AIR LIQUIDE
Creative Oxygen

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ŞİŞECAM

Paşabahçe

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Heat Oxy-combustion

ATIV, Parma 21/10/2016

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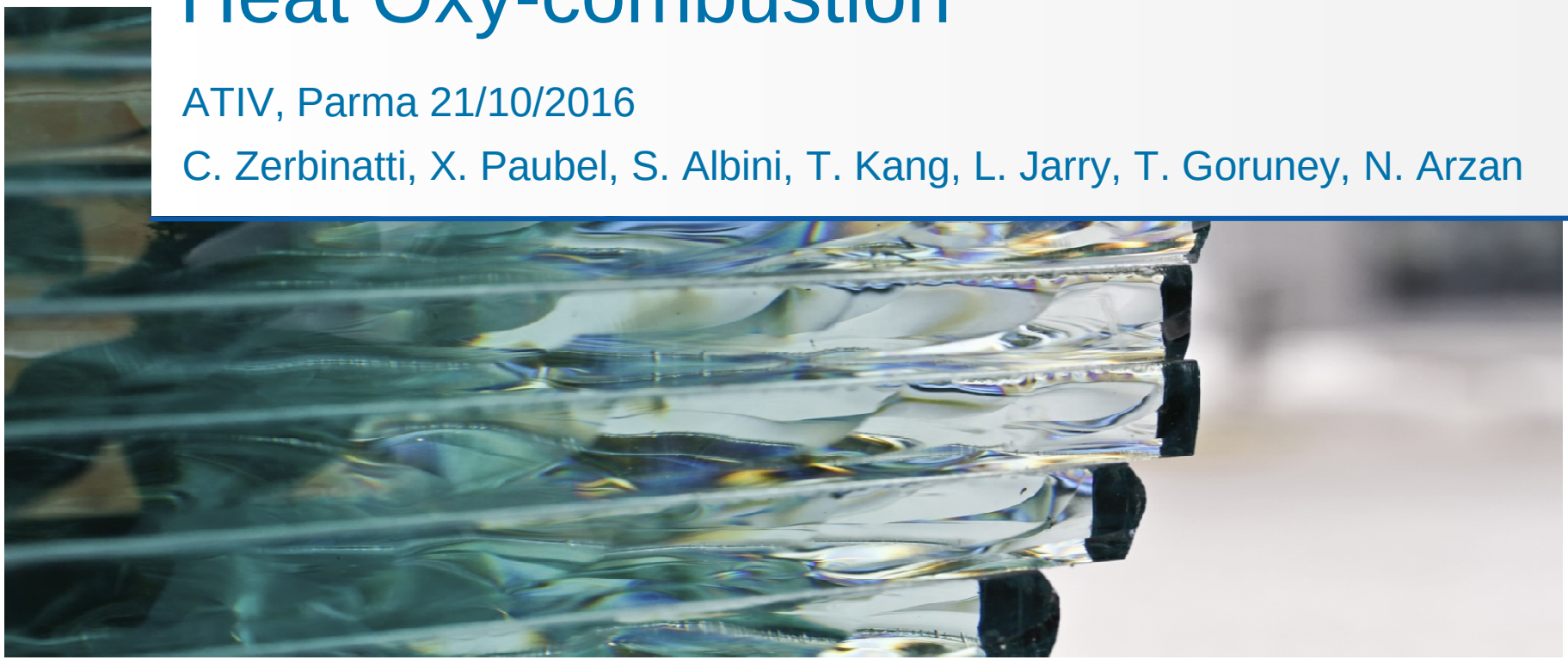

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Introduction to Air Liquide

World leader in gases, technologies and services for Industry and Health

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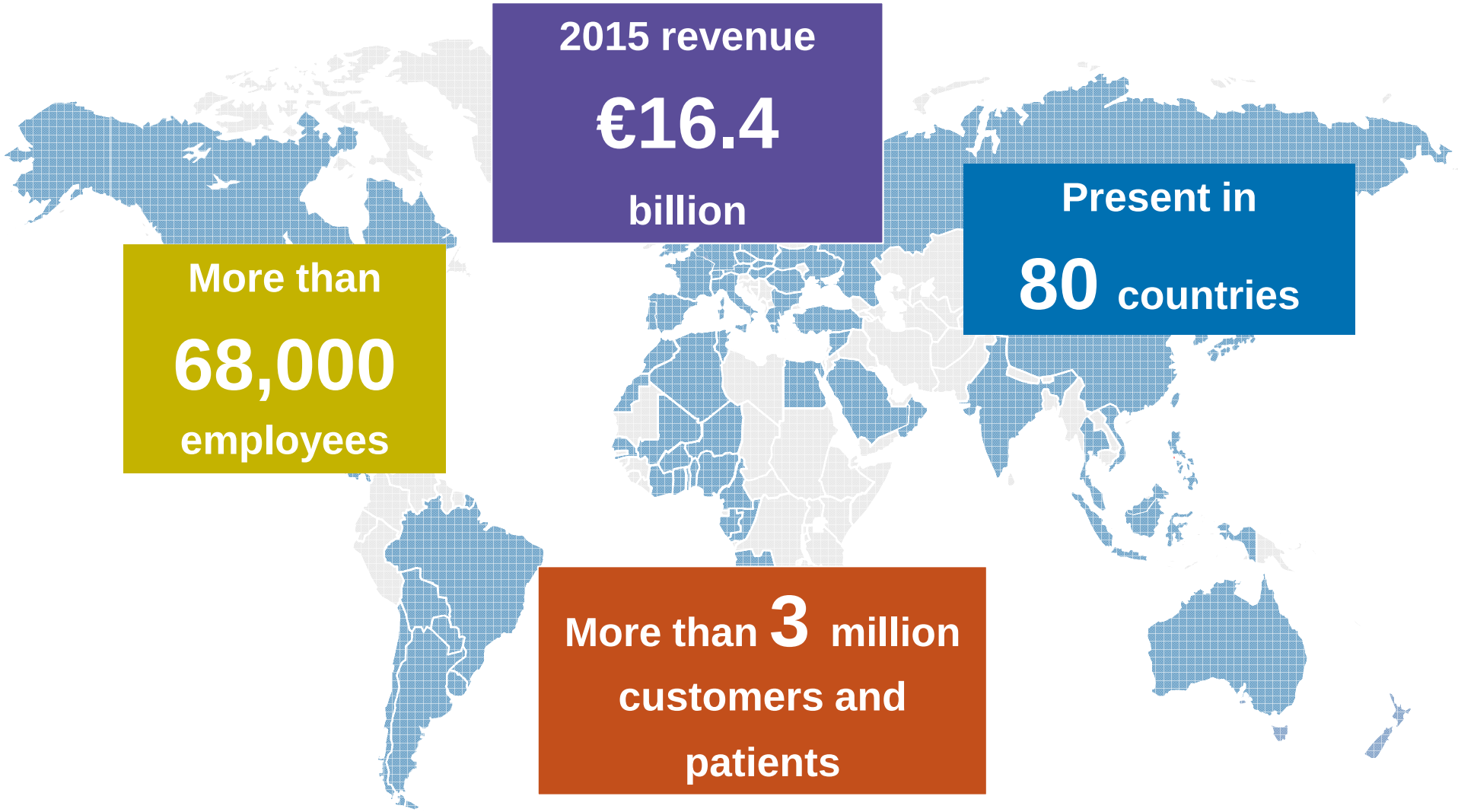

Addressing industrial customers and professionals' needs

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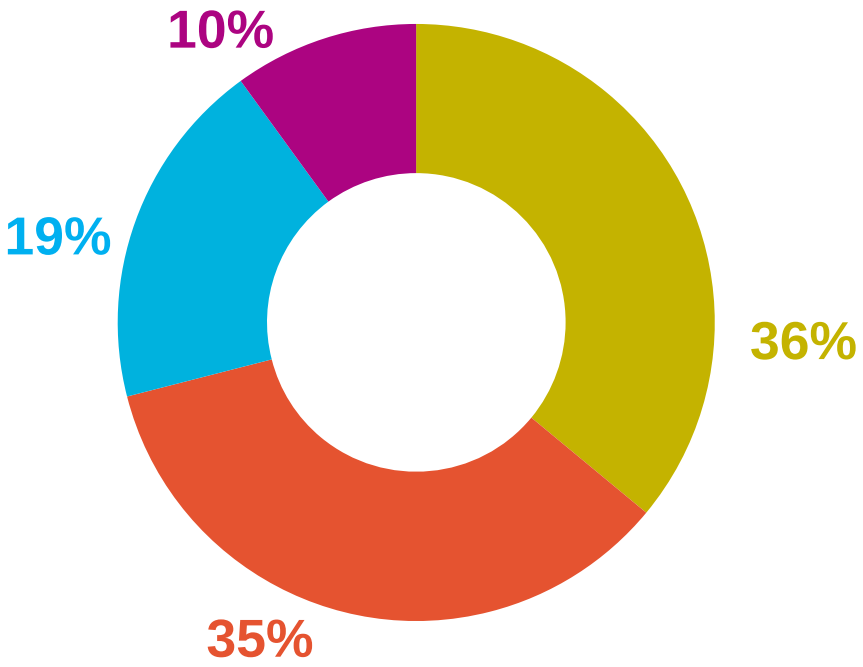
2015 Gas & Services revenue: €14.8 billion

Industrial Merchant

At the core of Air Liquide Gas & Services business, we provide industrial and specialty gases, application technologies and process expertise to our customers at every process stage.



