Energy efficiency in furnaces and production optimization

AGC GLASS EUROPE — LEADING FLAT GLASS PRODUCER

GLASS UNLIMITED

XXXI A.T.I.V. Congress

Fasilow Fabrice
Building & Industrial Division
Europe T&I Float Coordination - Global Business Excellence

Parma
21/10/2016

Outline

- Introduction : AGC Group
- Economical and environmental context of flat glass sector in EU
- Position and trend of AGC Europe in EU context
- Past and present efforts to reduce energy consumptions, emissions & improve operations
- New opportunities
- Conclusions

AGC GROUP

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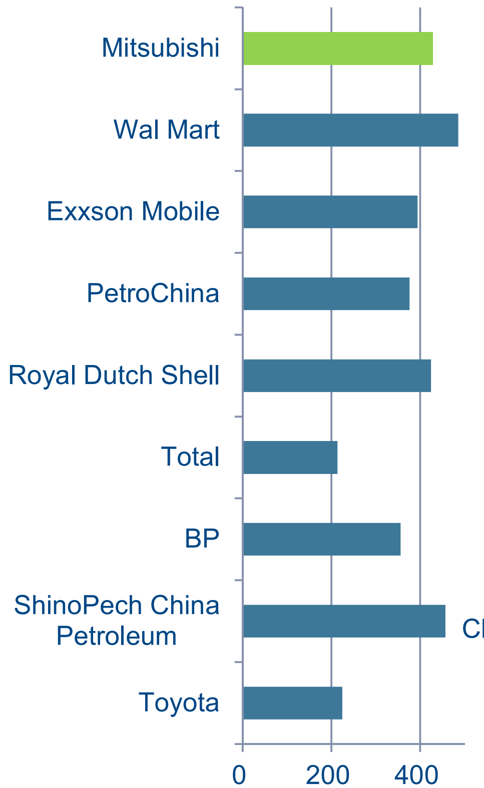
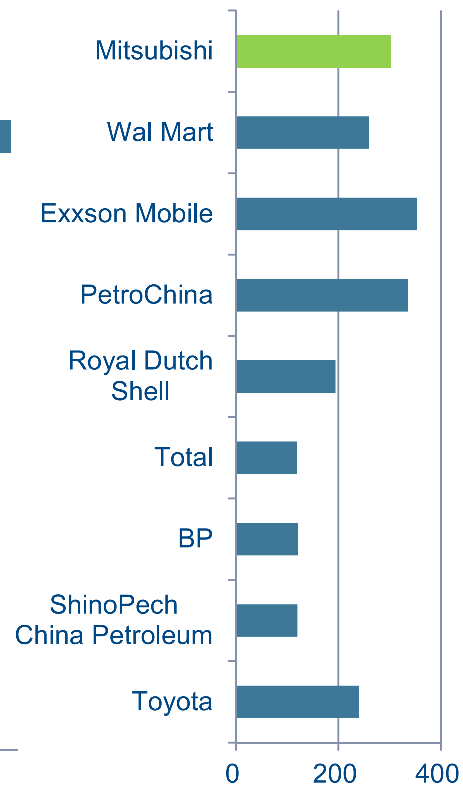
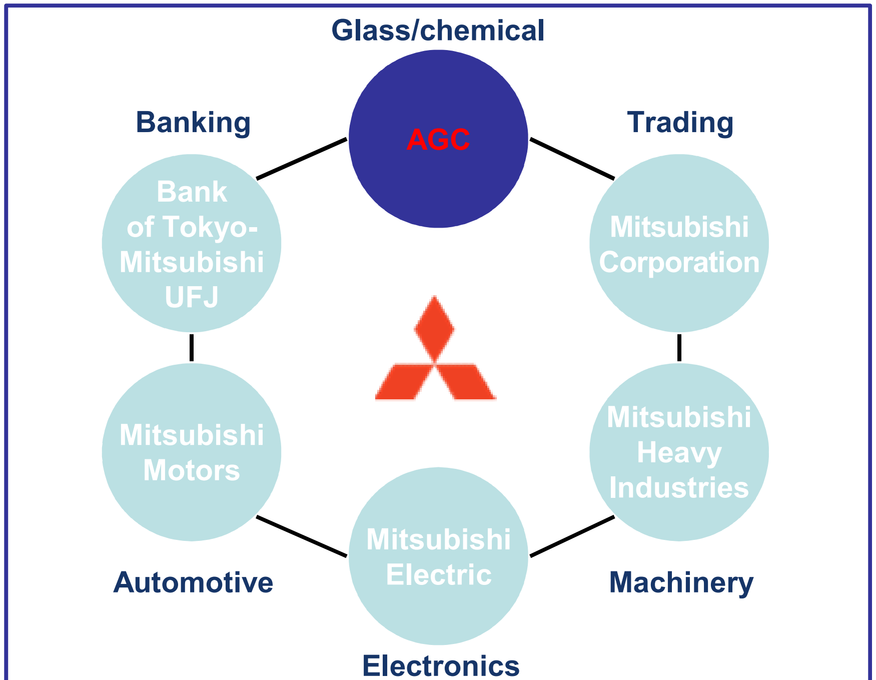
AGC is core member of Mitsubishi Zaibatsu group*1, the largest conglomerate network in Japan .

Sales
(bil USD, 2014)



Market cap
(bil USD, 2015)





Major group companies

- **Nikon** (Camera)
- **Kirin Holdings** (Food and beverage)
- **NYK (Nihon Yusen)** (Ocean shipping)
- **JX Holdings** (Oil)
- **Tokio Marine** (Non-life Insurance)
- **Meiji Yasuda Life Insurance** (Life Insurance)

1 Sum of "Friday Meeting" member companies (28 companies). EV is excluding unlisted companies (Meiji Yasuda Life Insurance, Mitsubishi Fuso Truck and Bus, Mitsubishi Aluminum) 2 1USD = 120 JPY 3 As of April 4th, 2015.

SOURCE: FT.com, Company web sites

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- 3 main business segments : Glass
  Electronics
  Chemicals

- Sales: € 9.6 billion*
- Operating profit: € 442 million*
- 51,000 employees*
- 200 companies in over 30 countries
- Headquarters and stock exchange listing: Tokyo

** 2014*

PROMINENT TECHNOLOGIES

Glass (48% / sales)

- Flat glass for buildings
- Automotive glass


Electronics (25% / sales)

- Display
  – LCD and PDP glass substrates
- Electronic materials


Chemicals (21% / sales)

- Fluorochemicals & specialty chemicals
- Chlor-alkali & urethane


N°1 glass producer (Glass)

Leading positions (Electronics, Chemicals)

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(*) Ceramic / Other : 6%

AGC Operations worldwide

Europe
14.600 employees
Sales: 2,27 billion €

GLASS
15 float plants
6 automotive plants
R&D Centre
14,400 employees

CHEMICALS

Japan / Asia
32.500 employees
Sales: 6,8 billion €

GLASS
13 float plants
12 automotive plants
R&D Centre
13,100 employees

ELECTRONIC materials
DISPLAY
CHEMICALS
CERAMICS

The Americas
4.000 employees
Sales: 1,01 billion €

GLASS NA
4 float plants
3 automotive plants
R&D Centre
3,700 employees

GLASS SA - Brazil
1 float plant
1 automotive plant
460 employees

ELECTRONIC materials
CHEMICALS

Year ended Dec. 2014

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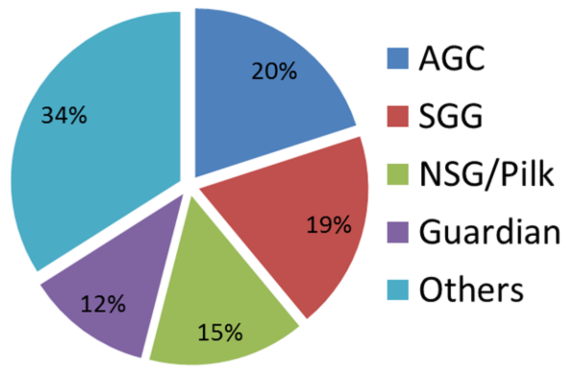
Economical context

- Flat glass business in Europe was in over-capacity after Lehman shock

Grand EU market share



- Low selling prices (from NW-EU to Russia) for commodities and specialities to some extends
- Adaptation of production capacities to match demand
- Huge pressure to reduce costs :
  - Energy BUT not only :
  - Raw materials
  - FTE
  - Investments & furnace life-time extension

→ **Big pressure on cost reductions and standardization programs**

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Environmental context (CO_2)

- EU-ETS Third period from 2013 to 2020
- Available allowances (Tons CO_2) from 2008-2012 were transferred

Number of Allocation (T CO_2) = BMp X HAL X CLF(k) X CSF(k)

- Product benchmark (Bmp)
  - Calculated as the average of the 10% best performers in EU27
  - = 0.453 Ton CO_2 per ton of melted glass
- Historical Activity Level (HAL)
  - Median value of the annual activity level (Gross Tons)
- Carbon Leakage Exposure Factor (CLEF)
  - Today, flat glass is considered as Carbon leakage industry
  - Exposure was re-evaluated in 2014

Free allocations	2013	2014	2015	2016	2017	2018	2019	2020
Sector exposed to CL	1	1	1	1	1	1	1	1
Sector not exposed to CL	0.80	0.73	0.66	0.59	0.51	0.44	0.37	0.30

