Technological and economical assessment on hydrogen energy conversion systems based in gas turbines

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1 - Introduction

Gas turbines + **Hydrogen** = **Smooth Energy Transition**


[1]

2 - Challenges

- **Combustion instabilities** for premixed DLN combustors
- **High NOx** emissions for non-premixed burners
- Increased **water content** in the ecosystem
- **High cost** of green hydrogen

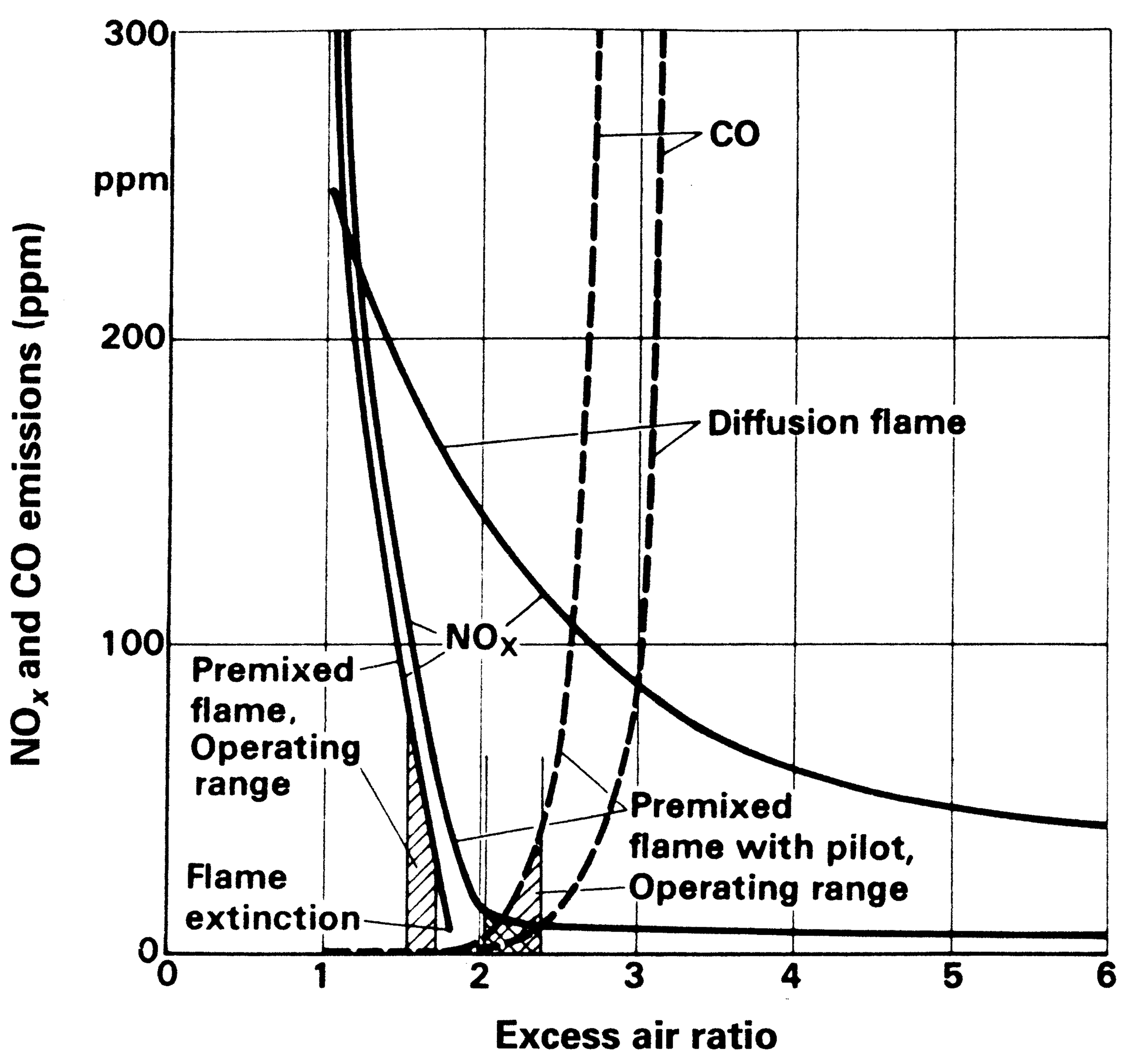
3 - Goal

Investigation of **current status, possibilities** and **limitations** of hydrogen gas turbine technology.

