LA MAISON FRANÇAISE DU VERRE

ICG International Commission on Glass

Glass for a sustainable future

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USTV UNION POUR LA SCIENCE & LA TECHNOLOGIE VERRIÈRES

Pyrex® Furnace : The decarbonation pathway of a borosilicate glass furnace

Successes & Challenges

PYREX®

BRUNIE Johann – *Group Technical Director*

*- La **M**aison **F**rançaise du **V**erre -*

2024/04/30

Context and Environmental ambitions

- **Global Warming : +1,1°C** during the last decade.
- **CO_2 concentration** is increasing and will affect the climate sustainably.
- **Extreme consequences** : heat waves, heavy rainfalls, droughts, stronger cyclones, impacts on carbon sinks and on biodiversity etc.…
- **Half of the humanity** is already impacted and/or vulnerable.
- **Human influence** is responsible, **unequivocally**.

IPCC Report

Fr. Industry Emissions*

17% of CO_2

Aims vs. 2015

2030	2050
-35%	-81%

ADEME (French agency for the Environment) deploys several transitions plans in different industrial sectors : Glass Sectorial Transition Plan (''PTS'') was released in 2024 April.

French SNBC

****Source :** Inventory CITEPA 2018 – perimeter : Climate plan Kyoto*

Summary

Pyrex® plant is fully involved and already set its decarbonation pathways.

1. How did we already reduce our emissions during the past 25 years ?
2. How did we improve our furnace during the last rebuilt, what are the results ?
3. What are our next challenges ?

Source : bonpote.com

Pyrex® : Pictures & Figures

≈ 55 kt

≈ 390
+100 (offices)

≈ 105 M€

≈ 62 GWh

≈ 56 GWh

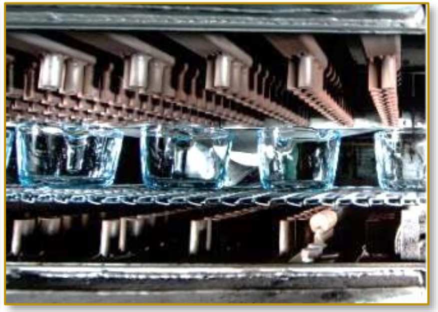
Gob loading

Pressing

Cooling

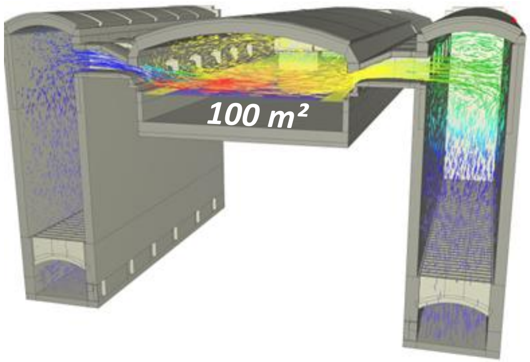
Reburning (Fire Polishing)