- Cross Sectorial Factor (CSF) : 0,893 in 2016 & 0,824 in 2020

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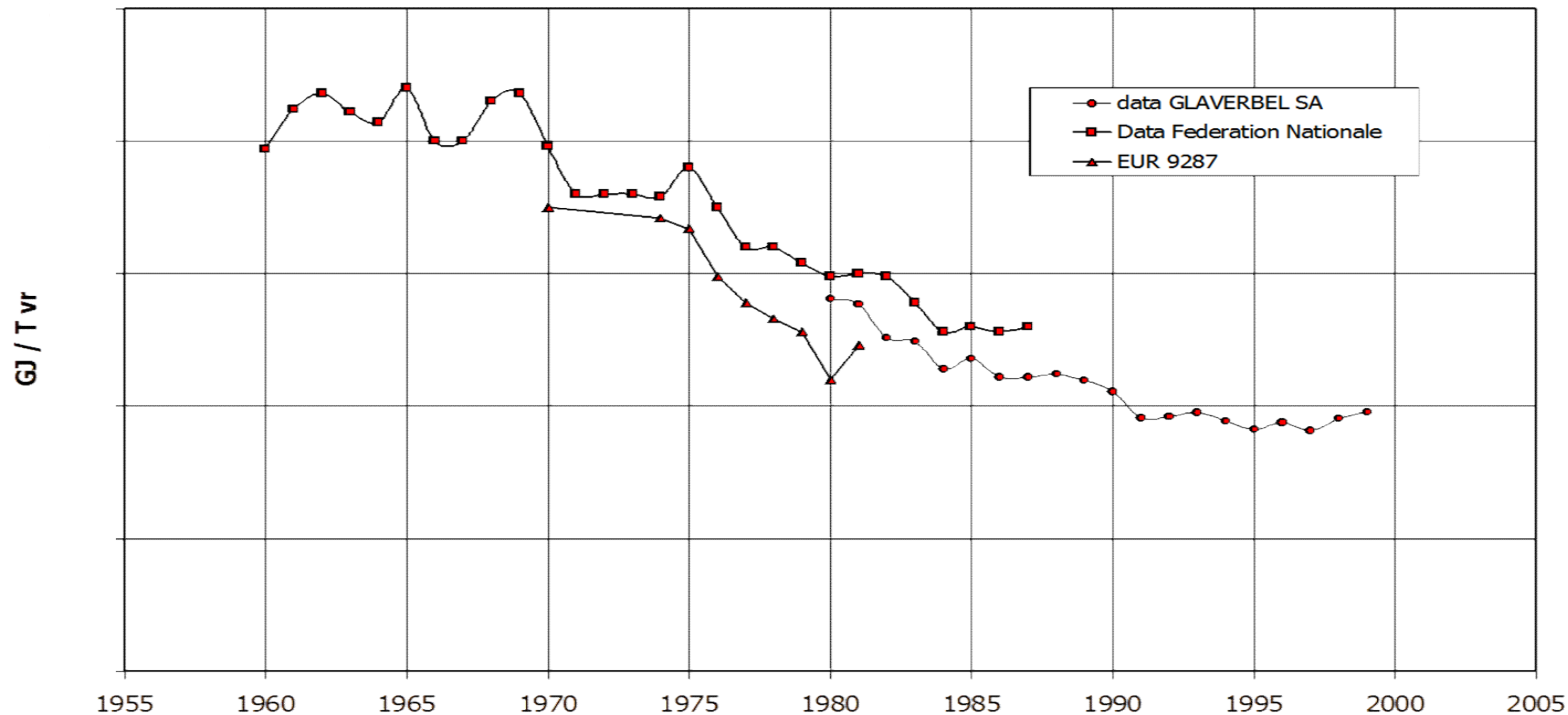
Energy use trend in flat glass sector



- Furnace evolution from 500 T/d to 1000 T/d
- Life time extension from 10 years (or less) to 18-19 years
- Quality improvements (not only with float process) but punctual quality requirements increase for mirrors, coatings, laminate, extra-clear, solar,…

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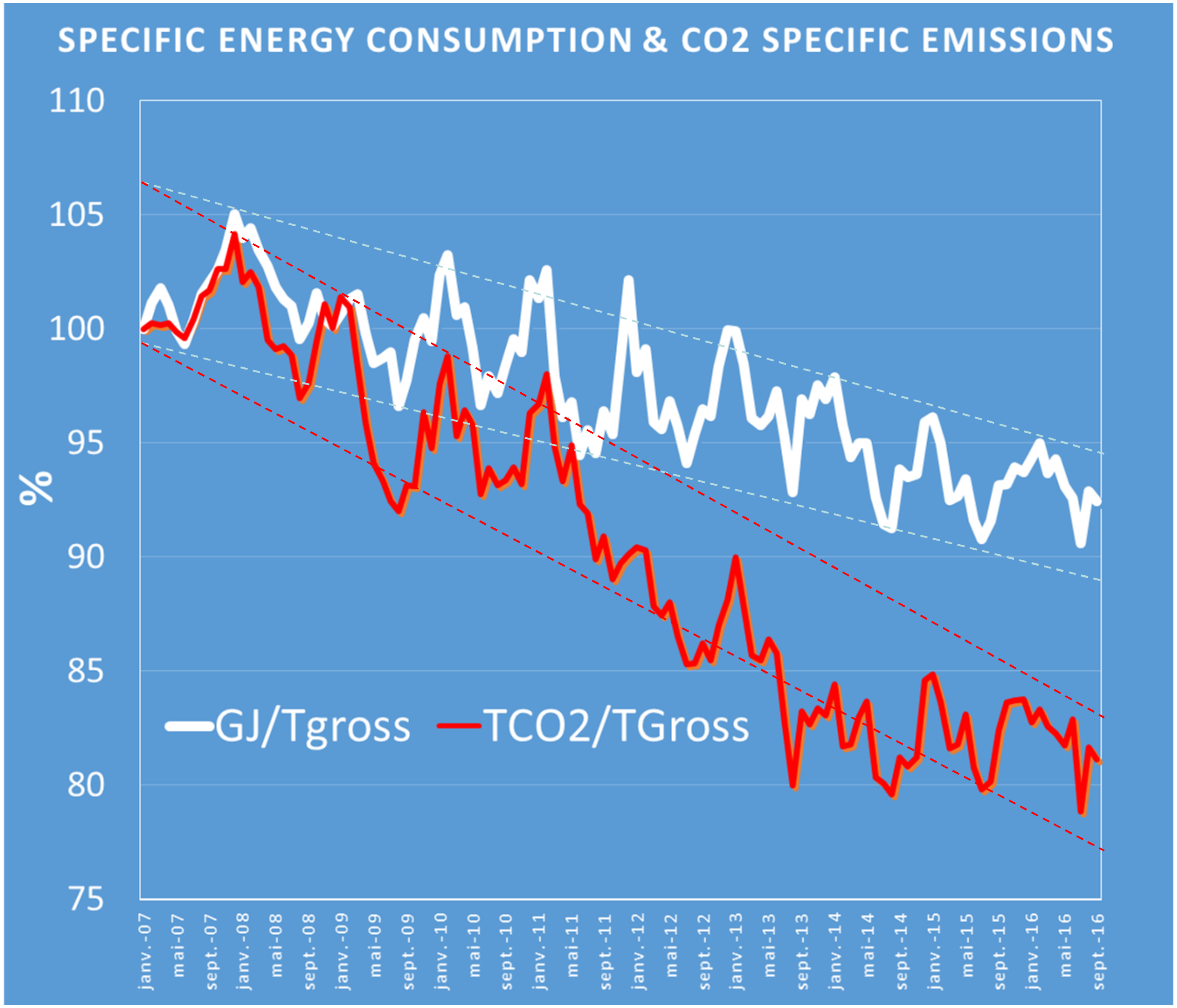
Energy consumption and CO_2 emissions trends



10% Energy reduction

20% CO_2 reduction

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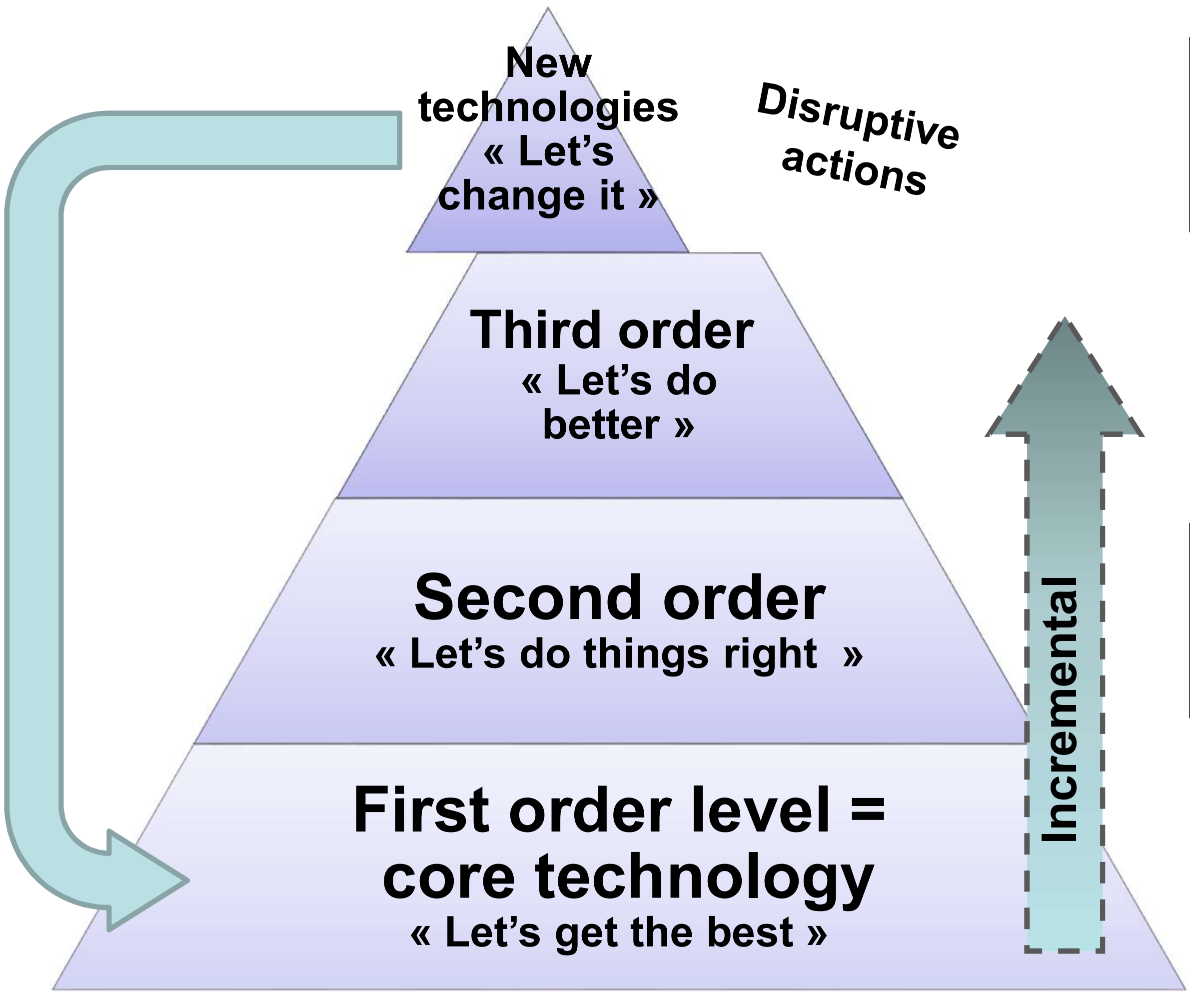
How these results were achieved ?