Modeling and simulation of combustion process of various fuels.

Techno-economic analisis and calculation of **green hydrogen cost** of production.

4 - Hydrogen combustion



- Premixed and non-premixed flame [2]
- NOx formation mechanisms [3]

5 - Reactor Simulation

$$(\alpha\ CH_4 + \beta H_2) + (2 \cdot \alpha + \frac{\beta}{2}) \cdot (\ O_2 + 3{,}76 N_2)$$

Fuel (n, Φ) → **Combustion chamber** → Products

Oxidizer (T, P, n) → **Combustion chamber**

6 – Cost of green hydrogen

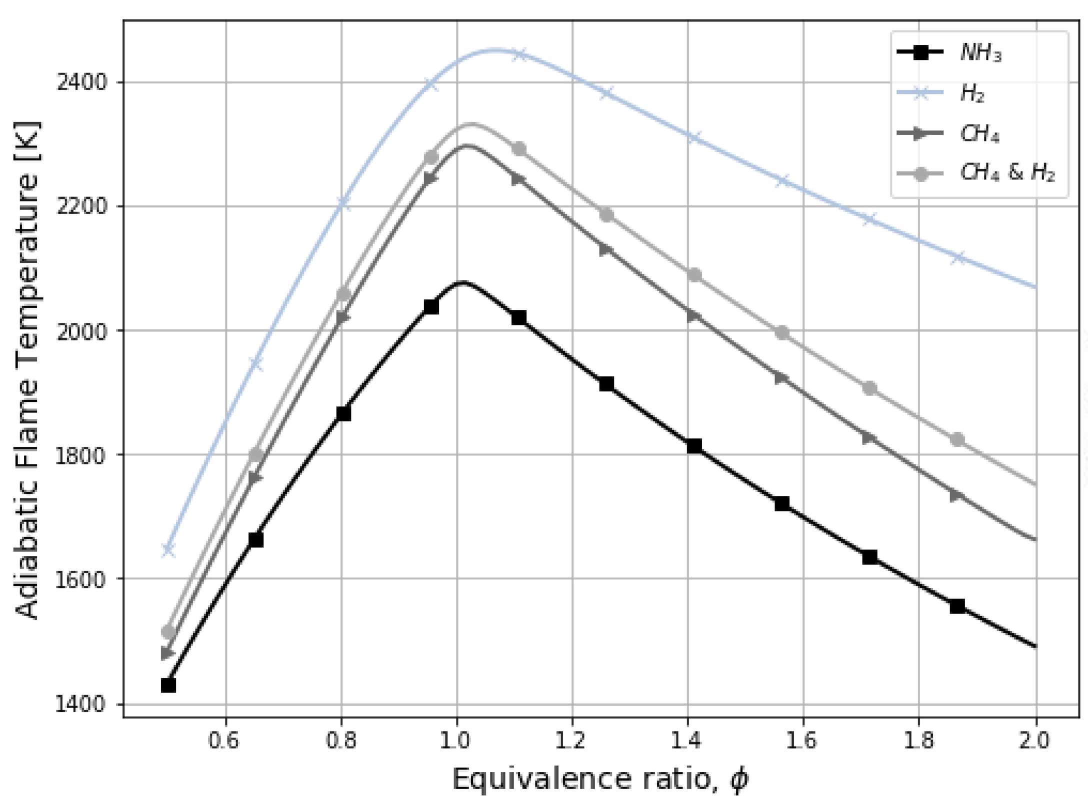
$$Cost_{H_2}\left[\frac{€}{kg}\right] = \left(\frac{electr.cost\left[\frac{€}{MWh}\right]}{1000} + \frac{CAPEX\left[\frac{€}{kW}\right]}{t} \cdot \frac{1}{ha}\right) \cdot \frac{H_2\ LHV}{eff} - O_2\ revenue\left[\frac{€}{kg}\right] \cdot 8$$

electr. cost – Price = **30 €/MWh**
1000 – conversion factor to kWh
CAPEX – cost of electrolyzer = **900 €/kWh**
t – lifetime of an electrolyzer = **10 yrs**
ha – utilization factor

