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Energy saving incentives for the European glass industry in the frame of the EU Emissions Trading Scheme

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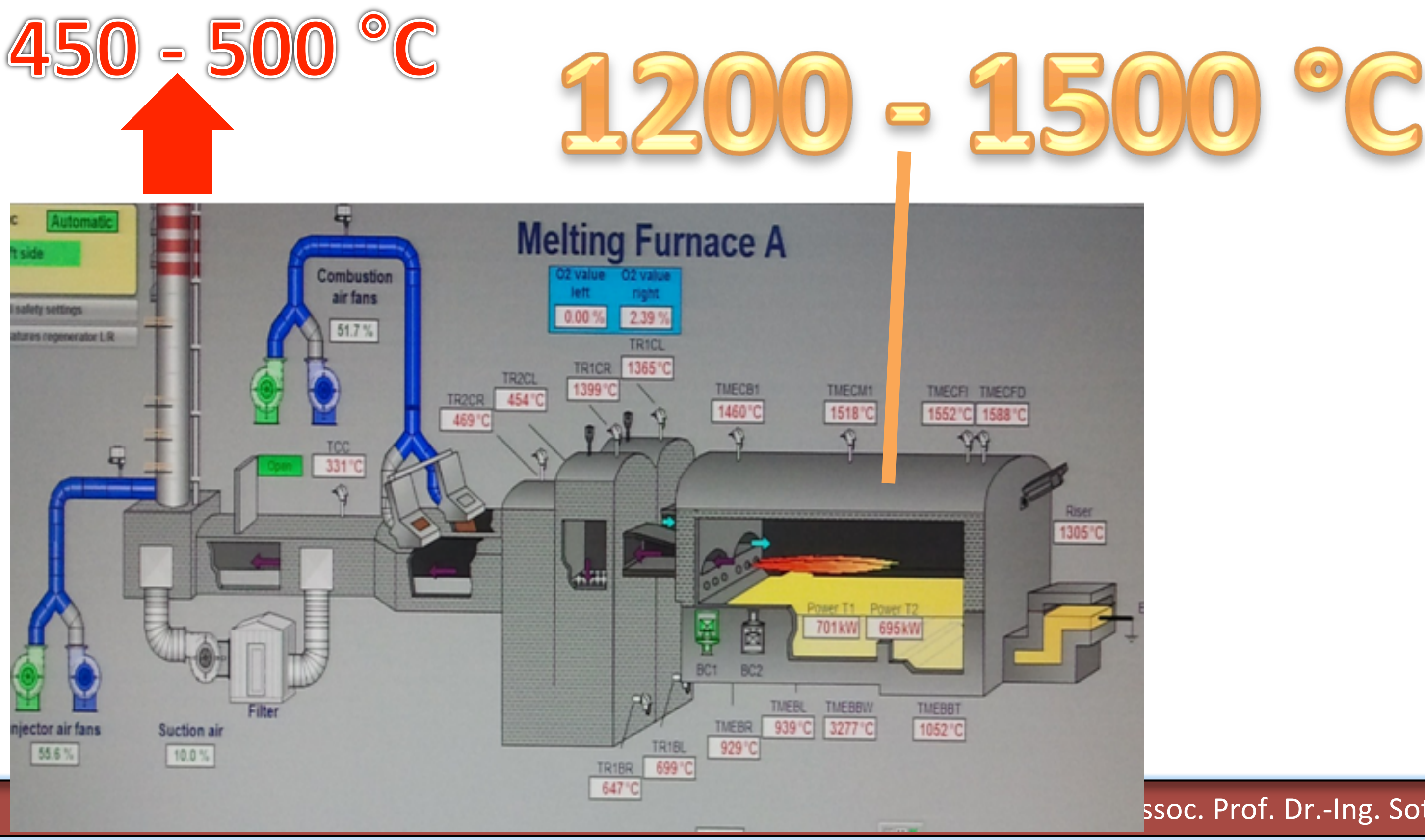
Motivation

- Glass industry is energy intensive
- 60 - 70 % of the energy is consumed inside the furnace
- High glass melting temperatures (1200-1500°C)
- High exhaust gas temperatures (450-500°C at regenerative furnaces, more than 700°C at recuperative furnaces and 1000°C at oxy-fuel furnaces)

