European Commission

CO_2 reduction in the ETS glass industry by means of waste heat utilization

"CO_2-Glass"

SILC-I (PROJECT id 621527)

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Deliverable D.1.1

<u>Description of waste heat recovery options in a small sized ETS glass industry</u>

Consortium Partners	
National Technical University of Athens (Coordinator)	NTUA
Drujba Glassworks S.A.	DRUJBA
Centre for Research & Technology Hellas / Chemical Process & Energy Resources Institute	CERTH/CPERI

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1. The "CO_2-Glass project" and the EU ETS glass industry

The scope of the "CO_2-Glass" project is to evaluate the waste heat utilisation potential at the coloured bottle and jars glass production plant DRUJBA STAKLARSKI ZAVODI in Sofia with approximately 40 ktCO_2 annual emissions and to apply a Waste Heat Recovery (WHR) technological intervention thus reducing the specific CO_2 emission intensity of this typical small sized EU Emissions Trading System (EU - ETS) glass manufacturing plant.

Drujba Glassworks S.A belongs to YIOULA group and is classified under NACE Code 2313 "Manufacture of hollow glass". Drujba Glassworks S.A is placed among the leading companies in Bulgaria and the Central Eastern Europe (CEE) region. The proposed technological intervention, **namely the inclusion of novel batch preheaters and the appropriate design of the whole system**, is expected to have short term results. The ultimate objective is to increase the energy efficiency and reduce the specific emission factor of the production process. A further goal is to create the potential for the exploitation of this intervention initially to the 4 additional plants of YIOULA group and then to disseminate the results of this technological intervention and its replication potential to all EU-ETS glass manufacturing plants which are over 400. EU-ETS Glass operators exploit their potential regarding the CO_2 emission credits' savings that can be accomplished according to the EU Emissions Trading Legislative Framework, differently in terms of the magnitude of emission credits transactions[1].

The ultimate scope of this proposed project is to support the **manufacturing of glass including glass fibre with a melting capacity exceeding 20 tonnes per day** according to the European Directive 2009/29/EC, (the "EU-ETS glass industry") to confront with the requirements imposed by the EU low carbon strategy and at the same time maintain its competitiveness. The project aims at identifying and applying a WHR batch preheating method on the one hand and enhancing carbon credit management on the other.

[1] "EU Emissions Trading Scheme application in Bulgaria, Greece and Romania", C.-S. Hatzilau, D. Giannakopoulos, S. Karellas, E. Kakaras, Istanbul Carbon Summit: Carbon Management, Technologies & Trade, 3-5 April 2014, Istanbul, Turkey

The specific Glass manufacturing plant in Sofia, Bulgaria, where the project will be implemented has a daily melting capacity exceeding 300 t while the waste heat flow is in the range of 450 °C at around 14.000 Nm^3/hr. possible waste heat utilisation is calculated up to a range of 2000 kWth. Technology, processes and equipment used on site are similar to typical European glass producers, so the results of the project could be replicable to small, medium or large ETS glass industrial sites.

2. Waste Heat Recovery in the Glass Industry

2.1 CO_2 reduction potential

Due to the high temperatures, at the level of 1200 - 1500°C, necessary for sand and additional raw material melting, glass industry is categorised as energy-intensive[2]. Approximately[3,4] 10% to 25% of the ETS glass manufacturing sector's CO_2 emissions are process based, originating by raw material during melting, so the effort for specific emission reduction is targeted at 75% - 90% of total emissions originating from fuel combustion. In the case of Drujba Glassworks SA, process based emissions exceed 30% of the total CO_2 emissions therefore the effort for a specific emission reduction needs to be even more enhanced.

2.2 WHR options

High temperature waste heat from the energy intensive industries in general can be used (individually or combined) for purposes of:

- **i.** power generation with the Steam Rankine process, the Organic Rankine Cycle[5] (ORC), or the Kalina Cycle.
- **ii.** utilisation within the plant's boundaries e.g. for steam generation towards hot water heating, building heating or for external use as for example for district heating that can be an interesting option for low heat flows[6].

