Air Liquide
creative oxygen

IMBL | Base

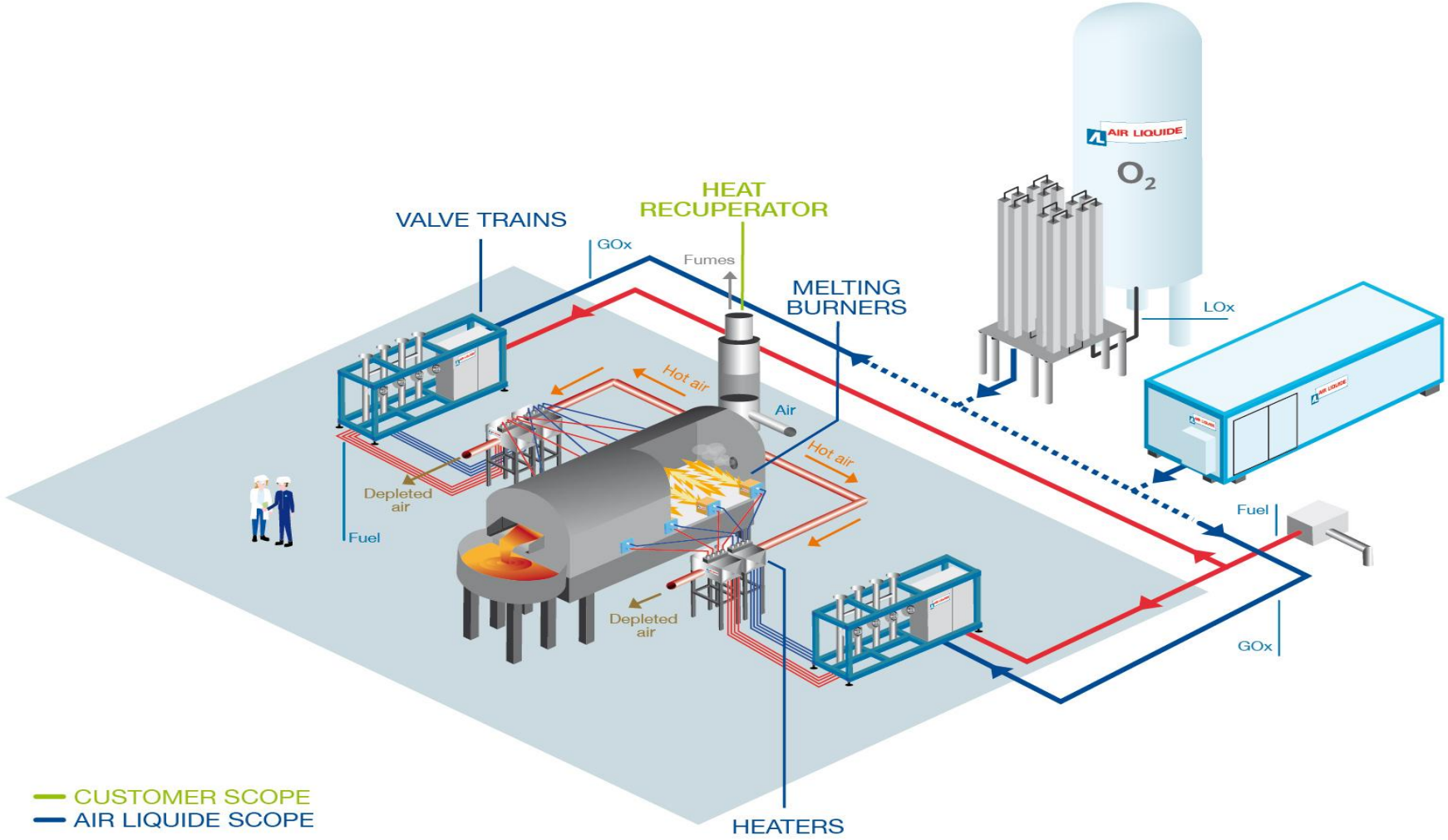
2017 ICG Annual Meeting
Combustion with oxygen and natural gas preheated at high temperature: latest results and new development

Istanbul • October 24th, 2017
Luc Jarry, Global Glass Market Director • IMBL I Base