Large Industries

- Air gases, hydrogen and CO
- 15-year contracts
- Pipeline networks
- Industrial basins

Healthcare

- Hospitals
- Home healthcare
- Hygiene
- Specialty ingredients

Electronics

- Carrier gases
- Specialty gases
- Equipment & installations

Market Trends & Needs

Statement with glass

Strong industrial constraints

- **Long** production cycles (8-15 years)
- **Energy intensive** (60-80% for melting)
- **Increasing regulation** on emissions and carbon footprint

Customer expectations

Cost savings and efficiency

- **Energy savings:** electric boosting, fuel and oxygen
- NOx and CO_2 **emissions reduction**
- **CAPEX:** 3 to 5 years payback

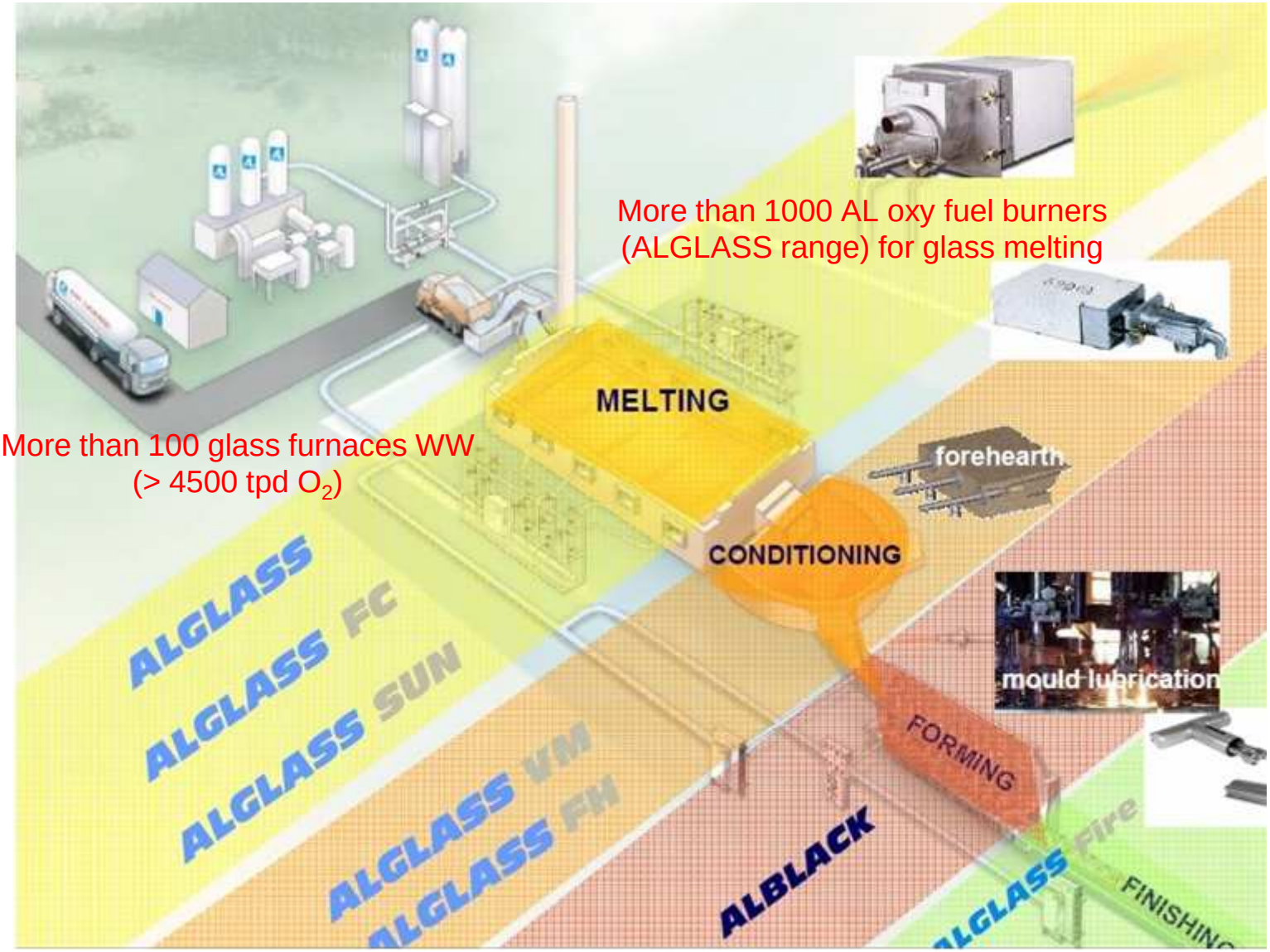
A proven experience in glass

- **More than 330 active patents** and 3 combustion platforms

- **Dedicated ALTEC experts** on 5 continents

- **A broad range of gases, equipments and services:**
  - ✓ O2 for melting and polishing
  - ✓ N2-H2 for tin bath blanketing
  - ✓ SiH_4, Kr, Ar, He for coating or insulating

Air Liquide O2 burners at every process step



Air Liquide oxy-burner range

ALGLASS – *First generation*

- Pipe – in pipe / Conical / Cylindrical flame

ALGLASS FC – *Full Coverage*

- Staged Oxygen flame / Separated jets / Low NOx / Flat flame

ALGLASS VM – *Variable momentum*

- Adjustable flame length

ALGLASS SUN – *Highly flexible*

- Ultra low NOx (flat flame)

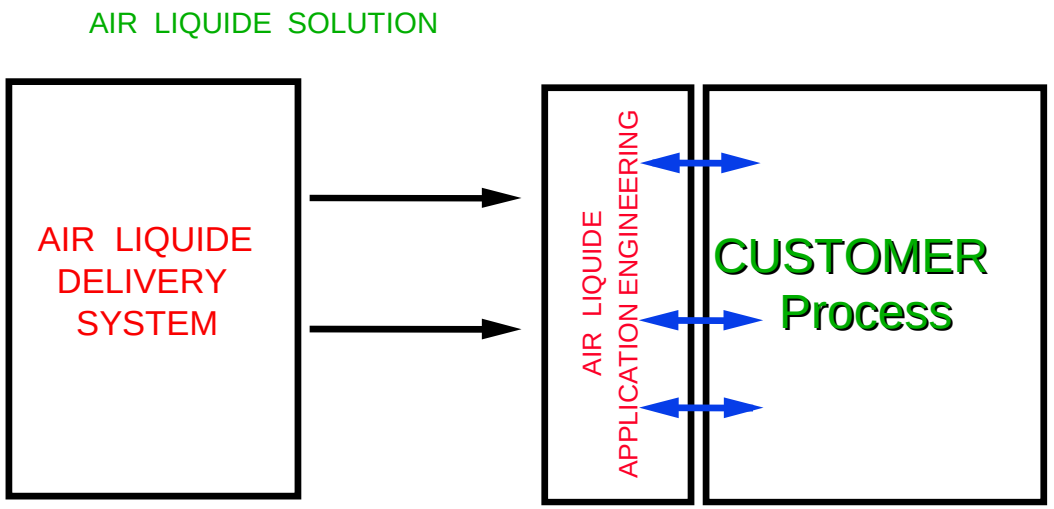
Air Liquide O2 burners main features

Main generic features of the burners

- Oxygen cooled – no water or other cooling agent requested
- Well connected to the refractory block – no air or flame leaks
- No pre-mixing: more safe (no backfire risk)
- High emissivity flames
- Robust – low maintenance frequency and easy inspection
- High turndown ratio (from 50% to 150 % nominal and more)

