ENERGY TRANSITION AND HYDROGEN COMBUSTON

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UN-ECE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

12 & 13 June 2023

ENERGY TRANSITION AND HYDROGEN TRANSITION

1. H2 production methods
2. Main thermal & economical data
3. H2 combustion & burners

H2 production methods

Technology	SMR / ATR	Electrolyser	Plasma
Maturity	TRL 9	TRL 9	TRL 5 – 8
Plant Capacity t/h	10-100	< 1 (2022 ↑) 2022 : 20 -30 MWe plants commissioned	1-5 (1 plant in the world)
Eq in MW th H_2 (for combustion purpose)	330 - 3300	< 33 (2022↑)	33 - 165
H_2 Cost in €/kg	1.5 - 3	4.5 - 6.5	3.5 - 5.0
Advantages	• Cost • Capacity	• Green (with green electricity)	• Electricity consumption • Solid C capture
Disadvantages	• CO2 recovery (70%) • CO2 storage chain maturity and cost • CH_4 feedstock	• Cost (High Capex/Opex) • Electricity consumption	• Maturity • CH_4 feedstock • High capex (prototype)

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Main thermal data

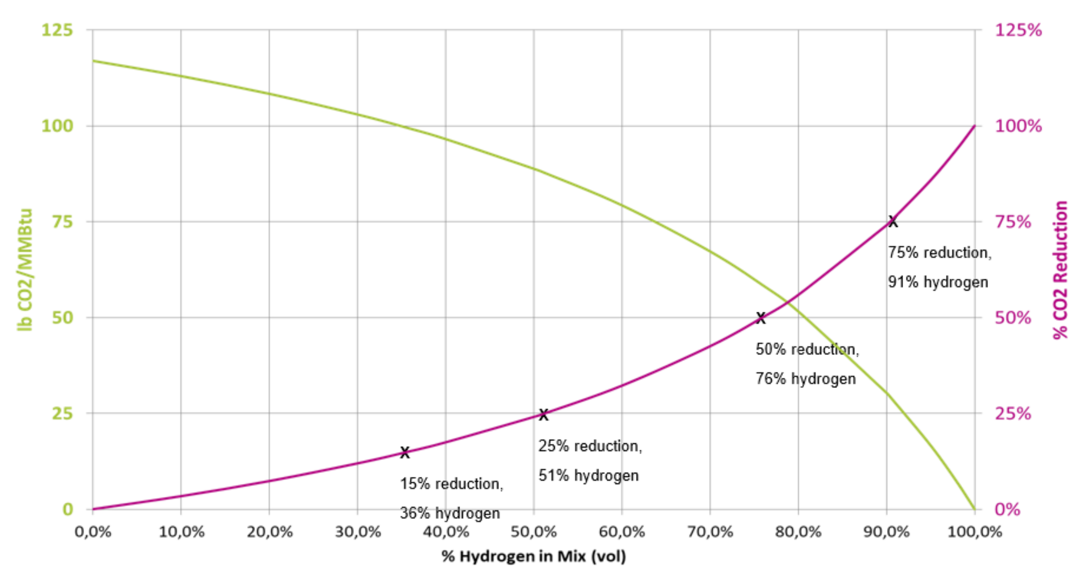
	NG	H_2	Unit	H2 vs NG
Density	0,72	0,09	Kg/Nm^3	/ 8 ➔ Easy to leak, required HP storage to be effective High velocity in piping, difficult to measure
LHV (vol)	10,2	3,0	kWh/Nm^3	/ 3 ➔ Much more volume to handle for same capacity
Stochiometric air ratio	0,98	0,8	Nm^3 air / kWh fuel	/ 1,2 ➔ Less air required / Hotter Flame
Energy of activation	0,29	0,02	mJ	/ 15 ➔ Low energy needed to ignit hydrogen