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[2] JRC Refference Report on BAT for the Manufacture of Glass, March 2012

[3] Glass for Europe's contribution to the consultation on structural options to strengthen the EU Emissions Trading System" , February 2013

[4] 10 Methodology for the free allocation of emission allowances in the EU ETS post 2012, Sector report for the glass industry, November 2009, ECOFYS

[5] S. Karellas et.al. 2013 "Energetic and exergetic analysis of waste heat recovery systems in the cement industry", *Energy*, *Volume 58*, *1/9/2013*.

iii. utilization of the waste heat for cooling of the buildings. This cooling can be produced by means of absorption or adsorption chillers.

iv. a combination of 1., ii and iii which can end up to a tri-generation system providing electricity (e.g. by means of an ORC), heating and cooling for adjacent buildings.

v. thermo-chemical recuperator system where the recovered heat is used for the production of hot synthesis gas i.e H_2.

vi. oxygen and NG preheating

vii. combustion air preheating (via regenerators)

viii. use within the process e.g. preheating of the material loaded into the furnace i.e. for pellet drying and preheating and for batch or cullet preheating.

In a glass manufacturing plant all the above WHR options can potentially reduce the energy operating costs. The current project aims at the **development and application of a heat exchanger for enhanced batch preheating.**

One of the Best Available Techniques (BAT) in the glass industry is[7] considered to reduce the specific energy consumption by using batch and cullet preheating where technically and economically viable, alone or in combination with other specified techniques increasing the energy efficiency. This BAT is applicable to fuel/air fired and oxy-fuel furnaces and for batch compositions of more than 50% cullet while currently Drujba Glassworks S.A. plant uses 40% cullet. **WHR for such a purpose is the subject of the current project.**

Examples of application of the above mentioned options (i) to (viii) in the glass industry are reported below :

<u>WHR option (i):</u> Total ORC power potential in the *flat* glass industry in EU27 is estimated[8] to 78,5 MW. For the *container* glass industry, the energetic and exergetic assessment at a plant with high temperature exhaust gases to the atmosphere has

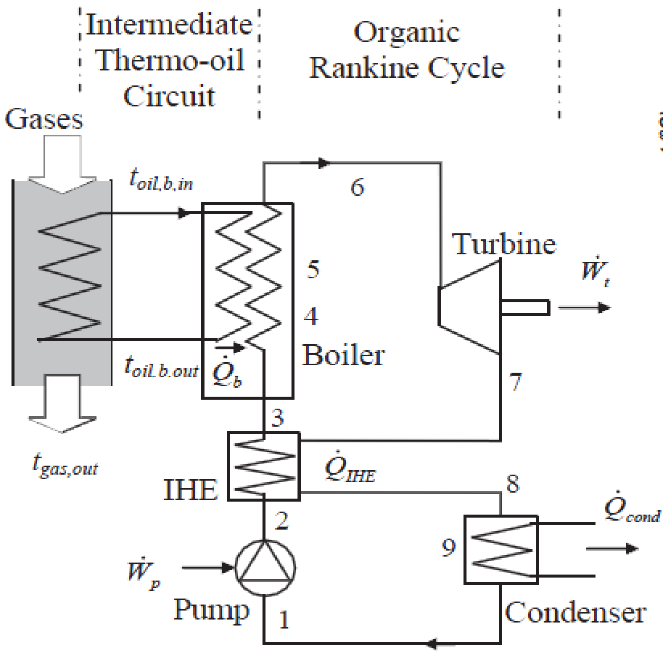
[6] GLASS Technology Research & New Developments: GlassTrend study tour 2012 "Overview of Methods to Recover Energy from Flue Gases of Glass Furnaces-Impact on Glass Furnace Energy Consumption"

[7] EC Decision 2012/134/EU establishing the best available techniques (BAT) conclusions under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions for the manufacture of glass.