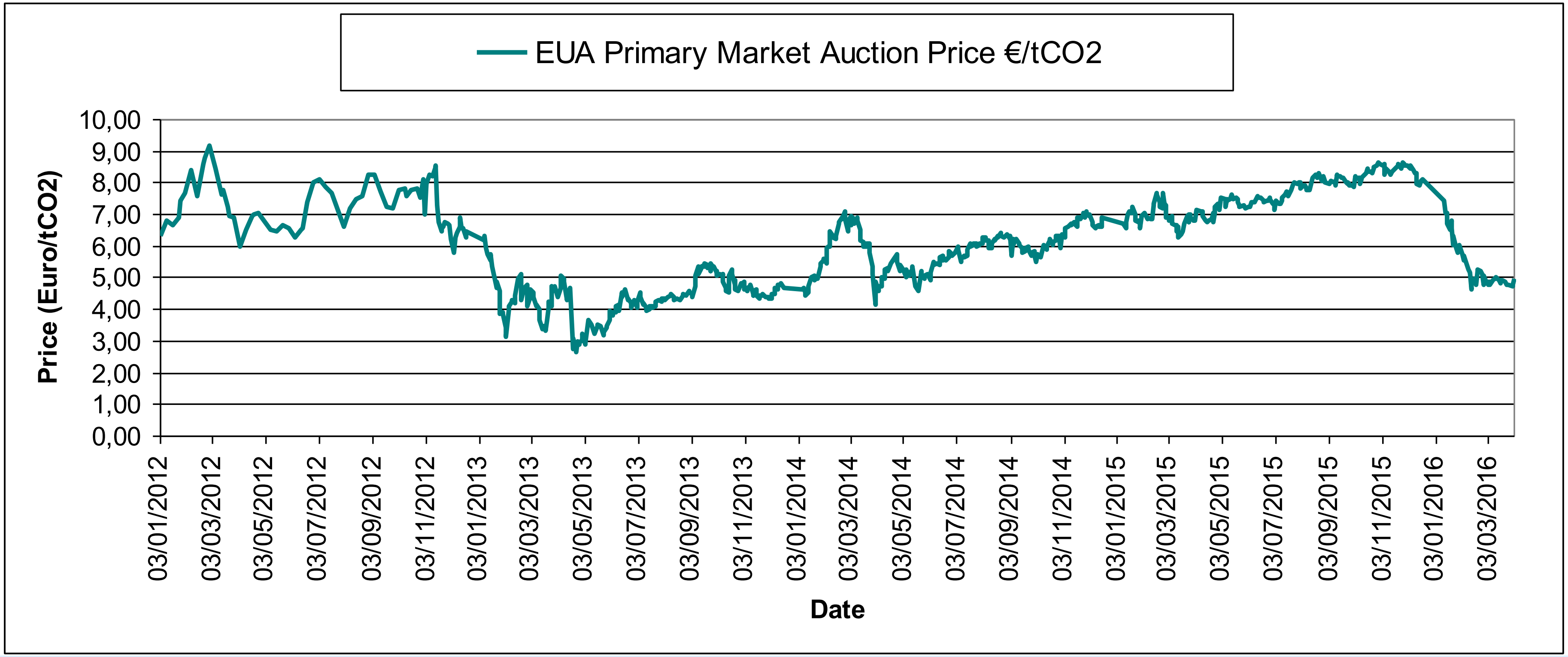


Scope

- Exploring Energy Saving Opportunities in the EU Glass Industry.
- Analyzing WHR through batch preheating.
- Developing a Case Study for a batch preheater installation.
- Estimating to what extend the EU ETS can become an energy reduction incentive.

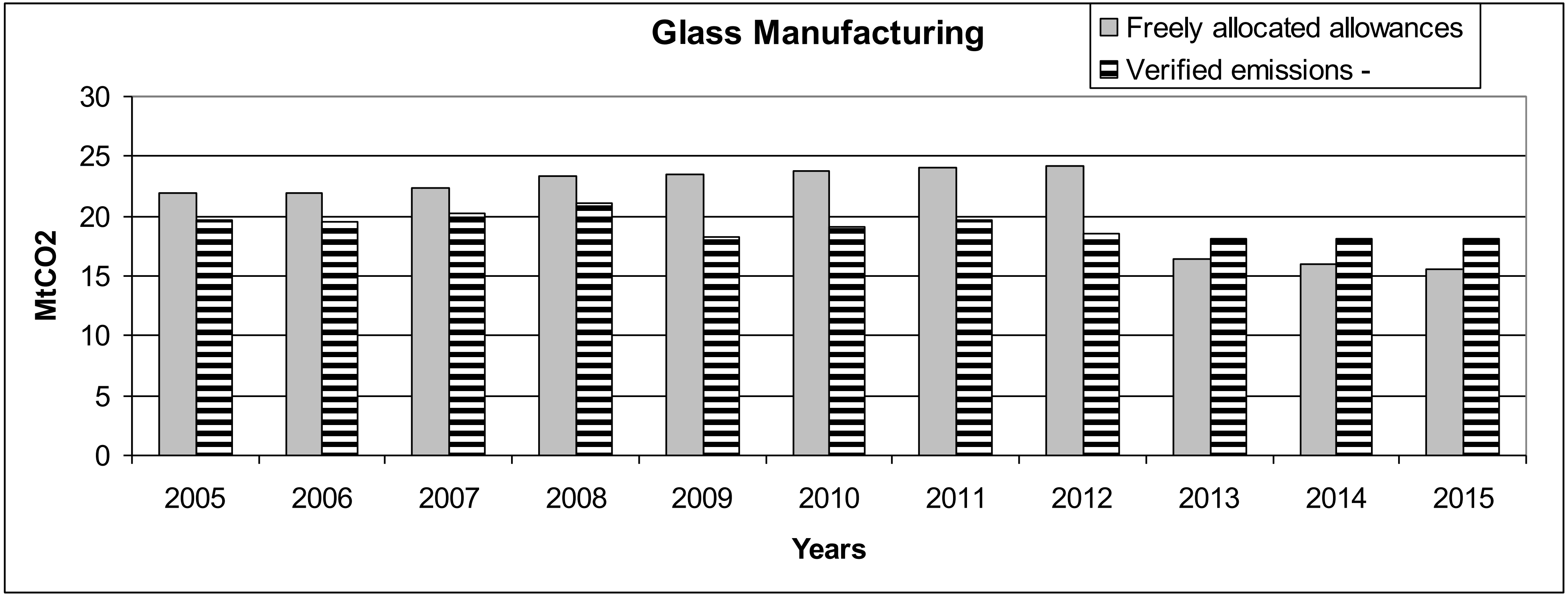
The EU Emissions Trading Scheme (EU ETS)

- Covering 45% of EU GHG emissions , ~12.000 installations
- World's largest emission trading system (~80% volume, 77% value)
- Current Price of EUA : ~4,0 €/t



The Glass Industry in the frame of the EU ETS

- EU ETS covers of installations with a melting capacity > 20 tones/day
- An 80% of produced volume is traded within EU borders



