CO₂ reduction in the ETS glass industry by means of waste heat utilization

“CO₂-Glass”

SILC-I (Grant Agreement SI2.666128)

Project co-funded by the Sustainable Industry Low Carbon Scheme – Short term innovation measures – SILC I programme under the Competitiveness & Innovation Framework Programme (CIP) of the European Commission, DG Enterprize & Industry

Deliverable D.3.2

Replication potential of WHR application with Batch Preheating for specific CO₂ emission reduction in the ETS Glass Industry.

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<td>Centre for Research &amp; Technology Hellas / Chemical Process &amp; Energy Resources Institute</td>
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1. Introduction

The project “CO₂ – Glass”, co-funded by the Sustainable Industry Low Carbon Scheme — Short term innovation measures—SILC I programme of the DG Enterprise & Industry and the Competitiveness & Innovation Programme (CIP) for 2007–2013 of the European Commission, has started in December 2013 with a project end scheduled for November 2018.

The project addresses over 340 container glass production companies falling within the scope of the EU Emissions Trading Directive 2009/29/EC (replaced by Directive 2018/104/EC) i.e. glass production sites with a daily melting capacity of over 20 tons.

Its aim has been twofold: On the one hand, energy recovery from waste heat from the glass production process (Waste Heat Recovery - WHR) and on the other, non-technical means and in specific carbon emissions management activities.

Waste Heat Recovery options suitable for the glass industry have already been discussed in the first public report of the project “Description of waste heat recovery options in a small sized ETS glass industry”. These options, include electricity steam or hot water generation, natural gas preheating, thermochemical recuperation and batch/cullet preheating. Waste Heat Recovery has been applied on site of the industrial partner of the project BA Glass in Sofia, Bulgaria, a company falling under the scope of the EU Emissions Trading Directive with annual emissions in the range of 35 to 40 kt CO₂. The equipment installed concerned a batch preheater while the design of the batch preheating process has been imposed by the Bulgarian national regulation transposing the Best Available Techniques (BAT) in the container glass sector.

Regarding the planned non-technical means, the carbon emissions portfolio of the company BA Glass Sofia in the second Kyoto commitment period 2013-2020 has been assessed based on the emission allowances (EUA) in the possession of the company along with any previously conducted emissions trading activities. Potential carbon portfolio suggestions have been made on a non-public report, based on projections of the company’s production forecasts and the EU ETS market’s evolution in prices and traded volumes.
2. The EU Glass Industry

Approximately one third of the total world glass production originates from the EU which is nowadays the world’s biggest producer of glass\(^1\). According to the European Container Glass Federation (FEVE)\(^3\), glass packaging production in Europe grew by 2.9% in volume in 2016 confirming the steady trend of the last 5 years. Germany is the EU’s largest producer with approximately one fifth of the volume, closely followed by France, Spain, Italy and the UK\(^4\).

Glass production is a capital intensive and an energy intensive process producing CO\(_2\) emissions through fuel consumption and process emissions. The most efficient options for the reduction of CO\(_2\) emissions that have been proposed and/or applied in the glass industry regarding fuel emissions can be divided in two categories. The first one to increase plant energy efficiency that leads to reduced fuel consumption and CO\(_2\) emissions by means of improved air preheating, oxy-fuel combustion, optimized process control, increased recycled cullet usage, waste heat recovery and improved refractory materials. The second option for CO\(_2\) emissions decrease is by substitution of fossil fuels with biofuels such as biogas or syngas which are considered CO\(_2\)-neutral. At the first public report of the “CO2-Glass” project , “Description of waste heat recovery options in a small sized ETS glass industry, August 2014”, it has been concluded that all Waste Heat Recovery (WHR) options which can potentially be applied at energy intensive industries in general can be also applied in the Glass Industry. The subject of the current project has been the application of a heat exchanger for enhanced batch preheating with a cullet ratio of at least 50%. This option constitutes a Best Available Technique according to the BREF Document of the JRC. Cullet recycling rate has increased from 43% in 1990 to 71% in 2013. Nowadays, According to FEVE, the average glass recycling rate in the EU28 is steady at 74%.

