Energy saving options for industrial furnaces – the example of the glass industry

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Abstract

In the industrial sector approximately 30 % of the fuels used are consumed by furnaces. On top of that, 10 % of the industrial electricity demand is used in furnaces. Prior studies on industrial furnaces and ovens have concluded that potential for efficiency improvements lie between 10 and 40 % depending on the sector and the application.

Within our paper we will describe an approach to assess the future energy demand of industrial furnaces. In addition, the corresponding CO_2-emissions and saving potentials will be determined. The timeframe of our analysis is from 2015 to 2030 considering the EU-28 countries and Switzerland, Norway and Iceland. To show the application of our methodology, we will present the glass sector as a case study. There, we will analyse the saving options corresponding to the furnaces used in glass making processes.

For the purpose of our study we have built a proprietary bottom-up simulation model for energy demand. We will present the underlying methodology and data of our modelling approach. The dataset represents a detailed representation of the EUs glass production sites. Therefore, we are able to model the diffusion of the efficiency technologies on a site level. In parallel, we will present an approach to derive a dataset from sources like the ETS register.

Finally, we will present the results of our modelling approach and discuss the potential impacts of energy efficiency technologies in the glass sector. Furthermore we will show the transferability of our approach to other sectors.

Introduction

The reduction of carbon dioxide emission (CO_2) and other greenhouse gases (GHG) is the key aspect for mitigating the consequences of climate change. These emissions increase the greenhouse effect and affect societies and economies all over the world. The International Panel on Climate Change (IPCC) pointed out that the worldwide GHG-emissions have to be reduced significantly to achieve a 50 % chance of a global warming beneath 2 °C compared to pre-industrial times. If this can be achieved, it is believed that climate changes, induced by the 2 °C warming, can be handled at acceptable social and economic costs (IPCC 2007).

In this context, all energy consuming sectors must be assessed to identify energy efficiency measures (EEM) that can help to achieve the proposed targets by reducing the energy demand and the CO_2-emissions. A suitable way to do this is to assess the processes in the respective sectors and to identify the possibilities to reduce the energy demand of these processes. In the industrial sector, approximately 30 % of the energy from fossil fuels, as well as 10 % of the industrial electricity demand, is used in industrial furnaces (Jochem 2009). A large variety of industrial furnaces are operated with fossil fuels as their main energy source. In these cases, the heating of the furnaces lead to CO_2-emissions directly from the furnace. If electricity is used as an energy source, the CO_2 emissions depend on the specific emissions of the electricity mix.

An Ecodesign study on industrial furnaces and ovens (Goodman et al. 2012) has concluded that improvements potentials in industrial furnaces can have an important role. The study states that the potential lies between 10 and 40 % depending on the sector and the application.

Table 1. Improvement potential for furnaces and ovens used in different sectors (Goodman et al. 2012).

Sector	Improvement potential of energy consumption
Large steel reheating	ca. 10 %
Glass melting and processing	10 to 20 %
Ceramics – large size	10 to 20 %
Metal melting/foundries/scrap refining	20 to 40 %
Medium sized ovens and furnaces – electric	ca. 10 %
Medium sized furnaces and ovens – gas/oil	20 to 40 %

Table 1 shows that it is believed that significant savings can be made within these sectors and furnaces. However, it has not yet been researched in detail, if and in what way these saving potentials can be exploited. Especially the EEMs available and their potential contribution to future energy- and CO_2-emission savings have not yet been examined in detail. A challenge for doing so is that industrial furnaces have a wide range of applications in which they are used and the existing variety of industrial furnaces. Although there are some main characteristics for furnace types that make them similar, furnaces are often designed and produced individually to meet the requirements of specific processes.

The central questions of this paper are, how the current and future energy demand, emissions caused by the energy demand and impact of EEM to energy and emission saving in industrial furnace processes can be determined and how they can contribute to the European targets for reduction of GHG-emissions and energy consumption. In this paper we will focus on the glass industry as a highly relevant example for the use of furnaces in an industrial application. The glass industry is one of the major energy intensive industries in Europe and its energy demand is dominated by the furnaces.

The Glass Industry

Glass, and products made of glass, is ubiquitous in everyday life. Glass is used in various forms and applications and is produced by melting raw materials (mostly silicon oxide) and casting it into the desired form. For this paper the glass products are distinguished into the following sectors (IPPC 2013a):

- Container glass for beverages and other liquids
- Flat glass for windows or windscreens
- Continuous filament glass fibre
- Glass used in other forms

The standard DIN 1259-1 states that glass is an "inorganic non-metallic material that is received via complete melting of a mixture of raw material at high temperatures, in which a homogeneous liquid is created, that is quenched until it reaches its solid state, usually without crystallization."