Main economical data

Production of Hydrogen & Energy cost

	H_2	Eq. Volume	Eq. Thermal	Elec req. (Electrolyser)	Oxygen (Electrolyser)
Production	1 T/h	11 kNm^3/ h	33 MWth LHV	55 MWe (e=60%)	8 T/h O_2

	cost	Eq Thermal Cost
NG (Europe 02/2023)		61 € / MWh LHV
CO2 (ref only - Europe)	100 €/T	22 € / MWh LHV (NG)
Elec (Europe 02/2023)		135 € / MWhe
H_2 (electrolyser ref)	5,5 €/kg	180 € / MWh LHV



- Effective Decarbonization needs high % vol of hydrogen fives

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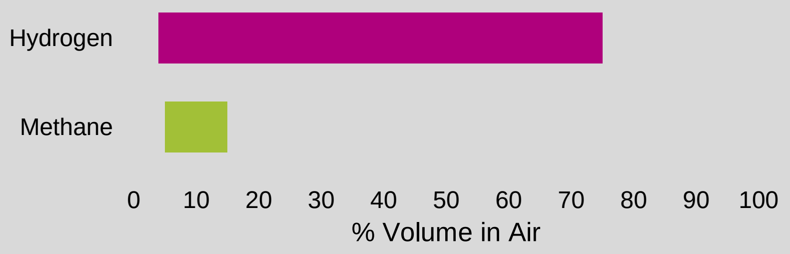
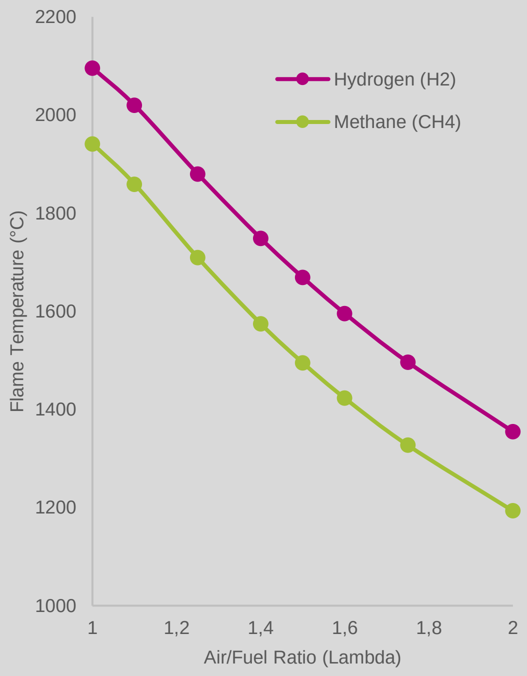
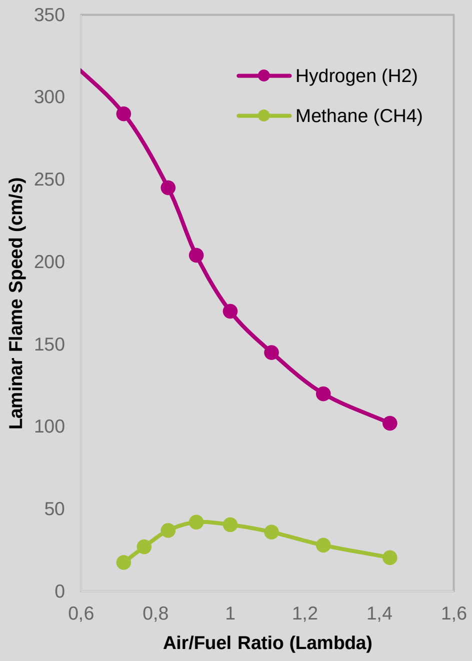
H2 combustion & burners

Main driver for combustion : Hydrogen vs Natural Gas

- Higher flame temperatures (+150°C)
- Faster flame speed x 5
- Wider flammability limits x 7
- Lower autoignition temperature -120°C