Air Liquide approach

- Assess customer's requirements
- Evaluate feasibility / interest & design solutions
- Provide customer with
  - ✓ Industrial gases
  - ✓ Equipments
  - ✓ Services
- Through technology knowledge



Air Liquide offer in oxy fuel glass melting

- O2 supply (bulk, on-site or pipe)
- Combustion technologies
  - Flow control equipment (FLAMOXAL)
  - ALGLASS burner family
  - Oxygen lances

  (in compliance with adequate safety regulations)
- Optimization services
  - Support design work through modeling services
  - Engineering, start up & maintenance
  - Combustion training
  - Furnace's audit (energy & environment)
  - Process control & supervision

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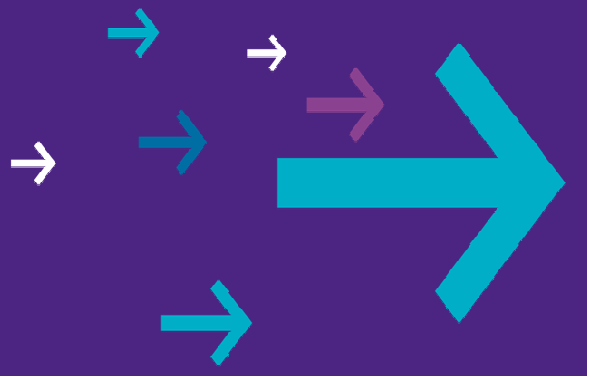
For Melting - Heat Oxy-Combustion

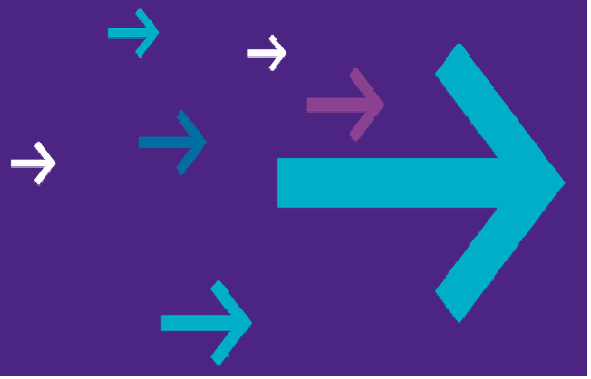
A simple solution

Add 10% additional efficiencies to oxy-combustion performance.