Overview of actions ranked in 4 main categories



For stronger improvement steps but cases by cases profitability contexts

e.g. « Intelligent » furnace control

Accurate sensors installation and use to monitor and optimize operations

Furnace specifications, furnace design and operations standardization

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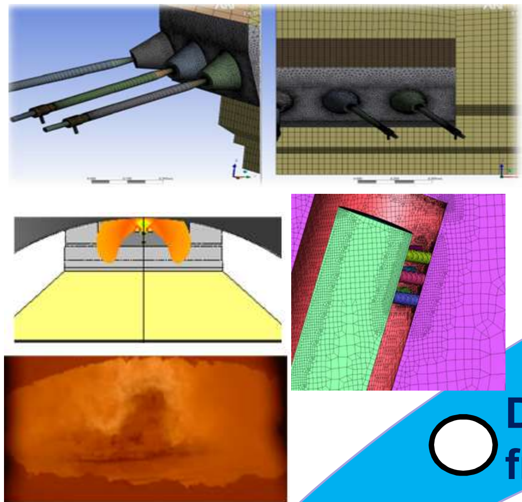
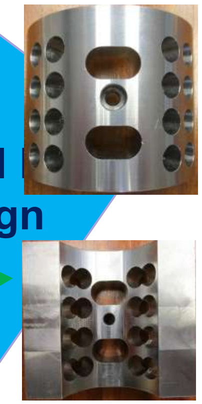
First order actions

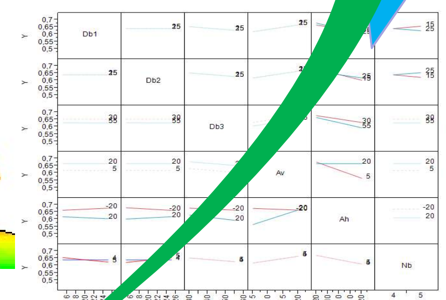
- CFD & statistical tools methods combination for furnace design and operations





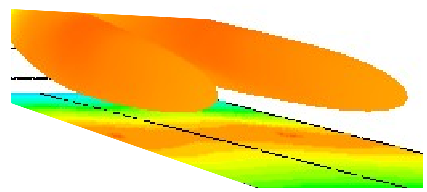
Statistical Optimization

Final design



$Y = \propto_0 + \sum \propto_i X_i + \sum \propto_{ij} \ldots X_j$

Numerical simulations = Experiment

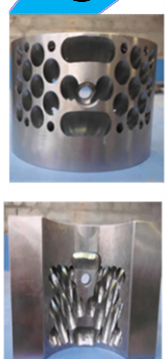


Degrees of freedom & DOE

- ✓ Nozzles design
- ✓ Burner height
- ✓ Gas Distribution
- ✓ ….

Validation

- ✓ Nu… ation
- ✓ Tria…

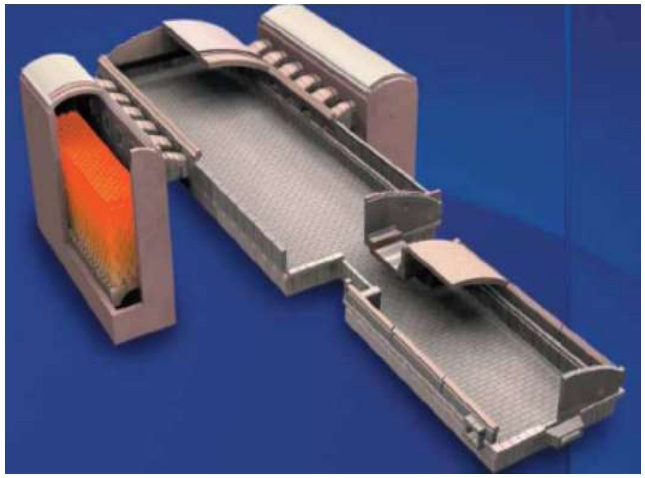


Débit gaz = 800 Nm^3/h et gaz Moustier (DOE)	Nb	Db1 (mm)	Db2 (mm)	Db3 (mm)	Av (°)	Ah (°)	Efficacité	Ecart type flux VR (kW)	O2 en sortie (%)	CO en sortie (%)
Settings brûleurs Klin	5	17	11,7	35	13	0	0,666	332	2,52	0
Config optimale eff/homog prévue	5	15	23,3	30	20	20	0,673	278	2,53	0
Config optimale eff prévue	5	15	25	30	20	-20	0,675	340	2,54	0
Meilleure config	4	15	15	30	20	-20	0,685	452	2,49	0
Ma config	4	16	24	30	13	-18	0,685	438	2,48	0

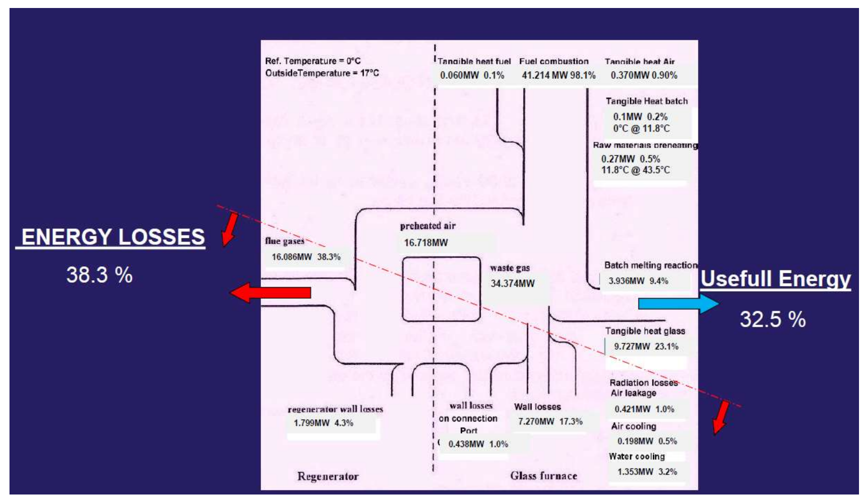
- r combustion, glass melt, regenerators, color changes, tin bath, lehr,…

First order actions

- Heat balances of furnaces, IR inspections, endoscopic inspections & audits
  - Internal AGC teams dedicated to these audits



  - Complete HB around furnace and checkers
  - +/- 3000 measurement points
  - Each furnace is done each 3-4 years
  - 15 years of HB experience
  - Highly skilled staff measuring & reporting
  - 5% of error maximum



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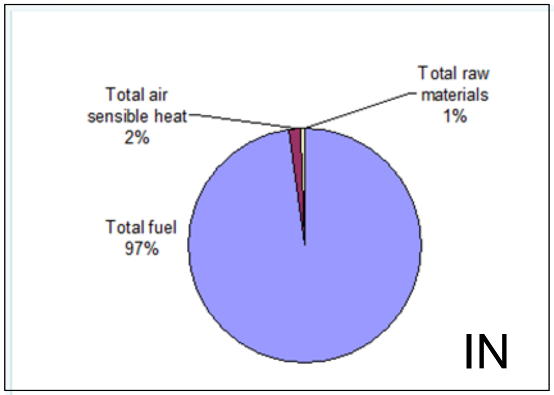
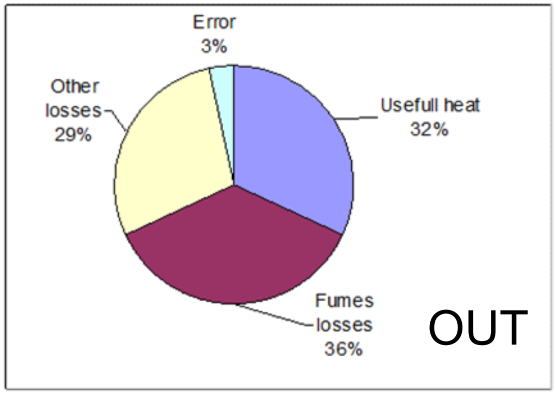
Heat balances results (general)

OUTPUT

Pull [T/d]		732		
Cullet / pull [%]		40%		
Specific Energy Consumption [GJ/T]		5.396		
				[MJ/T]
Batch Total Batch reaction	**4020 kW**	8.52%		475
Glass heat output at canal	**11038 kW**	23.40%		1303
Fumes heat Losses	**17083 kW**	36.22%		2017
Water cooling Total water cooling	**2249 kW**	4.77%		266
Wall Heat Losses Total Wall Heat Losses	**9894 kW**	20.98%		1168
Air Cooling	**461 kW**	0.98%		54
Air leakage – entrance	**876 kW**	1.86%		103
Unknown / error	**1545 kW**	3.28%		182
Total	**47166 kW**			5569