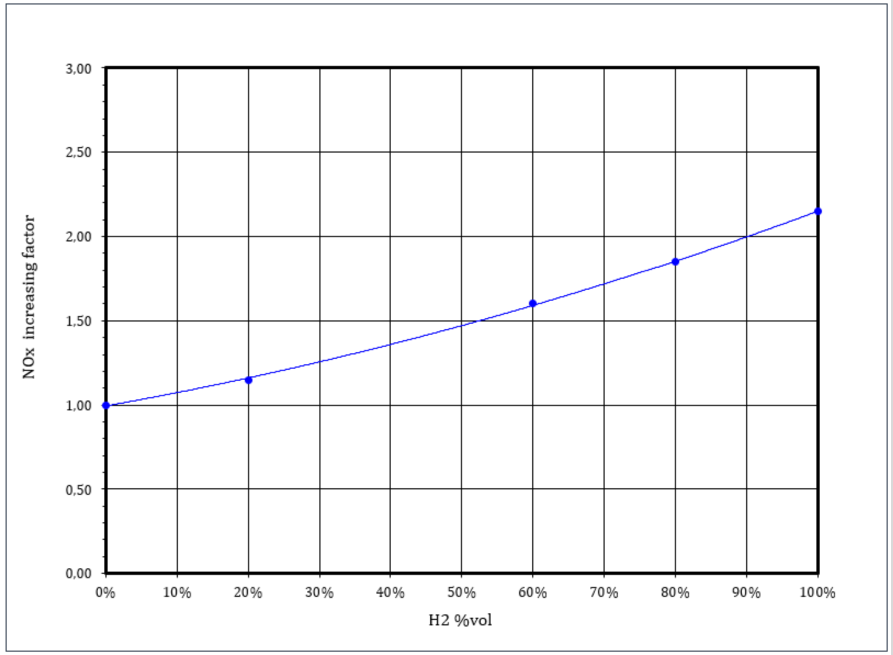




H2 combustion & burners

Main Impacts on burners :

- Warmer and more intense flames in the zone of primary combustion
- High formation of NOx of thermal origin and Prompt NO



1. **Sturdy, heat resistant and adapted burner designs**
2. **Adapted injection velocities**
3. **NOx increases : from few % to 210%
(burner techno dependant)**

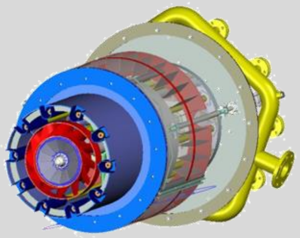
H2 combustion & burners

Fives Pillard - Large range of H_2 compatible burners for most of the industrial processes

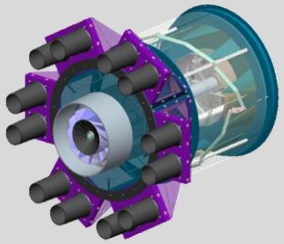
ENERGY / CEMENT / MINERAL

ENERGY

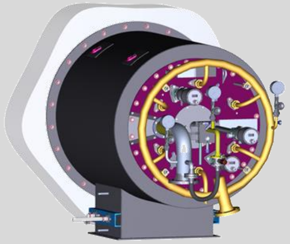
UP TO 100% HYDROGEN LOW NOX BURNERS FOR BOILERS



Pillard LONOxFLAM® G2

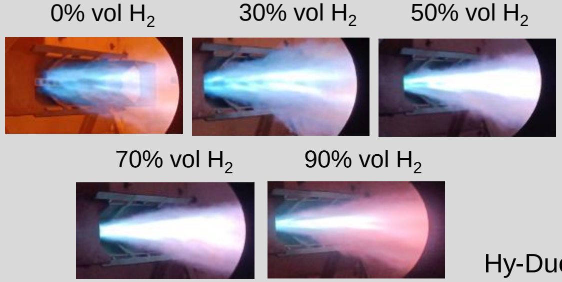


Pillard LONOxFLAM® AS



Pillard NANOxFLAM®

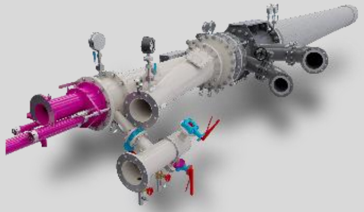
UP TO 100% HYDROGEN FOR HRSG POST FIRING INDUCT BURNERS



Hy-Ductflam™ (New patented product)