A simple idea

Recover energy from flue gases
to preheat oxygen and fuel



Oxygen and natural gas preheated at high temperature

Heat-Oxy combustion

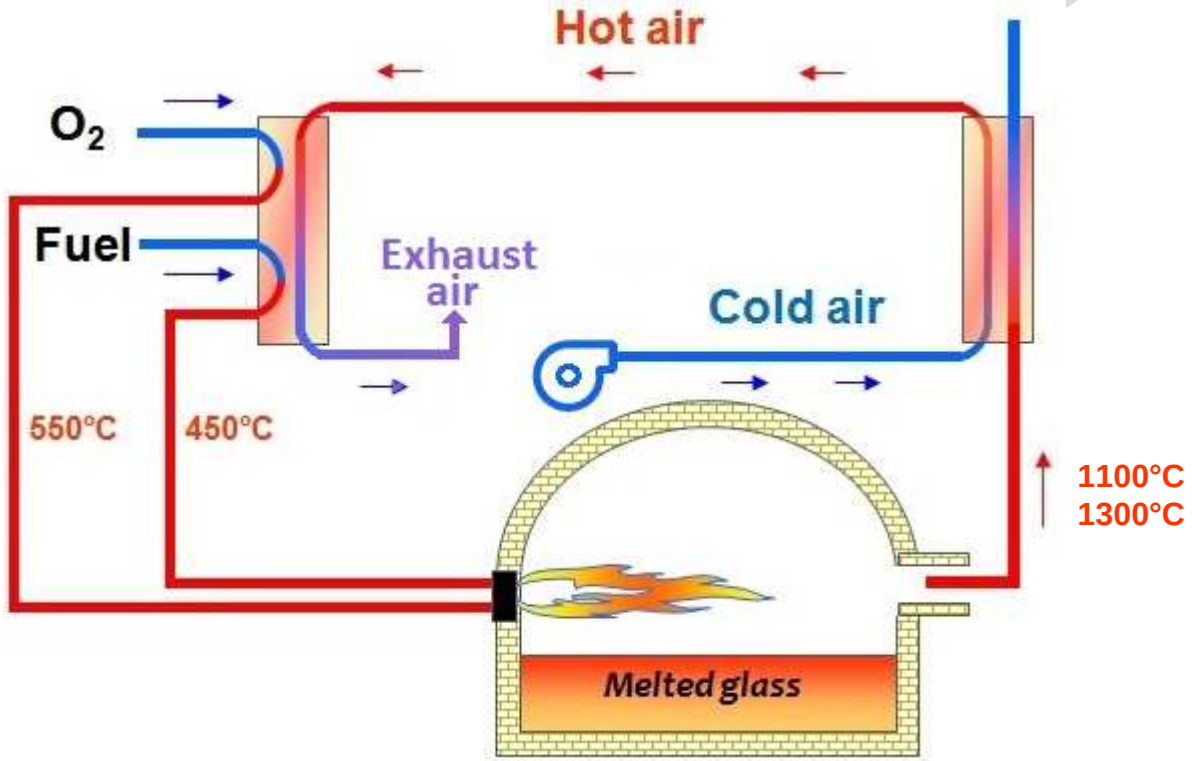
A GREEN SOLUTION

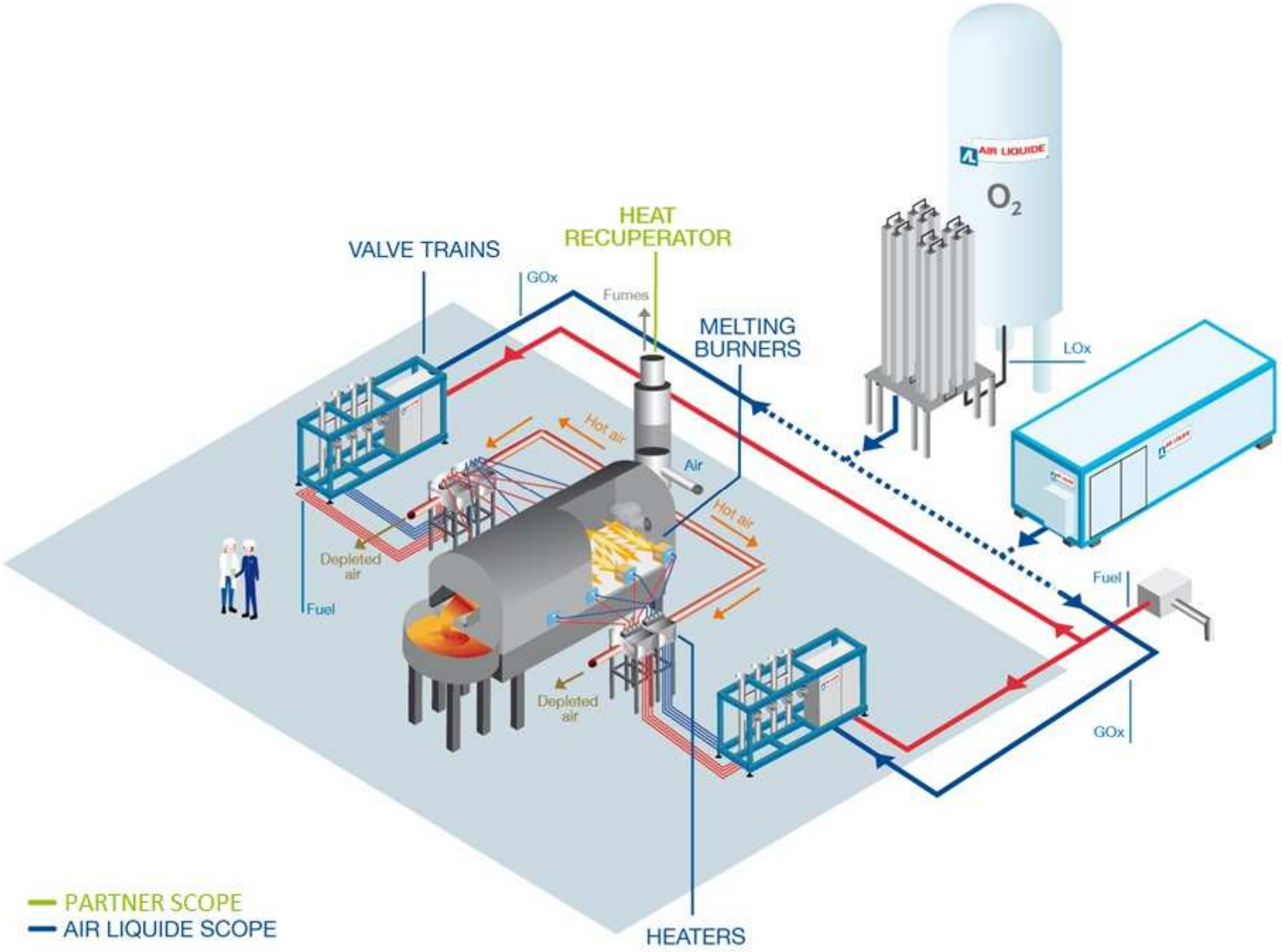
NOx -90%

CO_2 -35%

A COMPETITIVE SOLUTION …

Mixing advantage of oxy-fuel and heat recovery




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

Nexelia Heat-Oxycombustion

Oxygen preheating	Natural gas preheating
1% of fuel and O_2 savings each 100°C increase	1% of fuel and O_2 savings each 100°C increase

OXYGEN ~550°C

NATURAL GAS ~450°C

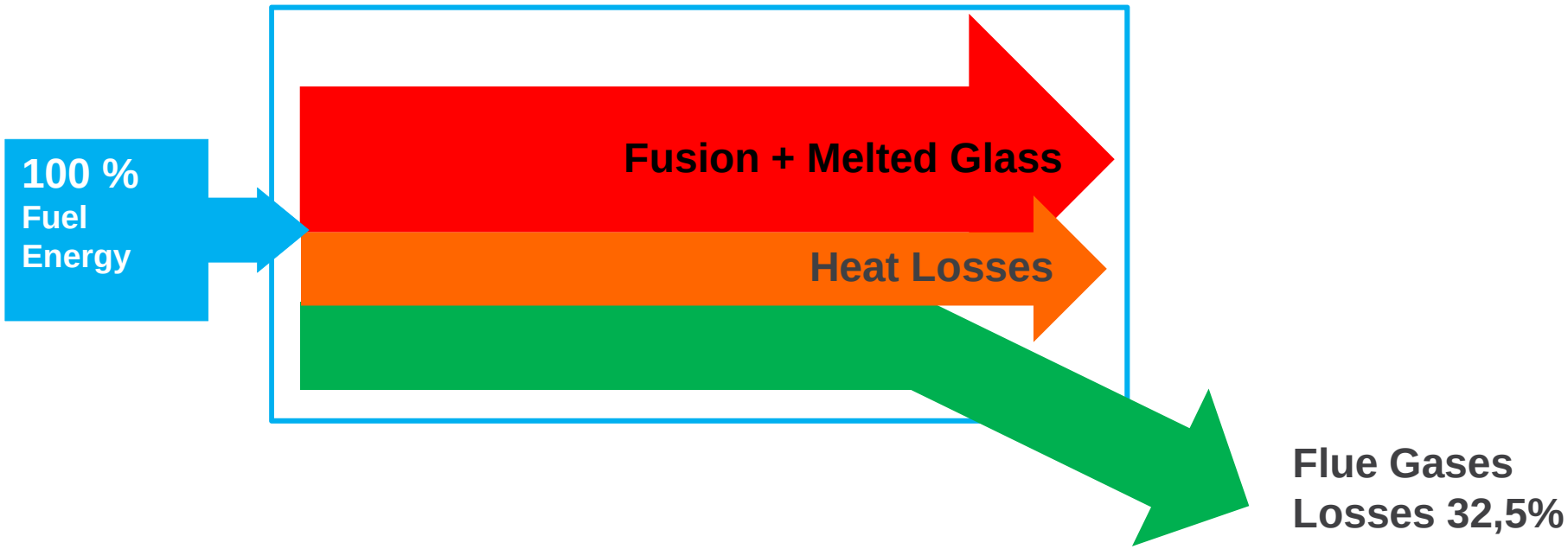
-10% fuel and oxygen

vs without pre-heating

and depleted hot air @ ~100 / 360°C available for production of hot water, steam, electricity…

ColdOx efficiency – schematic energy balance

- Oxy combustion with cold reactants – real case

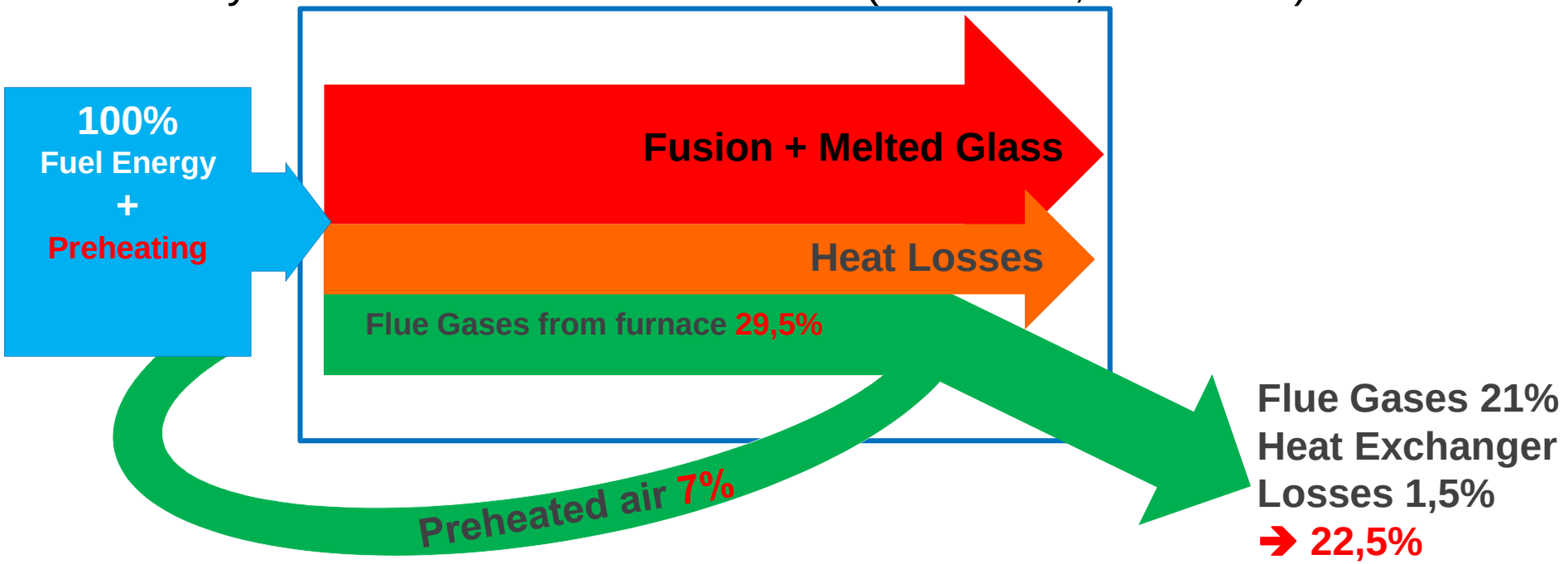


$$\text{Combustion efficiency Coldox} = \frac{\text{Fuel Energy at the burner} - \text{Exhaust gases losses}}{\text{Fuel Energy at the burner}}$$