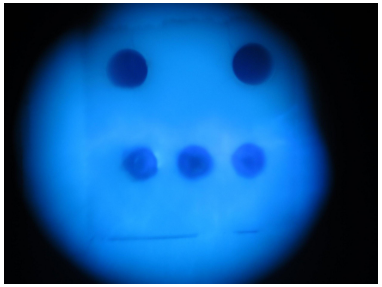
INDUSTRIAL MERCHANT

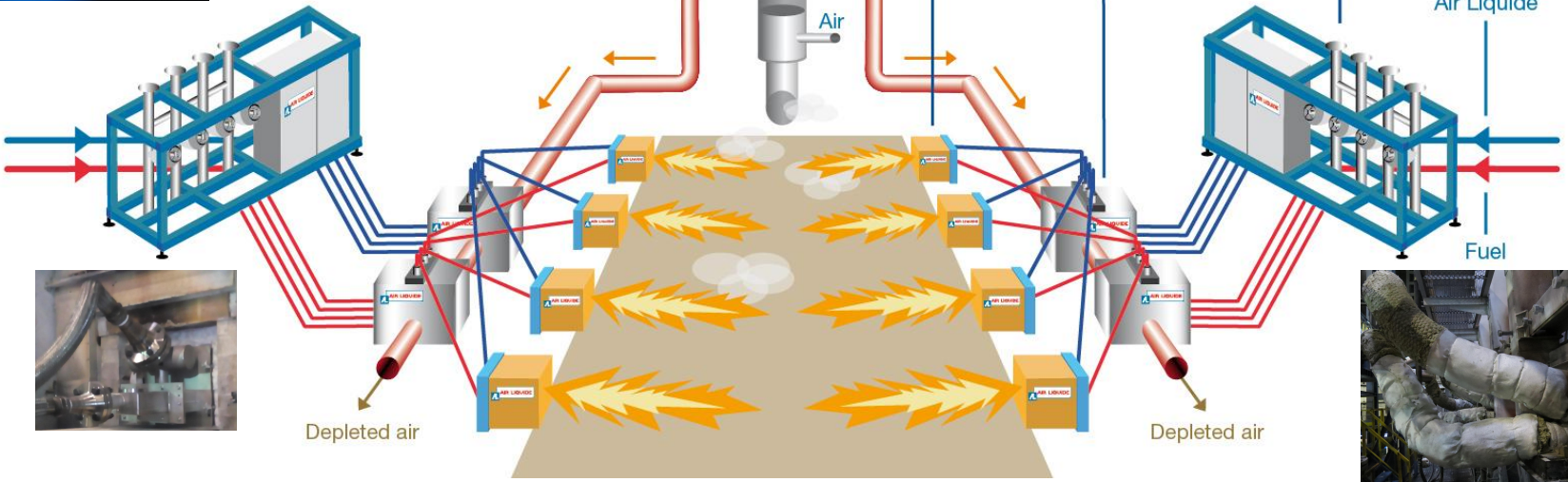
1

Heat
Oxy-combustion technology review


VALVE TRAINS
GOx
HEAT RECUPERATOR
Fumes
MELTING BURNERS
AIR LIQUIDE
O_2
LOx
Hot air
Air
Hot air
Depleted air
Fuel
Fuel
Depleted air
GOx
HEATERS
CUSTOMER SCOPE
AIR LIQUIDE SCOPE