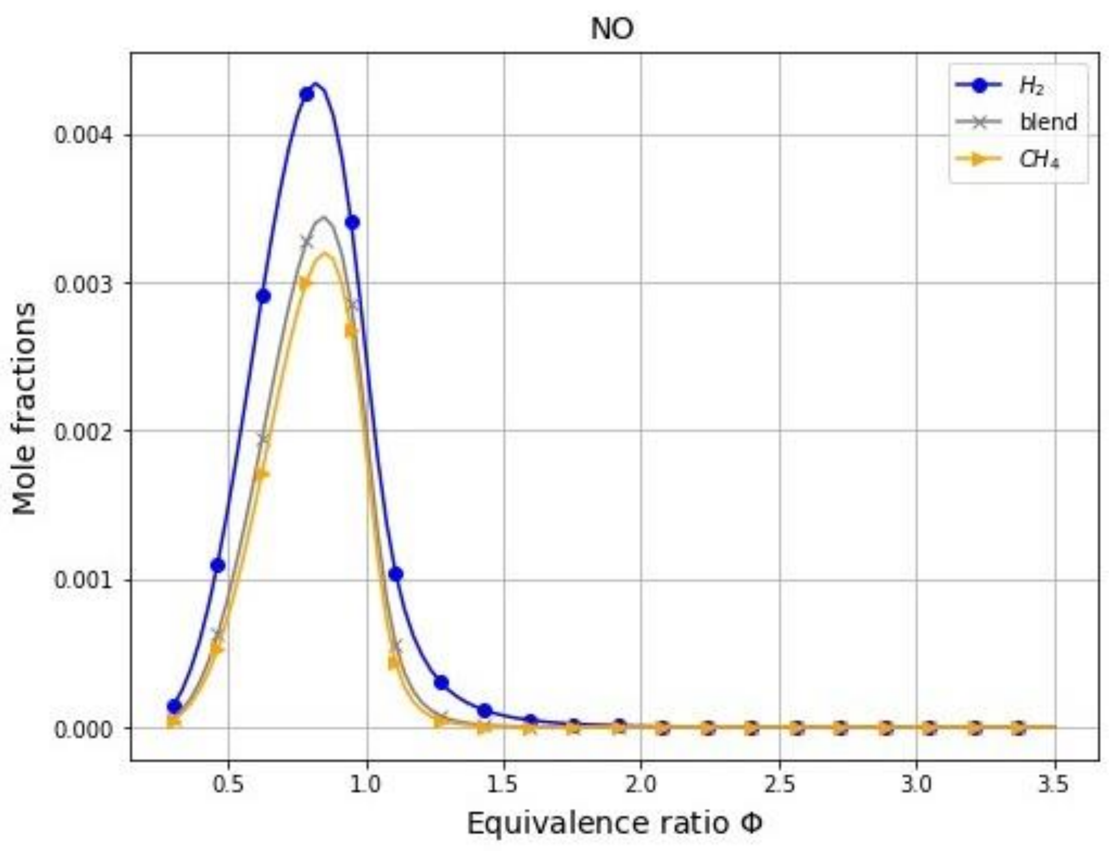
eff – electrolyser efficiency = **70%**
H2 LHV – H2 Lower Heating Value
8 – resulting from the reaction of water electrolysis.

For each 1 kg of H2 there are 8 kg of O2 produced [4]