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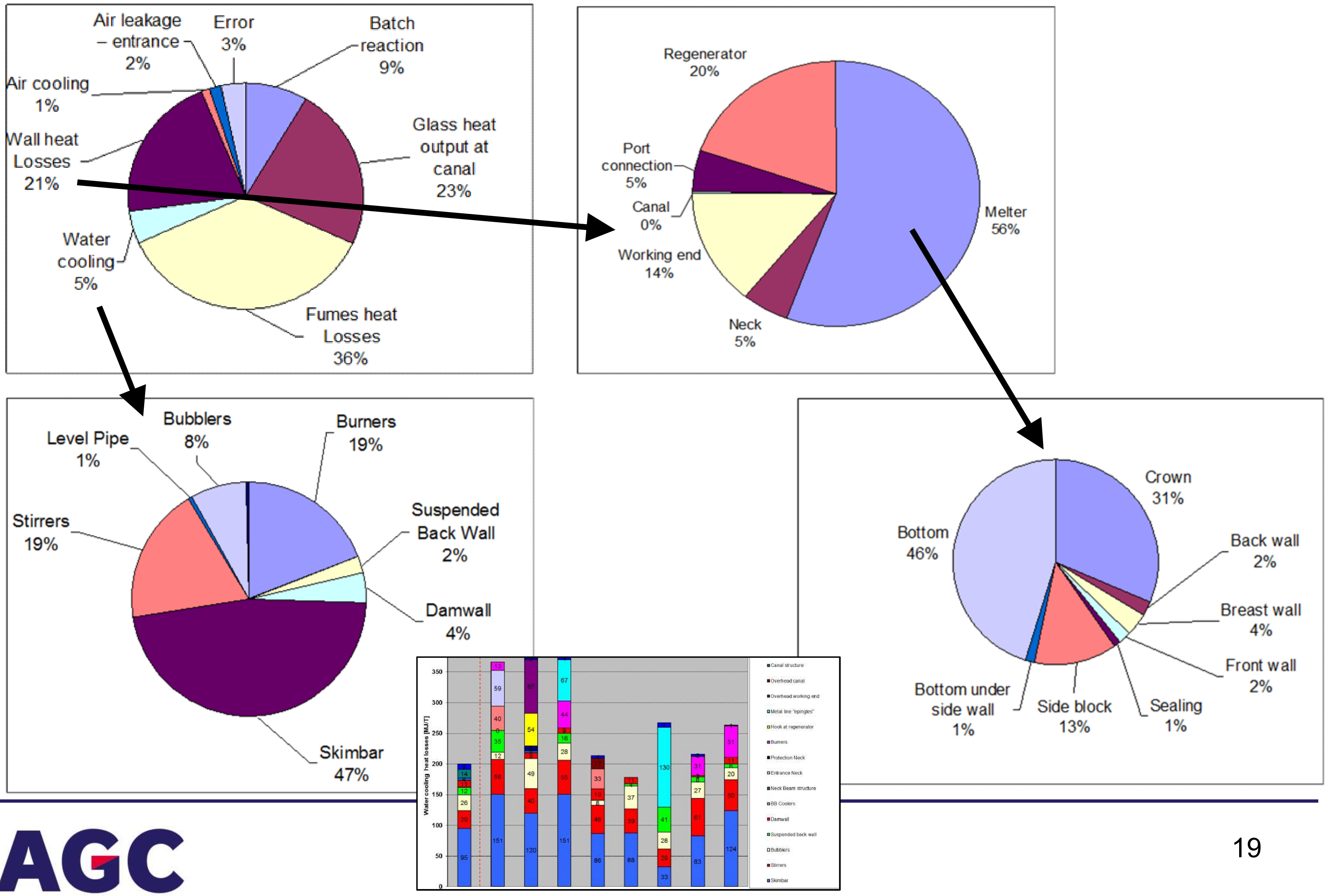
Heat balances results (details)



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First order actions results

- Comparison of furnaces during life-time and with others

[Heat efficiency]

$$\eta_e = \frac{glass \cdot chemical \cdot reaction \cdot heat + Glass \cdot heat \cdot output \cdot at \cdot canal}{oil \cdot chemical \cdot heat}$$

[Combustion efficiency]

$$\eta_f = \frac{oil \cdot chemical \cdot heat + oil \cdot sensible \cdot heat + heat \cdot recovery \cdot input - exhaust \cdot top \cdot fume \cdot heat}{oil \cdot chemical \cdot heat + oil \cdot sensible \cdot heat}$$

[Regenerator efficiency]

$$\eta_r = \frac{Regenerator \cdot top \cdot air \cdot heat - Air \cdot sensible \cdot heat \cdot at \cdot entrance}{Regenerator \cdot top \cdot fumes \cdot heat}$$

- Standardization and/or evolution of design (checkers, port-neck dimensions,…)
- Standardization of equipments (burners, waist coolers, bubblers,…)
- Standardization of practices (fire distribution, cooling,…)
- At least, better understanding of basic phenomena and guidelines to follow (or not to follow)

Heat balance equipment












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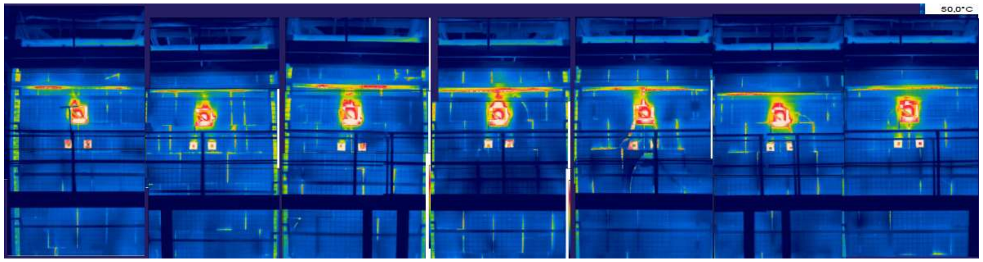
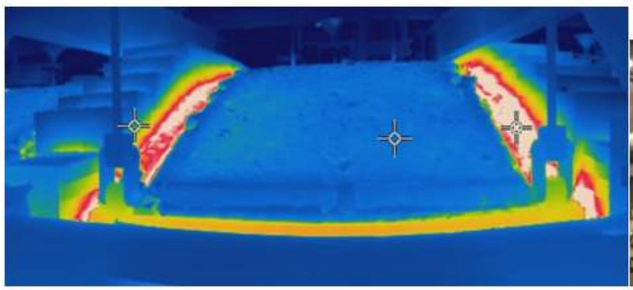
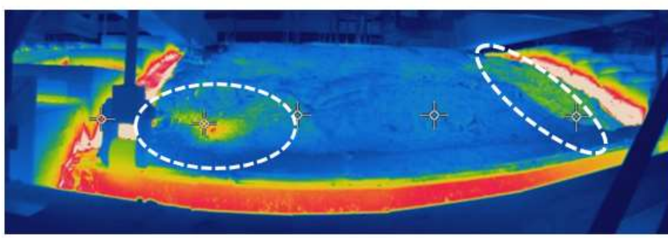
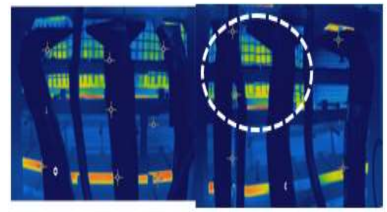
Infrared inspections



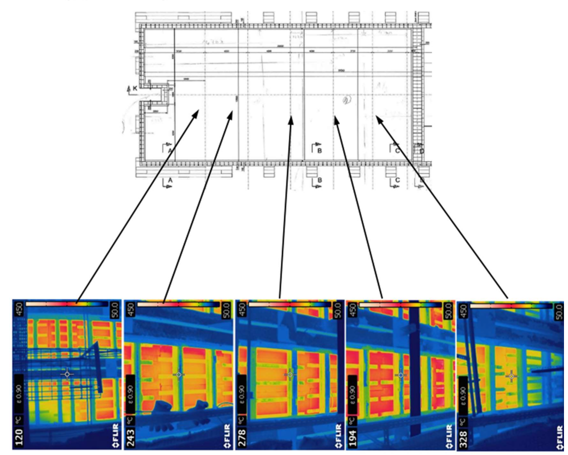




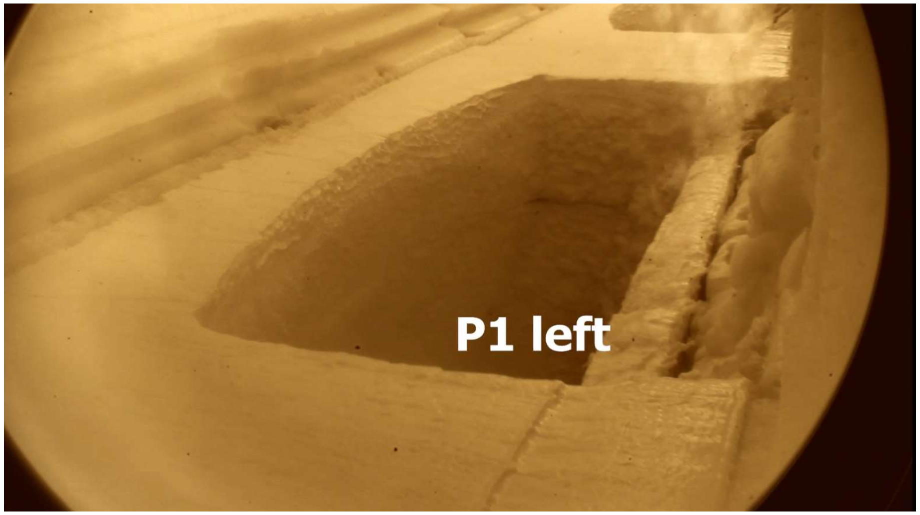


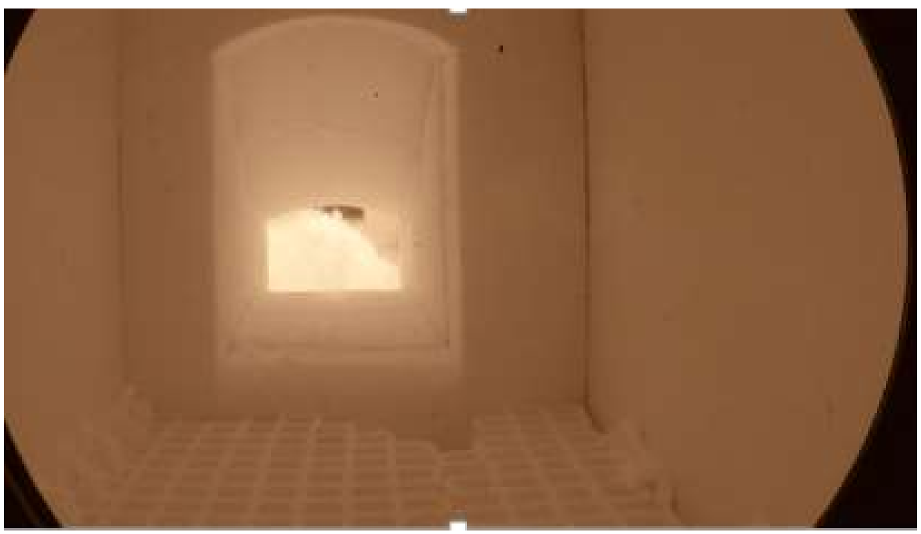
Burner 3 (glass →)