[8] Campana et. al, "ORC waste heat recovery in European energy intensive industries:Energy and GHG savings", Energy Conversion and Management 76 (2013)

shown[9] that for a 450 - 500 °C heat source temperature level, ORC systems recover energy more efficiently that water steam Rankine cycle systems, if the condenser is air cooled, while regenerative ORC increases the efficiency. In particular more than 600 kWe can be recovered with the application of an ORC system and in the case of a waste heat amount of approximately 2,5 MW_{th}, while the annual CO_2 emissions from natural gas combustion in the furnace reaches a magnitude of 30 kt per year. With the implementation of an ORC system, it is estimated that more than 600 kWe can be recovered.

In general the amount of energy recovered and the system's efficiency as a whole is related to many factors. The working fluid plays a vital role in the system's efficiency and for optimizing the system it is required that the working fluid is pressurized up to a pressure point close enough to its critical pressure. Elevating the pressure increases almost proportionally the costs of the construction, thus a thorough economotechnic investigation of the system is a prerequisite for an energy- and at the same time cost-effective system.



Graph 1 : WHR with regenerator[10]

[9] "Energetic and exergetic assessment of waste heat recovery systems in glass industry, S. Karellas, K. Zourou, K. Braimakis, E. Kakaras, ASME- ORC 2013. 2nd International Seminar on ORC Power Systems. October 2013, DeDoelen, Rotterdam, The Netherlands.

[10] F.J. Fernández, M.M. Prieto, I. Suárez , "Thermodynamic analysis of high-temperature regenerative organic Rankine cycles using siloxanes as working fluids, Energy Volume 36, Issue 8, August 2011, Pages 5239–5249

Another important factor is the issue is the presence of regenerator or not. With the use of a regenerator the heat transfer efficiency and the overall system's efficiency is increased radically. Increasing the exergetic efficiency at the heat transfer process diminishes the boiler's requirements and relevant costs.

WHR option (ii): steam generation for internal or external utilisation. The energy recovered from waste heat can be used to cover internal needs of the industry. The steam can be used to heat up for example water for the needs of the employees or can be distributed to the area close to the industry. It can also be converted into electricity by means of a steam cycle (in this case it is a variation of option number (i)) and either cover the needs of the industry or can be sold in the power market and contribute to the revenues of the company.

WHR option (iii): in the case that the cooling requirements of adjacent buildings are important, the waste heat can be used by means of a sorption chiller and transformed into cooling.

WHR option (iv): In the case that the WHR is used for power generation, heating and cooling, then the option of an efficient tri-generation system can be installed.

WHR option (v): Thermo-chemical recuperator (TCR) application in the glass industry can lead to energy and CO_2 emission savings[11] of 25 - 35 %. During the process hot synthesis gas is produced from methane with heat recovered from waste gas. The energy content of the produced gas is higher.