Glass is used in various forms and applications. It is used as container for beverages and other liquids, as windows, as glass fibre for reinforcement, in lamps, and other special applications. The glass used for the different applications differ from each other in purity and chemical composition. Depending on the demand and desired properties of a product different raw materials are used. The base materials for glass production are silicon dioxide, alkali oxides (sodium oxide, potassium oxide) or earth-alkali oxides (calcium oxide, magnesia oxide) (Wendehorst 2011). The following is a short description of the different sectors and their products:

Container glass is used mostly in form of bottles for beverages such as wine, beer, sparkling water and juices. Further products are jars and containers for food, cosmetics and perfumes, pharmaceuticals and technical products. The production of beverage containers accounts for 75 % of the total container glass production. About 20 % are produced for the food sector. Small bottles and containers for cosmetics, pharmaceuticals and technical products account for the 5 % of the production. There is quality, financial, environmental and aesthetical reason for and against the choice of glass as container. Advantages of glass are its chemical resistance and its ability to preserve the quality of its contents. Due to its merits with respect to appearance, it can support the identification of brands. Environmental and financial reasons can be its ability to be reused a number of times and its recyclability. Arguments against the usage of container glass are in a financial view the cost of transport due to its weight. Furthermore, it can easily break because of its brittleness (IPPC 2013a).

Flat glass can be divided into the main types of rolled glass and float glass. The difference of the two types lies in the way they are produced. For the former, the molten glass is rolled to a specific thickness between two rollers. For the latter, the production makes use of the physical property of the molten glass and the fact that it is lighter than molten tin and therefore floats on top of it. When floating on a tin bath the molten glass form a layer with a uniform thickness. After cooling down to a certain temperature the glass can be separated from the tin bath (IPPC 2013a). Float glass accounts for 95 % of the flat glass production and is principally used in the construction and automotive industries. Rolled glass, in the form of patterned or wired glass, accounts for approximately 3.5 % of the total output (IPPC 2013a). In the float glass production the construction and buildings industry is the biggest market. It accounts for 75 to 85 % of the output. The main processed products are insulated glazing as double or triple glazed units. Other products are silvered, coated, toughened, and laminated products. Most of the remaining share is used as glazing in the automotive industry. The glass is either simply cut to size or further processed into different products (IPPC 2013a).

The sector of **continuous filament glass fibre** is of minor relevance in terms of overall production. Fibres are used in the production of composite materials such as glass-reinforced plastics. The main advantages of these materials are their strength-to-weight ratio and their corrosion resistance (IPPC 2013a).

In the group **other glass** a couple of minor glass-producing sectors are aggregated. They are also referred to as "special glass". With approximately 4 % of the total output of the glass industry, this sector is of rather small relevance, as well. It products range from hand-made high quality and value products to industrially produced goods. It covers products such as: cathode ray tubes glass, lighting glass (tubes and bulbs), laboratory and technical glassware, ceramic glasses (cookware), optical glass and glass for the electronics industry (IPPC 2013a).

In general, the location of glass production sites depends on the availability of raw material and customers. For example, container glass sites are mostly within less than 500 kilometres of their customers to minimize shipping costs (IPPC 2013a). Large production facilities are found in regions with access to raw material sources. For example, large facilities exist in the areas of Aachen and Cologne in Germany due to large quartz deposits located nearby (Schaeffer 2014). Figure 1 provides an overview of the location of glass manufacturing sites in the EU-28.

Figure 2 shows the overall production volume of glass products by glass sector in Europe from 2005 to 2014. It can be observed that overall production has declined from 35,800 kt/a in 2005 to 33,700 kt/a in 2014.

In general, the **glass production process** consists of various consecutive steps (Figure 3). The raw materials are mixed and can be pre-heated in large silos. Afterwards, pre-mixed cullet can be added to the mixture. Cullet reduces the energy demand

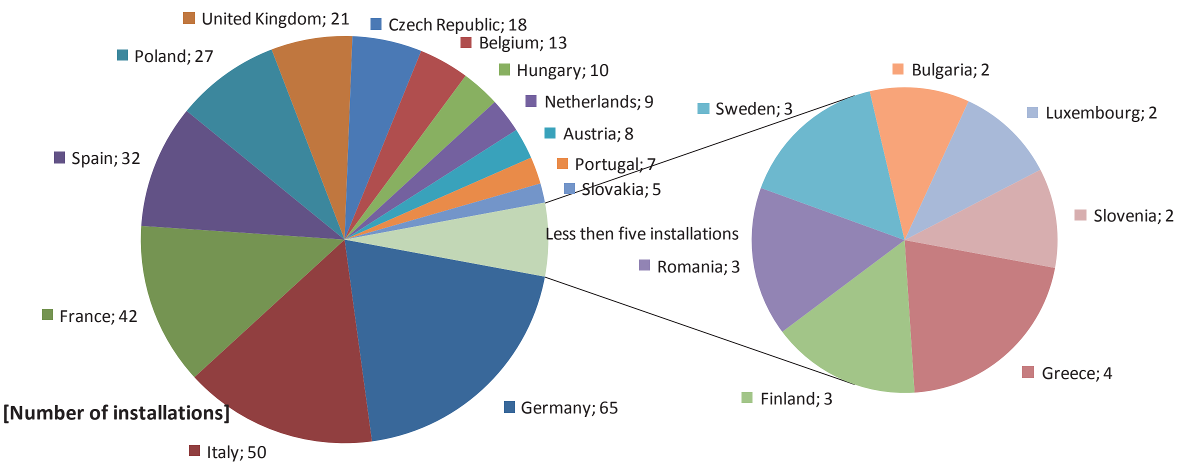

Figure 1. Glass manufacturing sites in the EU-28 (Source: IPPC 2013a).