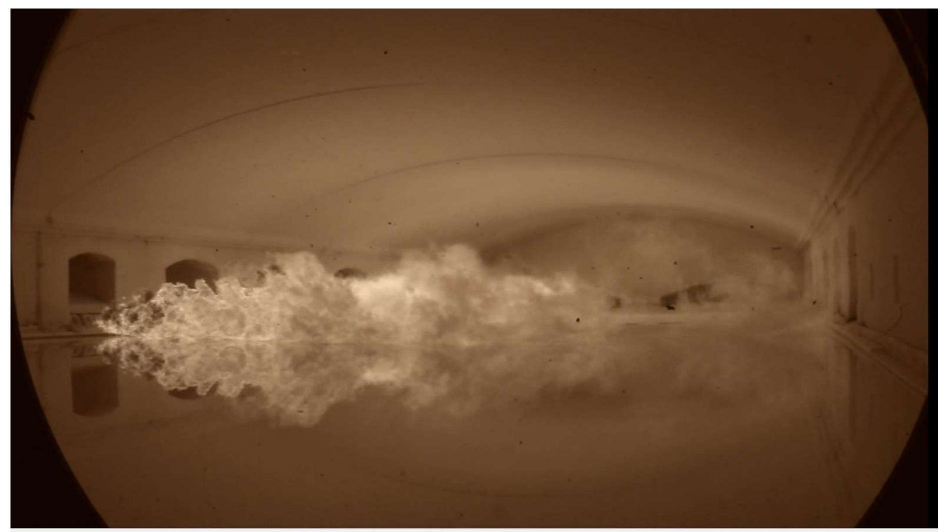
(← glass)



Endoscopic inspections







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Core business activities output

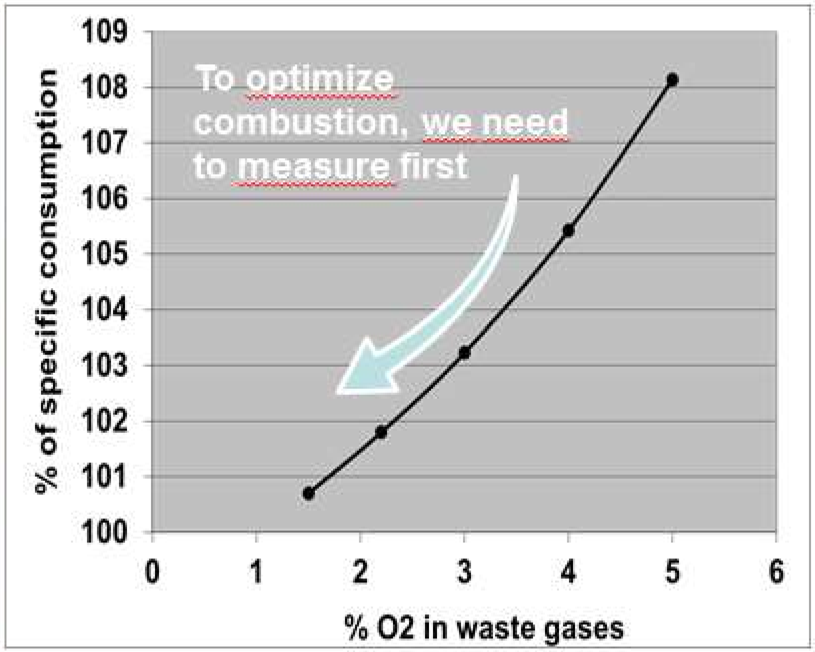
- With
  - Heat balances
  - IR inspection
  - Endoscopic inspections
  - Furnace audits (life-time extension)
  - Skills in ceramic welding
  - Exchanges of best-practices among plants
  - ...

AGC has built a systematic approach of the furnace design & management to improve its efficiency & also supported by CFD

- AGC has already realized in the past such « technical services » for non-competitors
- **AGC is open to offer such furnace « technical services » for non-competitors (fabrice.fasilow@eu.agc.com)**

Second order actions

- We need sensors/metering BUT good ones



Continuous O_2 measurement in waste gases enables to optimize combustion

1% O_2 reduction if too oxydizing conditions can save 1,5% energy

- Experience of more than 10 years with such sensors
- More than 90% of AGC lines in EU are equipped
- Having sensors is a first thing, a second one is optimizing the process and operators training/education

Second order actions

- Natural gas flow meters for invoicing consumed quantities on a regenerative furnace is of what kind ?

- Turbine
- More frequent
- Cheaper
- Less accurate

- Roots type & less frequent
- More expensive
- More accurate but by-pass needed

- Ultrasound
- Most expensive
- Not frequent
- The best accuracy

- Why to be carefull with a turbine flowmeter ?

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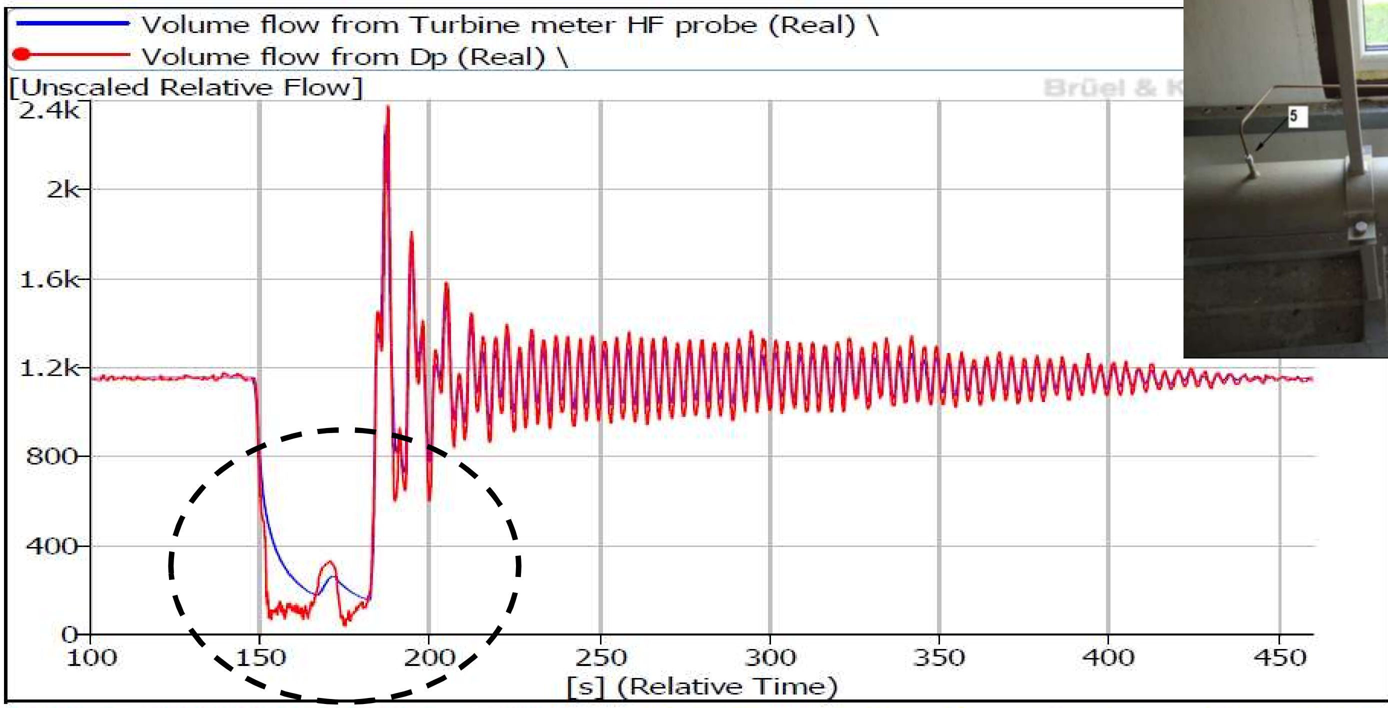
Lack of accuracy of turbine flowmeters



Red : volume flow derived from Dp measurement Blue : volume flow derived from turbine meter HF probe pulses

Fig 6.1 Indication of volume error due to turbine meter dynamics

- Deviations can occur during reversal
- Process can be adapted to avoid such phenomena but with some limits
- Systematic audits are done in plants to improve situation (& claim to gas distributors)