2.1 The Industrial Plant and the technical intervention

**BA Glass Sofia-Bulgaria** has a daily melting capacity exceeding 300 t/d and is listed No 60 in the EU ETS Transaction Log. It has annual emissions in the range of 40 ktCO\(_2\) and its production concerns colored bottle and jars glass (amber, green, olive) according to market demand diversification. It is classified under NACE Code 2313 “Manufacture of hollow glass” and is a representative installation of the EU-ETS container glass sector. It is energy intensive (maximum intensity is [8 GJ/t]) and 60 - 70 % of the energy is consumed inside the furnace. It is characterized by high glass melting temperatures (1200-1500°C). Its exhaust gasses range between 400 and

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\(^3\) FEVE [www.feve.org]
\(^4\) Glass Alliance Europe, 2018 [www.glassallianceeurope.eu/en/industries]
500°C. The furnace at the site is natural gas end-fired with electro-boosting using a regenerator for combustion air preheating.

**Figure 1: Glass Production Process at EU ETS BG-60**

**Batch and cullet preheating** deals with exhaust gas waste heat utilization to preheat the batch and cullet mixture which is normally fed into the furnace without any additional heating input. This concept returns the recovered energy directly back into the melting process and is consequently not susceptible to external factors while it can be applied at the existing glass production chain without interrupting the process. The cullet quantities used are app. 50%. In the Best Available Techniques (BREF document) issued for the Glass Industry in March 2012, batch preheating was included within the “promising technological innovations”. Despite the fact that batch preheating is a process that has been investigated for over 30 years, only a few systems have been in commercial use due to technical side effects that caused serious equipment and handling harms such as dusting issues. Nowadays the technology enabling the amelioration of dusting problems and the safe removal of humidity during batch preheating is developed according to current experience.
Energy savings for regenerative air-fired glass furnaces range between 12-20%\(^5\) have been reported while CO\(_2\) emissions were reduced in line with the energy savings since 70-90% of the CO\(_2\) emissions are linked to fuel combustion\(^6\). The concept of Batch Preheating has the following advantage: It can be applied at existing glass production chains without significant needs for modifications in the process, strengthening the viability of the specific sector in the context of CO\(_2\) emission reduction per product. The equipment installed on site has been provided by ZIPPE Industrieanlagen GmbH and it involves an indirect preheater.

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**ZIPPE BATCH PREHEATER**

The glass production is a very energy intensive process, where a large part of the spent energy, which is necessary for the melting process, is emitted to the atmosphere after without being used afterwards. To reduce the raising energy costs and to reach the aimed climate protection targets Zippe Preheaters are the ideal systems to significantly increase the efficiency of your plant and to decrease melting costs.

A preheater can be planned as a final and integral step of your batch preparation system (batch plant), but can also be installed as an add-on into existing situations.

By utilizing the high temperatures of the waste gas stream and an efficient heat exchange, the systems can preheat the batch and by such lead to a rapid melting.

From the beginning in the 80ies, Zippe Industrieanlagen GmbH has been a pioneer in that technology and has nowadays the broadest experience of such systems in the glass industry.

Over the years, the technology has reached a very high stage of development – the systems run safe are easy to operate and have no moving parts inside. Newest systems, such as the Advanced Batch Preheater (ABP\(^\circ\)) can operate practically independent of variables such as the cullet ratio.

If you require a preheater only for your cullet as an add-on, or a batch preheater as an integral part of your batch preparation system including a perfectly matching batch charger, please ask us for the realization of your expectations.

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**Figure 2: Preheater General Outline [source: ZIPPE]**

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2.2. The EU ETS - Glass industry

The European Emissions Trading Scheme (EU – ETS) covers approximately 45% of European Greenhouse Gases (GHG), 11000 stationary installations as well as aircraft operators. The EU ETS particularly affects the energy intensive industries while it imposes a significant risk of “carbon leakage”, i.e. the risk of EU industry departing to countries with weaker restraints on GHG emissions. The EU Glass industry, being capital intensive and also requiring long investment cycles, is the world's largest glass producer. The EU ETS market, has been up during the second commitment period 2013-2020, the largest Emissions Trading Market until 2017. When looking at the evolution of the total transaction volume and value of emission allowances traded between 2005 and 2015\(^7\) in all activity sectors, it can be concluded that the volume has been moving upwards until 2013 but has decreased in 2014 and 2015 while the value was uprising until 2011 and started dropping significantly in the period between 2012 and 2015 due to the drop in EUA prices. In the years 2016 and 2017 the traded volume has risen to more than 5000 MtCO\(_2\) annually with a respective decreased value when compared to the year 2015\(^8\). Overall Verified Emissions, Emission Allowances and the price evolution within the EU ETS are shown on the figures below.