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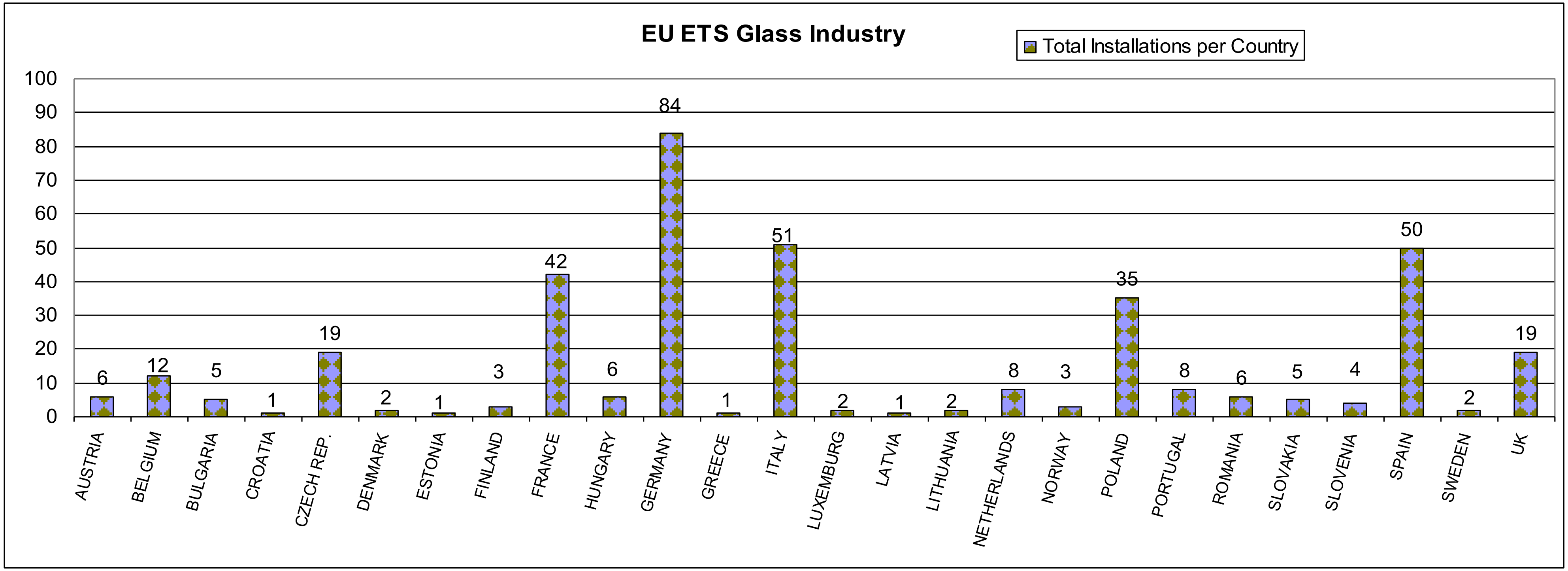
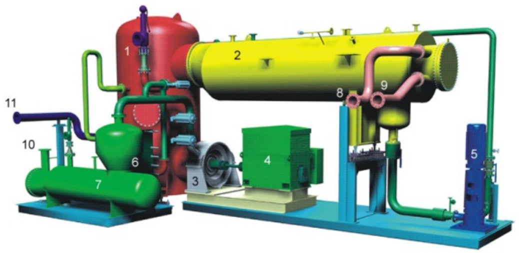


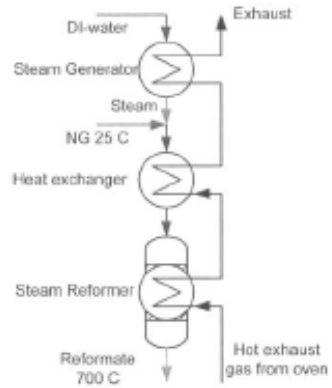
Waste Heat Recovery Options in the Glass Industry

Electricity Generation
- Steam Rankine Cycle
- Organic Rankine Cycle (ORC)



Steam / Hot Water Generation
- Building heating or cooling
- Industrial processes

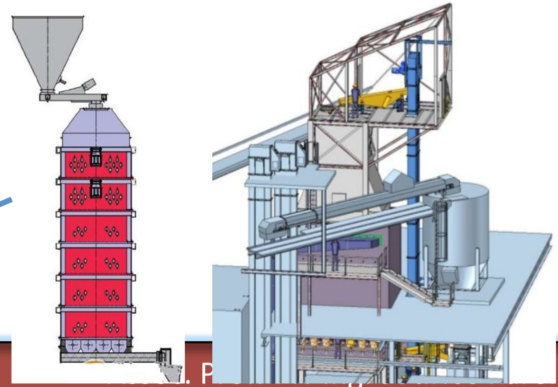
Thermochemical Recuperation (under investigation)
- Natural gas to Synthesis Gas (CO,H_2)
- Most appropriate for oxy-fuel or recuperative furnaces



Natural Gas Preheating
- Low energy savings
- Most appropriate for oxy-fuel furnaces

Batch & Cullet Preheating

BAT
- Cullet only/Batch & Cullet Preheaters
- Direct/Indirect systems
- Flue gas / Steam as heating medium



Batch & Cullet Preheating Applications

More than 10 installations over the past 30 years

- Batch and cullet preheat temperatures of about 300°C
- Flue gases cooled down by 200-300 °C
- Specific energy savings of 10-20%
  - reduced fuel input
  - reduced electricity consumption (in the case of electric boosting)
  - increased glass pull
- Reduced specific CO_2 emissions
- Technical defects
  - Dust carry - over
  - Raw material plugging