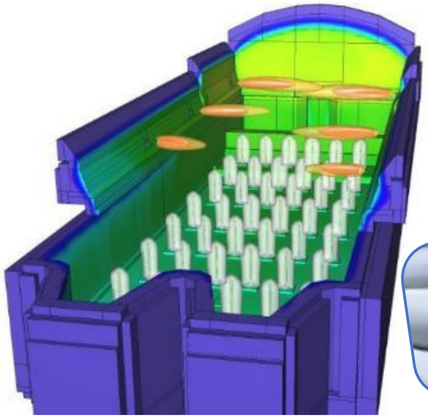
Tempering



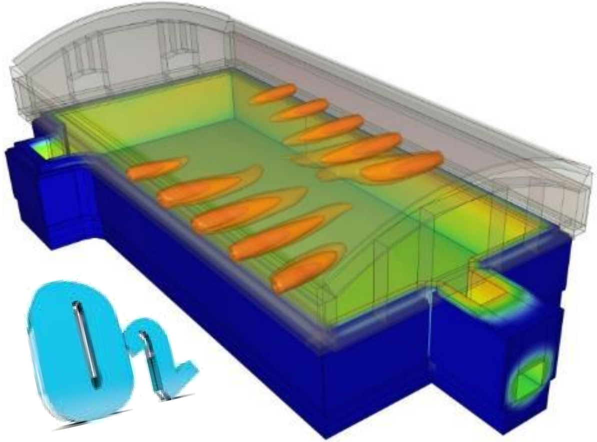
25 years of furnace evolutions

Drawings for illustrative purposes only, courtesy of Glass Service





Electrodes



1970 Cross-Fired Air-Gas

Corning

- 100% Air-Gas
- Cupola above the last zone
- 2*4 Regenerative chambers

→ Lifetime : **2 years**

1998 Hybridization + Air-Gas

- 45% Electricity + 55% Air-Gas

→ Energy Efficiency ***(≈ -25%)***

- Cupola above the last zone
- 2*4 Regenerative chambers

→ Lifetime : **3 years**

2005 Hybridization + Oxy-Gas

- 50% Electricity + 50% Oxy-Gas

→ Energy Efficiency ***(≈ -15%)***

→ Massive drop of Nox ***(≈ -95%)***

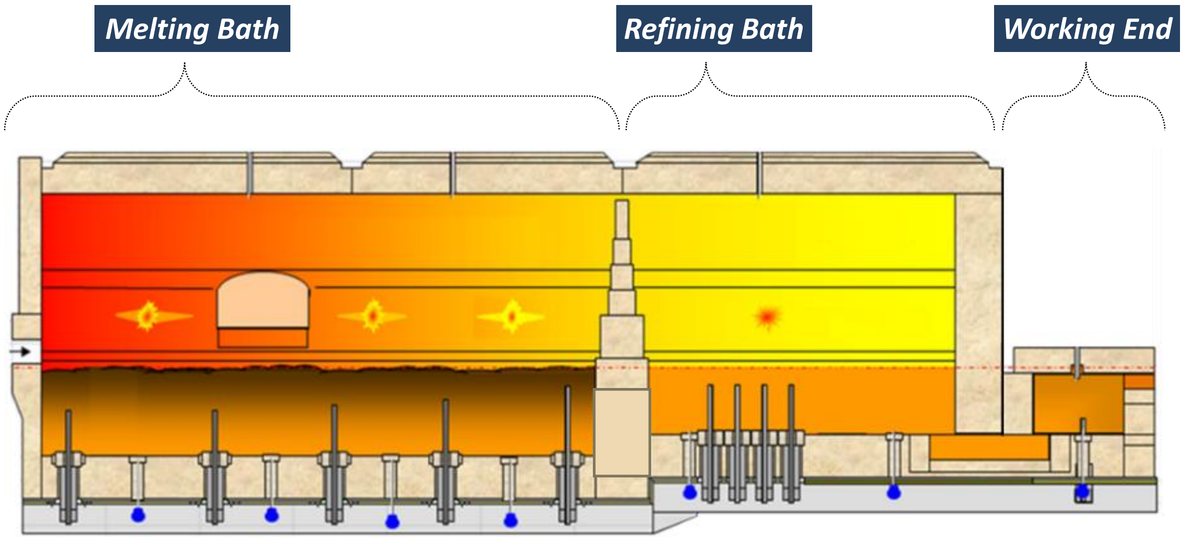
- Cupola above the last zone
- 6 burners : no more chambers

→ Lifetime : **4 years**

2012	**New Product Mix :**	- No more Cupola : new Working End	→ Lifetime : **5 years**
2017	**Drop from 45% to 25% Cullet**	- From 6 to 8 Oxy-Gas burners	→ Energy Efficiency

