CFD Simulation of Non-Premixed NG/H2 Combustion in Gas Turbines

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Acknowledgement

energies

MDPI

Article

Combustion Characterization in a Diffusive Gas Turbine Burner for Hydrogen-Compliant Applications

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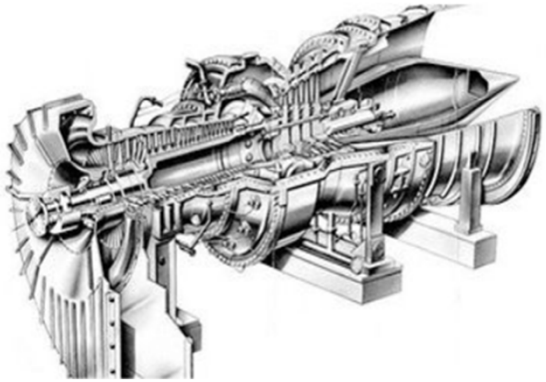
Energy transition: the Polito and EthosEnergy strategy



- **Increasing share** of Renewable Energy Sources (RES)
- GTs: flexible and well suited for frequent starts

  -> **complementary** to the time-fluctuating RES.

  -> **enabler** for the exploitation of **long-term energy storage**

Energy transition: the Polito and EthosEnergy strategy

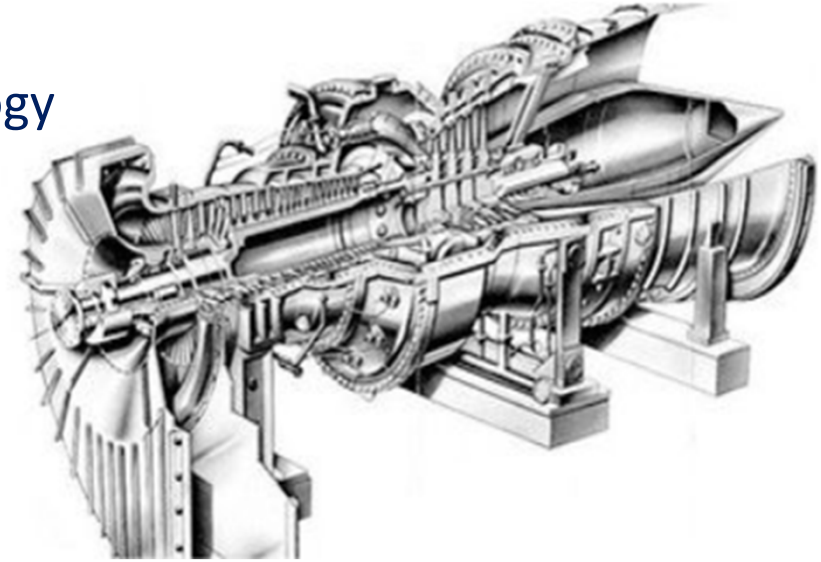
- Fuel **flexibility**
  - variable blending between NG and H2
  - H2 quality
- **Retrofitting** of existing turbines

  -> Lifetime extension -> ecomical and environmental benefits (LCA perspective)

  -> key **enabler** for the implementation of H2-GT technology

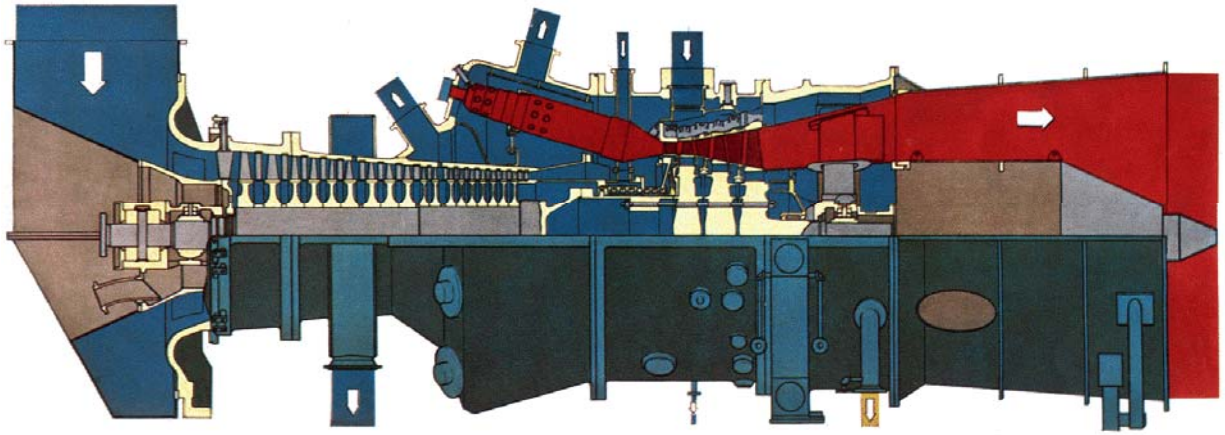
  -> small modifications of existing burners are expected

  -> increased **on-field experience** will enable further developments



Source: Hydrogen Gas Turbine Report, ETN, 2020

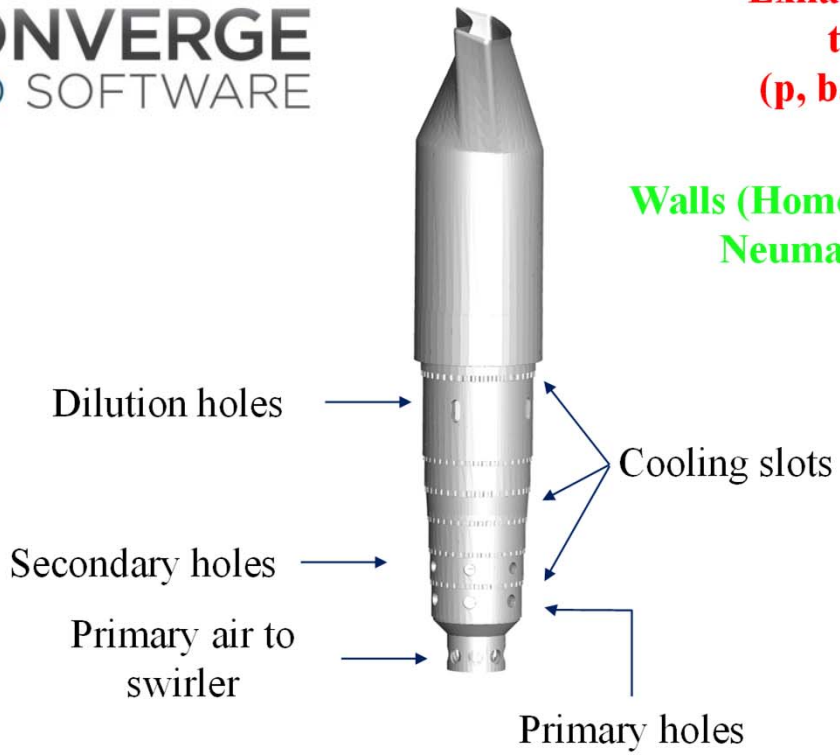
Case study / Which benefit can we expect?