Manufacturers

- Nienburger Glass / Interprojekt
- Zippe
- Sorg

Batch and Cullet Preheating CASE STUDY

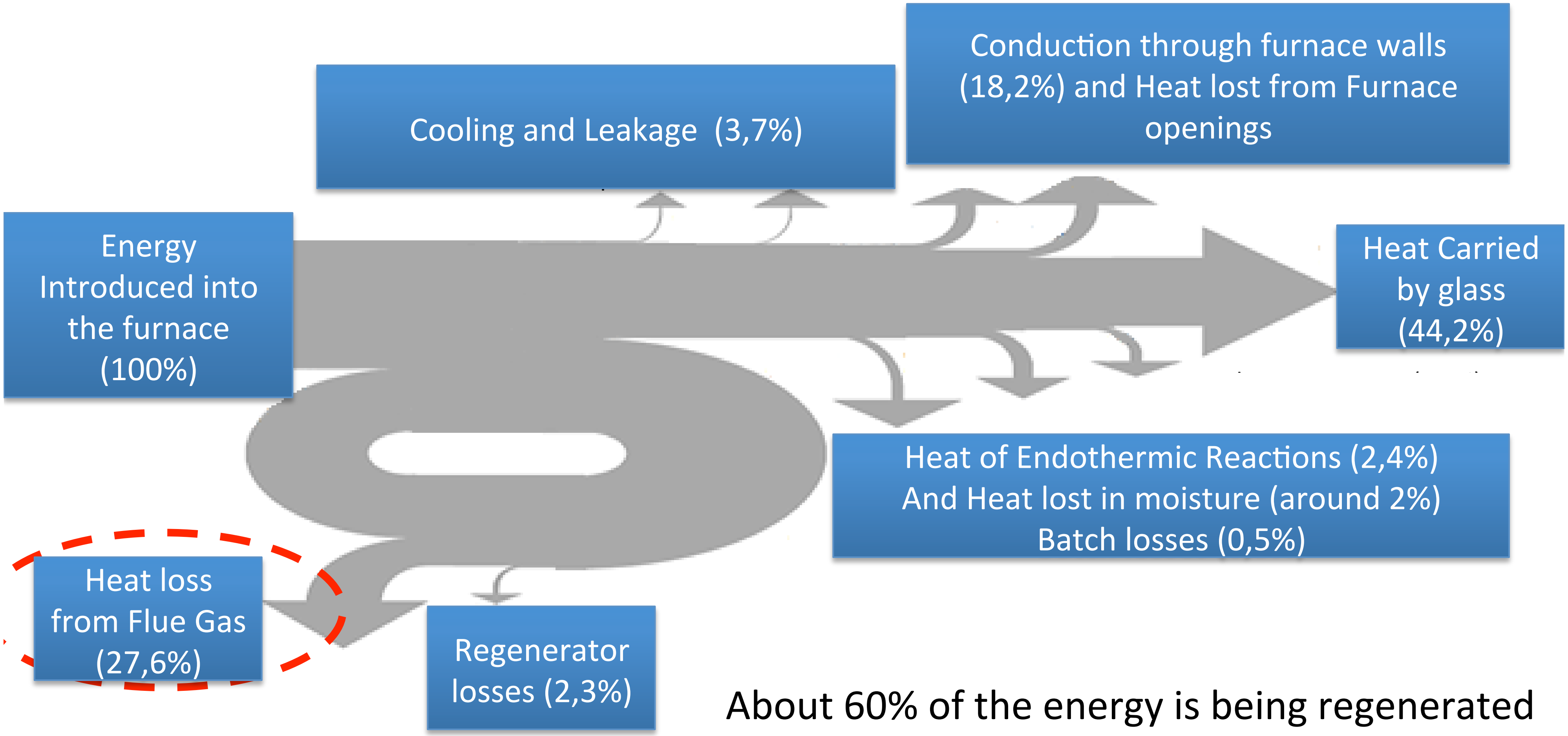
- Simulation of mass and heat flows inside the preheater with a 3-dimensional computational model.
- Case study on an end-port regenerative furnace.

Reference Case
(without batch preheating):
Glass pull: 260 t/d
Cullet in mixture: 83%
Batch humidity:2%
Energy consumption: 3620 kJ/kg
Electric boosting: No
Process CO_2 : 0,029 $kgCO_2$/kg glass
Overall CO_2 : 0,232 $kgCO_2$/kg glass
Flue gas volume: 14223 Nm3/h
(3.5% oxygen, T=476°C)

HEAT FLOWS	kW	kJ/kg Glass	%
Heat input			
Fuel	**10893.5**	**3620.0**	**98.7**
Batch	51.5	17.1	0.5
Air	94.1	31.3	0.9
Heat output			
Water evaporation + soda dehydration	177.7	59.1	1.6
Endothermic reactions	262.7	87.3	2.4
Heat carried by glass	4883.7	1622.9	44.2
Flue gases downstream the regenerator	**3043.5**	**1011.4**	**27.6**
Conduction through furnace walls	2016.8	670.2	18.2
Cooling and leakage	404.6	134.4	3.7
Regenerator losses	249.5	82.9	2.3

