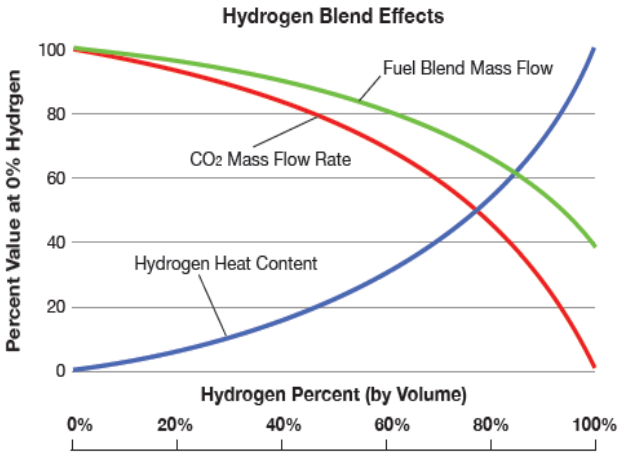
Hydrogen Impacts on Criteria Pollutants

Hydrogen has been identified as a clean alternative to traditional fuels like natural gas, as it can reduce greenhouse gas emissions. But what impact will hydrogen have on criteria pollutants like nitrogen oxides and carbon monoxide?

Traditional fuel combustion methods create and release carbon dioxide (CO_2) and other criteria pollutants, including particulate matter, carbon monoxide (CO), nitrogen oxides (NO_X), and sulfur dioxide (SO_2). The Environmental Protection Agency (EPA) has set forth standards and regulations to reduce the level of criteria pollutant emissions to offset the human health and environmental impacts, including local air quality. As a result, point sources are seeking to 1) reduce the criteria pollutants created by fuel combustion and 2) mitigate the emissions before they are released into the atmosphere. NOx emissions can damage local ecosystems and produce ozone, which creates smog and causes respiratory problems for nearby communities. While replacing natural gas with hydrogen will lower greenhouse gas emissions, the potential impact on criteria pollutants – particularly NO_X – is still being researched.

Hydrogen Combustion and Criteria Pollutants

Because hydrogen does not contain carbon, hydrogen combustion does not produce carbon monoxide nor carbon dioxide. When combusting a hydrogen-natural gas blend, onsite carbon emissions are therefore reduced compared to 100% natural gas fuel. The chart to the right shows the relationship between fuel blend mass flow, CO_2 mass flow rate, and hydrogen heat content. As the amount of hydrogen is increased, CO_2 emissions are reduced. However, hydrogen burns at a higher temperature than natural gas. With higher combustion temperatures (i.e., from blending more than 30% hydrogen), nitrogen molecules separate from the air and combine with oxygen more easily to create higher concentrations of nitrogen oxide pollutants.[1]