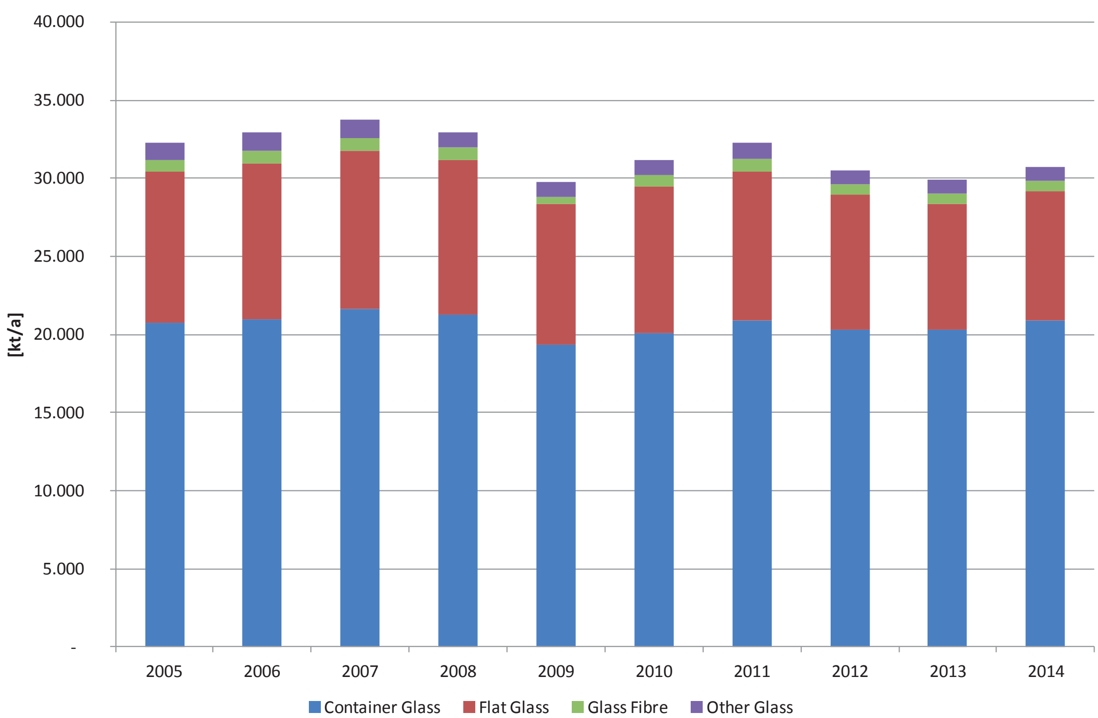

Figure 2. European glass production from 2005 to 2014 in [kt/a] (Source: Glass Alliance Europe 2015b).

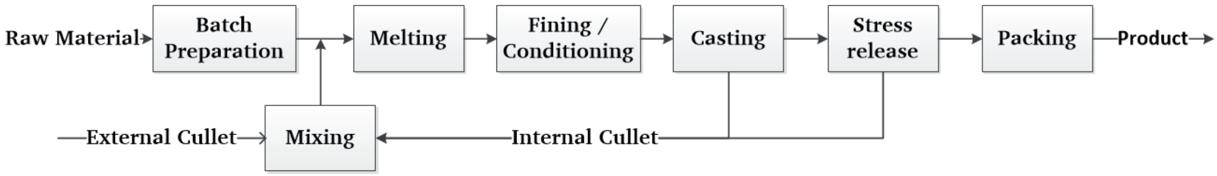

Figure 3. Glass production process (Based on: Fleiter et al. 2013; Worrell et al. 2008).

for the melting process. The mixture is then inserted into the furnace, where it is heated until it melts. It is then kept at a high temperature until the molten glass is homogenized and ready for casting. The furnace contains outlets which allow the molten glass to flow out for the subsequent production process. Depending on the product, the glass is blown into moulds or rolled/floated over a tin bath. The glass products must then be cooled down slowly. It is important that this is carried out very carefully since fast cooling leads to inner tensions in the glass which, adding to the brittleness of the products. The glass can then be packed and is ready for shipment (Fleiter et al. 2013).

The average **lifetime of a glass melting furnace** is up to 20 years (IPPC 2013a). After 8 to 14 years, a major renovation takes place, in which the refractory materials are changed and a general overhaul takes place (Jochem 2004). Exceptions are furnaces that are heated with electricity. Their typical lifetime is between 2 and 7 years (IPPC 2013a).

Efficiency measures for glass furnaces

Measures to reduce the specific energy consumption (SEC) can address different steps of the production process. The two basic approaches are to reduce the energy demand on the one hand and to utilize the waste heat on the other hand. This section explains the basic techniques that are used or can be used in order to decrease the SEC of glass furnaces. Additional savings can be achieved if the glass production process as a whole is assessed. In this case, the energy efficiency of auxiliary motors, conveyors and compressed air systems has to be assessed in order to determine the overall saving potential.

