Impact of hydrogen combustion on NO_X emissions – physical and regulatory considerations

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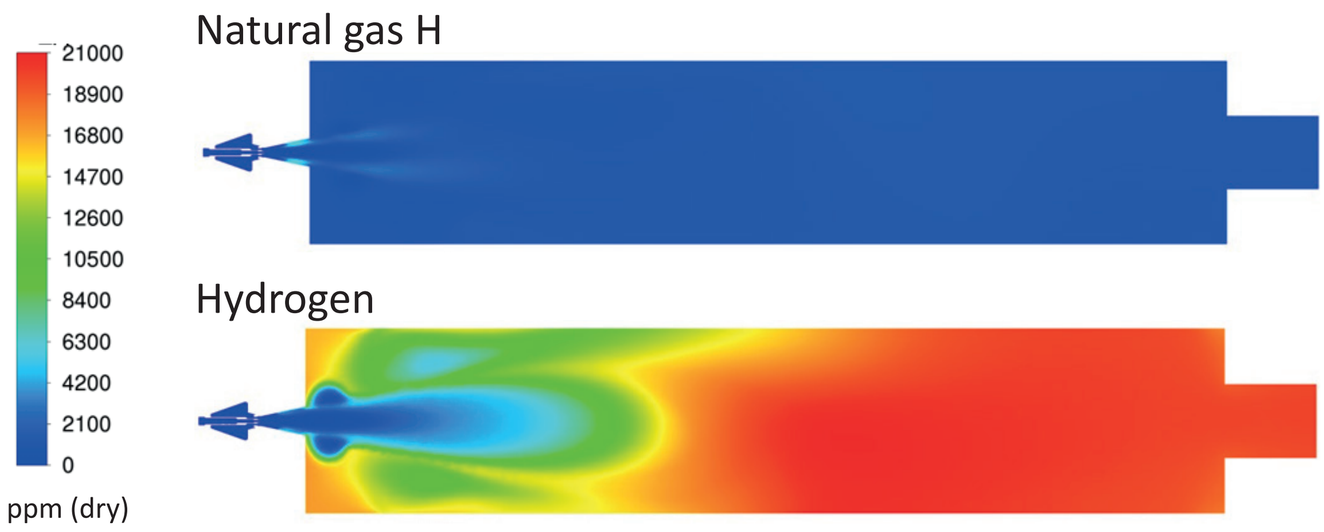
Motivation

Hydrogen is considered a key component of a future decarbonized energy system. Hydrogen is, however, also a very different fuel, compared to natural gas, with higher adiabatic combustion temperatures (in air), and thus higher potential to form thermal NO_X. However, most primary measures to reduce thermal NO_X have been proven to work with hydrogen as well.

Today, pollutant emissions are usually quantified as concentrations in the dry flue gas, in units such as [ppm] or [mg/m³]. Hydrogen forms much more water vapor during combustion and produces less flue gas per unit of energy, which means that dry NO_X emissions from hydrogen combustion are not directly comparable to those from natural gas combustion. The same issue arises for other pollutants and fuels as well.

Energy-referenced units such as [mg/MJ] or [mg/kWh] are better suited to allow for a consistent comparison.

Example: CFD simulation of NO_X emissions from a semi-industrial test rig (Oxy-fuel, P = 320 kW, λ = 1.05)