\(^7\) The potential of WHR/ batch and cullet pre-heating for energy efficiency in the EU ETS glass industry and the related energy incentives, Energy efficiency Journal 2018
\(^8\) Carbon Market Monitor 2018, Thomson Reuters Commodities
The verified CO₂ emissions from EU ETS Glass industries (Figure 6), correspond to approximately one percent of total emissions within the EU ETS and about three percent of the total Industrial EU ETS emissions. Although the EU ETS Glass Industry corresponds to a small proportion of the total Emissions Trading Scheme within the EU, its position is quite particular because the proportion of verified emissions to allocated allowances is significantly higher than the average ratio for the whole industry and has an increasing trend when compared to the overall ratio of all verified emissions to all allocated allowances (Figure 7). The deficit in allowances for the years 2013 to 2017 has already been 11 Mt\(^9\).

The current project is mostly focused to the container glass industry, since the implementation of the batch preheating process has been made to such a type of installation. The replicability to the flat glass production process, depends on the

\(^9\) EU ETL transaction log [http://ec.europa.eu/environment/ets/]
preheater dimensioning which needs to be proportionally designed since flat glass production concerns larger furnaces (in the range of over 800 t/d).

![Graph showing emission allowances and verified emissions (2013 – 2017) at Glass production installations falling under the scope of the EU ETS Directive.](image1)

**Figure 6:** Emission Allowances and verified emissions (2013 – 2017) at Glass production installations falling under the scope of the EU ETS Directive.

![Graph showing ratio of verified emissions to emission allowances.](image2)

**Figure 7:** Ratio of verified emissions to emission allowances

Most of the EU ETS container glass production installations are based in Germany, Spain, Italy, France and Poland, followed by the Czech Republic Belgium and the UK (Figure 8).
In July 2018, verified emissions between 2013 and 2017 were known and are depicted on Figure 9. According to the European Union Transaction Log (EUTL), Glass Industries had an allocation of 71 MtCO$_2$ for the period 2013-2017. Respective verified emissions were in the range of 82 MtCO$_2$ leading to a cumulative shortfall of 11,2 MtCO$_2$ for the period 2013-2017. For Bulgarian Glass industries, there has been a deficit of 0,5 Mt for the five in total Bulgarian glass ETS industries.

The industrial partner of the project, BA Glass in Sofia, is listed under the EU ETS Transaction Log List as one out of the five Bulgarian Glass production sites (EU ETS-BG – 60). According to the preliminary Carbon Leakage List for the period 2021-2030, the industrial partner of the project BA Glass Sofia as well as all glass production activities under NACE Code 2311 - Manufacture of flat glass, 2313 - Manufacture of...
hollow glass and Nace Code 2314 - Manufacture of glass fibres are included\textsuperscript{11} in the list and are considered to be exposed to the risk of carbon leakage, i.e. the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with less strict emission constraints. In particular for the glass production installation in Sofia Bulgaria, which is categorised under the NACE Code 2313, being a typical container glass production industry with an energy intensity of up to 8 GJ/product tonne and with annual CO\textsubscript{2} emissions of up to 40 kt this risk impacts its competitiveness in the EU environment. In Bulgaria there are five (5) EU ETS glass production sites, one of which is a large emitter covering more than half of total EU ETS glass emissions in the country.