Introduction of Modelization

Initial Case : Our Furnace in *2018*

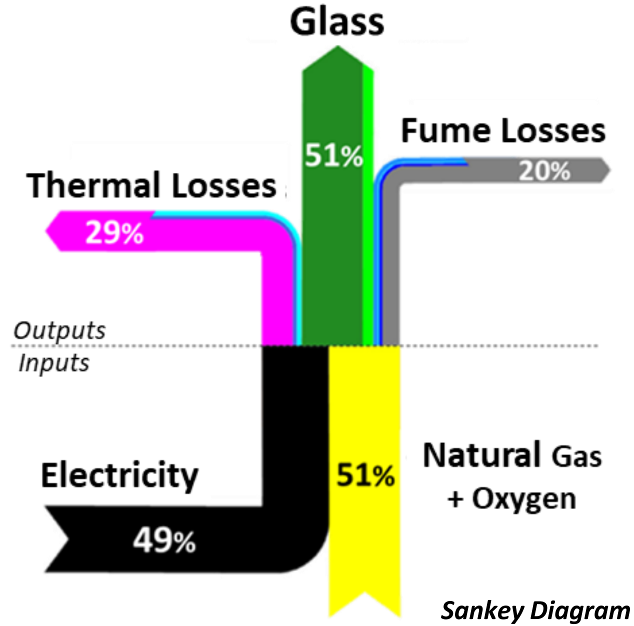


- 6 Oxy-Gas Burners
- 5 Rows of Electrodes
- Separating Crosswall

- 2 Oxy-Gas Burners
- 2 Rows of Electrodes
- Max Temp : 1550°C

Almost no CO_2 from batch

Max Pull (Borosilicate)	≈ 160	t/d
Average Cullet	≈ 25	%
Natural Gas (Fossil)	*620*	*kWh/t (LHV)*
Electricity	*600*	*kWh/t*
CO_2 Emission	*186*	*kg CO2e/t*

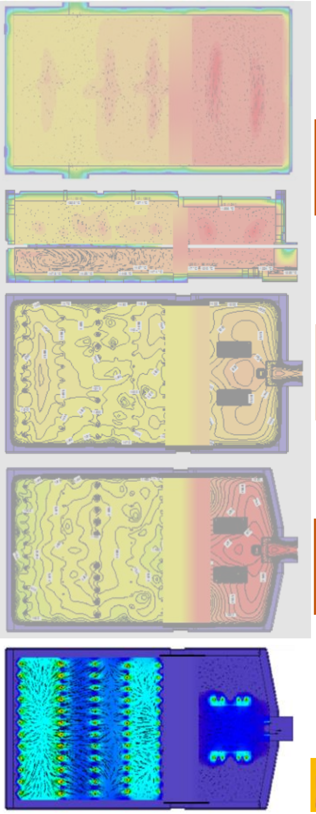


Sankey Diagram

2018 to 2022 : Partnerships for a new design

Modelization : ≈ 10 cases

Assessing Quality & Energy savings



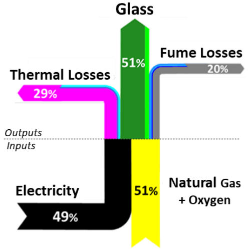
Combustion Zone

Boosting & Electrodes

Geometry

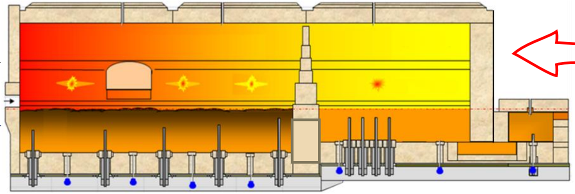
GS

F.I.C.



- *Energy & Mass balances, benchmarks.*
- *Identification of potential optimizations.*
- *Refractories & insulation reviews.*
- *Many design recommendations.*
- *Final audit after rebuilt.*

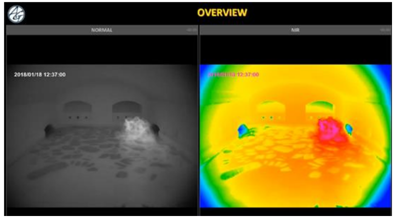
Full energy audit, refractories & construction knowledges

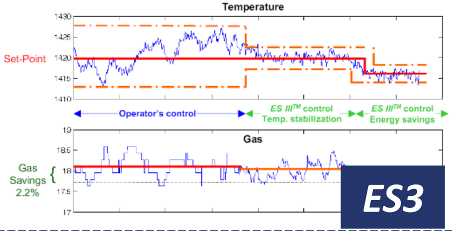


In-House Pyrex® teams

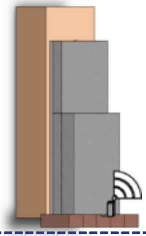
- *Solutions assessments*
- *3D & detailed drawings*
- *Erection supervision*

Metrology Improvements : NIR endoscope, Advanced control system, Corrosions monitoring





ES3



SEFPRO
BRIGHTER SOLUTIONS TOGETHER

Modelization of corrosions & SEFPROGUARD

The Rebuilt : According to the re-design

A. **Refining zone :** lower crown, optimized design of the front wall.

B. **Rear Zone** & view of soldier blocks.

C. **72 electrodes holders (F.I.C.) have been installed in the furnace,** allowing up to **63%** electricity in the energy mix.