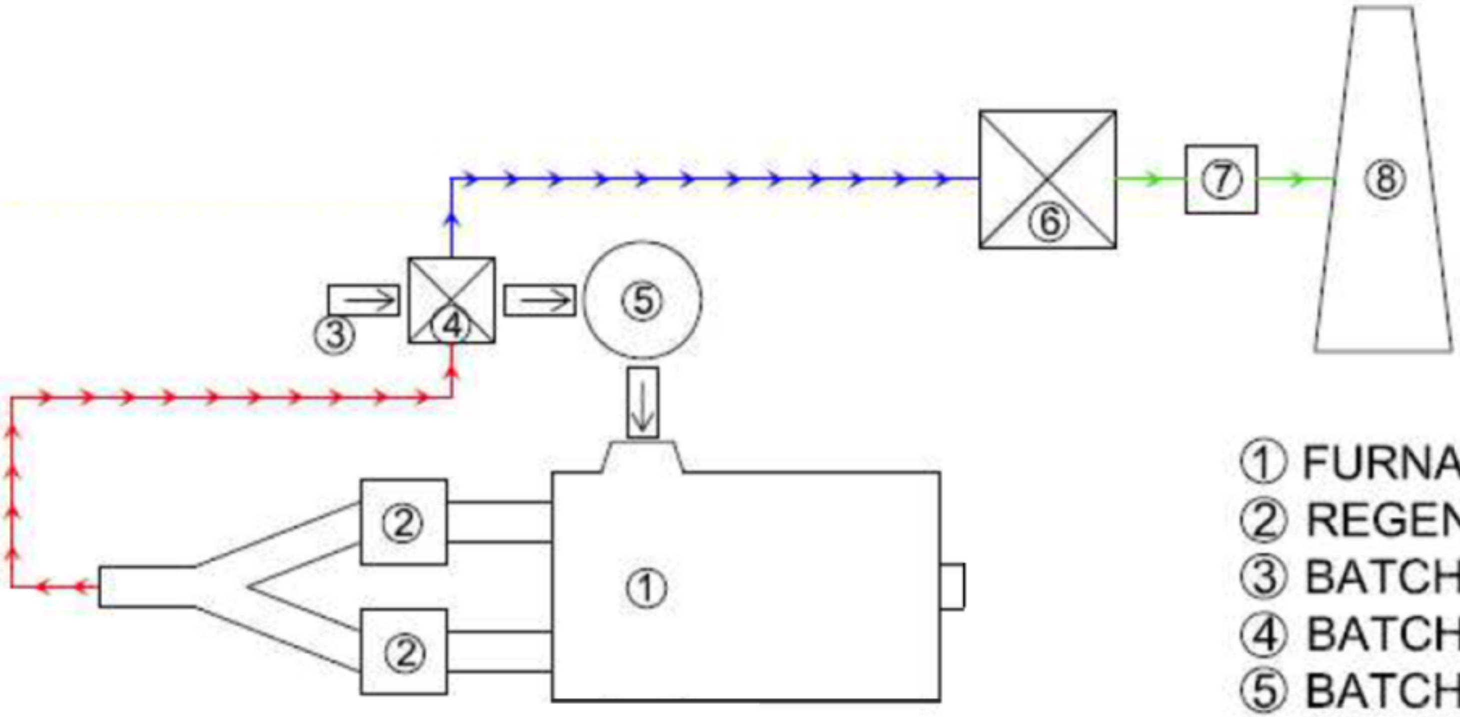
Energy Balance without preheating

Energy Flow Diagram (Sankey Diagram)



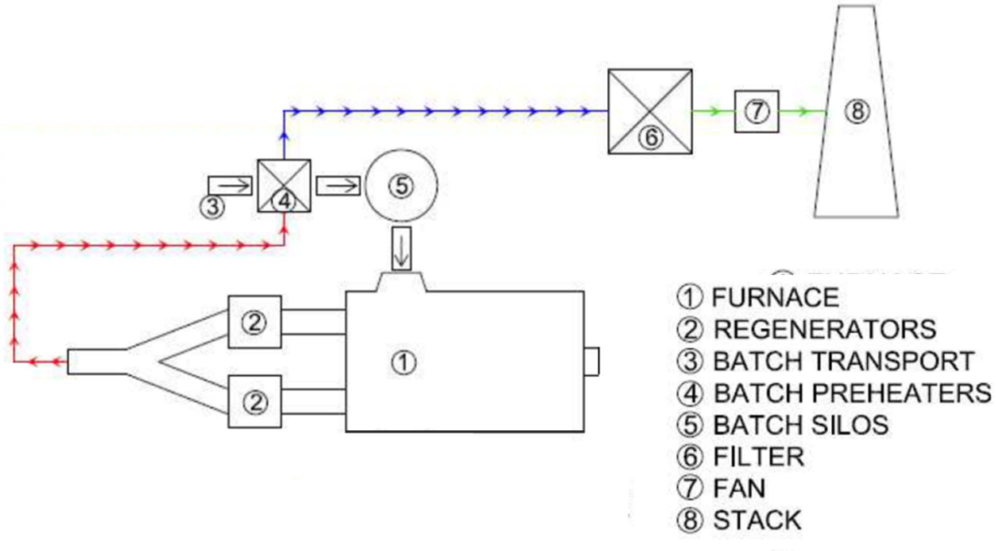
About 60% of the energy is being regenerated