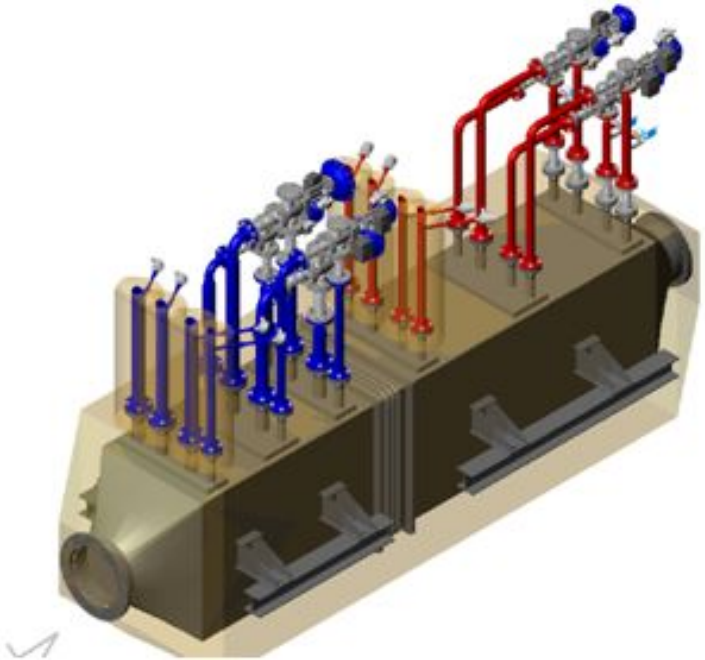
HeatOx 1G: Plug to your oxy-furnace





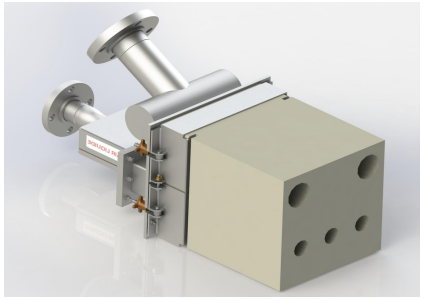
O2/NG heaters

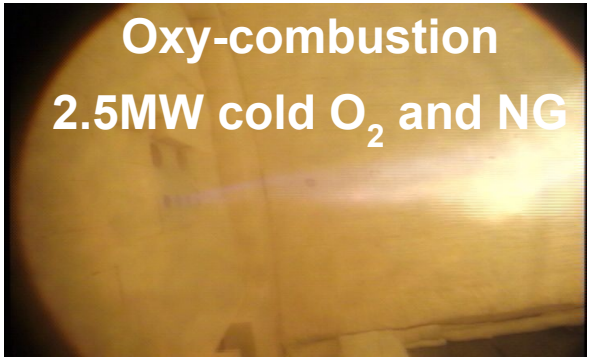
- Independent lines designed for max firing
- Special material for hot reactant
- By-pass valve for NG & O2 outlet T° control
- Instrumentation for process & safety control
- Compact equipment

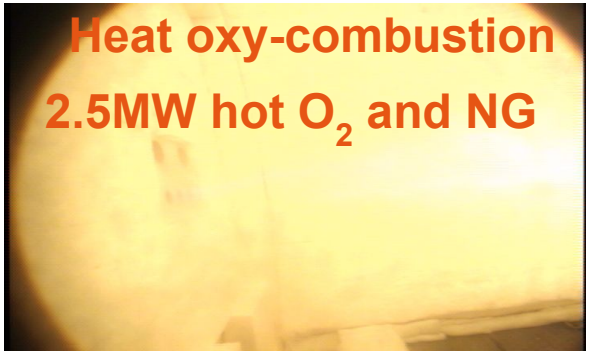


Patented burners

- Compact and operable with **hot Oxygen** and **hot Natural gas or fuel oil**
- Enable to **operate cold reactants** too (automatic setting) for safety concern
- **Constant flame length** (~ 3m)
- Could be **operated** with **Hot Air back up**
- **NOx level** between **0,2 to 0,5 kg/Tglass**
- Available **capacity**: **500 kW** - **1000 kW** - **2000 kW**
- **Operating Range** from **70%** to **150%** of nominal capacity

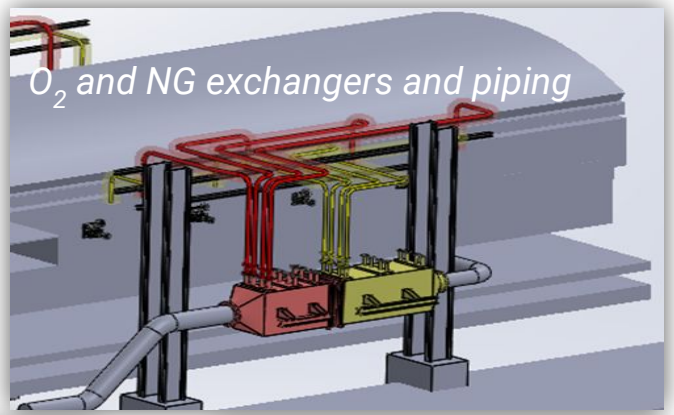






HeatOx Paşabahçe Erection

- Modification on existing flue gas channels prior to furnace start-up
- Relocation of intervening pipework
- Completed in 3 months
- Very tight space
- Compliance with architectural / structural limitations