The Result : Our Furnace in 2023

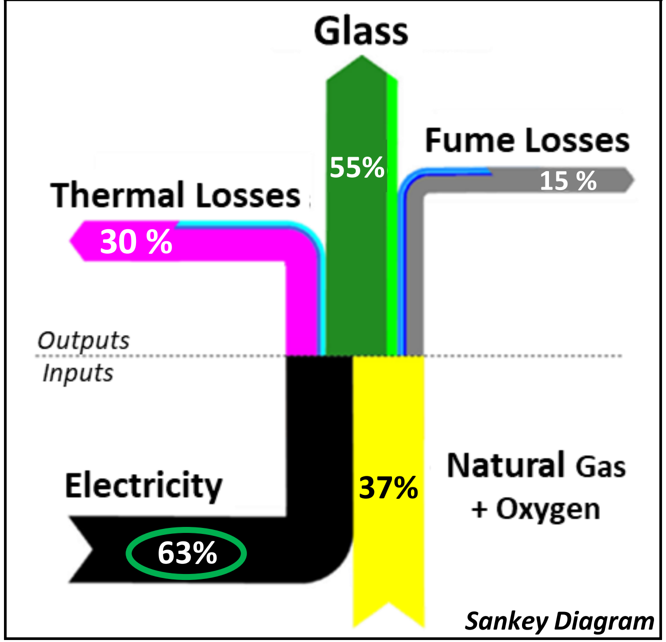
*Normalized hypothesis versus 2018

Max Pull (Borosilicate)	≈ 160 t/d
Average Cullet	≈ 25 %
Natural Gas (Fossil)*	420 kWh/t (LHV)
Electricity*	740 kWh/t
CO_2 Emission*	149 kg CO2e/t

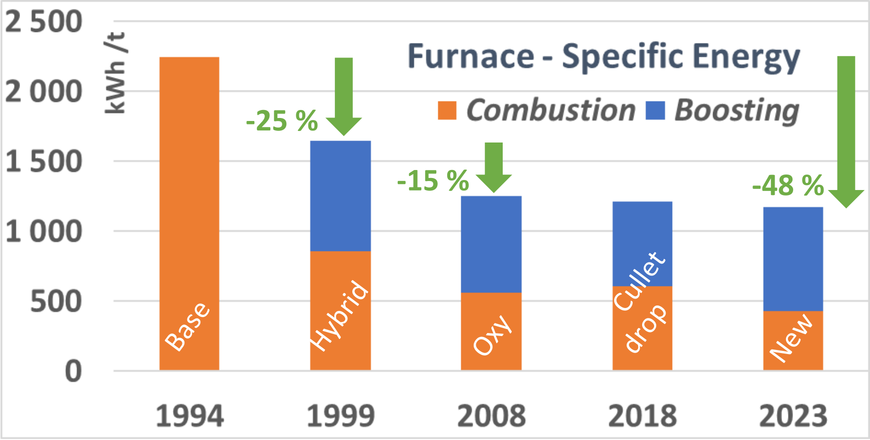
- Crown & Tank Design
- Boosting Optimizations
- Insulations & Refractories review

- Near IR Camera (GS)
- Tank Blocs Monitoring (SEFPRO)
- ESIII Control System (GS)