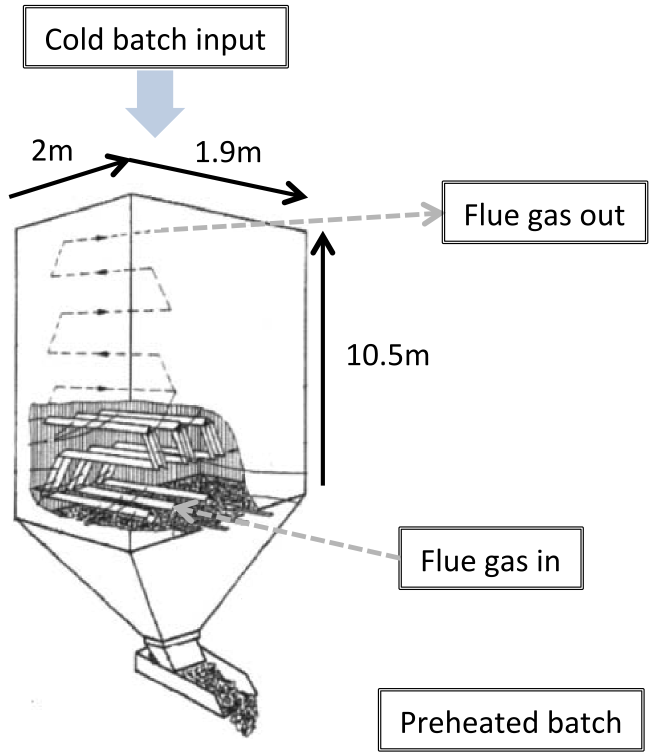
Preheater Configuration



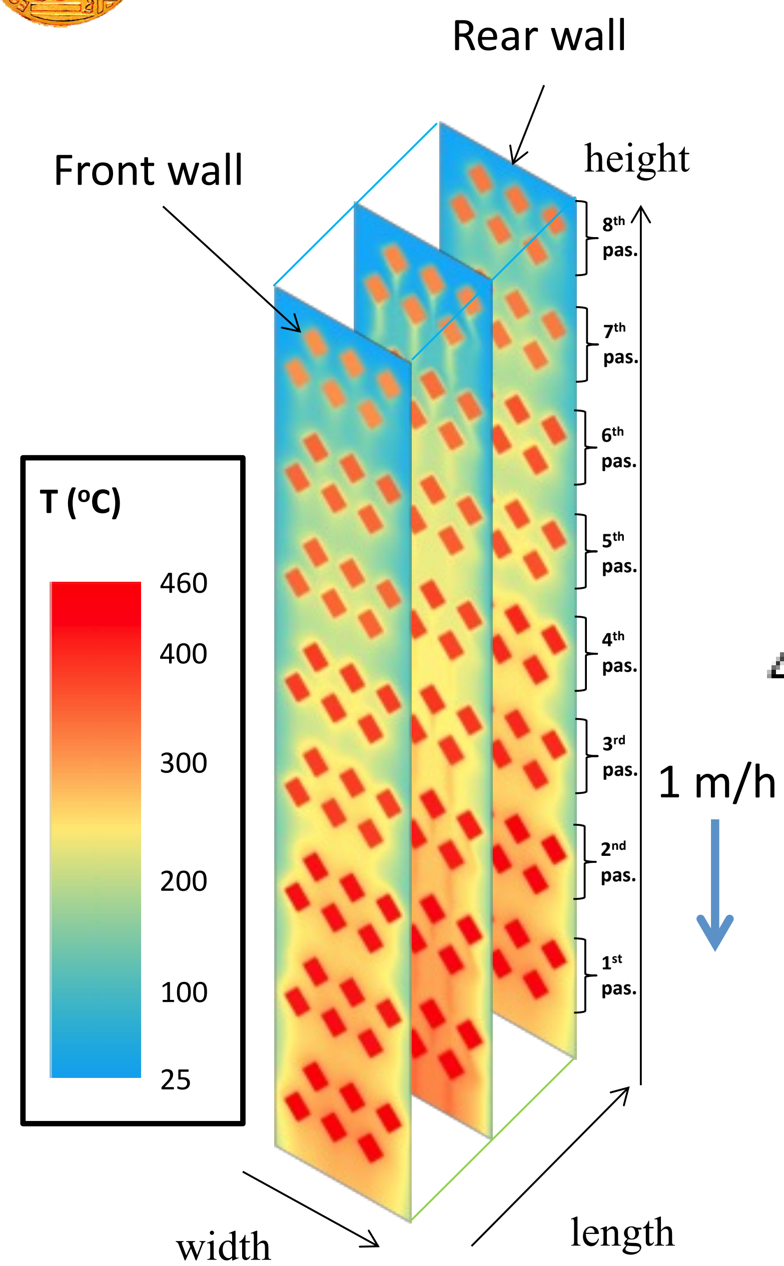
① FURNACE
② REGENERATORS
③ BATCH TRANSPORT
④ BATCH PREHEATERS
⑤ BATCH SILOS
⑥ FILTER
⑦ FAN
⑧ STACK

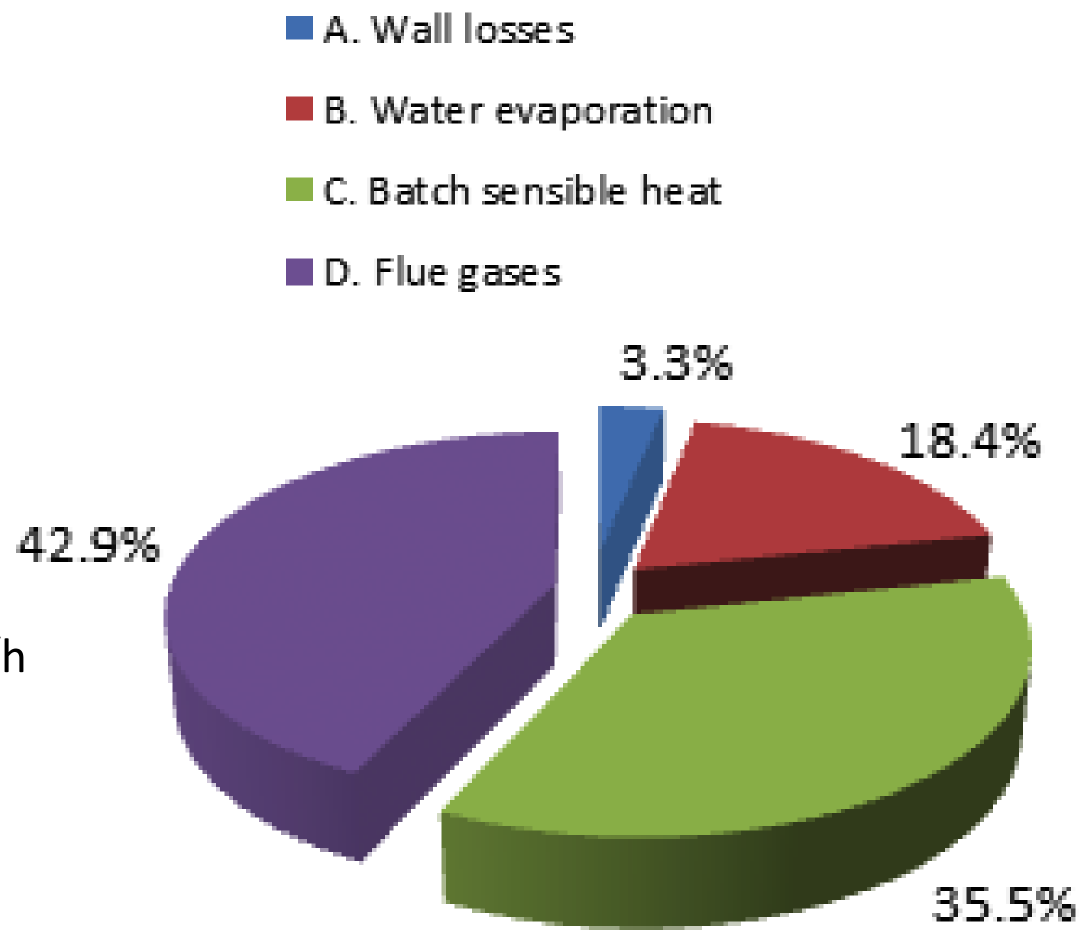
Preheater Configuration





Simulation Results





Preheater energy balance

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Fuel Reduction Case - 1
Constant Glass pull: 260 t/d
Energy consumption: 2988 kJ/kg (17,5% reduction)
Overall CO_2 : 0,196 $kgCO_2$/kg glass (15,4% reduction)