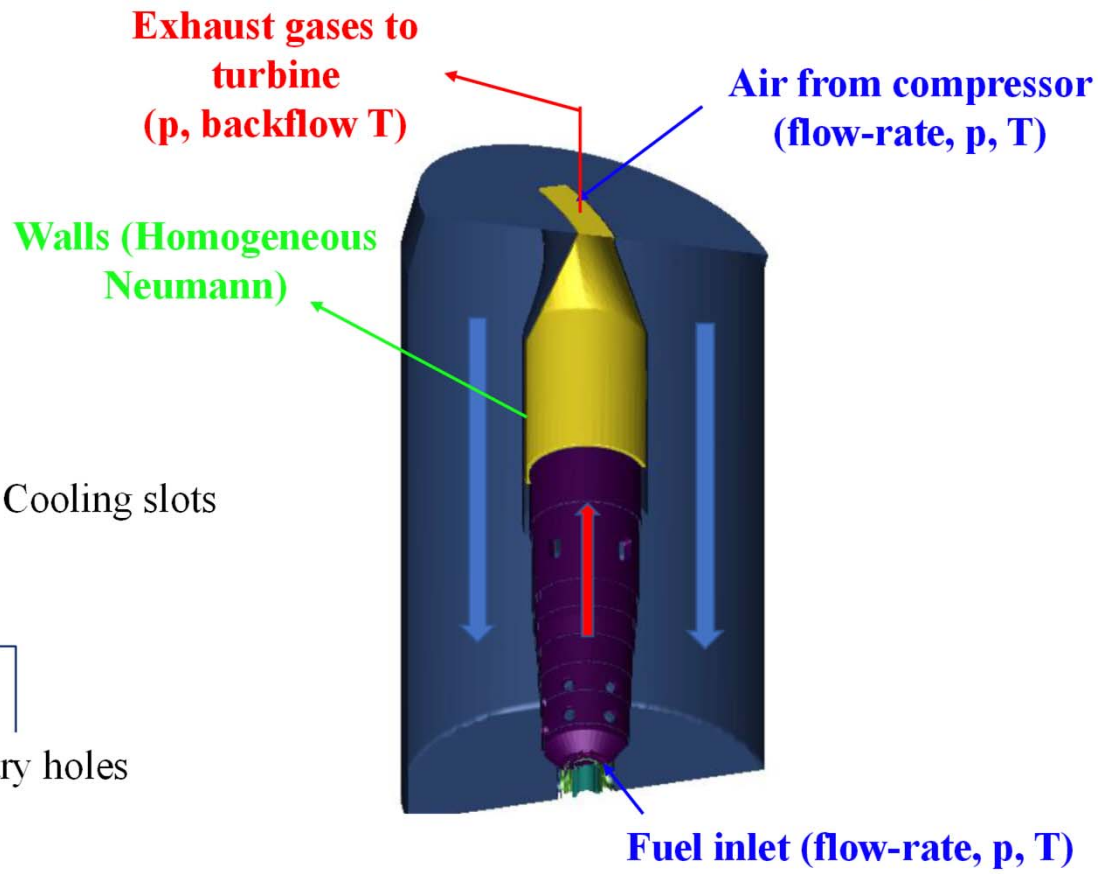


- **TG20 B7/8** turbine from EE portfolio
- Fuel rate adjusted to keep TIT constant

	NG	HCNG-15%	HCNG-25%	HCNG-50%
H/C ratio	3,3	3,6	3,9	5,9
LHV [MJ/kg]	41,6	43,3	44,7	50,3
Fuel rate [%]	100	96	93	83
CO_2 mass emissions [%]	**100**	**92**	**88**	**72**