3.1 Carbon Management at the EU-ETS BG 60 container glass production installation

The position of the EU ETS Glass Industry towards compliance with the EU ETS Directive 2018/410, is to be determined on the one hand by their shortage in emissions allowances, mainly however on the other hand on the evolution of the price of CO\textsubscript{2} allowances. The price evolution in the coming years will be determined by the extent to which the proposed market reform is implemented. Carbon price projections in mid 2016 showed that the carbon price in 2020 might go up to €15/tCO\textsubscript{2}\textsuperscript{12}. In October 2016, at the Thomson Reuters Carbon Market Survey 2016, survey participants’ forecast on prices varied, with average forecasts of €6.8/t for 2016 and €11.4/t for 2020. In more recent cases, analysts gave forecasts of €18.36/t for 2020\textsuperscript{13}. Taking into consideration the recent regulatory developments on the EU ETS Reform and assuming that the EU ETS Reform which is currently at stake, is conducted in such a way that the EU climate goals for 2020 and 2030 can be met, a price of 20 Euro per tonne could be applicable in 2020\textsuperscript{14}.

In order to assess the position of the specific industrial site within the EU ETS and to understand the extent to which this position might became an incentive for the replication of the batch preheating technique in similar industries, carbon management scenarios were investigated in combination with respective price evolution scenarios. Six (6) price evolution scenarios all starting with the average price of EUA in March/April 2017 and ending with the average price of EUA in March/April 2021 are shown on Figure 10. Prices started at €5.5/tCO\textsubscript{2} in March 2017 and are foreseen for the current study, to reach a maximum of €25/tCO\textsubscript{2} in March/April 2021. The 1\textsuperscript{st} and 3\textsuperscript{rd} scenarios concern linear evolution of prices up to €20/tCO\textsubscript{2} and to €18/tCO\textsubscript{2}. The 2\textsuperscript{nd} scenario retains a stable price of €15/tCO\textsubscript{2} (every year in March/April). The 4\textsuperscript{th} and 5\textsuperscript{th} scenarios show rapid and slow evolution of prices up to €20/tCO\textsubscript{2}. Finally the 6\textsuperscript{th} scenario “MAX25” shows a linear evolution from current prices up to €25/tCO\textsubscript{2} in March/April 2021. The differentiated price

\textsuperscript{11} European Commission 2018/C 162/01
\textsuperscript{12} EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050- Main results, EU Commission
\textsuperscript{13} Reuters, April 2018 [https://www.reuters.com/article/us-eu-carbon-survey/analysts-raise-eu-carbon-price-forecasts-on-emissions-rise-uk-brevity-clarity-idUSKBN1HI1L1R]
\textsuperscript{14} Mercator Research Institute http://www.mcc-berlin.net/en/research/emissions-trading.html
evolution scenarios are combined with five (5) categories of several actions/contracts of Emission Allowances acquisition. The categories of the five (5) actions/contracts are described on Table 1, to summarize the potential actions for BA Glass S.A towards achieving compliance under the EU ETS Directive.

The combination of the six price evolution scenarios with the five contract scenarios are here compared with a case of 6% emission reduction at the Sofia plant, to a basic reference scenario where no WHR takes place. With the current pattern of price evolution an early compliance is recommended for the covering of the total amount of foreseen deficit in any case (with or without WHR). This approach, envisages the prerequisite that Emission allowance prices will not go lower than today’s (July 2018) prices and that they will keep rising linearly or abrupt. There is a risk that prices will remain steady or falling if the EU ETS is not reformed properly.

Figure 10: Price evolution scenarios for CO₂ emission allowances
Table 1: EU ETS Compliance Contracts

| A) | Spot contracts at the beginning of each year 2018, 2019, 2020, 2021, purchasing every time the required amount of allowances for the specific year only. |
| B) | One spot contract in March /April 2018 covering the compliance requirements for 2017 and a further spot contract between May 2018 and December 2018 for buying the remaining deficit for the period at a price lower than the price in March/April 2017. |
| C) | A spot contract for covering the compliance requirements for 2017 and during 2018, a futures contract for all the remaining projected amount for compliance. |
| D) | A spot contract for covering the compliance requirements for 2017 and at the beginning of every subsequent year: future contracts for the remaining amount of compliance for that specific year up to the period's last year (March-April 2021 allowance submission for 2020 compliance). |
| E) | A spot contract for covering the compliance requirements for 2017 and for the remaining 3 compliance years, spot or future contracts for covering each year's requirements. |

| MIN without WHR | MAX without WHR | MIN with WHR 6% | MAX with WHR 6% |

Generally, expenses of the Sofia EU ETS-BG-60 plant in early compliance scenarios are 40-50% less than the “worst-case scenario” (i.e. spot contracts every year and 25 Euro/EUA price in 2021). Under unfavorable circumstances, expenses with WHR might be higher than expenses without WHR, solely due to bad timing in EUA contracting. This risk can be diminished with a less than doubling of the achieved CO₂ savings (A case of up to 12% reduction in CO2 emissions). On the following Figure 11, comparison is made of all cases of expenses for compliance with the EU ETS legislation, compared to the most expensive case (100%).