Increased Pull Case - 2
Constant fuel consumption: 3620kJ/kg
Energy consumption: 2736,4kJ/kg (24,4% reduction)
Overall CO_2 : 0,184 $kgCO_2$/kg glass (20,8% reduction)

Combined Fuel Reduction and increased Pull rate Case - 3
Glass pull: 286t/d (10% increase)
Energy consumption: 2736,4kJ/kg (20% reduction)
Overall CO_2 : 0,193 $kgCO_2$/kg glass (17% reduction)

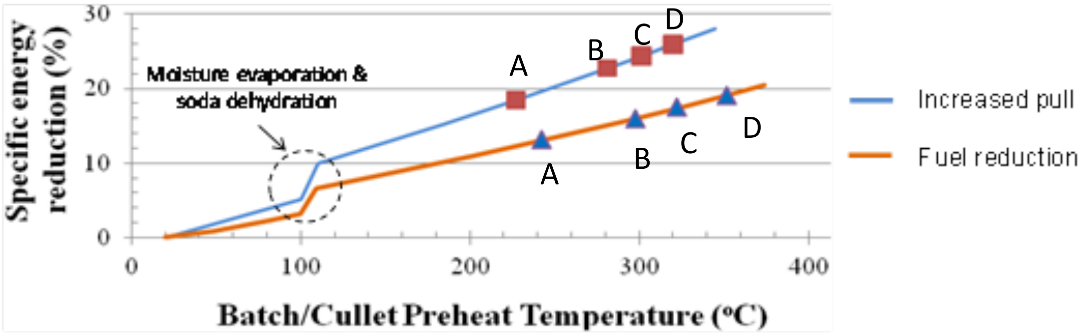
Batch and Cullet Preheating CASE STUDY

Furnace Energy Balance – batch preheater system

HEAT FLOWS	CASE 1		CASE 2		CASE 3	
	kJ/kg Glass	%	kJ/kg Glass	%	kJ/kg Glass	%
Heat input						
Fuel	2988,1	98,6	2736,4	98,5	2894,9	98,6
Batch	17,1	0,6	17,1	0,6	17,1	0,6
Air	25,8	0,9	23,9	0,9	25	0,9
Heat output						
Water evaporation + soda dehydration	59,1	1,9	59,4	2,1	59,4	2,0
Endothermic reactions	87,3	2,9	87,3	3,1	87,3	3,0
Heat carried by glass	1622,9	53,5	1622,9	58,4	1622,9	55,3
Flue gases downstream the regenerator	336,3	11,1	309,4	11,1	328,2	11,2
Conduction through furnace walls	670,2	22,1	506,6	18,2	609,3	20,7
Cooling and leakage	134,4	4,4	101,7	3,7	120,7	4,1
Regenerator losses	82,9	2,7	62,7	2,3	75,4	2,6
Preheater losses	37,9	1,3	27,4	1,0	33,8	1,2

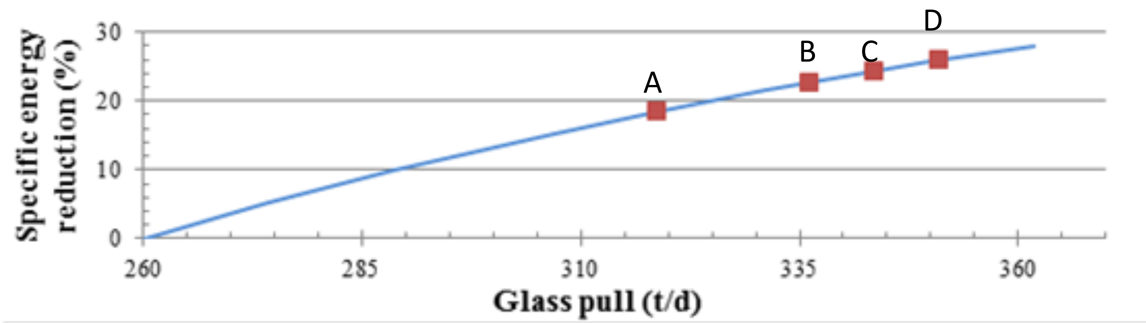
Batch and Cullet Preheating CASE STUDY

- **Sensitivity Analysis** - four designs (A, B, C and D) of the preheater, are examined based on the regenerative cont. glass furnace data (**Ref.Case**)
- Two configurations – Case 1 (glass pull constant) & Case 2 (fuel cons. constant).



Effect of preheated batch temperature on specific energy consumption for both configurations

Effect of an increased glass pull on the specific energy consumption while energy inputs remain constant, examined for the second configuration.