Case geometry and BCs

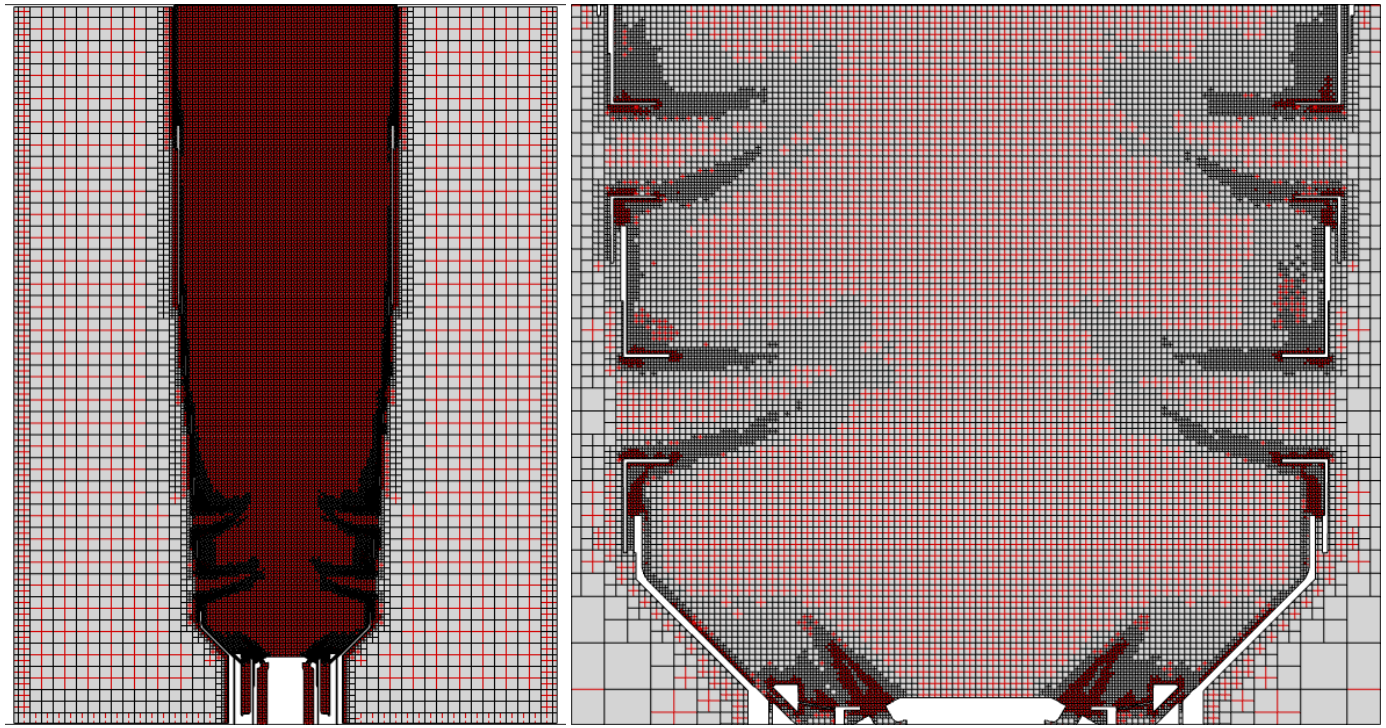




Case setup

Solver	Steady-state, PISO
Flux scheme	2nd order upwind (MUSCL)
Turbulence Modeling	k-ε RNG (RANS)
Combustion Modeling	FGM 1D diffusive
Reaction Mechanism	GRI-Mech 3.0
Initialization	Mapping from a 1st order solution
Base grid size	20 mm
Fixed embedding in casing and TP	5 mm
Miminum size (FE)	0,156 mm (injector holes)
Minimum size (AMR)	1,25 mm (Temperature, entire domain)

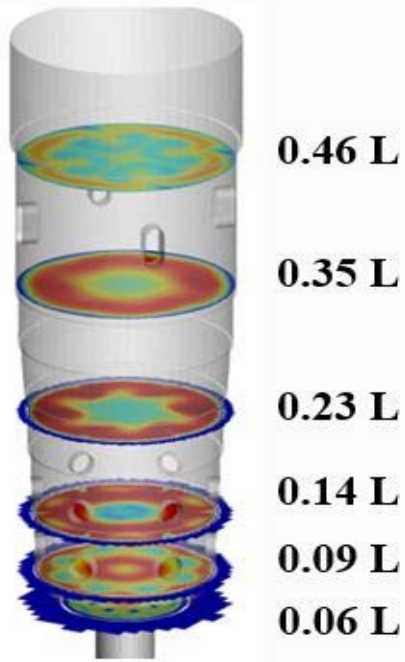
Grid independence analysis



Red lines
indicate that the grid size of the refined mesh is lower.

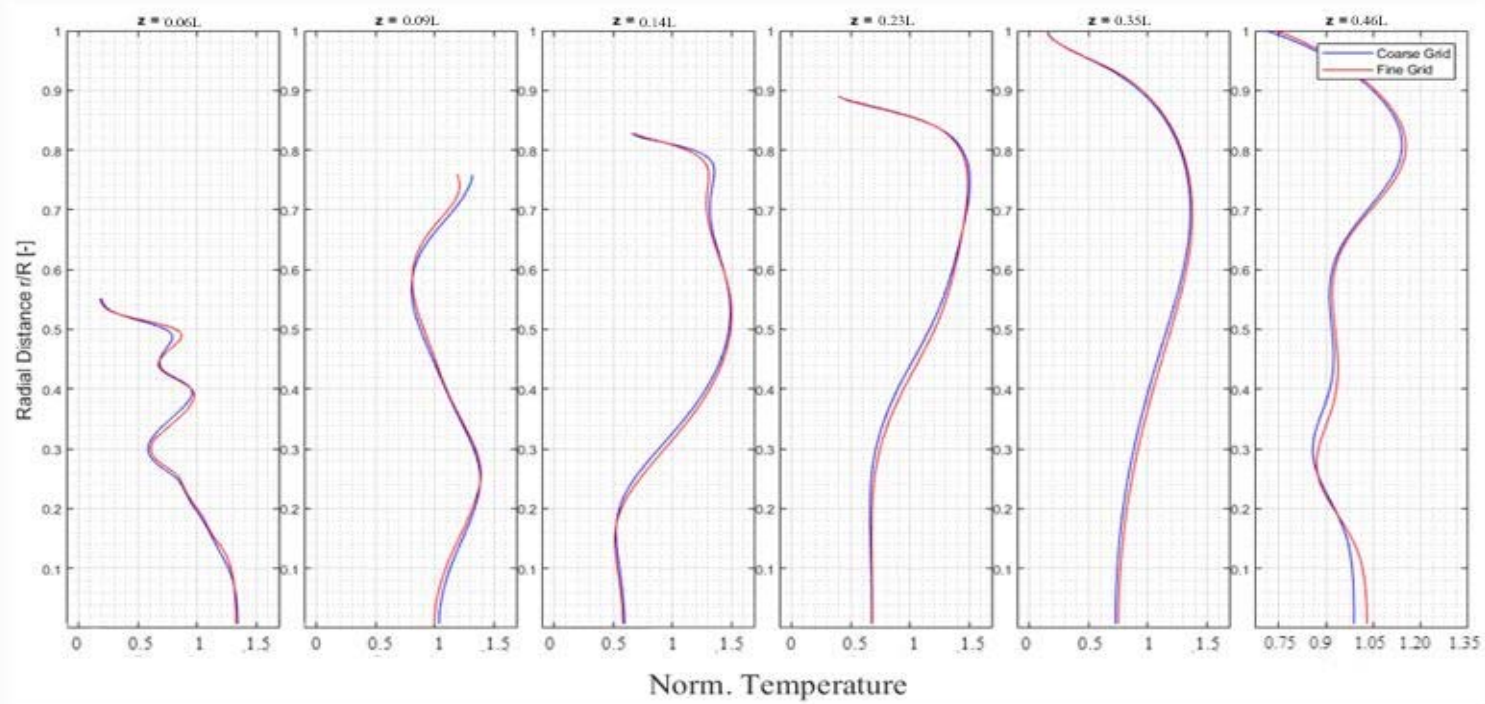
Average number of cells in the liner region (TP excluded):
5,5 M (**base**)
20 M (**refined**)