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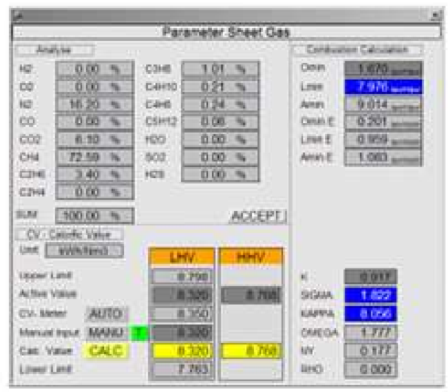
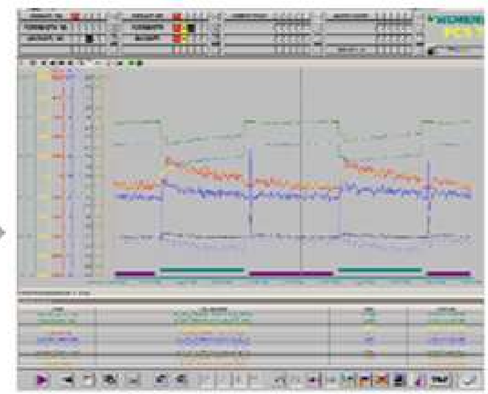
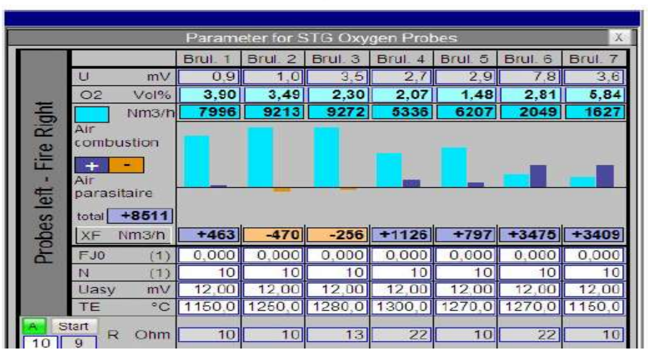
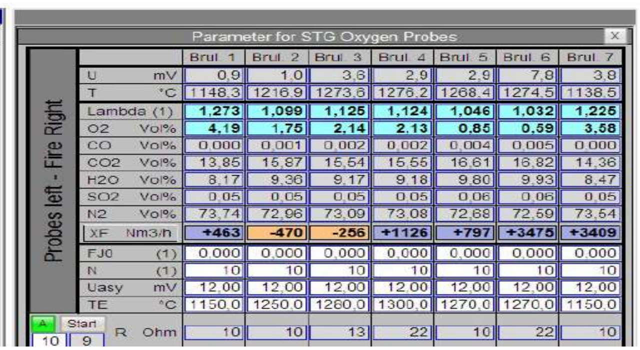
Third order actions

- Natural gas market liberalization induced in some plants huge variation of gas composition (then calorific power and Wobbe index) leading to process instabilities (energy and quality)
- Changes in gas composition modify the stoechiometric air/gas ratio
- Counter-action = closed loop control of gas power and air/gas ratio with on-line chromatograph and O_2 sensors









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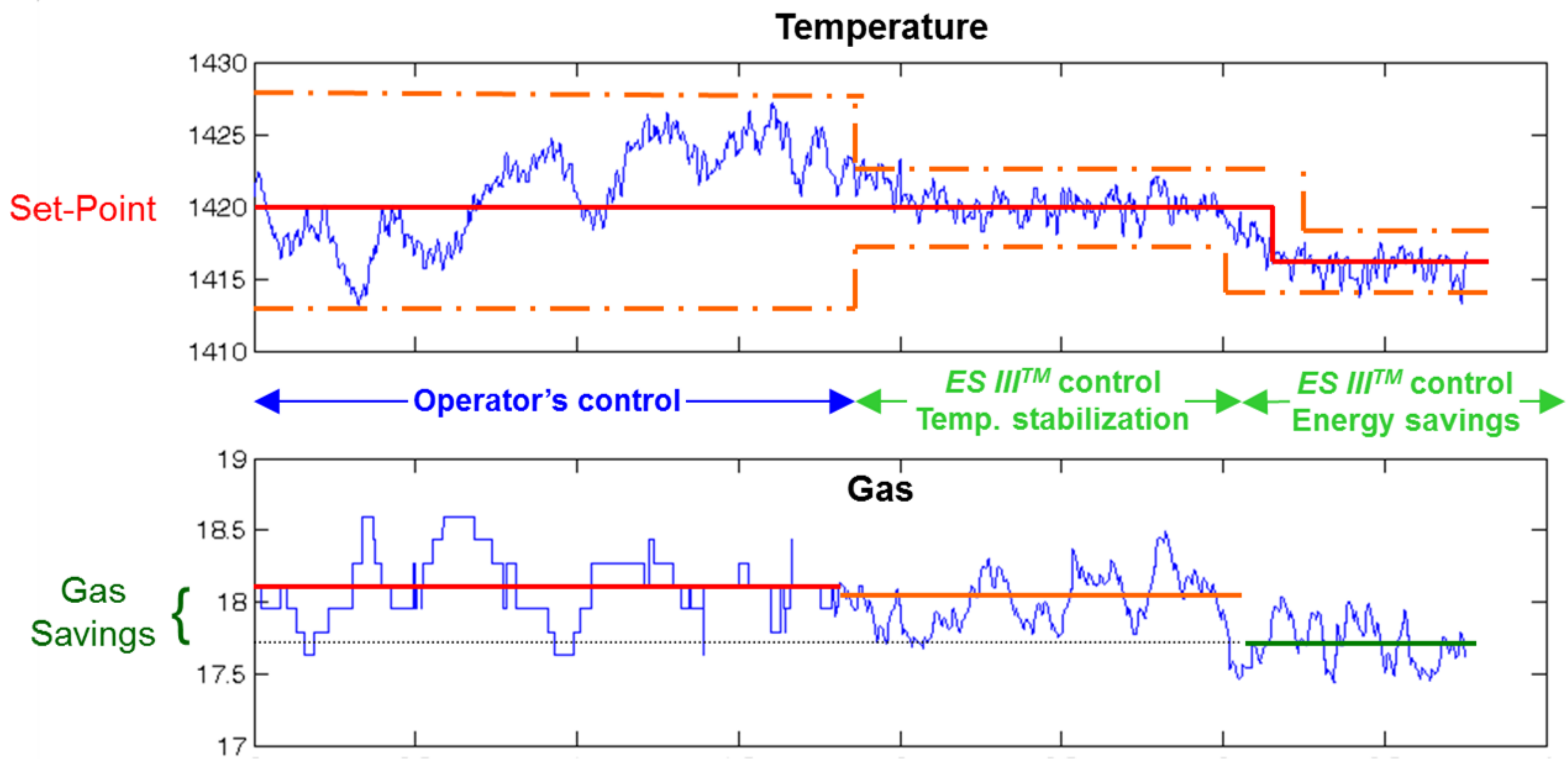
Third order actions

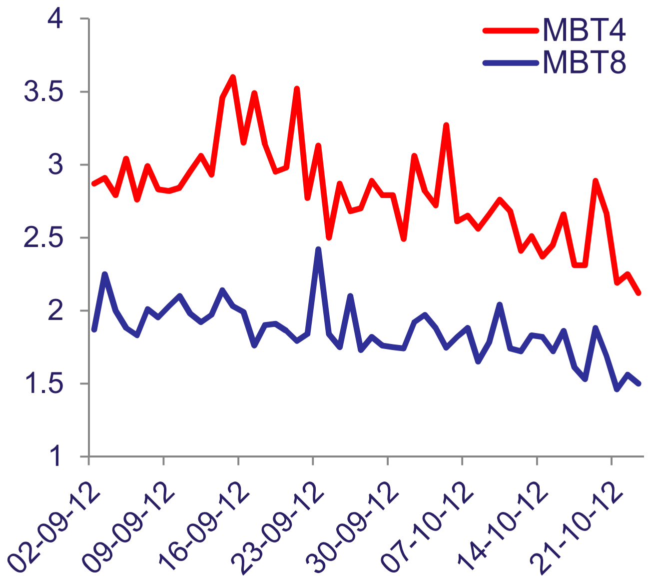
- Expert systems to stabilize crown & bottom furnace temperatures, glass level & canal temperature
- Theory :

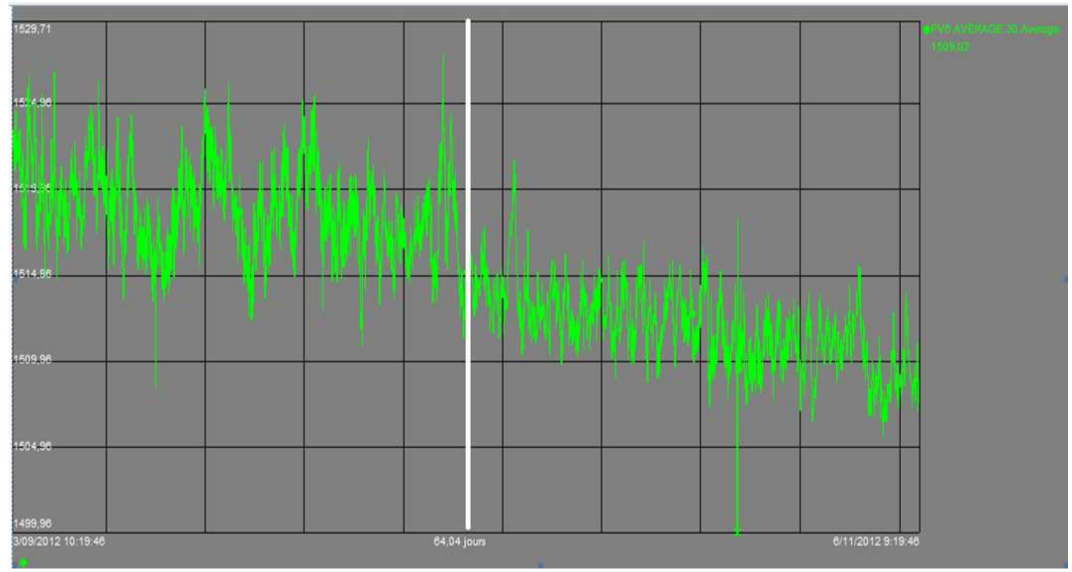


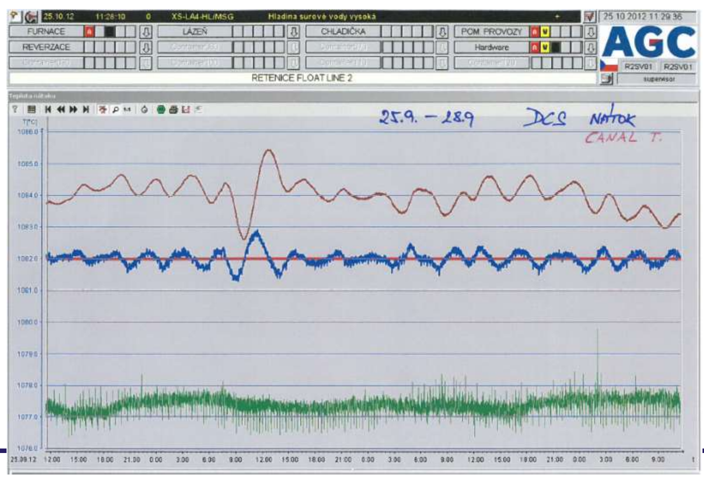
- And combination of different control strategies