Recuperator delivery

Recuperator installation

Recuperators in place

O_2 and NG exchangers

Summary

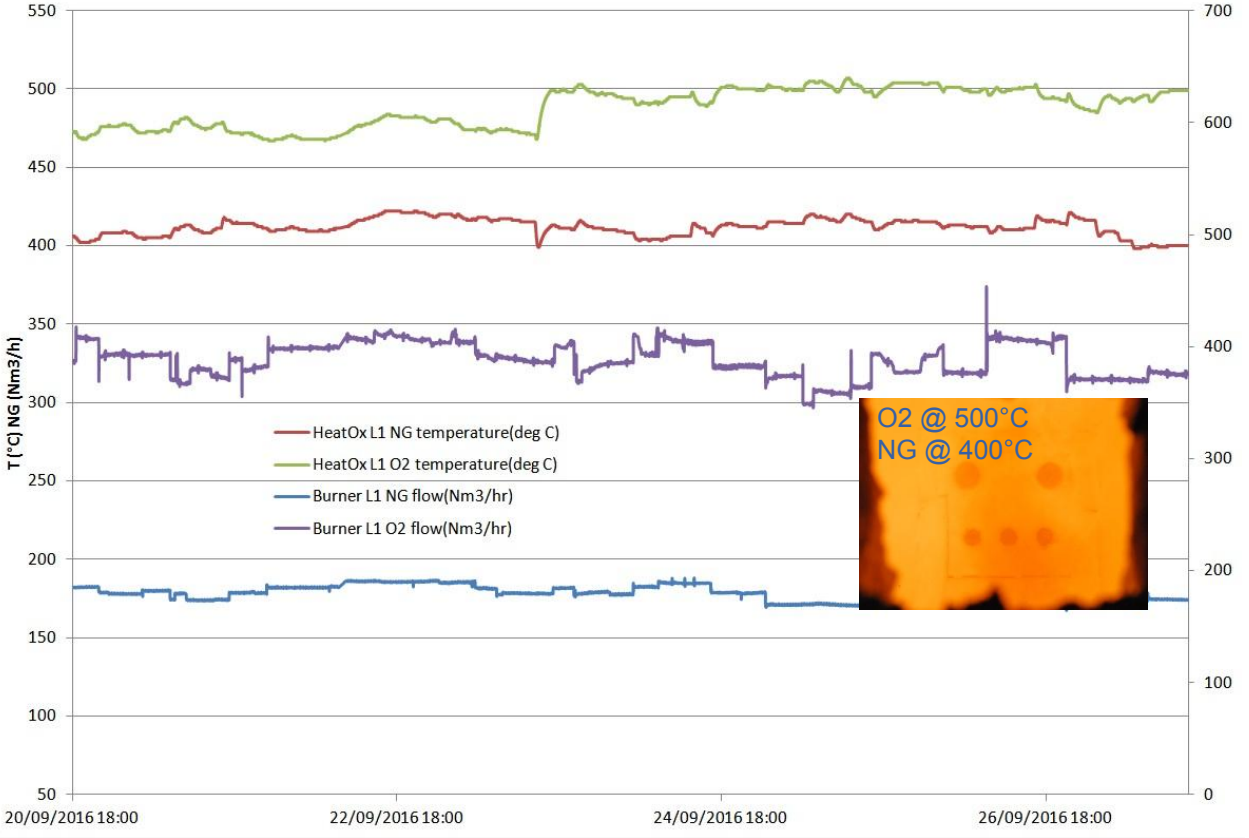
Aspect		*Experience from Project Şişecam and Paşabahçe.*
Safety		No issue reported
Glass Color & Quality		No issue reported
Furnace Aging		No issue reported so far, need to revisit at end of campaign
Energy (NG and O_2)		- Preheating: up to 9% fuel savings vs ColdOx demonstrated through detailed audit of furnace with cold and preheated reactant - Foam: initial results favorable compared to oxy-fuel
Emissions		Similar to oxy-fuel (~90% NOx reduction vs air-fuel)
Maintenance / Reliability		- Retrofit (architectural constraints, no-WHR mindset) - Learnings (flue gas and air) → leaks, clogging, dampers
Burner		- Minor maintenance for all burner capacity available 500-1000-2000 kW - Luminous & straight flame
Ease of Use		Start-up and shutdown with the push of a button Highly flexible and adaptable to variations in process
Project Management		On budget / On time