Grid independence analysis



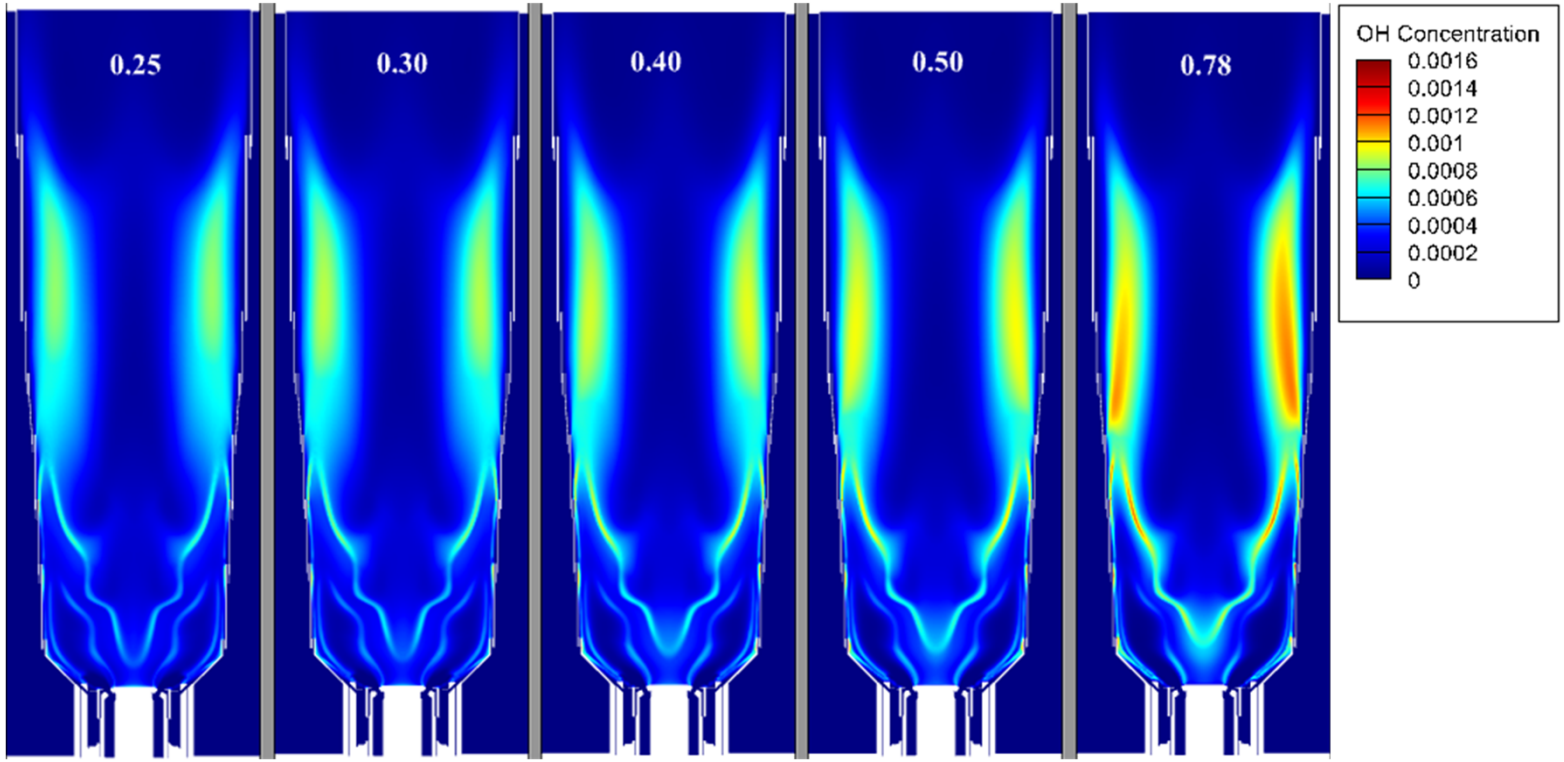
L= Combustor Length

N.B. Contour data are from fine grid.



Schmidt number sensitivity analysis (1)