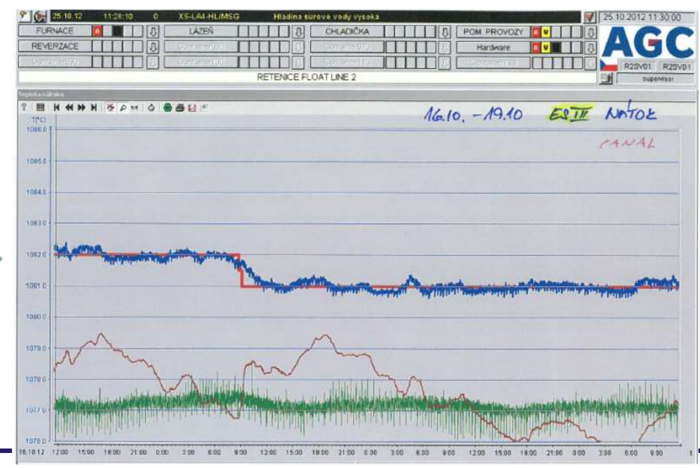
Third order actions

- Reality :









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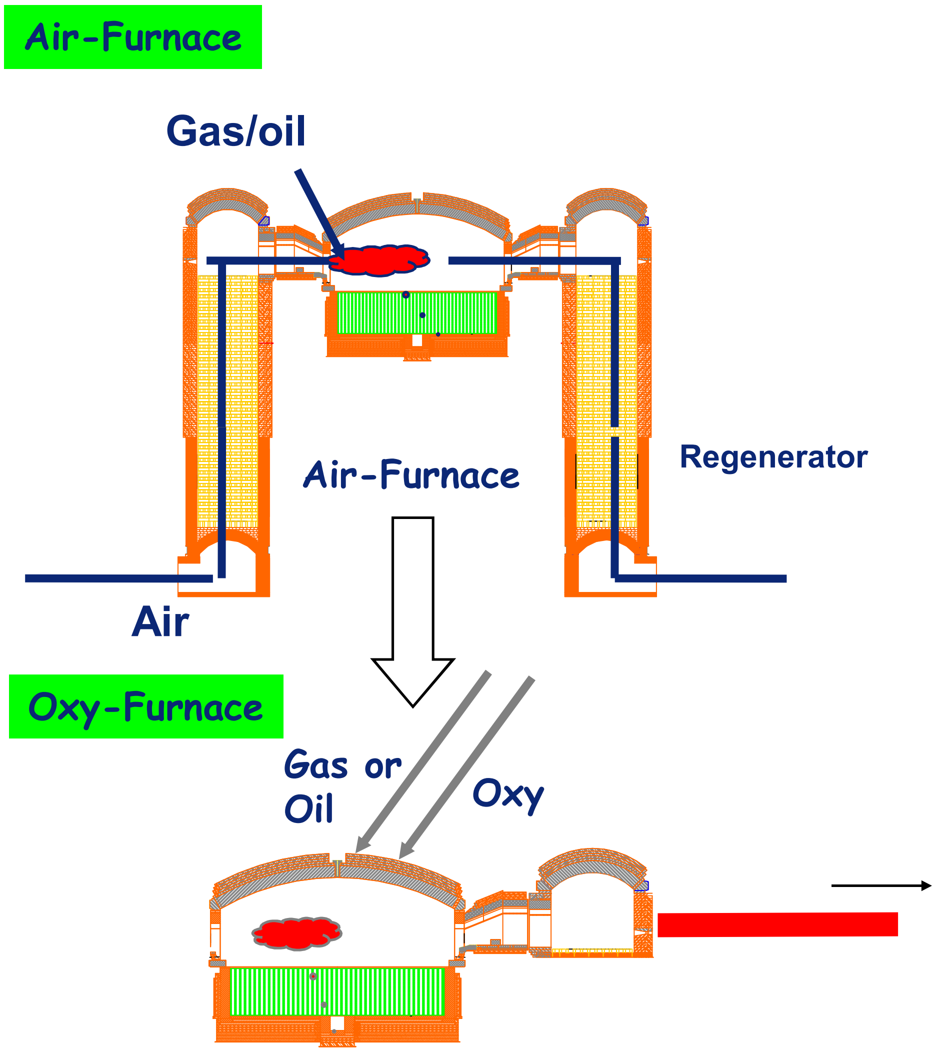
Disruptive actions – Hotox (HOxyGas)



<u>« Cold » oxygen firing :</u>

<u>Advantages:</u>

1) NOx decreasing (>50%)
2) Energy (~-14%) & CO_2
3) No regenerators
4) Furnace stability

<u>Drawbacks:</u>

1) Oxygen cost
2) Alumina crown

=> Cold oxygen = Negative profitability.

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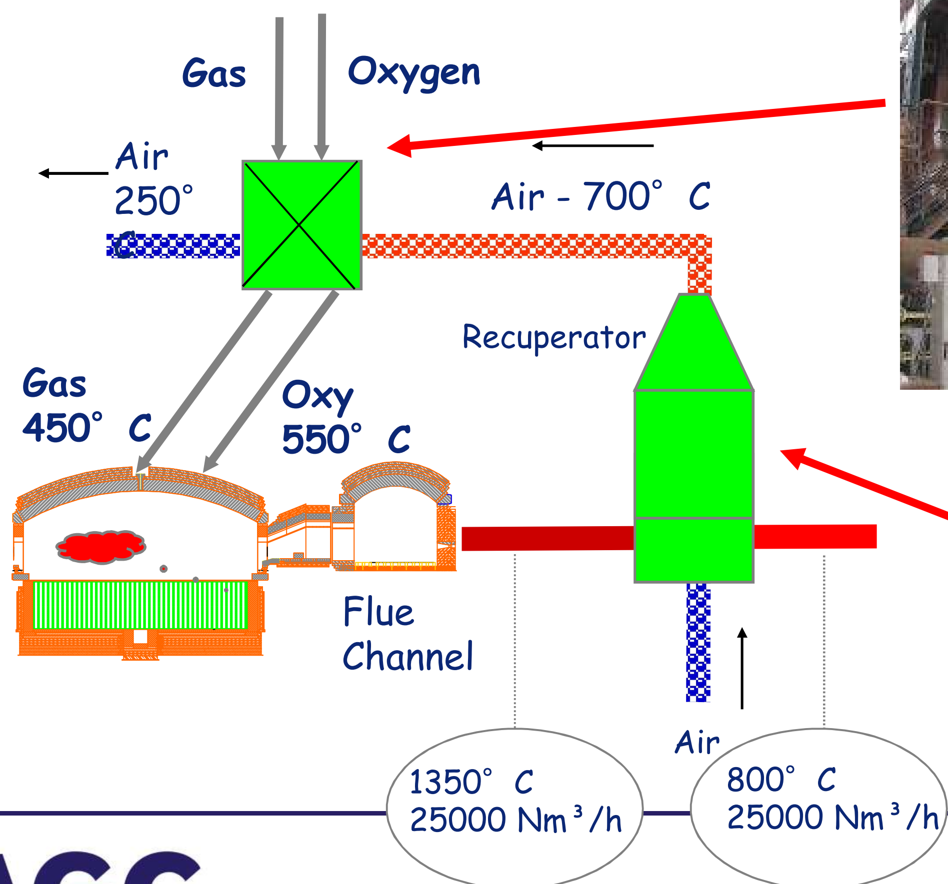
From Cold oxy to Hot oxy (HOxyGas)

- Economical interest of O_2 preheating is to increase the profitability of oxy-combustion by heat recovery and oxygen preheated at 550°C.