Combustion efficiency ColdOx = 67,5 %

HeatOx efficiency – schematic energy balance

- Oxy combustion with Hot reactants (550°C O2, 450˚C NG) - real case



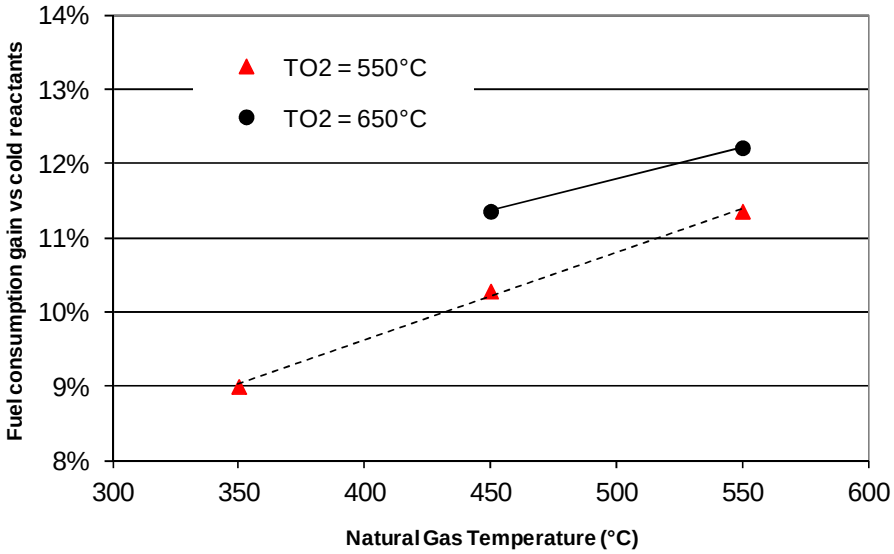
$$\text{Combustion efficiency Coldox} = \frac{\text{Fuel Energy at the burner} - \text{Exhaust gases losses}}{\text{Fuel Energy at the burner}}$$

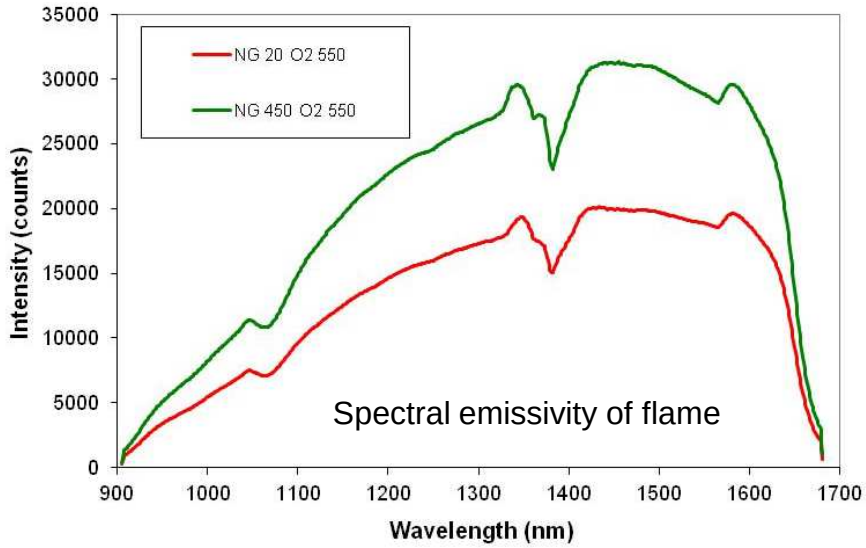
Combustion efficiency HeatOx = 77,5%

HeatOx efficiency breakdown

- Savings:
  - Reactants enthalpy → 6-7 %
  - Less fumes flow (-7,5% mass flow) → 2-3 %
  - Higher flame emissivity / (Fumes T° decreasing -50°C) → 1-2 %

HeatOx 10% additional savings vs ColdOx



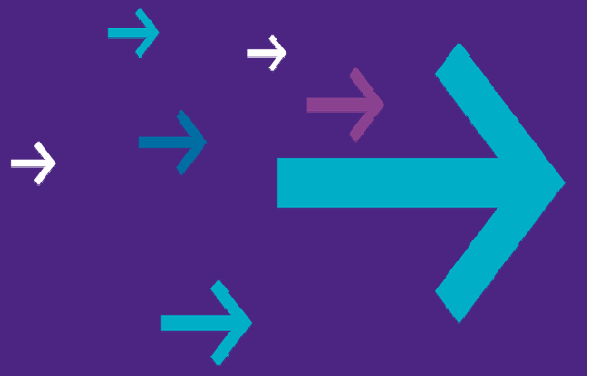


NEXELIA HEAT-OXYCOMBUSTION: MAIN FEATURES

- Oxy-combustion patented technology using exhaust fumes from the combustion to pre-heat oxygen and fuel
- Proven 10% additional savings compared to traditional oxy-combustion (+hot air available)
- Indirect pre-heating to ensure safety
- Designed to operate with hot or cold reactants
- Easy integration into standard furnace processes

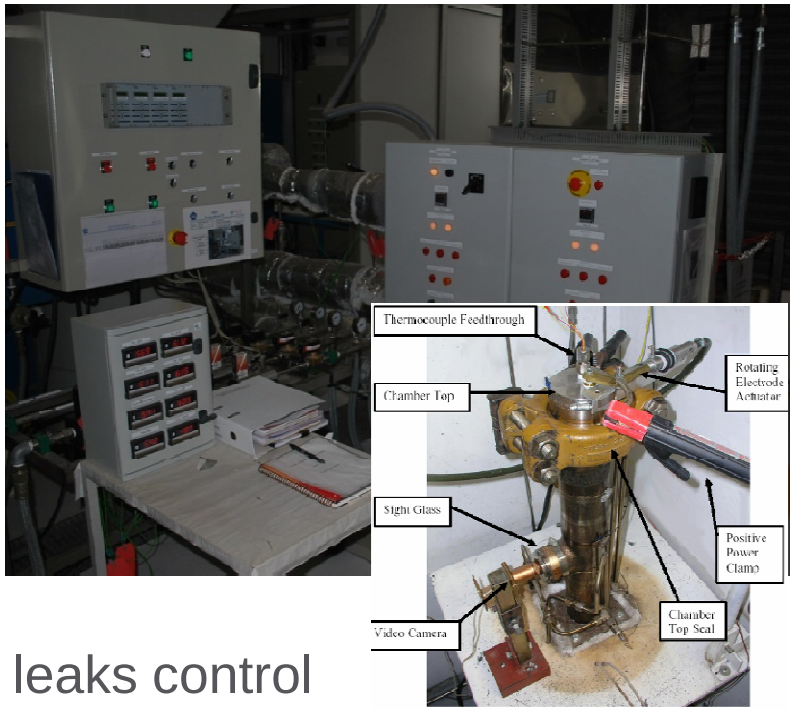
And safety !

... How to deal with Hot reactants safely?



10 years of experience

- One challenge of heat recovery project at the beginning was related to the evaluation of the preheated oxygen/natural gas hazards.
- Main risks :
  - Ignition & Flame propagation:
    → Promoted combustion study
  - Corrosion:
    → Cyclic oxidation tests
    → Long term exposure tests