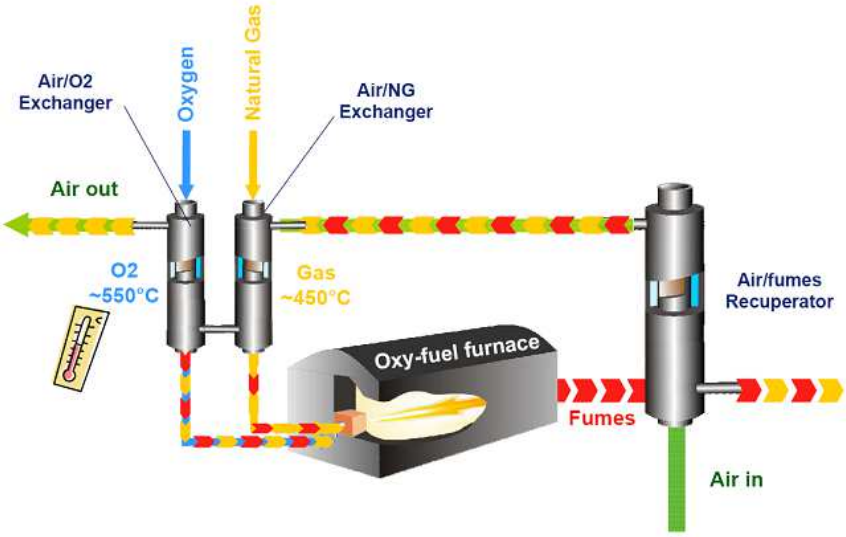
$$CH_4 + H_2O \rightarrow CO + 3\ H_2$$

In another energy intensive industry, in steel reheat-furnaces, the fuel calorific content of the enriched gas can be increased[12] up to 28%. The TCR concept can also be applied to other energy intensive industries such as aluminium scrap melting processes.

WHR option (vi): An oxy fuel float furnace where an oxygen combustion technology has been developed for oxygen and fuel (NG) indirect preheating. The technology involves indirect pre-heating of oxygen at 550°C and natural gas at 450°C in oxy-fuel

[11] Glass production dedicated Thermo Chemical Recuperator - Development of a new technology to improve the energy efficiency of glass furnaces , Celsian, Hygear, 23rd International Congress on Glass, Prague July 2013
[12] Energy Intensive Processes Portfolio: Addressing Key Energy Challenges across US Industry. US DOE, 3/2001

furnaces and leads to approximately 15% CO_2 reduction and 25% fuel energy savings[13]. The use of oxygen instead of air decreases furnace nitrogen and furnace waste gas flow by 70% and requires less particulate removal equipment. In addition, NOx emissions are also decreased by at least 75%. The technology is part of ALGLASS™ Heat Recovery Technologies developed by Air Liquide and glassmaker AGC Glass Europe.



Graph 2: ALGLASS™ HotOxyHeat Recovery technology [13]

WHR* option *(vii): Combustion air preheating (via regenerators). Air preheaters can be of various types with the most common being regenerative. There are two chambers made of firebricks in most of the cases. Waste gases from the furnace flow through the first chamber while the combustion air flows through the other one at temperatures up to 1350 °C if necessary. The flow is redirected among chambers periodically. Energy savings depend on the preheating temperature. For instance, 35% of energy can be saved if combustion air is preheated at 800 °C.

2.3 WHR for enhanced batch preheating

Enhanced batch and/or cullet preheating with exploitation of the waste gases (WHR option viii) can be applied at existing glass production chains without significant needs for modifications in the process, which strengthens the viability of the specific

[13] HotOxyGlass Life+ project [http://www.oxyfuel-heatrecovery.com]

sector in the context of CO_2 emission reduction per product. This specific intervention, though implemented at some extend in the past, had not yet had significant outcomes due to dusting effects. Despite the fact that energy savings in the margin of 10 – 15% had been achieved, batch preheating is a process that has not been widely utilised due to the side effects namely dusting inside and outside of furnaces and material clump formation (deriving from soda ash) blocking the process and requiring manual removal. The formation of these clumps takes place under low temperatures, when water reacts with sand and limestone.

Nowadays the technology enabling the reduction of the dusting problems in furnaces during batch preheating is developed and can have a high replication potential to additional ETS installations where bath preheating is applied.

In the latest Best Available Techniques Reference Document issued for the Glass Industry in March 2012, batch preheating is included within the "promising technological innovations". There are several types of batch/cullet preheaters, divided into two categories[14]; a) cullet preheaters[15] and b) preheaters for batch and cullet preheating. In the first category there are two types of preheaters. Those of flue gases direct contact with the cullet and those where a boiler is applied with different channels for steam and cullet. Under the second category there are five types of preheaters. There are those of direct contact i.e. that cullet and batch are in direct contact with the flue gases, (also with high temperature preheater) those with different channels for flue gas and batch (indirect), those with pellet dryers and preheaters or preheating by steam[16].