HeatOx 1G Paşabahçe Results

NOx ~ 0,25 kg/Ton of glass and 90% below air furnace

Energy efficiency gain 1% by 100°C of preheating of ONE reactant

up to Up to 9% today depending on O2/NG Temperatures



2

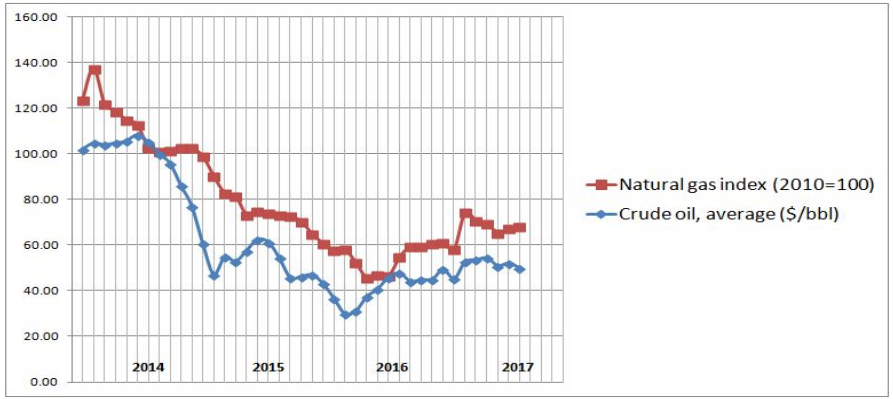
HeatOx 2G = New efficiency

Energy cost variation

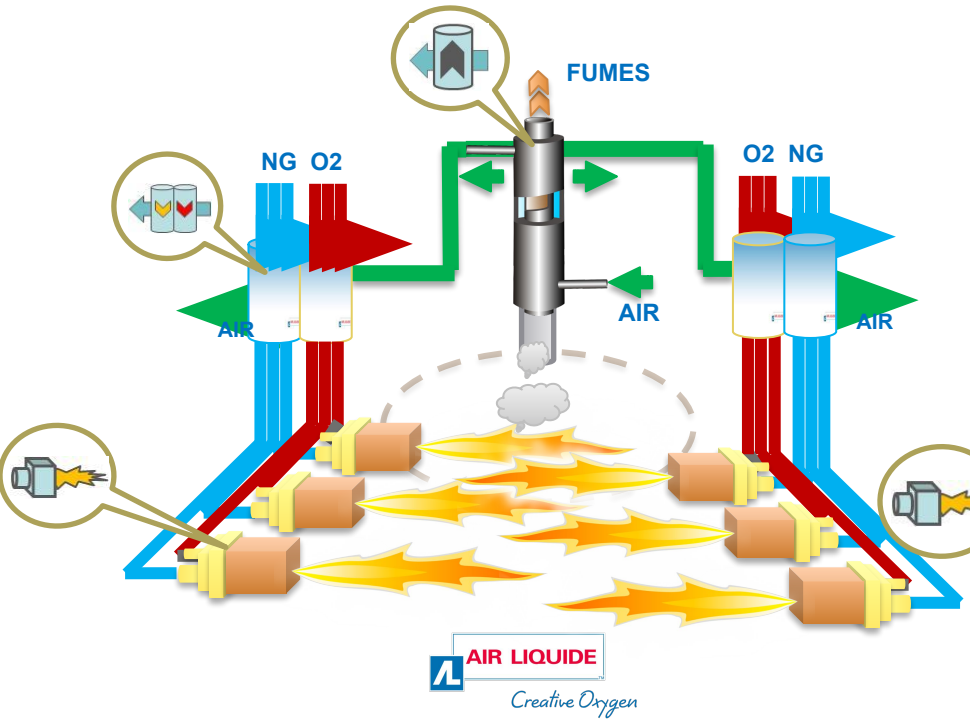
Natural gas and Crude oil still low.

On an average, the energy costs in the glass industry accounts for about 14% of the total glass production costs.

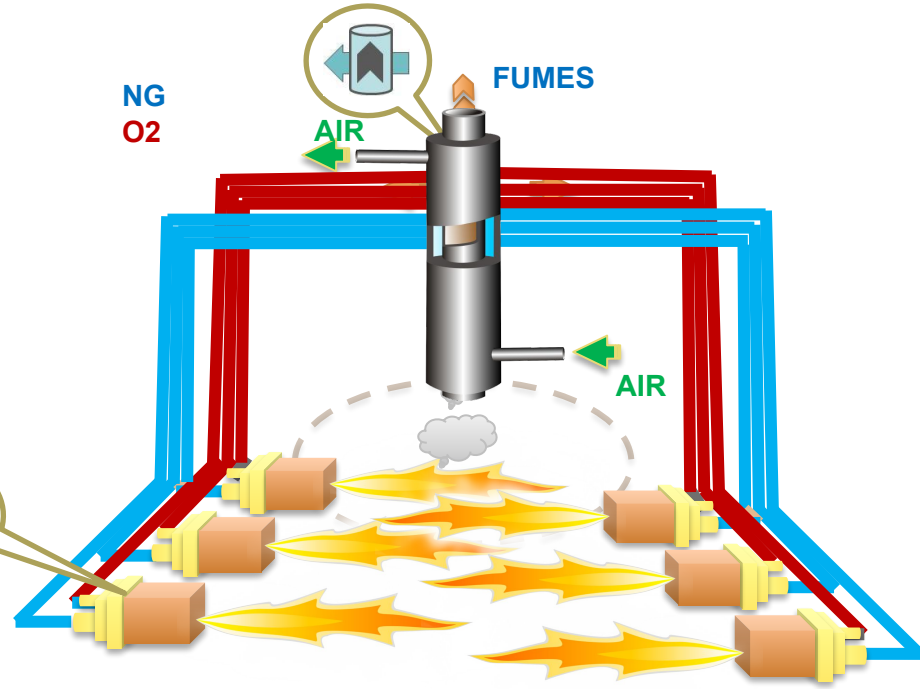
In the context where energy is decreasing, CAPEX would have to be reduced proportionally.