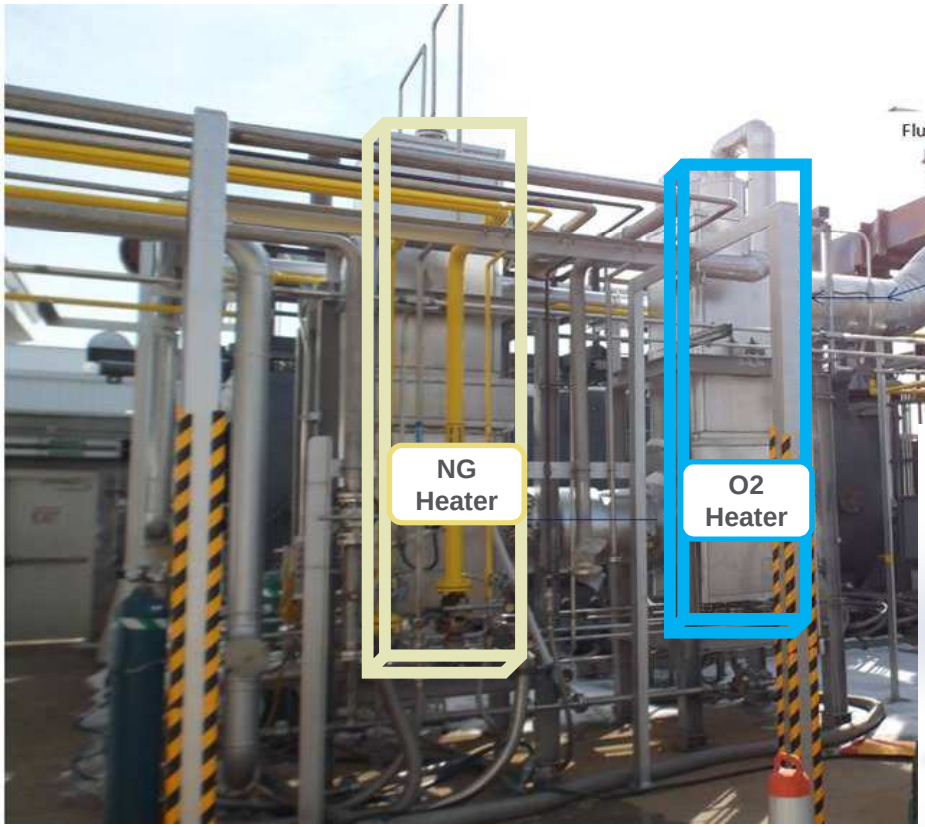
- *Specific Technology Design* :
  - Material selection for all equipments
  - Flange & piping design / Gaskets and leaks control
  - Automatic control and regulation of reactants temperature
  - Design requirements & manufacturing process for the O2 exchangers

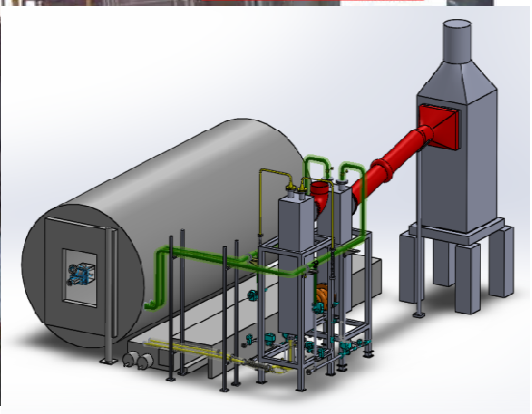
➡ Confirmed at industrial scale

Combustion Platform at DRTC - USA

HeatOx Pilot scale tests

- O2/NG heaters with multiple independent inlets/outlets to supply burners.
- Temperature control schemes were validated.
- HeatOx burners approved with cold and hot reactants in a furnace.





References

Boussois (FR) 2008 & Retenize (CZ) 2013

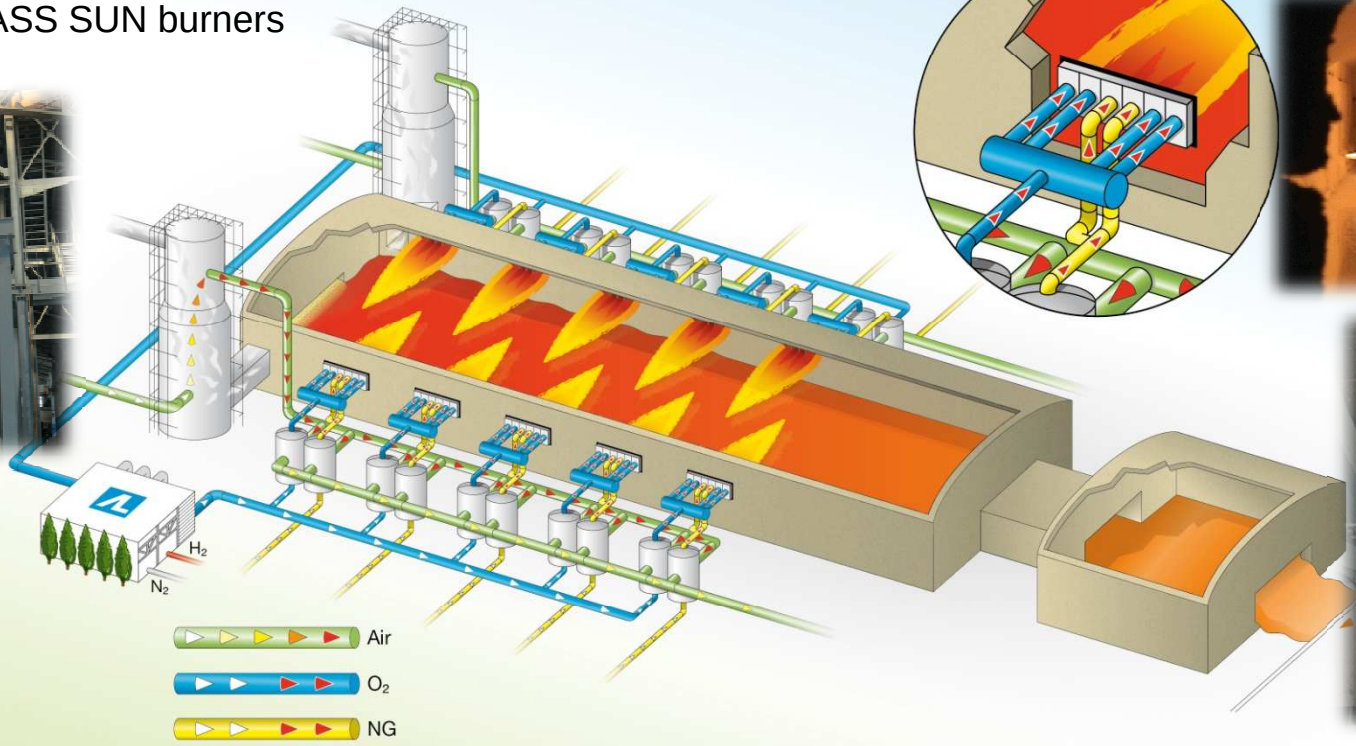
- Energy savings = **- 25% Vs Air** combustion
- CO2 savings from combustion= **- 25% Vs Air**
- Reduction of hazardous emissions = **- 83 % on NOx**

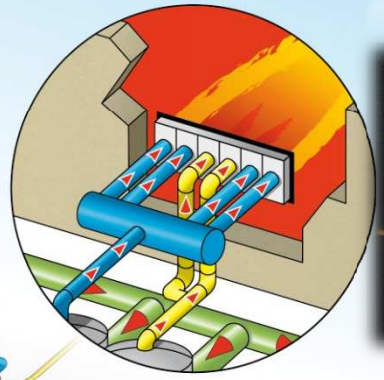
Trakya Glass (Bulgaria) 2016

- Energy savings objectives = - **20 % Vs Air combustion**
- CO2 savings from combustion= **- 20% Vs Air**
- Reduction of hazardous emissions= **- 90 % on NOx** emissions

ALGLASS HeatOx: Proven on float glass

- Air / fumes Recuperator (1 per side)
- ONE Air/O2 & Air/NG heater per burner
  - O2 @ 550°C & NG @ 450°C
- ALGLASS SUN burners

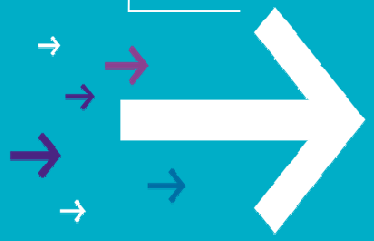




- ***ALGLASS*** **HeatOx** 25% fuel savings is validated with **two** float glass tanks.
- *Burner & HX technology adapted for float glass market segment*