Cullet preheaters are an alternative technological option, where there is no possibility for raw material heating. Cullet preheaters can be of an indirect type[16] (a

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[14] GLASS Technology Research & New Developments: GlassTrend Energy recovery and waste heat TCR study tour 2012 "Overview of Methods to Recover Energy from Flue Gases of Glass Furnaces-Impact on Glass Furnace Energy Consumption, Hans van Limpt , Ruud Beerkens, Andries Habraken.

[15] "Preheating of pellets", Pelletizing of Batch and Drying & Preheating of Agglomerated Batch by Flue Gases, Hans van Limpt, Mathi Rongen, Erwin Engelaar, GlassTrend Batch Seminar, October 2012

[16] Overview of Methods to Recover Energy from Flue Gases of Glass Furnaces, Impact on Glass Furnace Energy Consumption, Hans van Limpt, Ruud Beerkens, Andries Habraken, WHM Workshop, Waste Heat Management in the Glass Industry, 21/10/2010, Glass Manufacturing Industry Council

Steam Boiler and different channels for the steam and the cullet) while complete batch preheating can be combined with pellet drying Pellet dryer and batch preheater (Glass Trend) or can be undertaken by the use of steam following pellet drying (Optimum). In addition “Electrostatic Batch Preheating Technology” concerns a batch/cullet preheater that passes through an electrostatic precipitator, a hybrid system increasing energy efficiency.

Available types of preheaters are listed below:

A) Direct Preheaters

- **Nienburg**/Interproject (Ardagh Glass):

With this kind of preheater[17], flue gases flow directly into rhombus-shaped intersection channels of the preheating system and the flue gases move at different levels (in a zig-zag path) in cross counter flow through the batch and cullet. Channels are open at the bottom, therefore enabling direct contact between batch-cullet and flue gases.

- **PRAXAIR –Edmeston System: Direct preheater & Electrostatic Precipitator**

The particular system, applied in an oxygen-gas fired glass furnace [18] in the US and previously also in an EU air-fired glass furnace, which is however not operating anymore, concerns approximately 50% cullet that is dried and preheated to 300 – 350°C. Flue gases and dust particles flow through an EP filter. Energy consumption assisted by oxy-firing is about 3,2 GJ/ melted metric ton.

- **SORG Direct Preheater**

A novel batch preheater is part of the so called SORG BATCH 3 concept which is comprised by the preheater, a charging machine (EME-NEND®) that consists of multiple screw charges and a pusher and a new specially designed doghouse (IRD®). A full scale pilot plant for a melting capacity of 260t/d was installed in October 2011, inspected and tested in April 2012. Specific energy requirements decreased by 12,13% the dryness of the preheated batch is avoided since water that derives by

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[17] Proceedings of the 69th Conference on Glass Problems , Ceramic Engineering and Science Proceedings, Volume 30, 2009.

[18] Proceedings of the 69th Conference on Glass Problems , Ceramic Engineering and Science Proceedings, Volume 30, 2009.

soda ash at low temperatures is removed by a fan (along with dust) continuously while in addition the preheater components are being vibrated when needed and clumping that may have occurred is destroyed. The design of this type of batch preheater allows indirect contact with the flue gases and the latter pass through closed ducts. In addition, the batch is fed to the preheater from above, while the extraction of water is made at temperatures above 34°C. The batch charger charges the batch in the doghouse using two screws, operating in a variation of speeds meeting any possible need of the industry. It can operate with high cullet percentage (85%) provoking no effect to the screws. The batch is driven by the pusher arm, with accuracy in the sealed doghouse. Since the input of batch is that accurate and the doghouse is sealed, no dusting enters the doghouse, as well as no induced air. The doghouse is designed in such a way so as to positively affect the melting rate and the furnace performance since it improves the energy transfer to the batch and decreases the time needed for converting the batch to a melt.