Source: Gas Turbine World

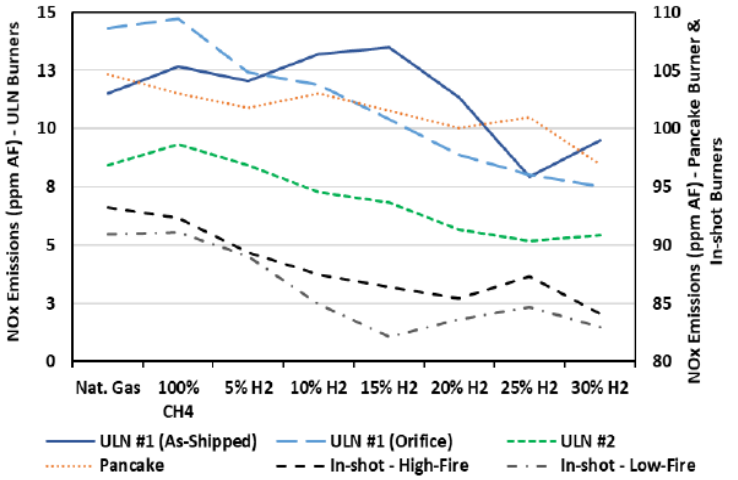
Hydrogen Blends and NO_X Emissions

A 2022 study conducted by the Gas Technology Institute (GTI) concluded that the concentration of NO_X emissions remains relatively stable or decreases slightly up to a 30% hydrogen blend by volume.[2] The decline in NO_X emissions was particularly evident for both water heater and furnace burners with increasing hydrogen blends. This decrease in nitrogen oxide emissions is the result of air dilution impacts observed at these burners, thus reducing the effects of this criteria pollutant at end-use appliances. Following this study, GTI worked with New Mexico Gas Company to test hydrogen fuel blends for in-home appliances at the New Mexico Gas Leak Town Training Facility, a controlled environment of homes with various gas-powered appliances, including cooking ranges, water heaters, and space heaters. These tests confirmed that there are no significant increases

[1] Ambient conditions impact CO and NOx emissions: part II (digitalrefining.com)
[2] (PDF) Impact of Hydrogen/Natural Gas Blends on Partially Premixed Combustion Equipment: NOx Emission and Operational Performance (researchgate.net)

in NO_X or CO emissions at end-use applications[3]. Up to a 15% hydrogen-by-volume fuel blend was tested successfully on appliances manufactured between 1950-2021 with no increases in NO_X production.[4].

Hydrogen-natural gas blends exceeding 30% hydrogen by volume tend to result in significantly higher levels of NO_X emissions if no control measures are applied[5]; however, natural gas operators have thus far limited hydrogen blends to the 20-30% range while they continue to study the impacts of higher blend percentages to both natural gas infrastructure and end-use appliances. For higher percentage blends, selective catalytic reduction (SCR) can be used to prevent NOx emissions. A 2022 demonstration of up to a 44% hydrogen-by-volume fuel blend at a power generating plant indicated a nearly 14% reduction in CO_2 and an 88% reduction in CO, while NO_X emissions were kept within the allowable limits using SCR control systems.[6] Catalytic combustors paired with SCR control systems can significantly reduce the risk associated with higher concentrations of nitrogen oxides and limit these emissions. Water injection and air premixing can also be used to mitigate NOx emissions as hydrogen percentages are increased.



Impact of Hydrogen Blends up to 30% on ULN, Pancake, and In-shot Burners
(Source: Gas Technology Institute, 2022)

H_2 % by Vol	CO_2 [ton/hr]	NO_X [lb/hr]	CO [lb/hr]
0	26.4	35.4	39.2
5	26.0	33.8	38.0
15	25.1	34.3	24.8
25	23.9	33.2	17.9
30	23.3	34.9	14.0
35	22.7	34.9	12.2

Hydrogen Cofiring Demonstration for Brentwood GE LM6000 Gas Turbine (Source: EPRI)

100% Hydrogen Combustion

Combusting pure hydrogen while also controlling the associated nitrogen oxide emissions and ensuring an upkeep in efficiencies is an engineering challenge, but manufacturers have started developing and testing HVAC appliances specifically designed for 100% pure hydrogen fuel[7,8]. Mitigation methods for end-use applications are also being tested to ensure NO_X emissions are kept within the allowable limits[9]. These developments will help ensure net zero goals are achieved in the coming years as more emphasis is placed on replacing natural gas and other traditional combustion fuels with a cleaner alternative, hydrogen.

[3] Angela Serrano de Rivera - AEE WORLD | Energy Conference & Expo
[4] 2023-AEE-World-Proceedings.pdf (aeecenter.org)
[5] (PDF) Investigations on performance and emission characteristics of an industrial low swirl burner while burning natural gas, methane, hydrogen-enriched natural gas and hydrogen as fuels (researchgate.net)
[6] Executive Summary: Hydrogen Cofiring Demonstration at New York Power Authority's Brentwood Site: GE LM6000 Gas Turbine (epri.com)
[7] HydrogenReady SmartBurner for Heat Treatment Furnaces | Tenova
[8] Combustion | Hy-Ductflam™ - Hydrogen duct burner - Fives Group
[9] (PDF) Domestic hydrogen boilers in practice: enabling the use of hydrogen in the built environment (researchgate.net)