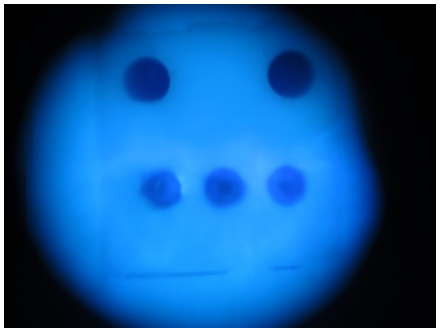
NEW PATENTED AL TECHNOLOGY FOR SMALL & MEDIUM FURNACES

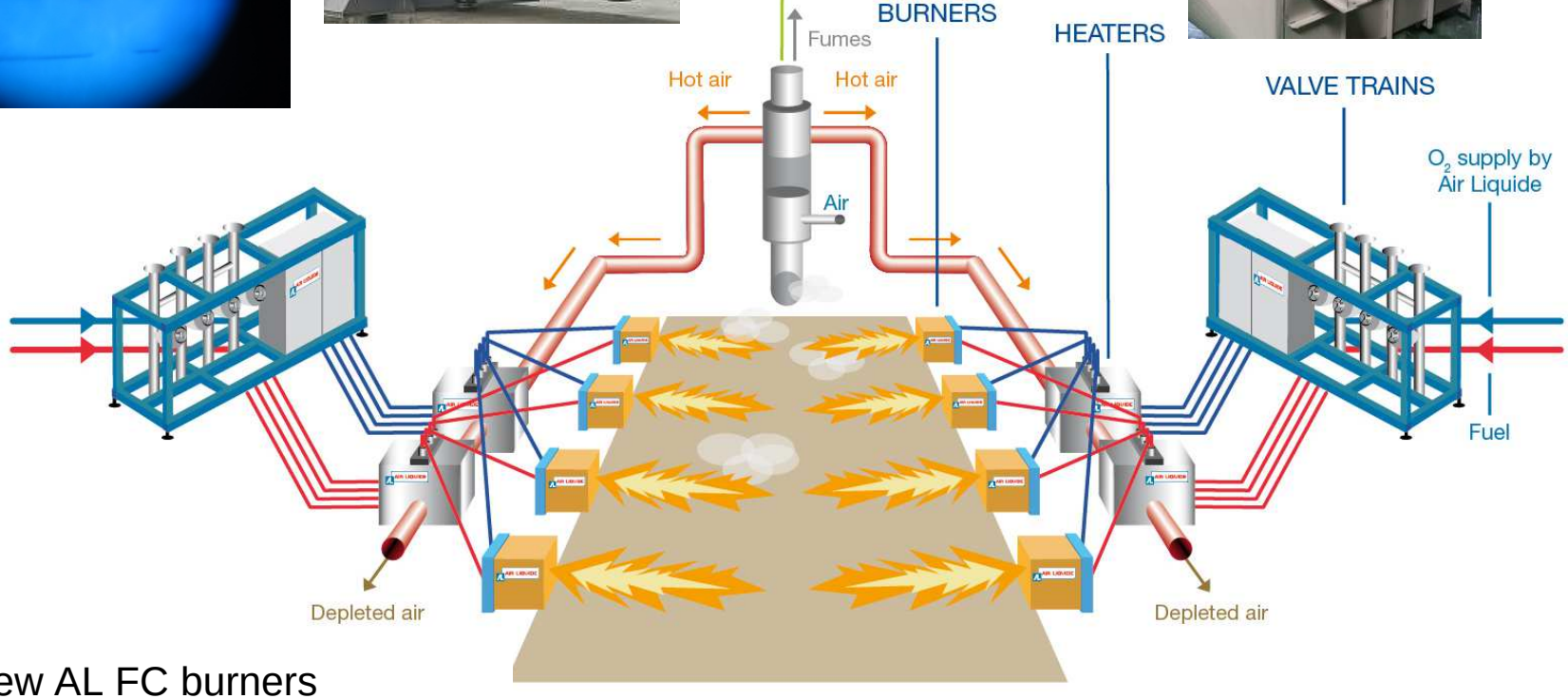
- One heat exchanger (O2/NG) can accommodate multiple burners
- Flow rate and temperature can be controlled individually
- New burner HeatOx FC
- Lifetime for 2 furnace campaigns



CAPEX savings and smaller footprint

Heat Oxy-combustion solution for small/medium furnaces



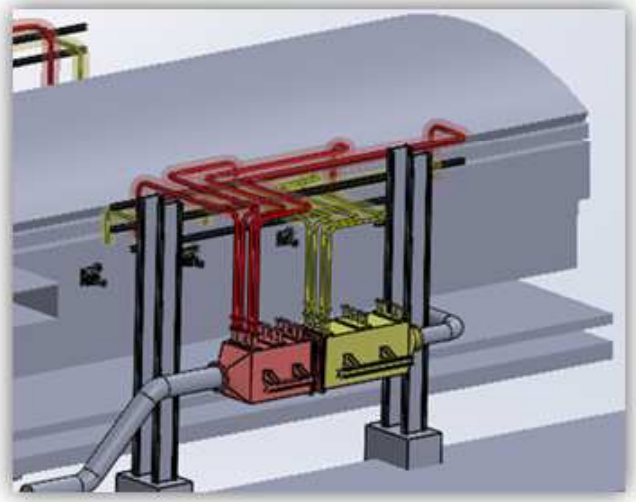


- ✓New AL FC burners
- ✓New AL O2 & NG Heaters

HeatOx Şişecam installation

- Installation on the fly after furnace start-up (3 months)
- Compliance with architectural / structural limitations

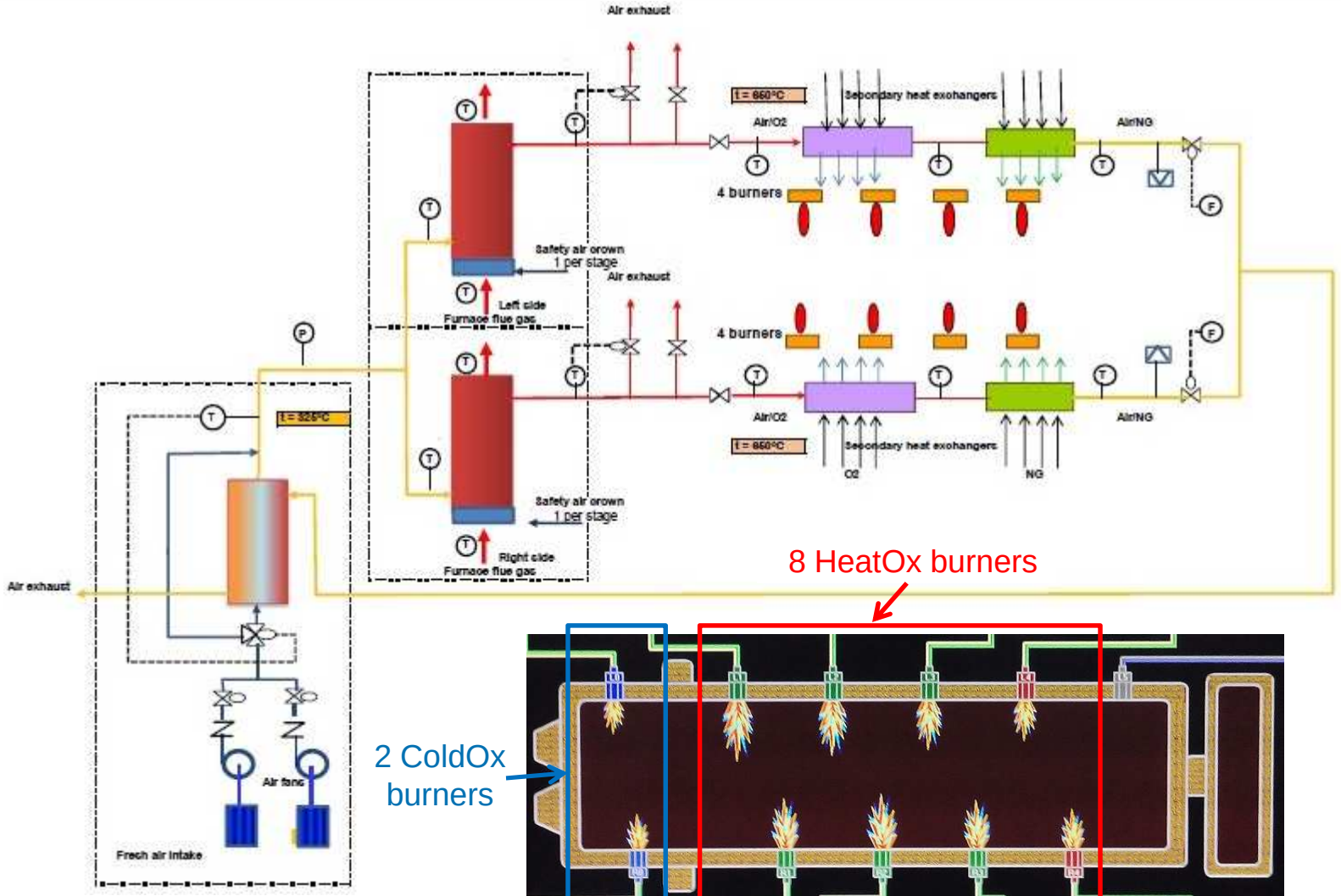
Air fumes heat exchanger during installation