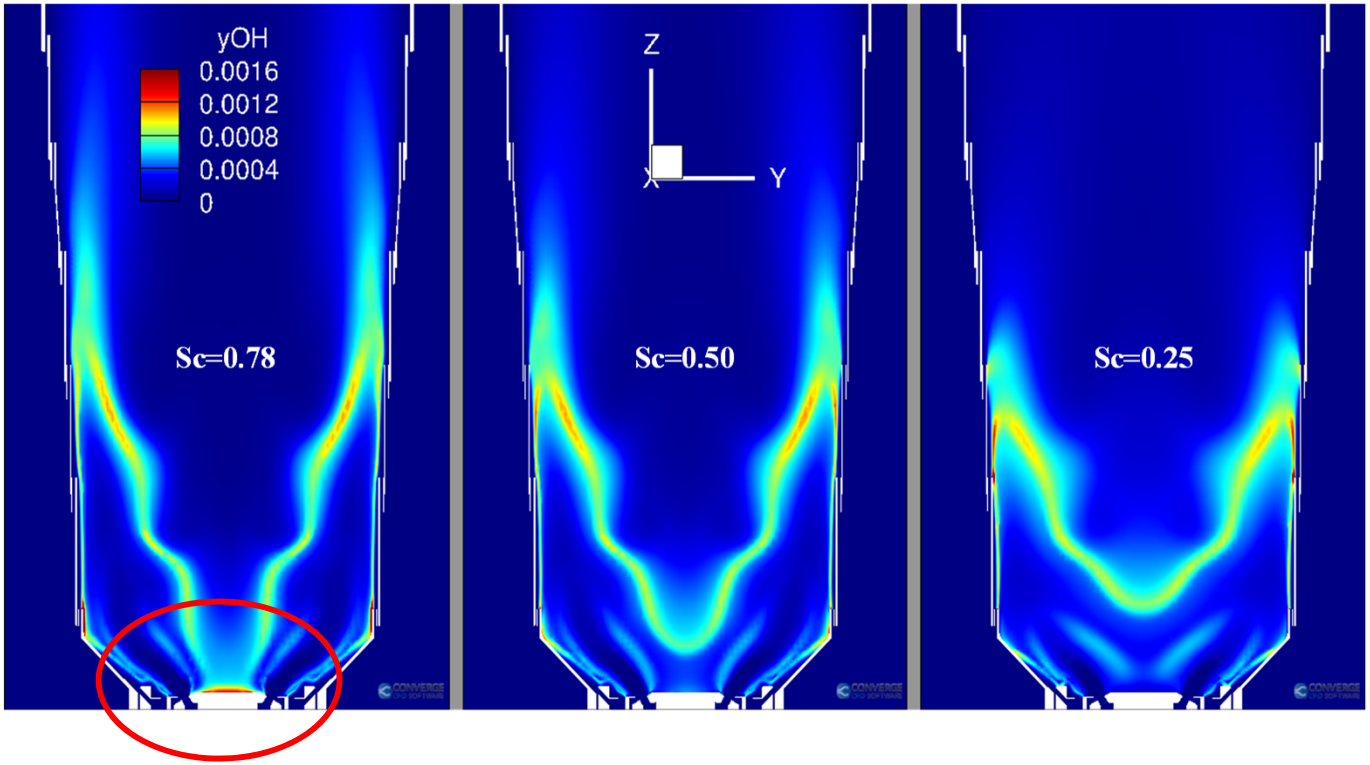
Base load condition with NG



Schmidt number sensitivity analysis (2)

70% load case with NG

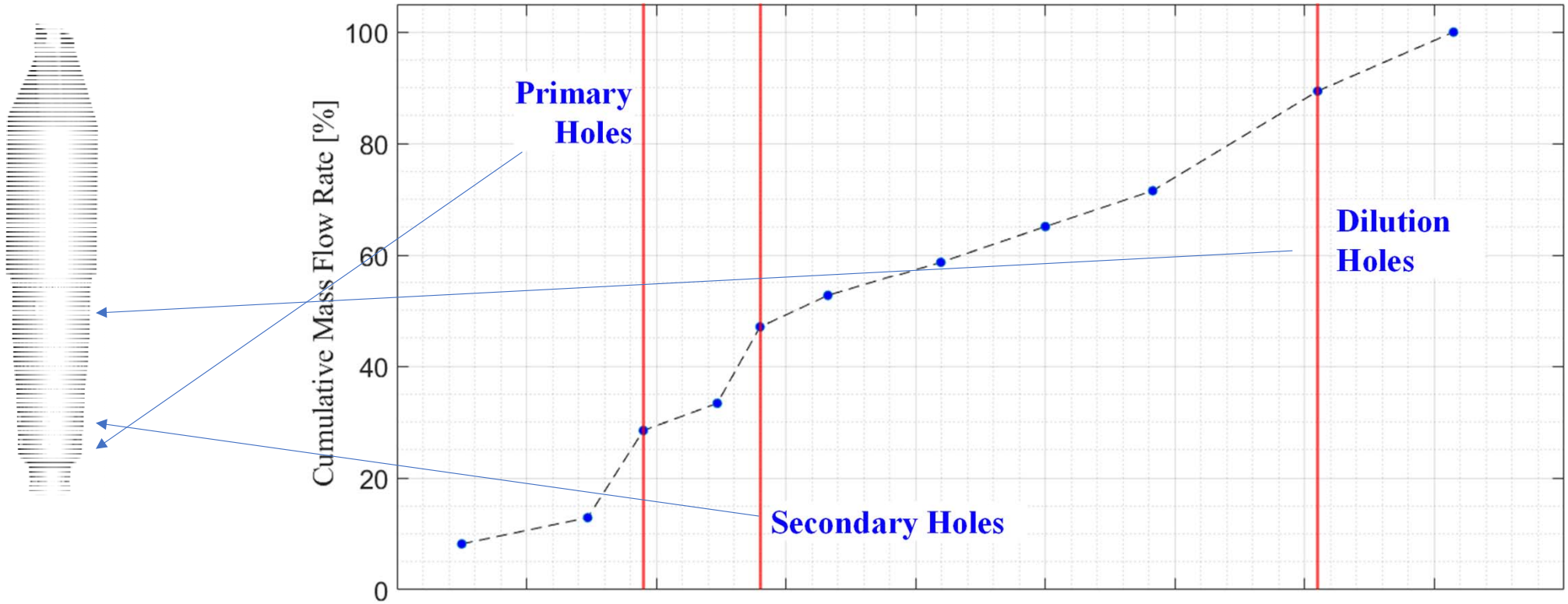
- Same **air** mass-flow rate as base load
- Lower **fuel** rate