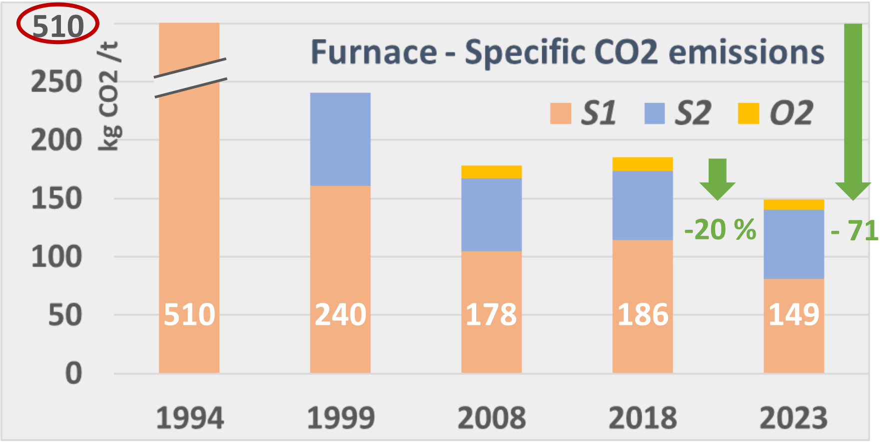
-20%* CO_2 versus 2018

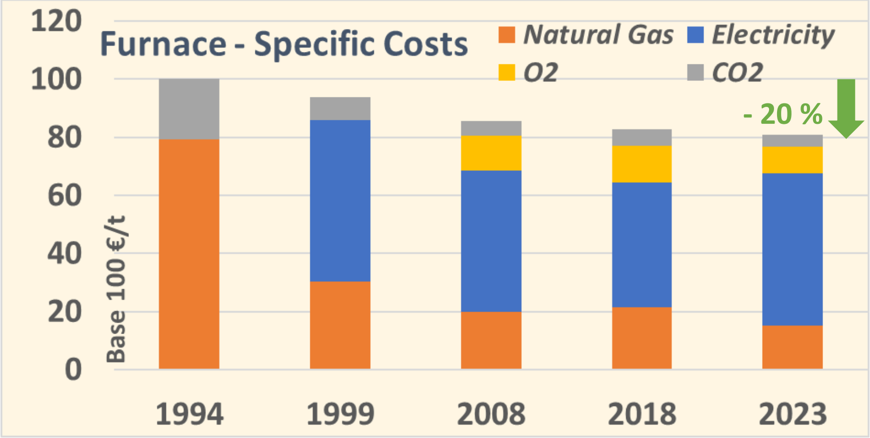


Global results – From Pyrex® Point of view



Natural Gas : *187 kg/MWh* ***– French Electricity Mix:*** *57 kg/MWh*





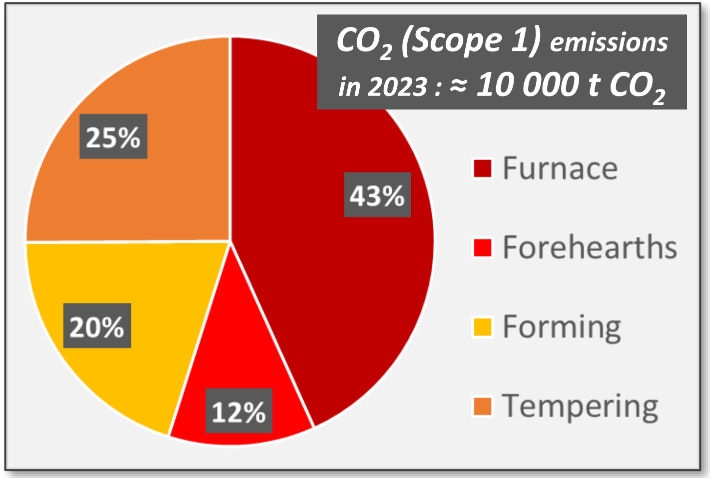
Specific Energy : After huge drops linked to hybridization, tangential gains are still feasible but challenging : fumes losses are still to be tackled.

CO_2 Emissions : Our furnace achieved a two-thirds reduction compared to a standard 100% gas design.

Energy specific costs (fixed supply prices) : We've maintained stable costs over the past few years, achieving a 20% reduction from the initial design.

Natural Gas : *45 €/MWh*
Electricity : *110 €/MWh*
CO_2 : *70 €/t (without free quota from ETS)*

What are our next steps ?



Furnace : Geometrical and refractories optimizations to increase lifespan and reduce radiative losses, using **more and more modelization and monitoring**.
Feeders : Generalization of the HVP design.

Design

Furnace : Up to **80% hybridization**, keeping horizontal tank for flexibility purpose.
Feeders : Evolution to fully electrical HVP concept.
Tempering : Renewing obsolete conception to 100% electric.

Electrification

Hydrogen : Validate usage for furnace and forming (oxy-combustion).
Green Methane : Wait for physical and economical availability from suppliers.
Green Syngas : Complex and expensive solutions : our ''Plan B''.

Alternative Fuels

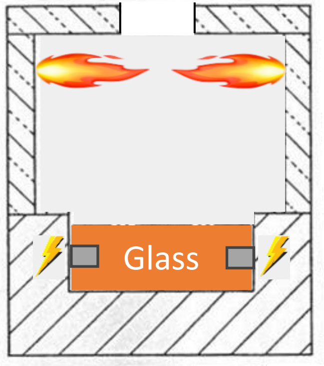
2033 ?

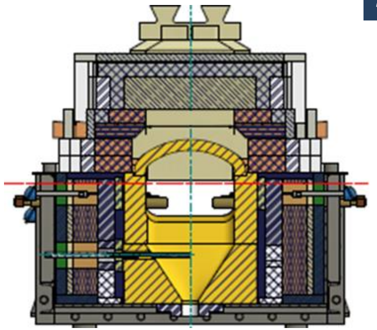
Decarbonation : Scope 1 ≈ 0 kg CO_2
Energy efficiency (furnace) ≈ 1000 kWh/t

Raw Materials (Scope 3) : Assess potential CO_2 reduction with suppliers (Borax).
Distribution (Scope 3) : Contract with suppliers for low-carbon solutions (Trucks).
CCU / CCS : Assess potential CO_2 capture and usage from our fumes.