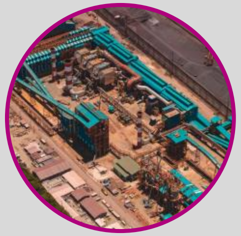
CEMENT

ROTARY KILN BURNERS TO SUSTAIN HYDROGEN AND ALTERNATIVE FUELS FIRING

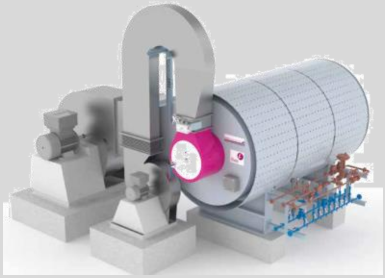


Pillard NOVAFLAM® Evolution & Pillard ROTAFLAM®

PELLETIZING



HYDROGEN COMPATIBLE HOT GAS GENERATOR FOR DRYING PROCESS

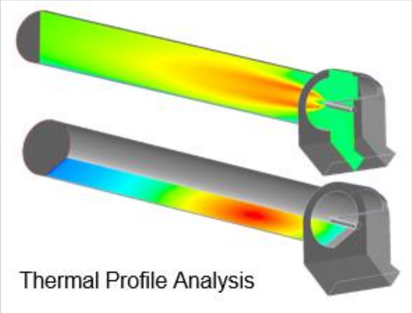


Pillard® Heat Gen System

H2 combustion & burners

Fives Pillard - CFD advanced process modelling for H2 combustion

- Advanced kinetics models / Advanced turbulence models
- New CFD models : standard RANS method vs new LBM method



$$H_2 + 1/2\ O_2 \rightarrow H_2O$$

Too simple model

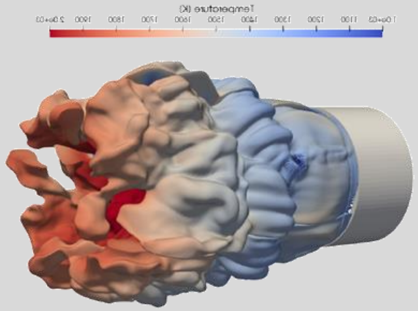
Reduced model

$$3H_2 + O_2 \Leftrightarrow 2H_2O + 2\ H$$

$$H + H + M \Leftrightarrow H_2 + M$$

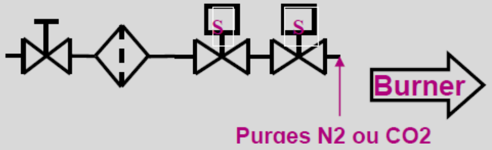
Detailed approach

H2 + O2 = OH + OH
H + O2 = OH + O
O + H2 = OH + H
H + O2 + M = HO2 + M
H + O2 + O2 = HO2 + O2
OH + HO2 = H2O + O2
H + HO2 = OH + OH
O + HO2 = O2 + OH
OH + OH = O + H2O
H2 + M = H + H + M
O2 + M = O + O + M
H + OH + M = H2O + M



H2 combustion & burners

Fives Pillard – Valve skids, Piping & Instrumentations - Safety



- Material compatibility
- Piping codes to apply (PED, ASME, API…)
- Leakage test and line purging
- Flame detection and ignitor
- Risk assessment and regulation (EN 746-2 / NFPA)
  - *At that stage of know-how about H2 implementation, a global risk analysis managed by end-user with equipment suppliers and third party (Hazop type) is recommended*

Conclusions

- **Green H2** still not competitive compared to existing industrial hydrogen production
- Usage of **H2 for burners** needs some **adjustments** and **precautions**, but nothing prohibitive
- Development of **ultra-low NOx burners** is needed for H2 firing
- **NOx regulation** for H2 firing still be to adapted

THANK YOU FOR YOUR ATTENTION !

QUESTIONS…

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Acronyms

- SMR = Steam Methane Reforming
- ATR = Auto Thermal Reforming
- NG = Natural Gas
- LHV = Low Heating Value
- CFD = Computational Fluid Dynamics
- RANS = Reynolds Averaged Navier-Stokes
- LBM = Lattice Boltzmann Method
- PED = Pressure Equipment Directive
- ASME = American Society of Mechanical Engineers
- API = American Petroleum Institute
- EN = European Norm
- NFPA = National Fire Protection Association
- HAZOP = HAZard and OPerability