B) Indirect Preheaters

- **ZIPPE** Industrieanlagen GmbH

With the indirect preheater of ZIPPE[19], a 15% economy of fossil combustibles and electrical energy is achieved as well as a consecutive increase in the furnace tonnages. Two batch preheaters with different channels for the flue gas and the batch-cullet, have been installed by the company ZIPE in a glass industry in the Netherlands in 2010 and 2011. The first preheater concerns a capacity of 340 t/d and 80-90% cullet and the second a capacity of 400 t/d and 50-60% cullet.

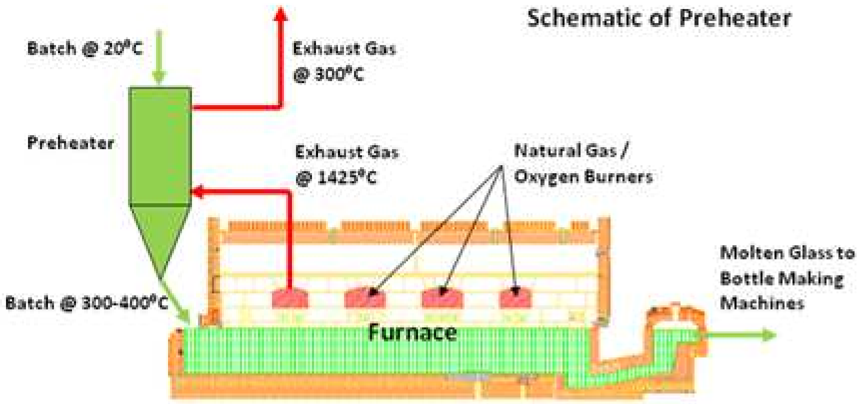
C) Other systems

- **Johansson industries' preheaters**

The US Johansson company has developed a cullet[20] and a batch[21] preheater with a temperature output of cullet 425°C and a temperature output of batch 300°C. Two full scale commercial installations are operating on oxy-fuel fired container furnaces,

[19] ZIPPE Batch preheater
[20] US patent #5,556,443, "Method for Cullet Preheating and pollution emission reduction in the Glass Manufacturing Industry"
[21] US Patent #6,615,612, "Electrostatic Batch Preheater and method of using the same"

one in the US and one in the EU. The same technology can be applied to air fuel fired furnaces and float furnaces.



Graph 3: Johansson technological concept [22]

[22] http://www.johanssonindustries.com/bcp

3.1 Expected Results and Dissemination Activities

The project's results can assist the energy intensive EU-ETS Glass industry in maintaining its competitiveness by confronting potential shortfall in carbon credits in 2013-2020. The expected results of the project "CO_2-Glass" are listed below:

- Concluding on a specific WHR intervention for CO_2 emissions reduction in the ETS Glass manufacturing plant
- Producing an advanced Production Process reduction in the specific ETS Glass manufacturing plant concerning batch handling at the furnace.
- Increasing the Energy efficiency of the whole process targeting higher than 15 % and decreasing specific CO_2 emissions by 8% respectively. The assessment of the CO_2 emissions of the new configuration under various operational conditions
- Carry out a Cost-Benefit Analysis based on operational data of the advanced process leading to WHR
- Determination of the position of the ETS-BG-60 in the 2013-2020 period (Carbon portfolio management)
- Determination of the replication potential to 4 ETS Glass operators and their respective position
- Three Events in 2016 considering the dissemination of the projects' results in Sofia, Brussels and Frankfurt (120 ETS operators are expected to participate).
- Publication of results and dissemination to all ETS – Glass Operators.

The status of the project (Deliverables and Events) is continually updated on the Websites of the Consortium's partners:

1. http://www.lsbtp.mech.ntua.gr
2. http://www.drujba.bg
3. http://www.lignite.gr/en/index.htm