In general, the use of **heat recovery** is very well implemented within the glass industry. Especially **air pre-heaters** are commonly installed where fossil fuels are used to heat up the furnace.

The **pre-heating of cullet and the raw material** is not yet very common in the European glass industry. Only four installations are known that already use this technique (IPPC 2013a). Barriers to implementation are currently high installation costs and technical difficulties if no cullet is used. The pre-heating of input requires a share of 50 % of cullet (but it has also already been operated with 30 % of cullet). Generally, energy savings of 10 to 20 % can be achieved by this measure.

Waste heat boilers have a smaller impact on the energy consumption .The amount of energy recovered is smaller than 0.1 % per ton of molten glass (IPPC 2013a). Since the installation costs can exceed 1 million EUR and the payback time of the measure is up to 10 years, its implementation is little attractive for operators of glass furnaces (IPPC 2013a).

The **use of cullet** is one of the most effective ways to reduce the energy demand of a glass furnace. As a general rule, energy savings of 2.5 to 3 % can be achieved for every 10 % of cullet added to the input material. The amount of external cullet usage varies throughout the different glass sectors due to different quality requirements. In container glass production, the average usage of cullet is 50 %, but shares of up to 90 % have also been reported. For the other glass sectors, the shares of cullet in the input have been reported to be in the range of 25 to 50 % (IPPC 2013a). Internal cullet is usually reused in all glass sectors. A problem that has to be solved is quality issues related to using external cullet.

The use of different **fluxing agents** and **preliminary treatment** of input material (reduction of moisture / selective batching) can lead to significant energy savings as well. Energy savings in the range of 5 to 10 % are reported due to a switch of fluxing agents. Reduction of moisture by 1 % can lead to energy savings of 0.5 %. Selective batching can lead to considerable savings in the range of 20 to 33 % in the furnace. However, it is unclear how much energy is used for pre-treatment of the input material (Worrell et al. 2008).

The effective control of the furnace with **process control system** can lead to energy savings in the range of 2 to 8 %. The payback period for this measure can be less than a year. The literature on the measure referred to older statements. We believe that nowadays these systems are already implemented in a large number of furnaces due to their high potential (Worrell et al. 2008).

Another measure for assuring energy savings assessed here is the improvement of **furnace insulations.** By using refractory materials and by insulation against false air, savings can be achieved. A new furnace crown design can lead to energy savings between 2 and 3 %. Reducing false air by 5 % can lead to energy savings of 2 to 3 %. Unfortunately, it has not been stated in what extend these measures already have been implemented.

An energy demand model for industrial furnaces

This section illustrates and explains the model that has been developed to calculate and forecast the energy demand of industrial furnaces and the corresponding CO_2-emissions for the European glass industry. For this reason the model considers certain specific influences on the energy demand of this sector.

The developed model can be classified as a bottom-up model that uses a simulation approach for the consideration of diffusion of energy EEMs.

The basic structure of the model is shown in Figure 4 which shows the input data for the model and its results on the macro level. The model can be divided in three parts. Data on individual plants as well as techno-economical parameters on production, capacity utilization, EEMs, lifetime, and the SECs of the furnaces are essential inputs to the model. Combination these two parts allows for calculating the overall production, energy demand and CO_2-emissions.

The starting point of the modelling is a stock of furnaces that contains information on the respective production plants. The stock model contains data on the technologies that are used in the respective plants and their capacity. Furthermore, the type of glass product, their age and their location in terms of countries is covered. In addition, the technological data contains information about the age of the furnaces.

The second important set of input data is techno-economical parameters. With these parameters, the development of the production output is forecasted. The impact of EEMs is determined and at what speed they enter the market. Furthermore, the energy consumption of the furnace depends on technology, age and the glass type.

With the combined information of the plant statistics and the techno-economical parameters, the overall production, energy demand and CO_2-emissions can be calculated for single furnaces. This data can then be aggregated into the respective glass sectors on national and international level.

In order to use the energy demand model, it is important to gather the required data. Data is needed for the plant stock, and the techno-economical parameters. The **furnaces** must be described in the following regards on the **technology stock level**:

With the data shown in Table 2 every single furnace can be described in detail. With data given on the location of the furnace and its capacity, it can be determined per country how much glass can be produced and how energy is required for that. Age, capacity, type of glass and the technology all influence the specific energy demand per ton of glass.