Figure 11: Five (5) scenarios of EUA acquisition contracts during 6% CO₂ reduction.
4. Replication Potential - Conclusions

The examined concept of WHR can be potentially applied to all the 344 EU ETS Container Glass industries in the EU. There seems to be no restrictions for the flat glass industry either, however since there were no actual data from such an intervention and since that process is an entirely different one, no position is being made for that types of industrial sites due to the differentiated necessary sizing of the batch preheater equipment.

The implementation of the WHR concept at the EU ETS BG-60 Plant in Sofia has shown that some prerequisites and restrictions towards the implementation of WHR with batch preheating in the EU ETS Glass container Industry concern:

1) Temperature of exhaust gases: The exhaust gases that enter the system, need to reach a particular level of temperature (320°C to 360 °C). In order to achieve this, app. 70% of the gases coming from the regenerator, enter the batch preheater while an additional 30% enters with a by-pass the furnace directly once reunited with the exhaust gases from the preheater. This prerequisite is partially due to the regulation regarding the necessary DeNOx process that needs to take place in the filter.

2) Quantity of cullet available: Another issue imposing the applicability or not is the cullet available on sites. The amount of cullet to be used needs to be at least 50%.

3) Type of cullet available: In addition, the type of glass (clear, amber, green) also defines the applicability of WHR again based on the cullet available. The mixed coloured cullet can be used only for green glass production, while the manufacturing of clear or flint glass, and, to a lesser extent, amber glass, require cullet of the same colour. Therefore the type of cullet available becomes also a parameter\textsuperscript{15}.

The foreseen evolution of EUA prices seems to be an incentive for the implementation of WHR at the specific glass production plant. Both technical means and carbon management activities are necessary for maintaining a competitive status.

4.1 Direct Beneficiaries of the project’s results

The Group of Companies to which the EU ETS BG-60 plant belongs to, also owns additional container glass industrial sites. In South East EU those are the Plovdiv site (ETS-BG-59), the Athens site (ETS-GR-1), Bucharest site (ETS-RO-197) and additionally eight (8) installations: In Germany: ETS-DE-4135, in Poland the ETS-PL-412 and ETS-PL-510, in Portugal the ETS-PT-185, ETS-PT-186 and ETS-PT-198 and in Spain the ETS-ES-300 and ETS-ES-626, as listed in the EU Transaction Log. Therefore the project is considered to have four (4) direct beneficiaries and eight (8) additional indirect beneficiaries.

\textsuperscript{15} Long-Term Sustainability from the Perspective of Cullet Recycling in the Container Glass Industry: Evidence from Italy, MDPI, October 2017
The evolution of the deficit in emission allowances in those industries is shown below. Their position might become an incentive towards WHR implementation.

Figure 12: Emissions and Allowances for the four (4) sites addressed by the SILC CO2 Glass project [(Sofia (ETS-BG-60), Plovdiv (ETS-BG-59), Athens (ETS-GR-1), Bucharest (ETS-RO-197)]. [Source: EU ETS Transaction Log]

Figure 13: Emissions and Allowances all twelve (12) sites belonging to BA Group [Source: EU ETS Transaction Log]

Industrial Emissions within the EU ETS concern approximately 30% of total EU ETS stationary emissions (i.e. total emissions without aviation emissions. Out of these 3% concern the Glass industry and 1.5% concern the twelve (12) installations which are directly or indirectly addressed by this project (from BA Group). The total volume of CO$_2$ emissions in 2017 were 278 kt for the four direct beneficiaries and additionally
621 kt CO₂ emissions for the eight indirect beneficiaries. That is close to 0.9 Mt of CO₂ emissions.

Figure 14: Project’s Direct Beneficiaries

5. Further Reading