Assoc. Prof. Dr.-Ing. Sotirios Karellas

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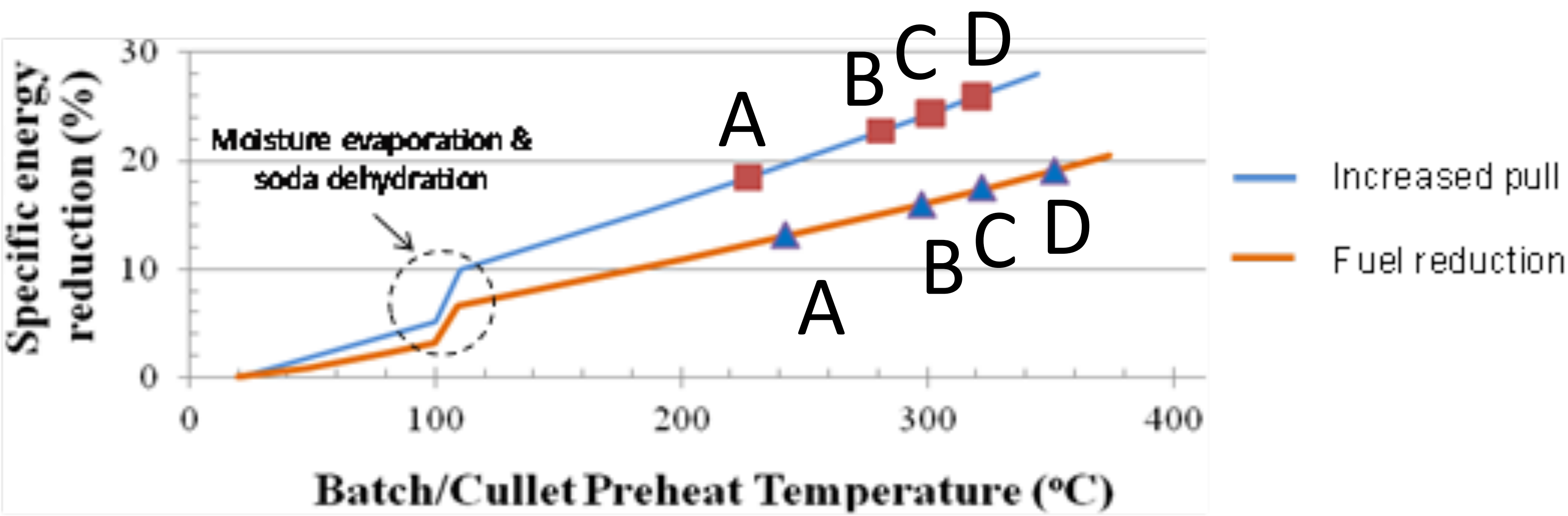

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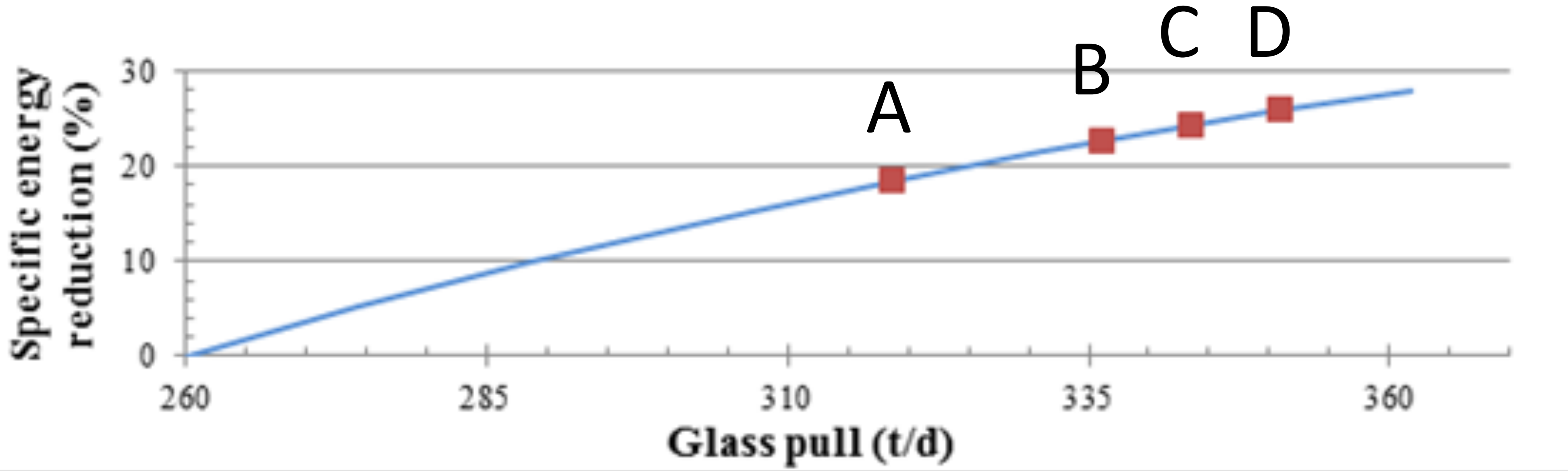

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Energy reduction incentives and the EU ETS - Conclusions

- Reducing energy consumption is an economic imperative and constant goal for all glass manufacturers.
- Types of profits induced by the EU ETS:
  - From overall location of free emission allowances through selling the surplus in the market,
  - From using CDM/JI credits for compliance which have a mean lower price than the allocated EUAs (profiting from spread)
  - Profits from passing through the opportunity costs of freely obtained allowances in product prices (windfall profits).
- Incentives for Energy Reduction:
  - Shortfall of Allowances: For the three first years of the third phase of the EU ETS i.e. 2013-2015, a rough shortfall in the range of 6,5 million emission allowances has appeared for the sector.
  - Risk of "Carbon Leakage" i.e relocation of installations outside the EU borders.

Energy reduction incentives and the EU ETS - Conclusions

- Batch preheating is one of the BAT (High Production Rates, low CO2 emissions)

- Emissions of CO_2 in the case study presented were reduced by 15,4% to 20,8% (reduction of emissions by increasing energy efficiency with a batch composition with over 80% cullet mix).

- If the WHR application of batch preheating is applied for the years 2016-2020 to a group of installations emitting 15 % of total emissions and considering a modest 12% reduction of CO_2 emissions due to specific fuel consumption decrease:
  - A reduction of almost 2 Mt CO_2 would be achieved.
  - At EUA prices in the range of 5 to 10 Euro per EUA this could interpret into a modest estimation of savings of 9-17 million Euros for the 5-year period from 2016 to 2020.

CO2-Glass

NTUA

CERTH/CPERI

CPERI
Chemical Process and Energy Resources Institute

DRUJBA GLASSWORKS

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GLASSWORKS S.A.

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Thank you for your attention!

Ich danke Ihnen für Ihre Aufmerksamkeit !

Ευχαριστώ για την προσοχή σας!