A number of **parameters** must be selected on the **techno-economical level** in order to calculate the output, the energy demand and the CO_2-emissions. Table 3 lists the **economical** assumptions that are needed for the modeling. First of all, a projection of the production volume is required. This is difficult since the production of glass cannot be linked to the development of for instances the GDP or capacity utilization in the whole industry, because the trends of production and the GDP have shown contrasting developments. The second assumption concerns the speed at which EEMs will enter the market. This

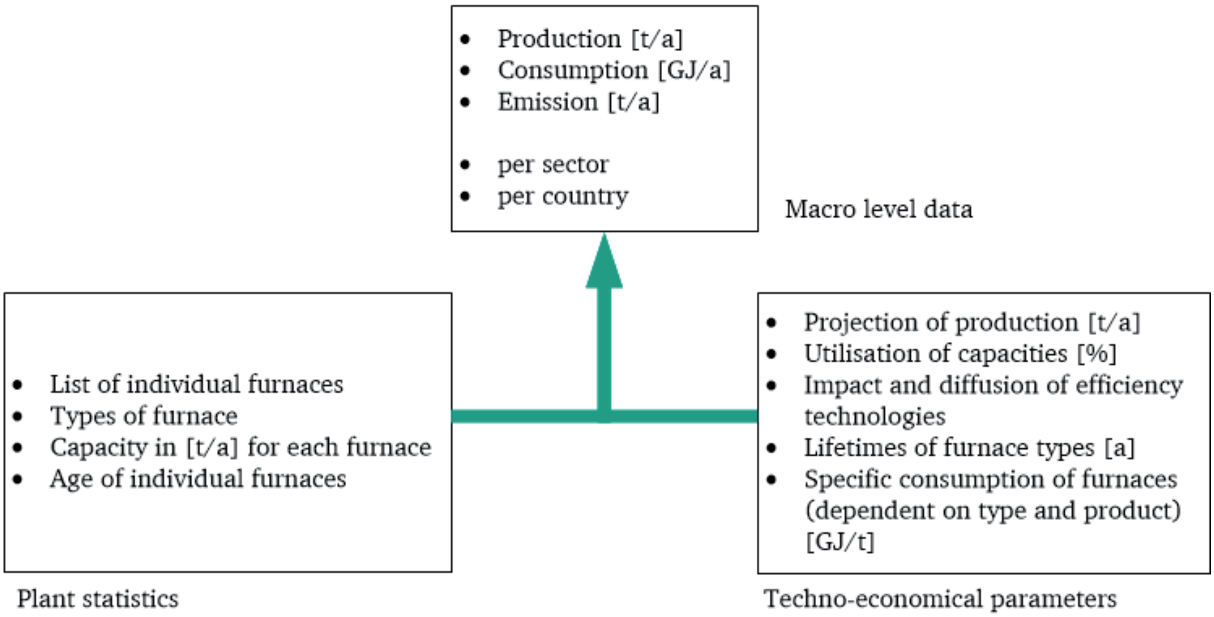

Figure 4. Structure of the energy demand model.

Table 2. Technological stock data.

Data	Description
Location	Country in which the furnace is operated
Capacity	Amount of glass in ton per year that can be produced
Age	Date of (new-)construction of the furnace
Type of glass	The type of glass that is produced with the furnace
Technology used	The technologies that are used in the furnace

Table 3. Required economical assumptions.

Data	Description
Future Production	Development of annual glass production per sector
Diffusion of Technologies	Speed at which EEMs are introduced into the market

development is described by a logistic growth function. However, the variables of this function must be determined.

With respect to **technological** information, a couple of variables must be defined, as well (Table 4). The most crucial factor is the specific energy demand of the furnaces. As it was highlighted before, the energy demand of furnaces depends on a large variety of factors and a review of available data has shown that there is a considerable range of energy demand figures in literature. The lifetime of a furnace technology determines in which year a furnace can be renewed and new technologies can be introduced. Furthermore, factors affecting the energy demand must be determined to calculate the SEC. Especially aging seems to be a crucial factor affecting the energy demand of a furnace. Finally, the impact of EEMs must be determined, i.e. the estimated savings that affect the overall SEC.

Data sources

This section presents an overview of the data sources that have been used to derive the input data for the energy demand modeling and the assessment of the EEMs. The data on the technologies used was derived using different sources of literature. In order to give a full picture of the technological details it was important to assess how different sources describe the technologies used and how the authors specify the operational data and the impact of EEMs and techniques for reduction of GHG-emissions.

In terms of technological stock data, information from the plants.glassglobal database was used as key input on the technological stock. As an example, Figure 5 provides an overview of the capacity distribution by country and glass sector.

In terms of economic assumptions, the future production is estimated. The past production cannot be linked to the GDP or other values. For this reason, the development of the production is projected using a floating average of the past years productions. For this, the past ten years are taken into account. The container glass sectors continue to produces two thirds of glass output, with amounts pending slightly above 20,000 kt/a. The second largest output comes from the flat glass sector with a share of 30 % or slightly below 9,000 kt/a. Glass fibre accounts for 2 % of the output or around 700 kt/a. Other glass is in the range of 3 % or slightly below 1,000 kt/a.

With regard to technical assumptions, Table 5 shows the SEC value of the different furnace technologies for the four glass

Table 4. Required technological assumptions.