No flame lift-off

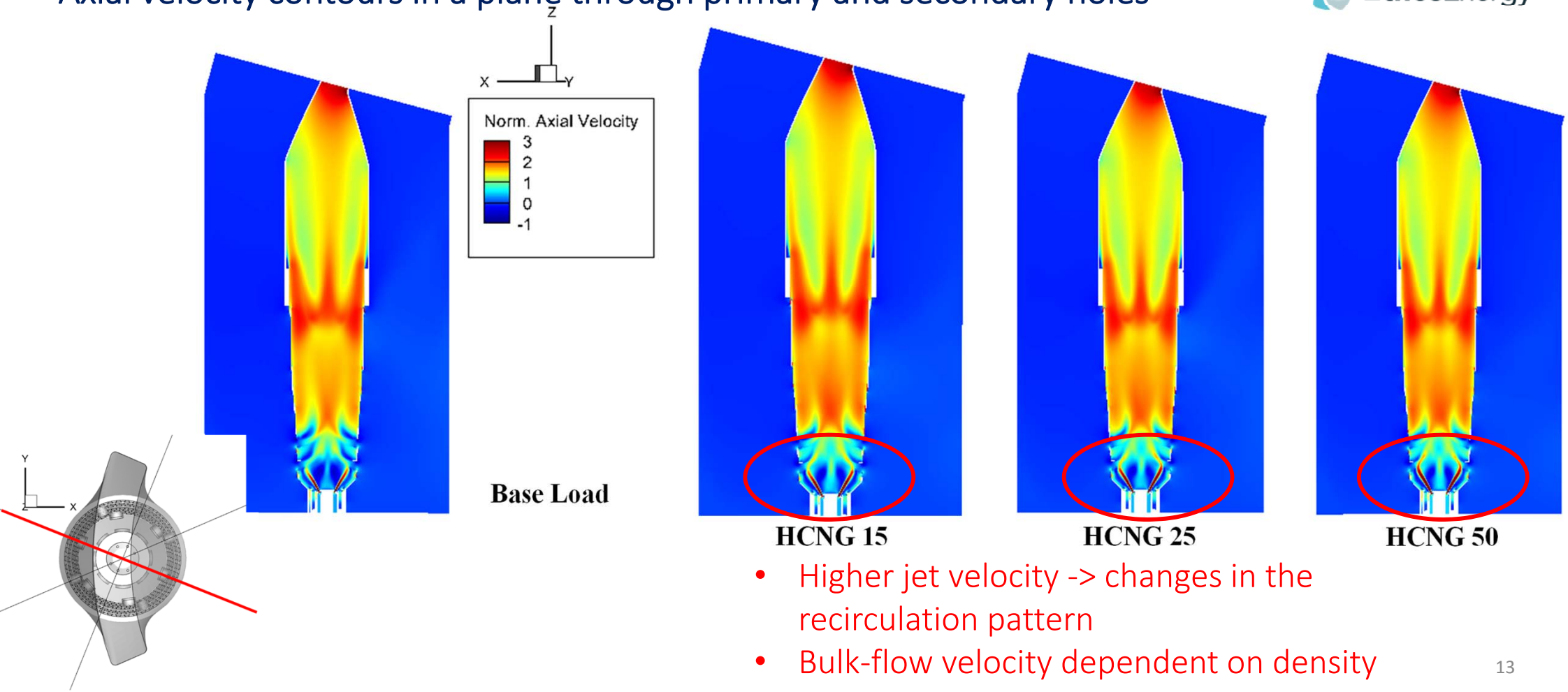
Results

Total mass-flow rate vs. axial position



Results

Axial velocity contours in a plane through primary and secondary holes

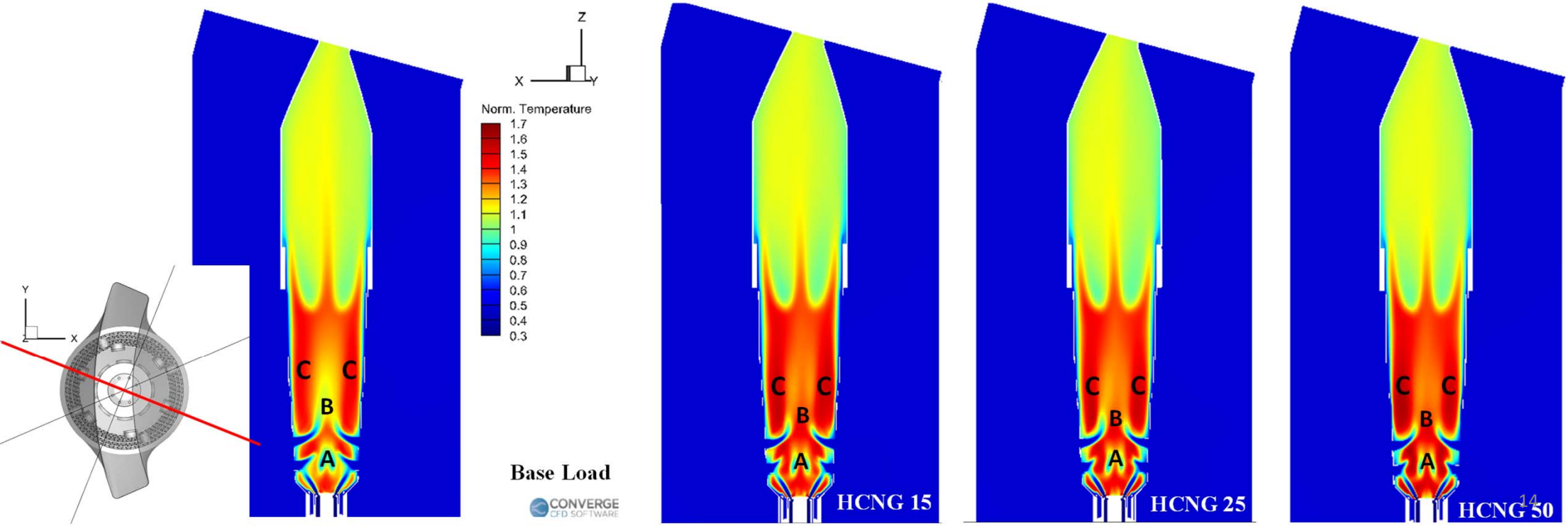


- Higher jet velocity -> changes in the recirculation pattern
- Bulk-flow velocity dependent on density