HeatOx 1G

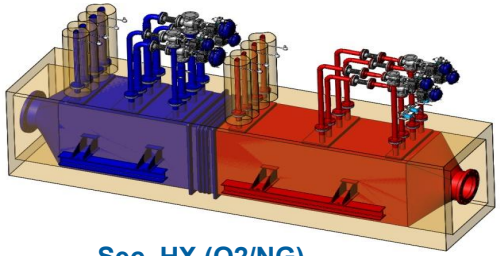


R- HeatOx 2G



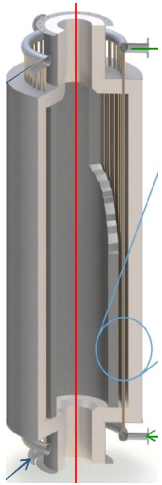
Technology route to ~13% efficiency gain

1G



Sec. HX (O2/NG)
Primary HX (Flue/Air)

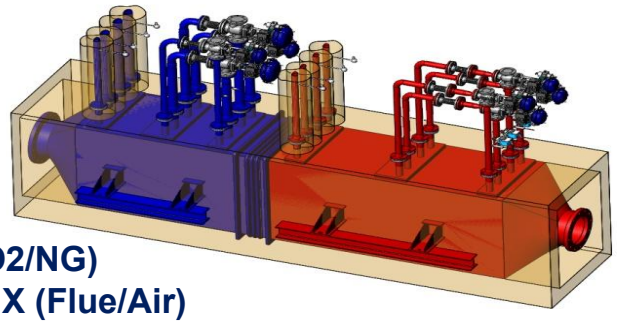
2G



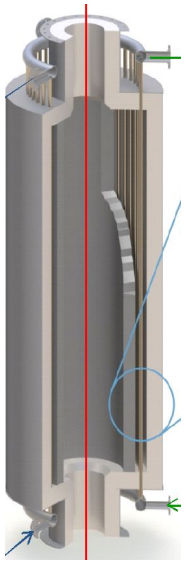
Radiative heat exchanger installed to a flue

	Target O2 temp	Target NG temp	Technology	NG/O2 saving	Target CAPEX
HeatOx 1G	550C-600C	450C-500C	Air/Flue HX, O2/air HX, NG/air HX	-10%	
HeatOx 2G	800C	450C-500C	Radiative HX	-13%	> -50% compared to 1G CAPEX

Proven today – even better tomorrow



Sec. HX (O2/NG)
Primary HX (Flue/Air)