Data	Description
Specific Energy Consumption	Demand of each furnace type dependent on glass type
Lifetime	The time a furnace is used before is replaced or renewed
Impacts on SEC	Factors that influence the energy demand, e.g. aging
EEMs	Impact of different efficiency measures

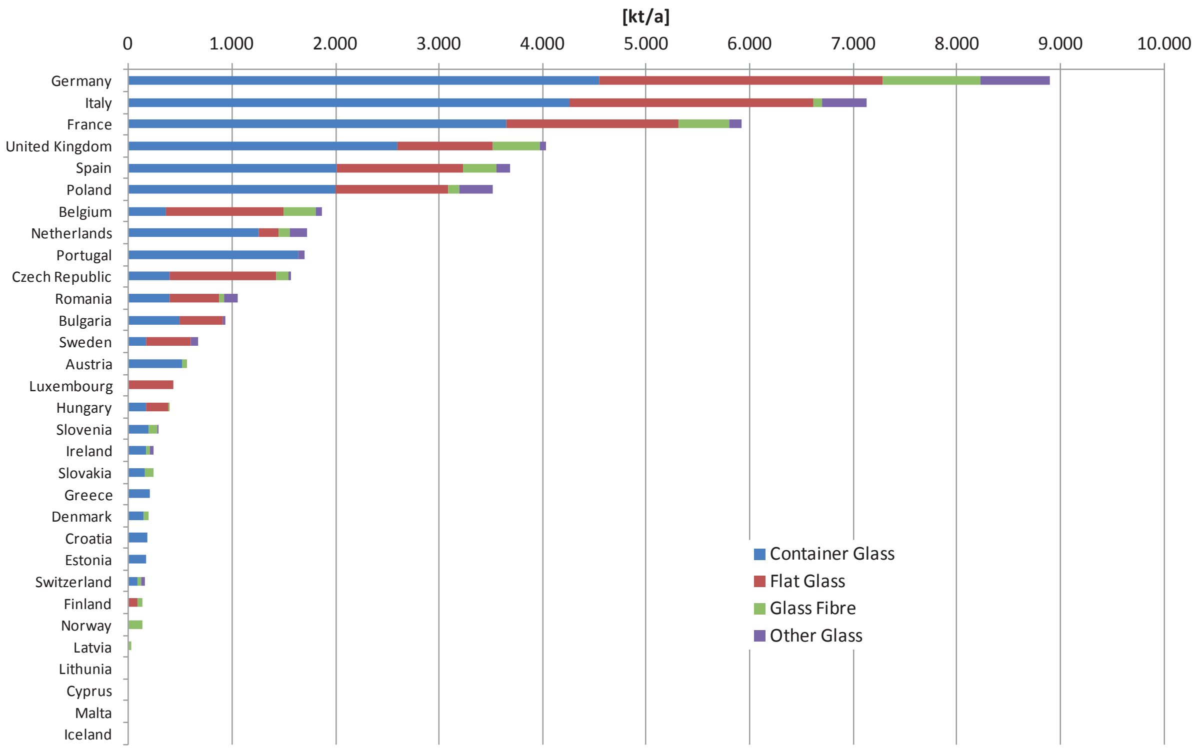

Figure 5. Capacity [t/a] of the EU28 + 3 glass sectors in the respective countries (Source: plants.glassglobal).

Table 5. Chosen SEC of different furnace types in GJ/Mg (based on IPPC 2013a and Worrel et al. 2008).

Glass Sector Furnace type	Container Glass	Flat Glass	Glass Fibre	Other Glass
Regenerative End Fired	5.4	7.0	12,5	6.1
Regenerative Side Fired	5.2	7.7	12.5	10.5
Recuperative	7.1	–	8.2	9.7
All Oxygen Fired	5.3	6.3	8.7	6.5
Electric Melting	3.7	–	6.5	6.5

Table 6. Chosen lifetime of different furnace types in years (based on IPPC 2013a).

Furnace Type	Lifetime
Regenerative End Fired	12
Regenerative Side Fired	12
Recuperative	12
All Oxygen Fired	10
Electric Melting	5

Table 7. Assumptions on the use of cullet in different glass sectors.

	Container glass	Flat glass	Glass fibre	Other glass
Usage in 2015 [% of input]	50 %	10 %	10 %	10 %
Maximum Input Share [%]	80 %	50 %	50 %	50 %
Annual Growth Rate [%]	2 %	1.5 %	1.5 %	1.5 %

sectors as used for the analysis. The choice of these values is based on a literature review considering the different technical and operational conditions of the glass sectors and furnace types. Where possible, the mean values have been taken. If no value was available for the precise combination of furnace and glass sector, an assumption has been made and the value was set by comparing it to other values in the specific sector.

Concerning the lifetime of the furnace technologies, it has been decided to use the time after which furnaces usually receive a general overhaul. Table 6 gives an overview over the selected lifetimes.

The following technological options have been chosen for the modelling process, as they appear as promising options with regard to reducing energy demand and emissions of the glass production processes:

- Pre-heating of the input material (EEM 1)
- Advanced process control (EEM 2)
- Pre-treatment (selective batching) (EEM 3)

For advanced process control and pre-heating the mean value of the values stated in literature is used. In contrast, only a third of the savings reported for preliminary treatment is used because of the high uncertainties regarding the energy demand of the pre-treatment.

Next to the three EEM, the use of cullet is considered as a resource efficiency option with an impact on energy demand.

With regard to the implementation, three different assumptions are made. For all technologies, the base year is set to 2015 and the maximum diffusion to 95 %. The most important factor, the diffusion in the base year, is selected individually for each technology.