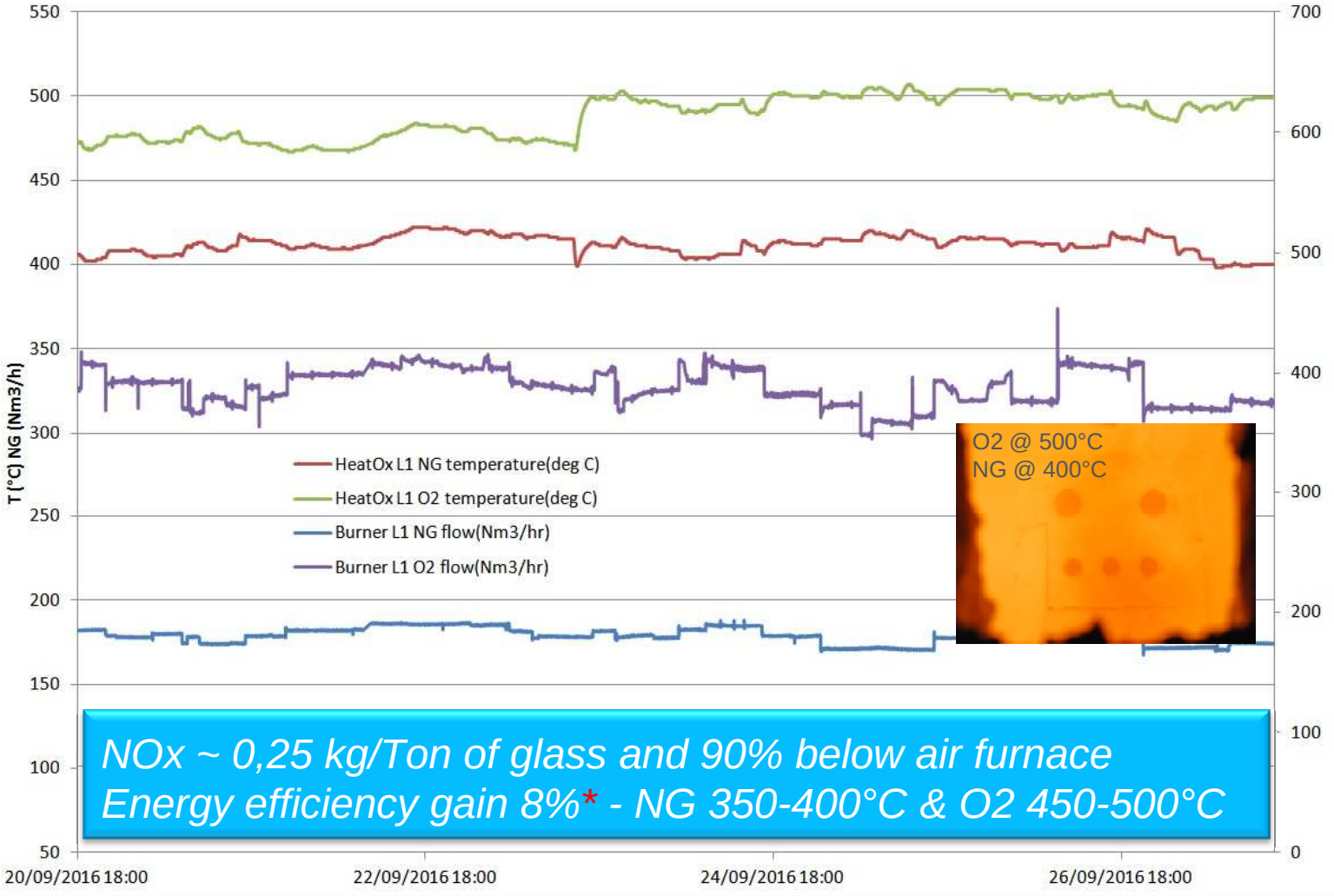
Piping lay-out

Secondary heat exchanger during installation

HeatOx Şişecam configuration

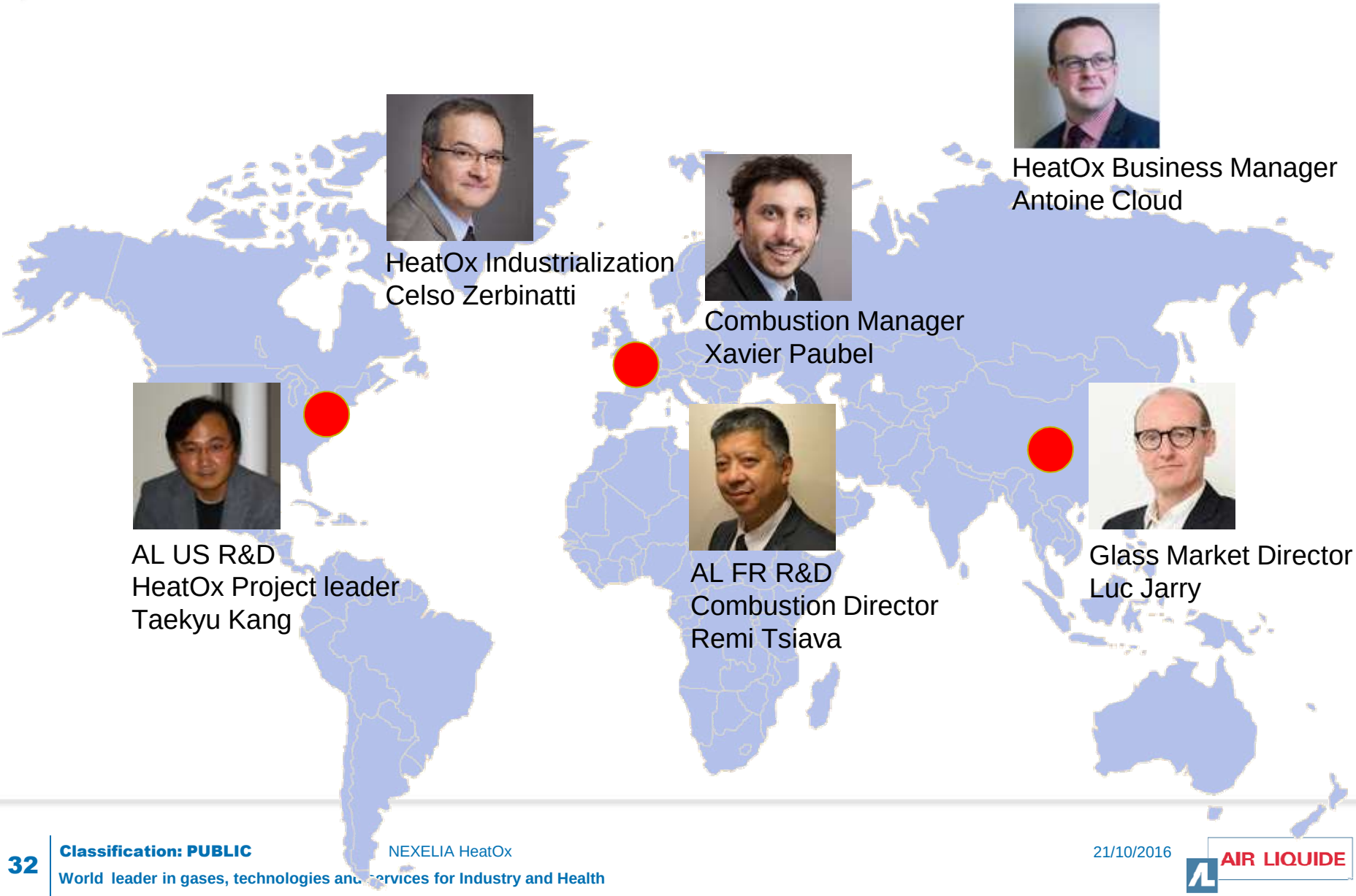


HeatOx Şişecam results



* 1,0 – 1,5% more savings expected at design conditions with improvements in progress

AL project team for HeatOx



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THANK YOU FOR YOUR ATTENTION

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