Stand-alone radiative heat exchanger

1G **2G**

CAPEX

125 % | 100% | 50% | 50%

~ 1 to 3 year payback

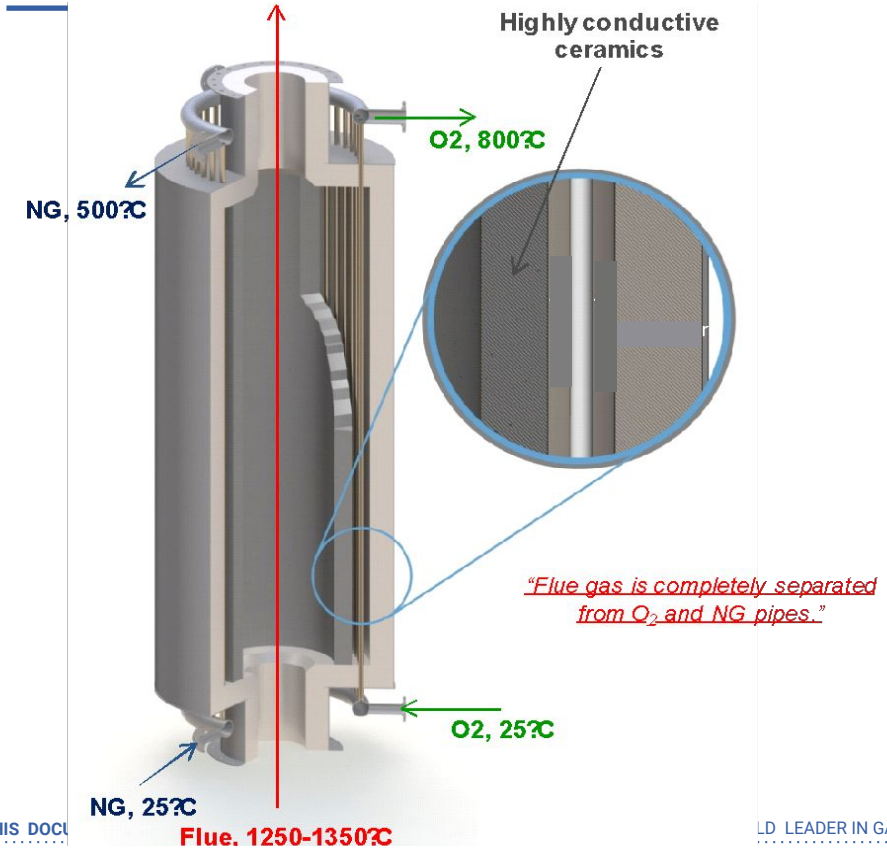
2015 | 2016 | 2017 | 2018

- 10 % | - 13 %

Fuel and Oxygen savings

Heat Oxy-Combustion is rapidly improving in both efficiency gains and competitive equipment cost

Preliminary radiative heat exchanger design

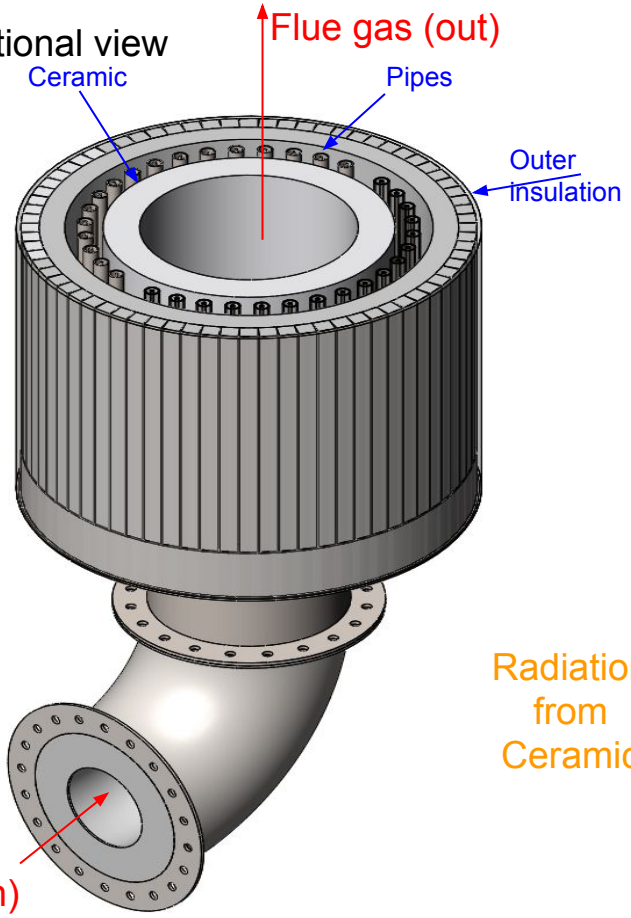


Patented concept
+
Patents pending

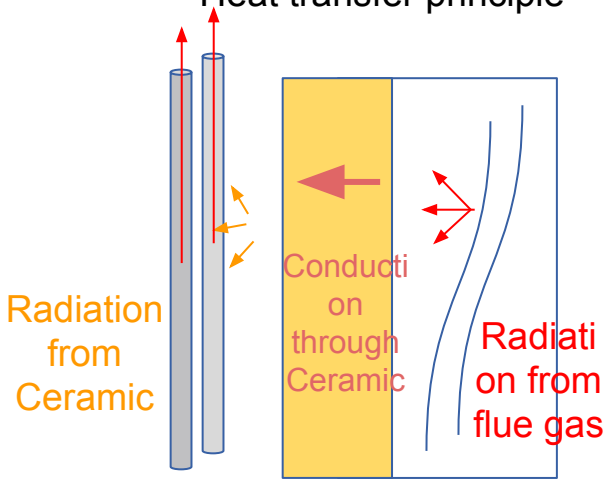
- R-HeatOx **CAPEX reduction**
- **Oxygen and fuel savings= 13%**
- **Easy to operate and maintain**
- **Can be installed on the fly**