For the advanced process control, it is believed that many furnaces already use these technologies. The diffusion in the base year therefore is set to 50 %. Based on additional assumptions on the future diffusion of this EEM, the diffusion rate reaches 92 % in the 2030 in the model. Since it is stated that only few furnaces use cullet pre-heating so far the diffusion for this technology must be lower. It is set to 5 % in the year 2015. This leads to a diffusion rate of 60 % in 2030. As mentioned above, the preliminary treatment of input material is considered a future technology. Because of this, the diffusion of this technology is set to only 1 % in 2015. Due to this the diffusion only reaches 25 % in 2030.

The following approach was used for the usage of cullet. The four glass sectors are believed to show different intensity of cullet usage (Table 7). This is based on the fact that different quality demands lead to restrictions in the amount of cullet that can be used. The use of cullet is adjusted by sector. For the cullet usage in the container glass sector, the factor was set to 50 % which represents the mean value as stated in literature.

For the other three sectors, no statement was found. However, since it is mentioned that flat glass producers tend to use little amounts of cullet the input level has been set to 10 % which is basically the share that internal cullet can have in the flat glass production. Since there has been no data on the cullet usage in the production of glass fibre and other glass, it has been decided to use the lower values that are used for flat glass as well. The upper limit and the annual growth rate are lower for these three sectors for the same reason.

Results and discussion

In Figure 6, the impacts of all factors are compared. It can be noted that the aging of the furnaces and the cullet usage have the strongest impact on the energy demand. In the year 2026, the negative effect of aging is almost as big as the savings that can be achieved by the use of cullet. They are both in the range of 9 %.

The effects of all EEMs combined exceed the effect of aging first in 2027. They reach the same impact as the cullet usage in 2028. Looking at the total savings, it can be noted that the savings continuously grow. The growth rate is smaller in the first couple of years but grows larger after 2018. The gap between 2026 and 2027 can be explained by restrictions of the stock modelling approach.

Figure 7 shows the absolute results that have been calculated in the model for the total energy demand when all impacts/EEMs are applied as compared to the bottom line. The overall energy demand decreases from ~180 PJ/a in 2015 by 12 % to ~157 PJ/a in 2030. This is remarkable, since the production amount remains almost constant throughout the years. Compared to the bottom line scenario, the energy demand is 24 PJ lower in 2030.

In Figure 8 the development of the overall energy demand by glass sectors is shown. When looking at the single sectors, it can be pointed out that the relative (as well as the absolute) amount of energy saved is different for all sectors. For all glass sectors, the achievable relative savings in energy demand until 2030 are in the range of 10 and 14 %.

It can be observed that the **aging of the furnaces** causes an increase of the overall energy demand. An interesting detail is the fact that in 2027 there is a huge reduction of the impact of saving. This reduction can be explained by looking at the database and the set lifetime of the furnaces. The set lifetime is between 5 and 12 years, with most of the furnaces having lifetime of 12 years (all regenerative and recuperative furnaces). The stock data on the furnace contained furnaces that have been built in the time period between the year 2000 and 2015. Since the model checks, whether a furnace has reached its end of lifetime for each year this leads to a large amount of furnaces that are renewed in the bottom year 2015. In this first year, all regenerative furnaces that have been built between the years 2000 and 2003 are renewed and their lifetime starts to be counted from zero. After 12 years, this effect again has an impact on the overall energy demand, since all of these furnaces are renewed together.

The effect is weaker for the **EEM** savings. For the EEM, it is smoothened out by the diffusion simulation. This simulation prevents that all furnaces that are renewed in a specific year are equipped with all technologies available. If this was not the case the leap between the years 2026 and 2027 would have been stronger. Regarding the impact of the EEMs, it can be observed that three different characteristics have been created by using the impact of the EEMs and assuming specific diffusion rates. EEM 1 can be recognized as a technology that is already implemented in a large number of furnaces. Consequently the growth of savings from this EEM is rather low. EEM 2 is a technology that has is responsible for the largest amount of savings in the observation period. This is caused by its potential which was assumed to be the highest and its, compared to EEM 3, faster diffusion rate. Finally, EEM 3 can be considered a future technology that is introduced much later. At the end of the observation period its effect has reached the same magnitude as the effects of EEM 1.