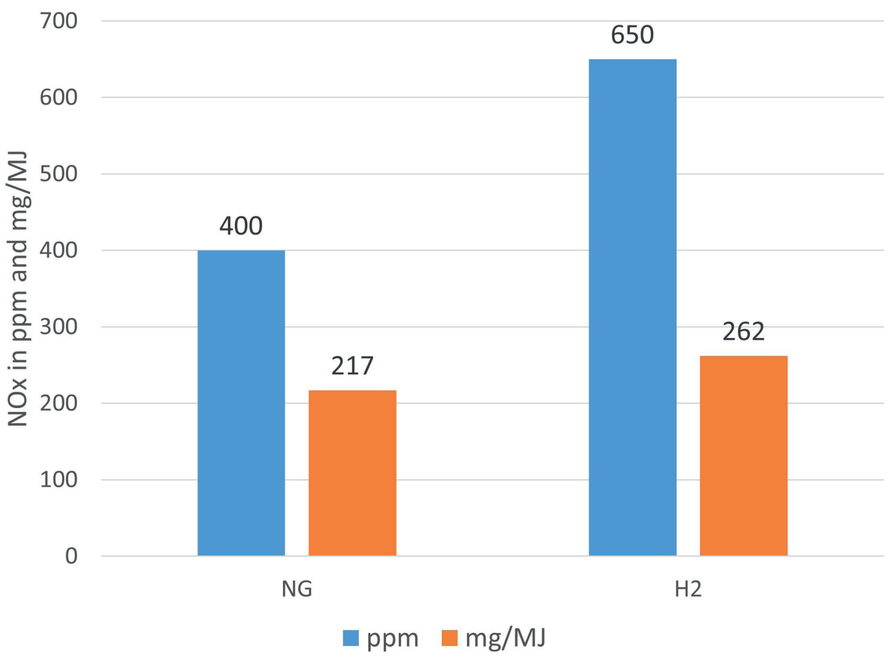
Flue gas values:
1,576 ppm (dry)
567 ppm (wet)
$\dot{m}_{NO}$ = 21 mg/s

Flue gas values:
19,821 ppm (dry)
366 ppm (wet)
$\dot{m}_{NO}$ = 15 mg/s

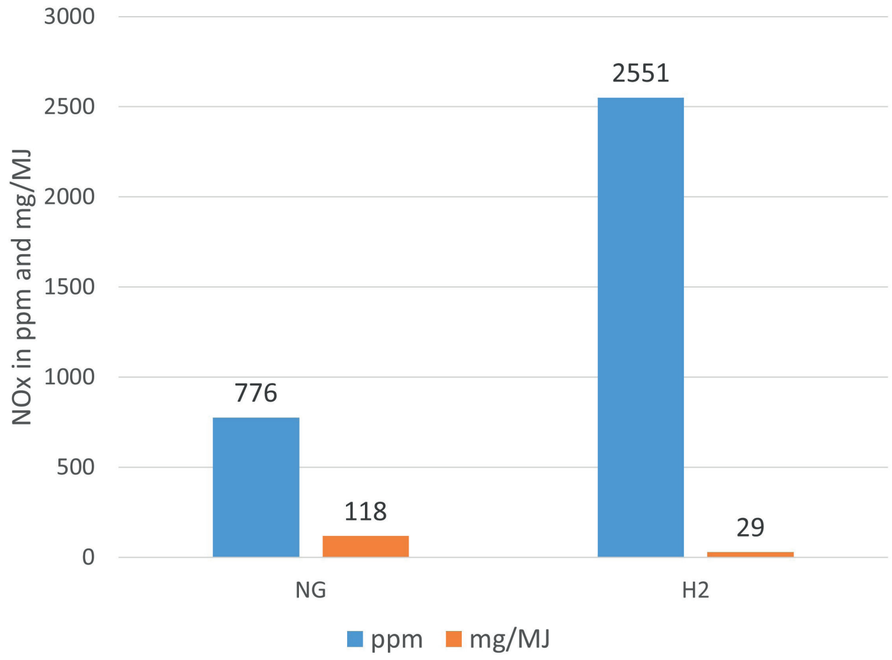
Note: In oxy-fuel combustion, thermal NO_X formation is controlled by the availability of N.
In these simulations, 1 vol.-% of N_2 was added to the oxidizer to account for impurities and infiltration air.

Example: experiments in semi-industrial combustion test rigs

Air, P = 500 kW, λ = 1.1, T_{air} = 1,150 °C



Oxy-fuel, P = 320 kW, λ = 1.05



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