U.S. Department of ENERGY | Office of Energy Efficiency & Renewable Energy

Life Cycle GHG Emissions Assessment of Hydrogen Used as a Fuel or Feedstock in 2025

An Assessment Using R&D GREET 2024

Argonne National Laboratory's Research & Development Greenhouse gases, Regulated Emissions, and Energy use in Technologies (R&D GREET®) model analyzes the life cycle impacts of vehicle, fuel, chemical, and material technologies. These analyses guide research and development and decision-making for current and future transportation and energy systems.

What is Hydrogen?

Hydrogen is a colorless and odorless gas that is an essential feedstock for industrial processes, such as petroleum refining and ammonia production and can be used as an energy carrier for energy storage or transportation. This fact sheet compares emerging use cases of hydrogen with incumbent technologies for heavy-duty truck transportation and ammonia production using the latest data in R&D GREET 2024.

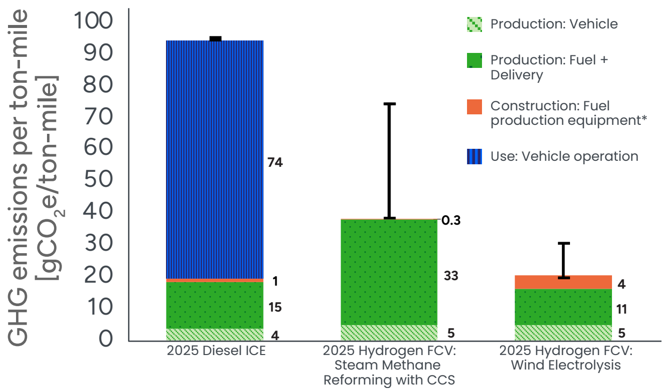

Figure 1: In 2025, life cycle GHG emissions of hydrogen fueled fuel cell trucks are less than conventional diesel trucks

*The life cycle GHG emissions on a per-ton-mile basis for representative 2025 sleeper-cab heavy duty trucks (Class 8) with a 19-ton payload. FCVs assumed to have 700 bar on-board gaseous storage tank, 500-mile range. Life cycle GHG emissions include those from construction of the fuel production equipment (*e.g. wind turbines + concrete foundation, electrolyzers, oil well equipment, grid electricity generation equipment), vehicle production (including end-of-life disposal methods), and production and use of fuel in the vehicle. Error bar on diesel ICE and steam methane reforming reflects a literature estimated range of upstream natural gas recovery, processing, and transmission emissions from ~0.7% up to 5%. CCS assumes 96% capture rate. Error bar for wind electrolysis reflect a range of onshore wind capacity factors across the USA (0.11 to 0.55, see ref i). Source: R&D GREET 2024; Simulation year: 2025.*

Evaluating the GHG Emissions of Heavy-Duty Trucks

Compared to diesel internal combustion engine (ICE) trucks, hydrogen fuel cell vehicles (FCVs) have zero tailpipe emissions since the byproduct of a fuel cell operating on hydrogen is only water vapor. However, there are some upstream emissions associated with hydrogen production and delivery and with vehicle/component manufacturing. Using R&D GREET 2024, Figure 1 compares hydrogen fuel cell and diesel-ICE heavy-duty (Class 8, sleeper cab) trucks produced in 2025. It includes two different hydrogen production methods with different emission rates and compares the emissions produced per ton-mile traveled, which accounts for the distance traveled and payload that each truck can carry. R&D GREET 2024 shows that:

- For the ICE, fuel use (i.e., diesel combustion in the vehicle during use) is the greatest contributor (~80%) to life cycle GHG emissions.
- For fuel cell trucks, the GHG emissions depend on how the hydrogen was produced, but all pathways examined here result in emissions less than the ICE, ranging from 20% to 80% reduction relative to the diesel vehicle.
- Wind powered electrolysis (water-splitting) with gaseous delivery results in the least life cycle GHG emissions — a 70% to 80% reduction from the conventional ICE depending on where the wind turbine is located.[i]
- Wind turbine construction contributes ~20% to the life cycle GHG emissions of hydrogen produced by wind electrolysis.
- Uncertainty in upstream methane emissions from natural gas extraction results in significant uncertainty in life cycle GHG emissions for hydrogen produced from steam methane reforming (SMR) with carbon capture and sequestration (CCS). Even when accounting for this uncertainty, an SMR with CCS hydrogen fueled FCV still has lower life cycle GHG emissions than a diesel ICE truck.

Impact of Hydrogen Production Method on Ammonia Life Cycle Emissions, the Key Ingredient in Synthetic Fertilizers

Hydrogen plays an essential role as a feedstock in the production of chemicals, notably ammonia (NH_3), the primary feedstock used to produce fertilizers. Ammonia production is one of the largest near-term demands for clean hydrogen deployments.[ii] Currently, the hydrogen used for ammonia production is primarily produced from conventional SMR.

Using R&D GREET 2024, the data in Figure 2 provides a comparative analysis of the GHG emissions from ammonia production pathways using current technologies. A few key takeaways are:

- The life cycle GHG emissions of NH_3 production can vary 2-13x depending on the technology used to produce the hydrogen.
- Deploying CCS (e.g. 96% CO_2 capture rate) represents a near-term opportunity to reduce GHG emissions of large-scale facilities by over ~50%.
- Use of electrolysis with wind power can reduce emissions by over 80% to 90%. The remaining emissions associated with the process are predominantly from the use of grid power necessary for the separation of nitrogen from air. Unlike the transportation case study above, hydrogen for ammonia production is assumed to be produced onsite and does not include emissions related to delivery.

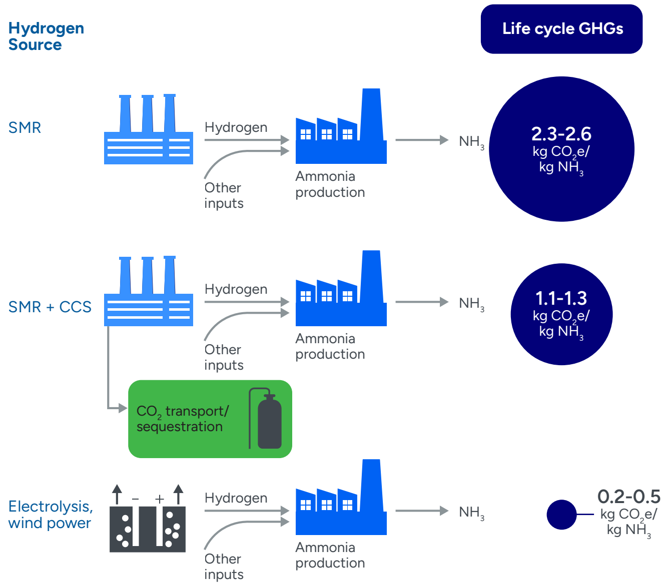

Figure 2: Life cycle GHG Emissions from Ammonia Production
*Values shown are life cycle GHG emissions from production of raw materials through ammonia production including construction of equipment (*e.g. wind turbines + concrete foundation, electrolyzers, oil well equipment, grid electricity generation equipment). CCS assumes 96% capture rate. Ranges shown here were developed using the same assumptions to develop error bars in Figure 1.*

References

i https://globalwindatlas.info/en; https://pubs.acs.org/doi/10.1021/acs.est.3c06769

ii https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap

For more information, visit:
energy.gov/eere/argonne-rd-greet-model

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