R&D Test

Cross-Sectional view



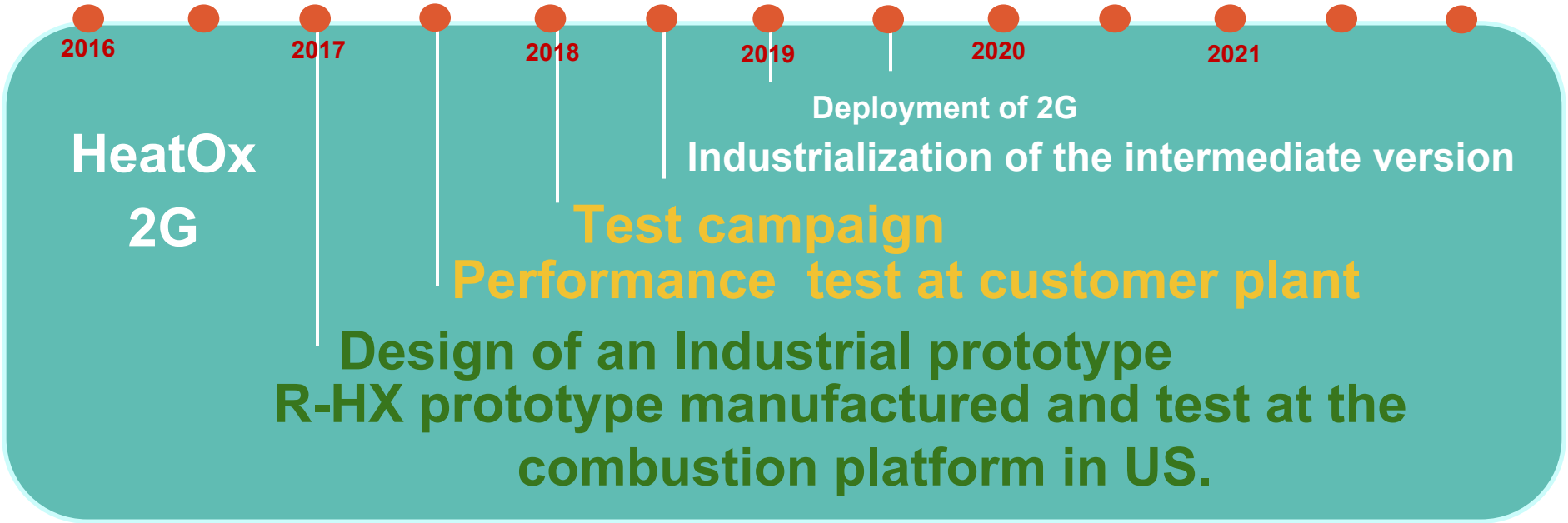
Heat transfer principle



HeatOx 2G: CleanOx

- **LIFE+ CleanOx**: new funded project by European Commission (July 2017)
- **Demonstration** of an innovative **radiative heat exchanger** based HeatOx solution.
- **Process benefit targets:**
  - Reduction of GHG emissions linked to tableware glass production: 30% less CO2 and 90% less NOx emissions compared to end-fired regenerative air-fuel furnace.
  - Increase of thermal efficiency in tableware glass plants: 13% (Phase I) compared to traditionnel oxy-fuel furnace & 18% (Phase II)/ColdOx
  - Lower 1G CAPEX: up to 75% savings
- **The project** is running **from 01/07/2017 until 30/06/2021 with Şişecam and Paşabahçe.**

Launch Plan


2016
2017
2018
2019
2020
2021
HeatOx 2G
Deployment of 2G
Industrialization of the intermediate version
Test campaign
Performance test at customer plant
Design of an Industrial prototype
R-HX prototype manufactured and test at the combustion platform in US.

Air Liquide
creative oxygen

Thank you

EC LIFE+ acknowledgement for CleanOx with project number LIFE16 CCM/BG/000059

25 YEARS Life 1992 - 2017

THIS DOCUMENT IS ••Public

Istanbul • October 24th, 2017

Luc Jarry, Global Glass Market Director • IMBL I Base

INDUSTRIAL MERCHANT

DISTRIBUTION LIST : 2017 IGC Annual Meeting