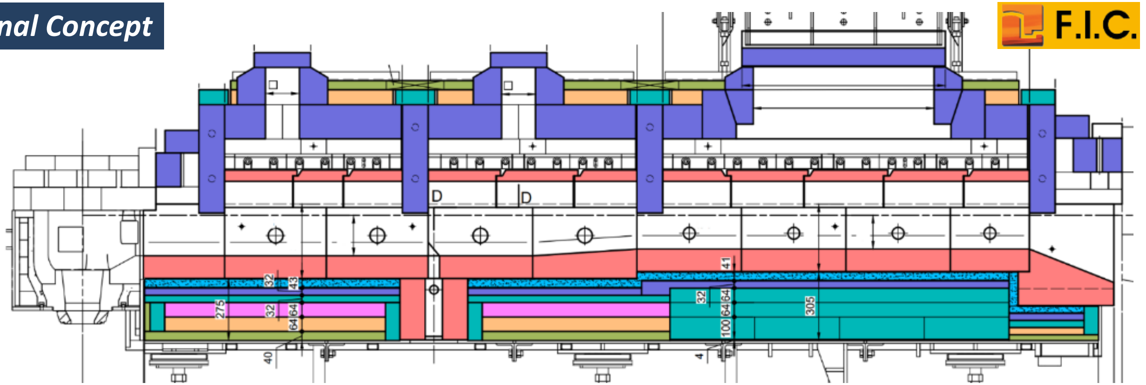
But also…

Optimization of a forehearth





Final Concept



Initial setup : 100% gas, cristobalite at low pull, linked to evaporation of boron from glass.

Design (F.I.C) : High Vapor Pressure Forehearth

- Inner superstructure : Muffle tiles
- Superstructure heating : Gas (or electricity)
- Glass heating : Electrodes

Benefits : No additional refractory in contact with glass, closed burdened atmosphere, no direct flame radiations on glass, efficient electricity transfer.

Electrodes

Muffle tiles

The result : our HVP Feeder *in 2023*

Product	Before	With HVP
169B	9,10%	0,05%
241B	4,52%	1,67%
178B	12,53%	1,12%

Production Gains : Reduction of up to 10 points of non-quality and improvement up to +10% in rate (gob stability).

Decarbonation Gains : As gas is solely used to keep the temperature of the muffle tiles stable, we achieved a reduction of up to 60% CO_2 specific emissions.

Next steps : Generalize this design to all forehearths, switch from gas to electricity (radiant heaters ?) for muffles, to cancel on-site CO_2 emissions completely (-20 kg CO2/t ?).

Hydrogen : Trials & future on-site production

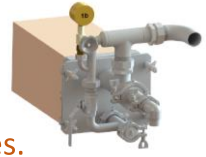
June 2022 – Furnace H_2 trial – 20% in power
(partnership with SEFPRO, Air Liquide, GRTGaz and French Glass Federations)

November 2023 – Reburning H_2 trial – 20% in power

Furnace

Regulation and combustion of a 20% H_2 blend (in power) within our natural gas main supply, during around **60 hours**, using optimized burners and injectors.

Energy transfer to the batch and the glass bath quite similar to 100% natural gas usage, potentially offering marginal efficiency gains. (5% ?).



No detected variations on glass properties and forming.

On-going longer laboratory trials to assess impacts on refractories.

Reburning

Regulation and combustion of a 20% H_2 blend (in power) within our natural gas main supply, during around **72 hours**, using standard oxy-combustion burners.

Energy transfer to the glass quite similar to 100% natural gas : same reburning result and efficiency.

On-going design studies to reduce potential leakages of H_2 from burners.

Production

H_2 distribution through pipelines in central France is not likely to happen.

First solution using electrolyze has been described and rejected (> 8 €/kg H_2).

$$H_2O \rightarrow H_2 + ½\,O_2$$

On-going studies to assess pyrolyze of CH_4 with microwaves : **4 €/kg H_2 ?**

$$CH_4 \rightarrow 2\,H_2 + C(s)$$

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Thank you for your attention !

PYREX®

BRUNIE Johann – *Group Technical Director*
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