Results

Temperature contours in a plane through primary and secondary holes

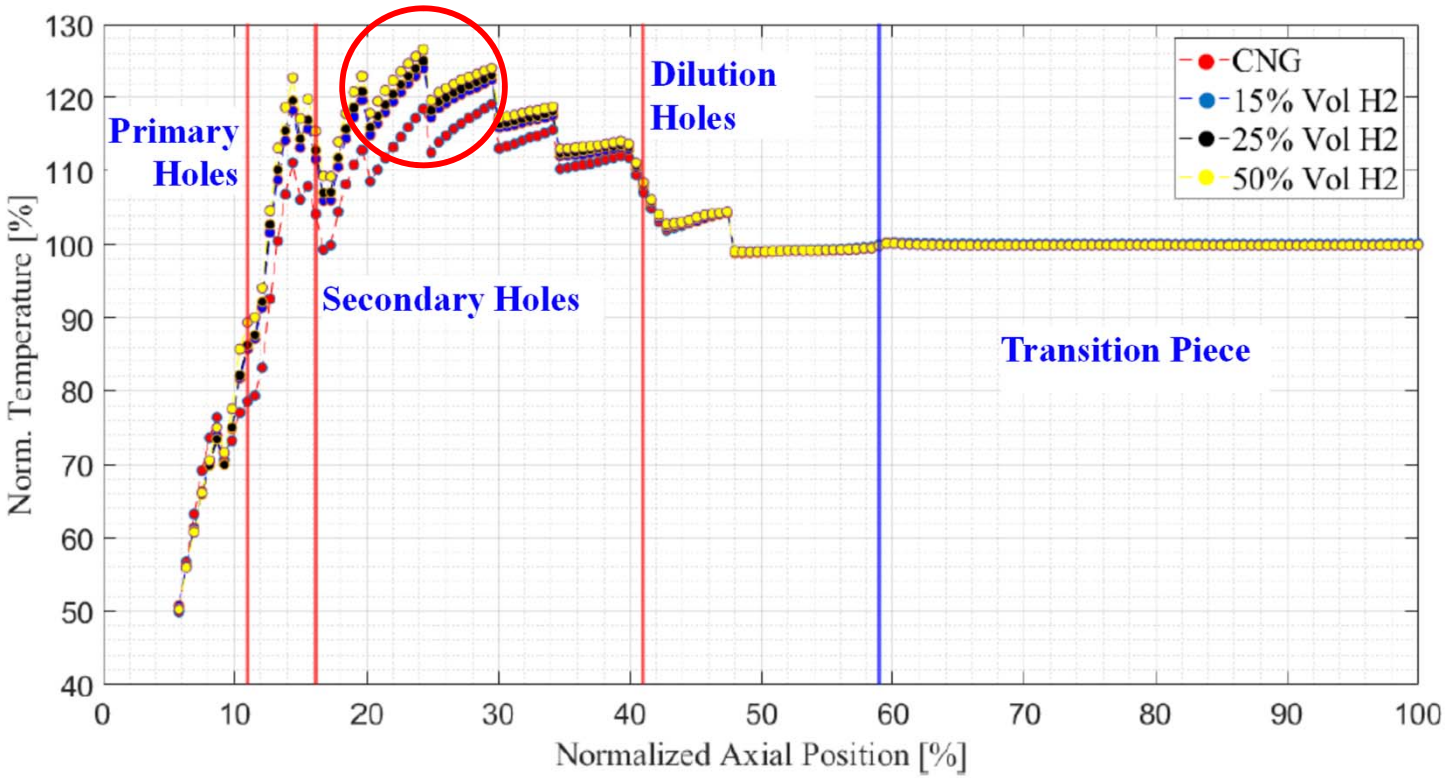
A: recirculation
B: ‘central’ hot zone
C: ‘peripheral’ hot zone



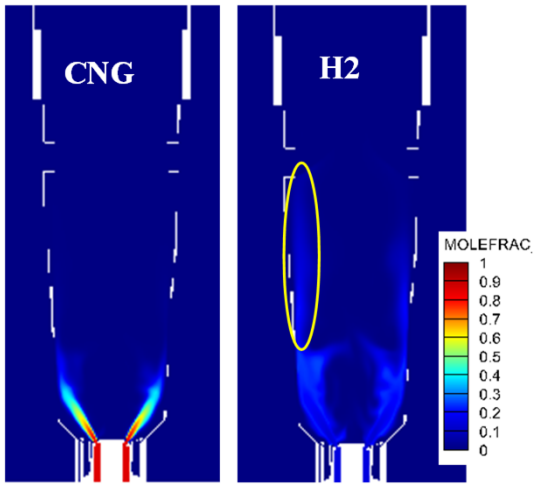
Results

Average temperature vs axial position

HCNG-50 -> +8%



Nonlinear behavior:
longer path for H2

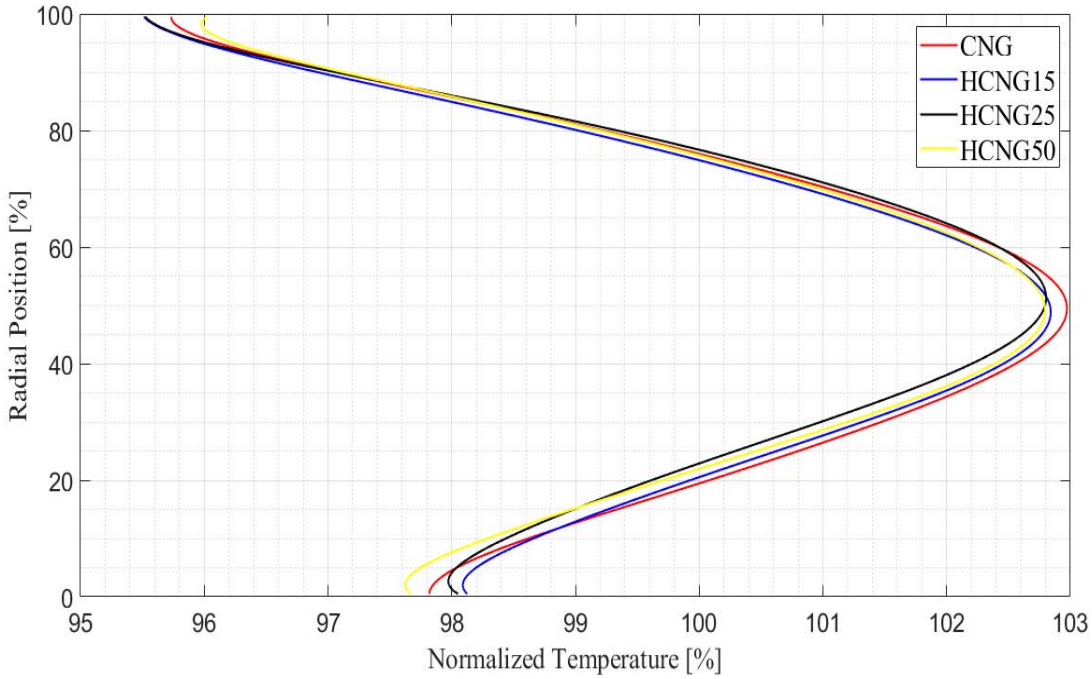


Hydrogen:

- 2,4 x $(LHV)_{NG}$
- 2 x $(A/F)_{st,NG}$

Results

Radial temperature profile



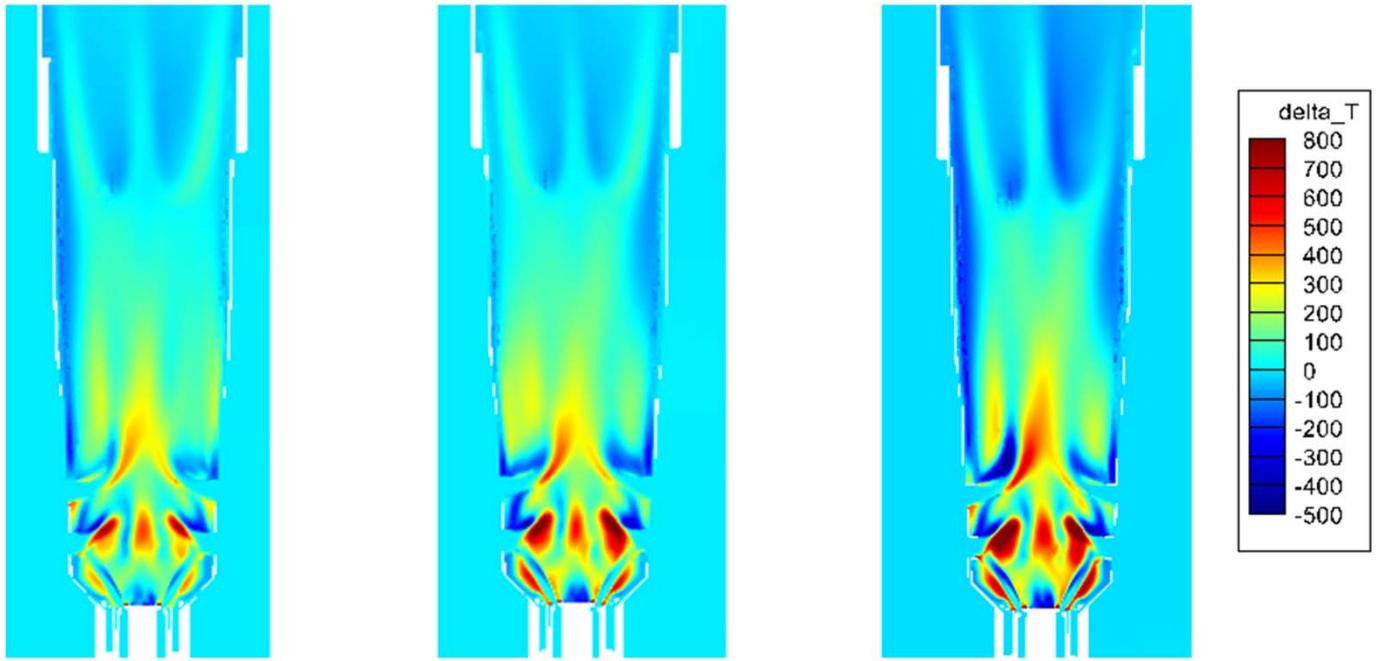
No significant changes if H2 is added to NG (being TIT fixed)

-> Constant pattern factor

Results

‘Differential’ temperature maps

$$\Delta T = T_{HCNGy} - T_{CNG}$$



HCNG 15 HCNG 25 HCNG 50

Maximum temperature increase as high as 800 K

- NOx ?
- Mechanical stresses ?

(Currently under investigation)

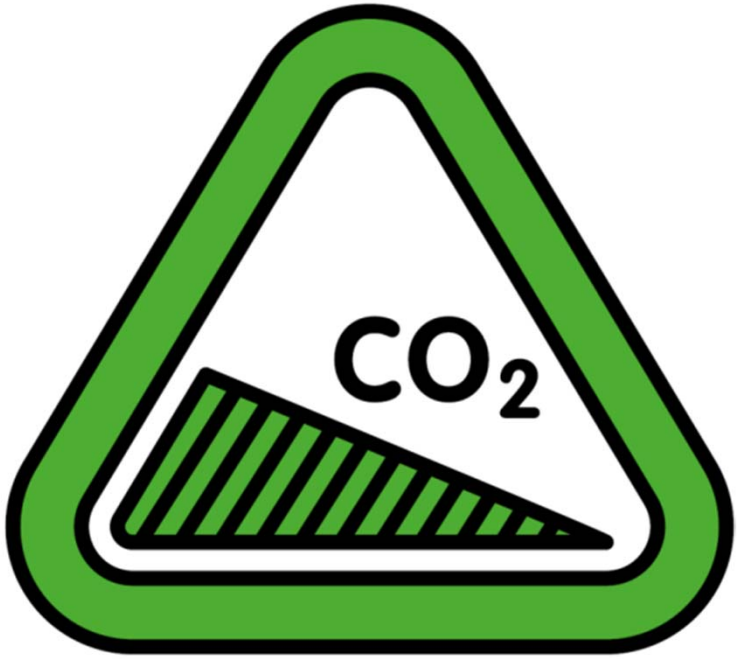
Conclusion (1)

- Model development and application successful
- The combustion process in a non-premixed gas turbine burner, which is originally designed for CNG fueling, was characterized for different hydrogen blends.
- The analysis was aimed at finally retrofitting a 40 MW heavy-duty gas turbine.

Conclusion (2)

- A local increase in the temperature up to 800 K was obtained, as a combination of the LHV, $(A/F)_{st}$, and increased diffusivity effects.
- Further work is required before the effective retrofitting can be realized :
  - Careful consideration of the NOx compensation strategies (water injection and/or turbulence optimization)
  - Injector and swirler thermal stresses analysis
  - Assessment of possible design changes (taking also fuel flexibility into account)

Thank you for your attention!



Questions?

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