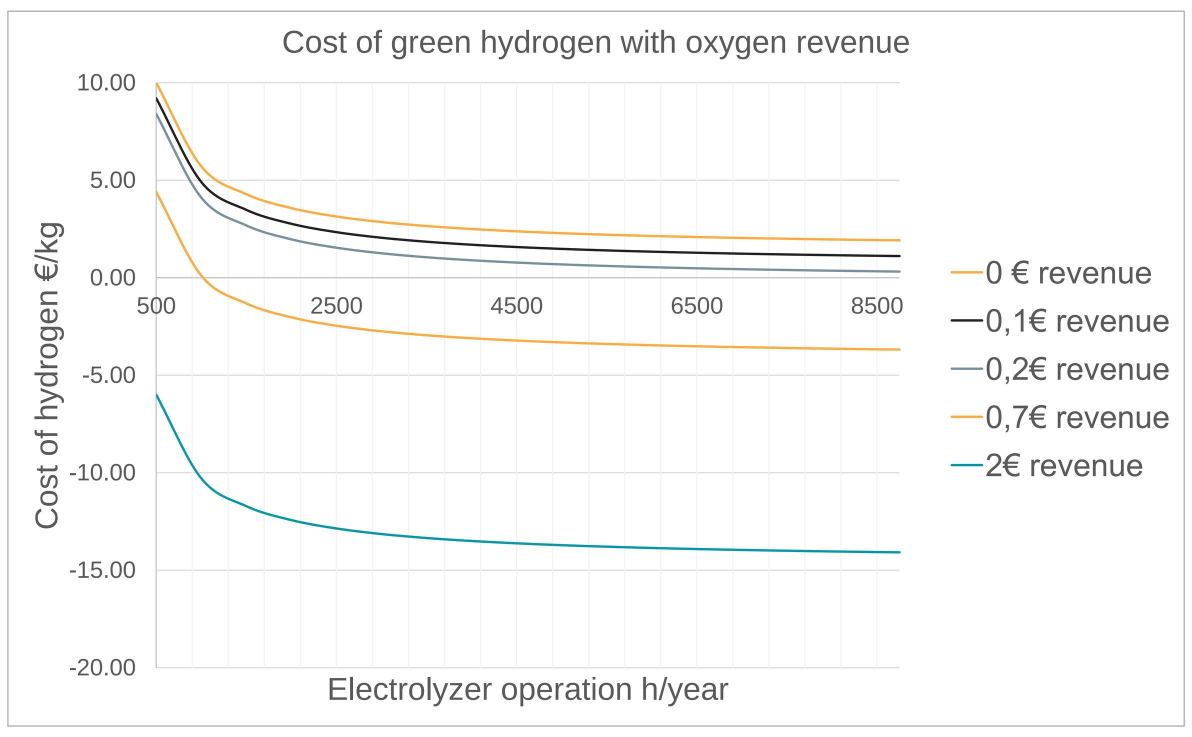
7 - Results and conclusions



Adiabatic flame temperature for various fuels combustion in air at T=300 K, P=1 atm.



Emission formation, combustion of H2, CH4 and CH4 blend with 50% H2 at T=300 K and P=1 atm.



Green hydrogen cost including the revenue coming from selling electrolysis by-product in form of oxygen and different cost scenarios [5] [6] [7]

- The highest emission contribution from **thermal NOx** due to high temperature of combustion.
- **Ammonia** as an alternative solution for hydrogen combustion.
- In large scale applications, amount of **water produced** should be taken into account.
- Revenues from selling oxygen could contribute to significant **reduction of green hydrogen cost**.

References

[1] Mitsubishi Heavy Industries https://solutions.mhi.com/casestudies/decarbonizing-gas-turbine-by-hydrogen-firing-technology/
[2] Moore MJ (1997) Nox Emission Control in Gas Turbines for Combined Cycle Gas Turbine Plant. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy. 211: 43-52.
[3] Lefevbre, Arthur H.; Ballal, Dilip R. Gas turbine combustion: alternative fuels and emissions. CRC press, (2010).
[4] Rui Costa Neto IN+, LARSyS, IST, Universidade de Lisboa . [Online]. Available: https://www.linkedin.com/in/rui-costa-neto-60106920/ .
[5] M. Hurskainen, „Industrial Oxygen Demand in Finland," Helsinki, (2017).
[6] Kato, Takeyoshi, et al. Effective utilization of by-product oxygen from electrolysis hydrogen production. Energy, (2005).
[7] Nicita, A., Maggio, G., Andaloro, A. P. F., & Squadrito, G. (2020). Green hydrogen as feedstock: Financial analysis of a photovoltaic-powered electrolysis plant. International Journal of Hydrogen Energy.