- **~ 20% energy consumption gain**
- **80% NOx reduction**
- **Versus air firing**

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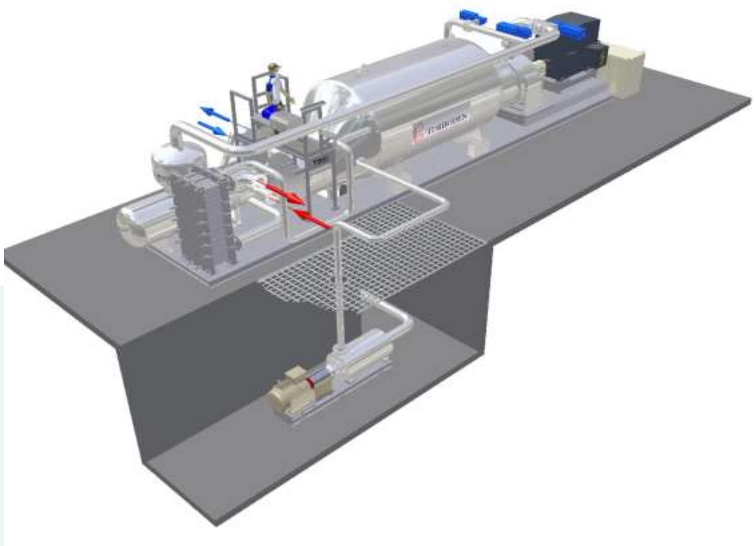
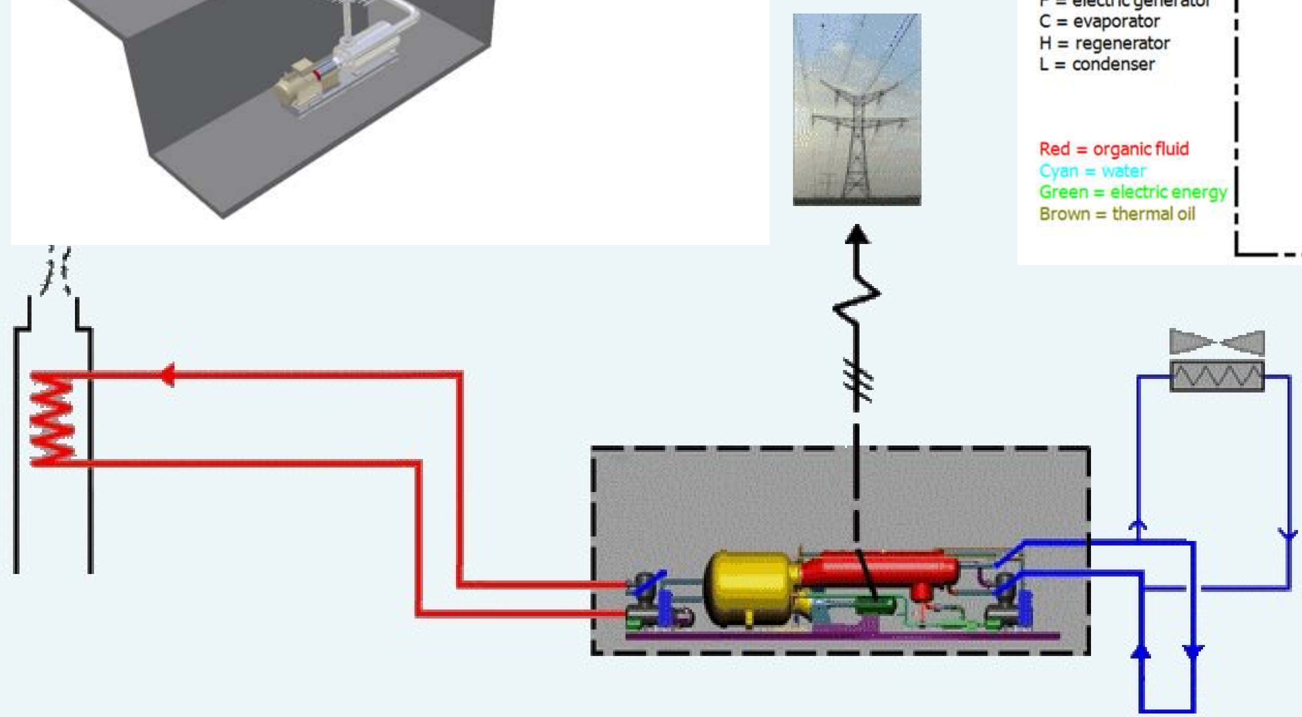
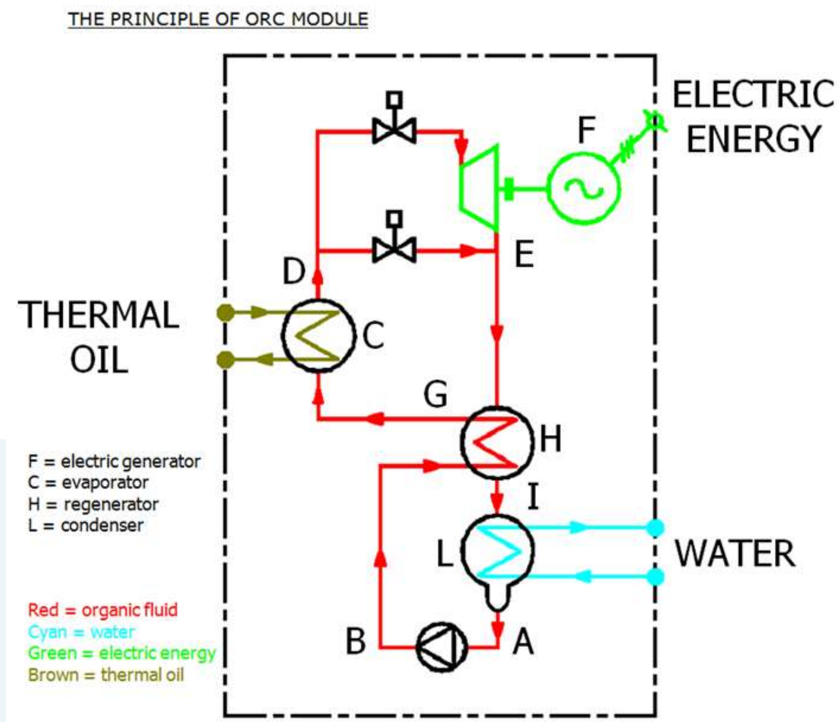
Other disruptive action : ORC on waste gases







Today

1 MW electricity production full time

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New opportunities…

- Depending on local constraints of energy prices, level of investment, area availability, tonnages/plant size,… different options can be considered to reduce melting energy & improve performances :
  - Raw materials preparation
  - Syngas production and use
  - Alternative sources of energy (electricity & biogas)
  - Heat recovery (e.g. By ORC) downstream of the float process (lehr,…)
  - CCS or CCU
  - « Smart factory » concept
  - …

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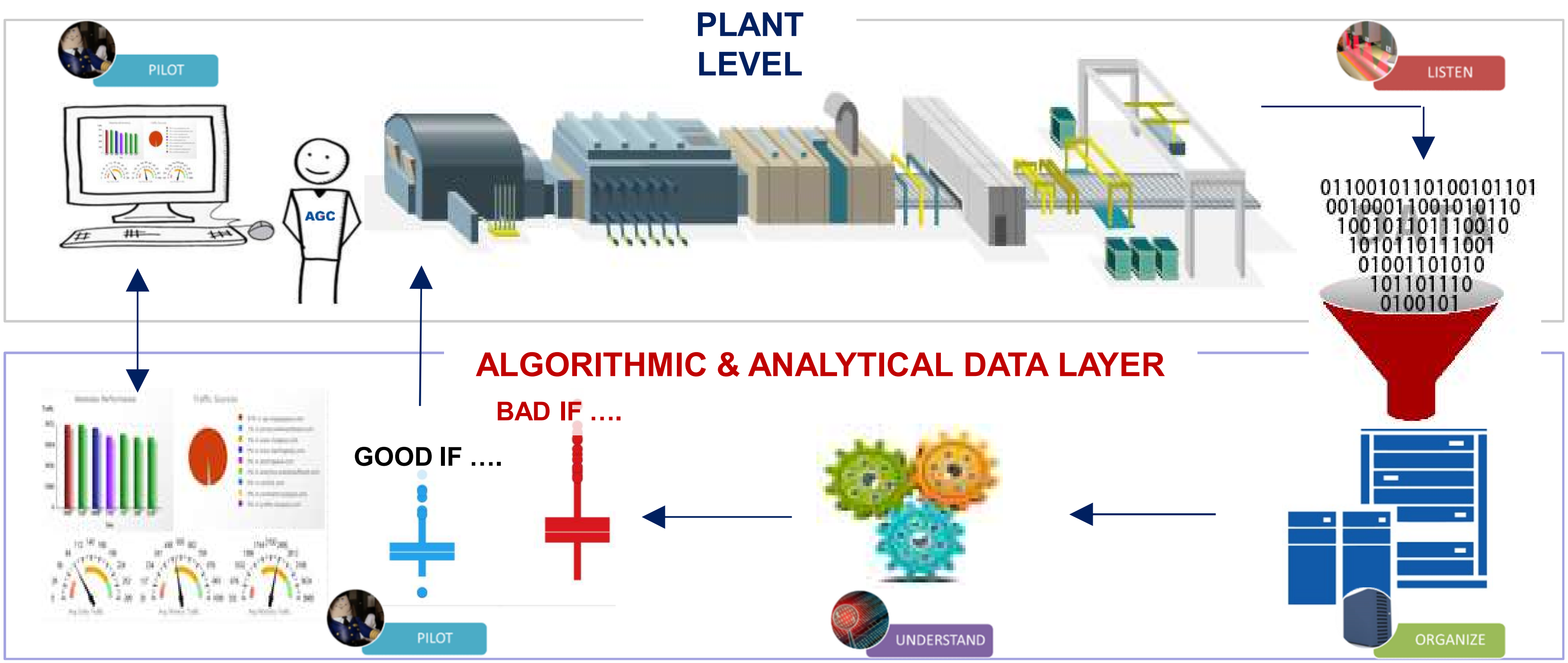
Smart Factory concept



Conclusions

- AGC like other EU float producers faced and are facing strong economical environment with CO_2 emissions constraints
  - Future will be even more difficult with « post 2020 » ETS
- Thanks to its efforts by systematic, incremental and disruptive actions, AGC energy consumptions and CO_2 emissions have been strongly reduced during last 10 years
- Nevertheless, efforts are still necessary to reach EU targets and enhanced competitiveness
- There are no miracle solutions (or not a miracle technology) but a set of solutions locally profitable according the context
- But long term challenges are huge (80% CO_2 reductions by 2050)
  - Probably more collaboration between float producers could be usefull to unite forces & ressources to find technical viable solutions for the future generations

Thank you very much for your attention

LIFE11 ENV/CZ/000488

HOxyGas project is funded by EC Life+ program

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