent countries' regulations adopted over the period of 1990-2020.

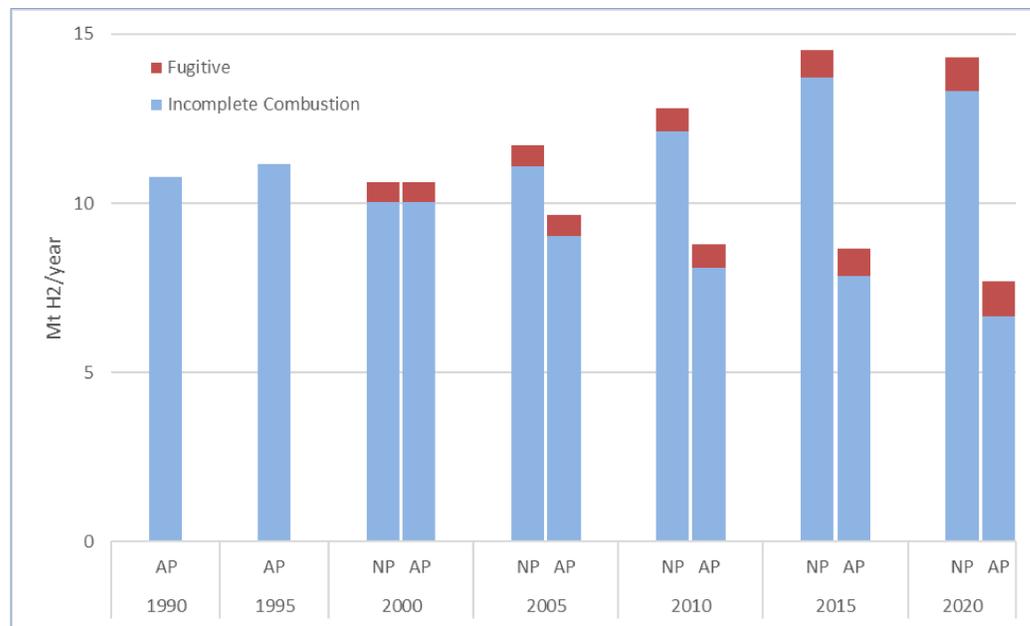


Figure 1: H2 Emissions from 1990 - 2020.

Source: GAINS

AP: Applied Policies, NP: No Policy Improvement (in relation to 2000)

## Impacts of hydrogen

Despite its short atmospheric lifetime (4-7 years), studies estimate that hydrogen atmospheric interactions could lead to a Global Warming Potential over 100 years (GWP-100) ranging from 6 to 18. Moreover, hydrogen production and combustion might lead to emissions of human health pollutant (PM<sub>2.5</sub>, CO, NO<sub>x</sub> and NH<sub>3</sub>) and other greenhouse gases (CO<sub>2</sub> and CH<sub>4</sub>).

## Results & Conclusions

As shown in Figure 1, global hydrogen emissions in 1990 were approximately 10.9 Mt H<sub>2</sub> (66–180 Mt CO<sub>2</sub>eq). These emissions were primarily driven by fuelwood in residential sector and gasoline in the transport sector (Figure 2). By 2020, total emissions had declined to 6.7 Mt H<sub>2</sub> (40–120 Mt CO<sub>2</sub>eq), as represented by the AP scenario in Figure 1. Had policies remained at the levels 2000, with no further improvements, total emissions in 2020 would have been nearly twice as high, as indicated by the NP scenario in Figure 1. This decline underscores the effectiveness of air pollution control strategies—which played a key role in reducing hydrogen emissions over time.

Although incomplete combustion is currently the primary source of H<sub>2</sub> emissions, future expansion of a hydrogen economy may lead to increased fugitive emissions. Such emissions accounted for less than 1 Mt H<sub>2</sub> per year between 1990 and 2020. Fugitive emissions can occur at any stage of supply and demand chain and may be either intentional or unintentional (Esquivel-Elizondo et al., 2023). Significant uncertainty remains regarding their magnitude, largely due limited availability of empirical data on hydrogen leakage from existing systems.

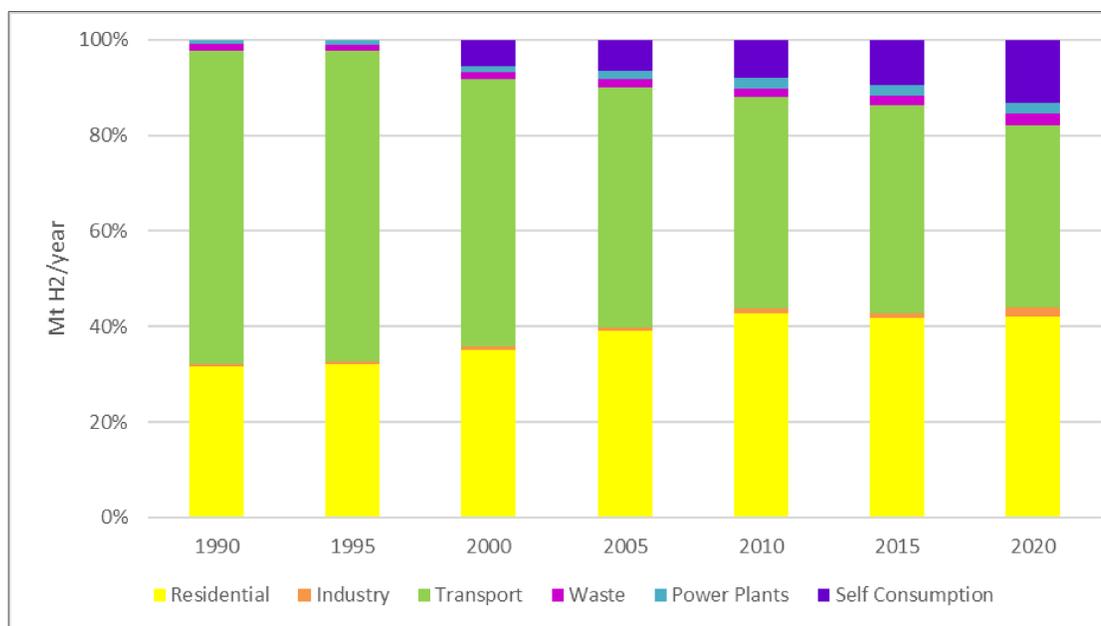


Figure 2: Sector shares of H2 emissions from 1990 - 2020.

Source: GAINS

## Objectives

The GAINS framework evaluates impacts of the hydrogen supply chain, accounting for different energy demand scenarios and mitigation policies.

This study specifically investigates hydrogen emissions from incomplete combustion. We quantify emissions from 1990 to 2020 and compare their CO<sub>2</sub>-equivalent contribution. In addition, we evaluate the influence of policy measures on reducing these emissions.

## Further Studies

This research is part of the Hyway Project Working Package 2, which will provide hydrogen and other pollutant emissions inventory, based on emission factors from literature and measurement campaigns. Global gridded datasets with 0.1x0.1 degree spatial and monthly temporal resolution will be developed for relevant species.



Funded by the European Union



CLIMATE IMPACTS OF A HYDROGEN ECONOMY: The pathway to knowledge

This research has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101137582 (HYway).