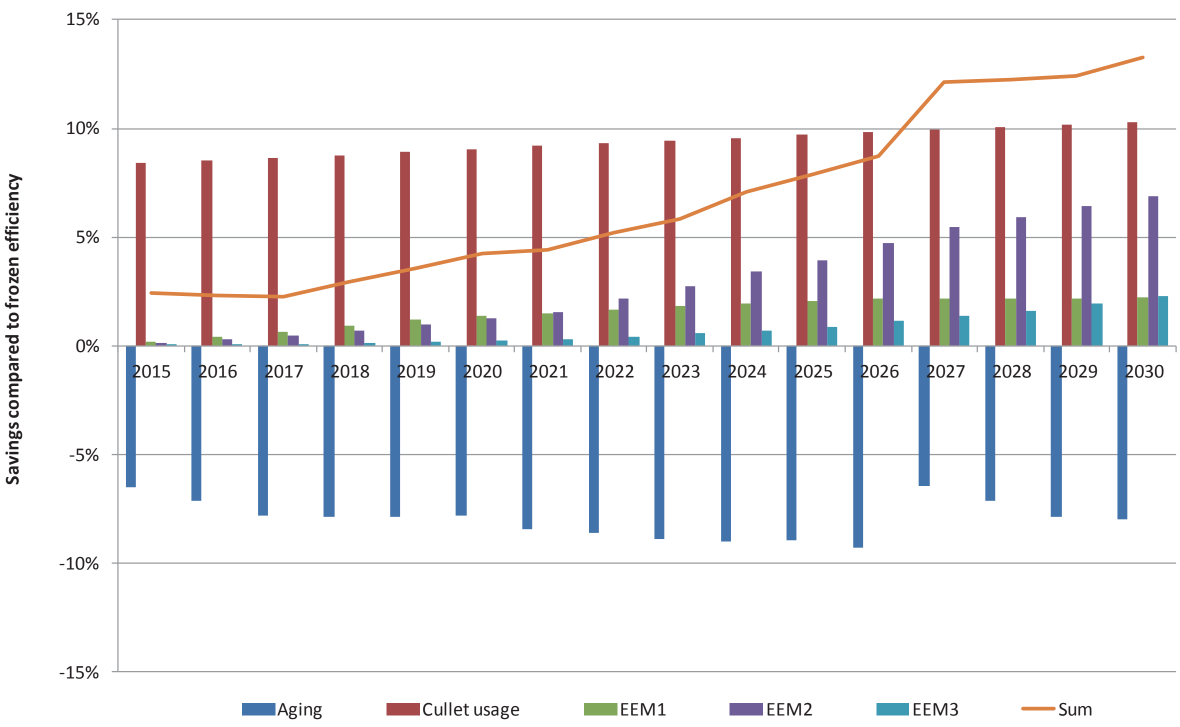

Figure 6. Relative impacts of the technological options and aging on the overall energy demand [%] (Source: own calculation).

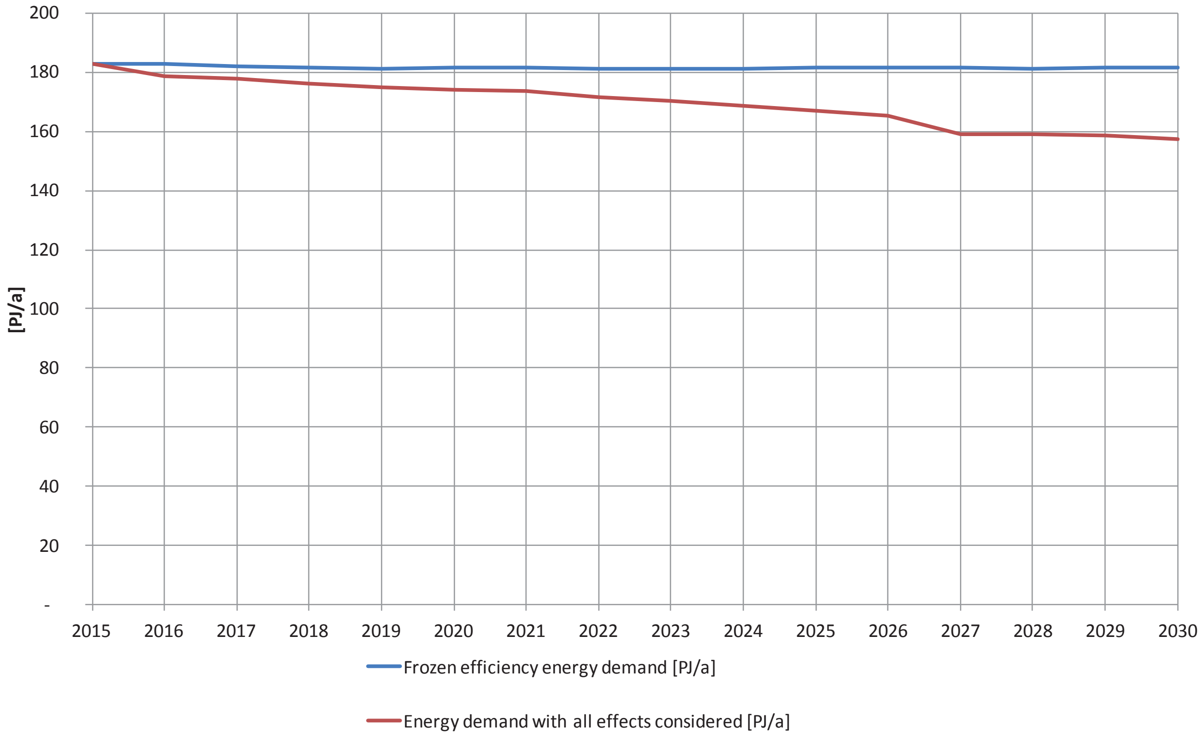

Figure 7. Energy demand with all effects considered as compared to the frozen efficiency [PJ/a] (source: own calculation).

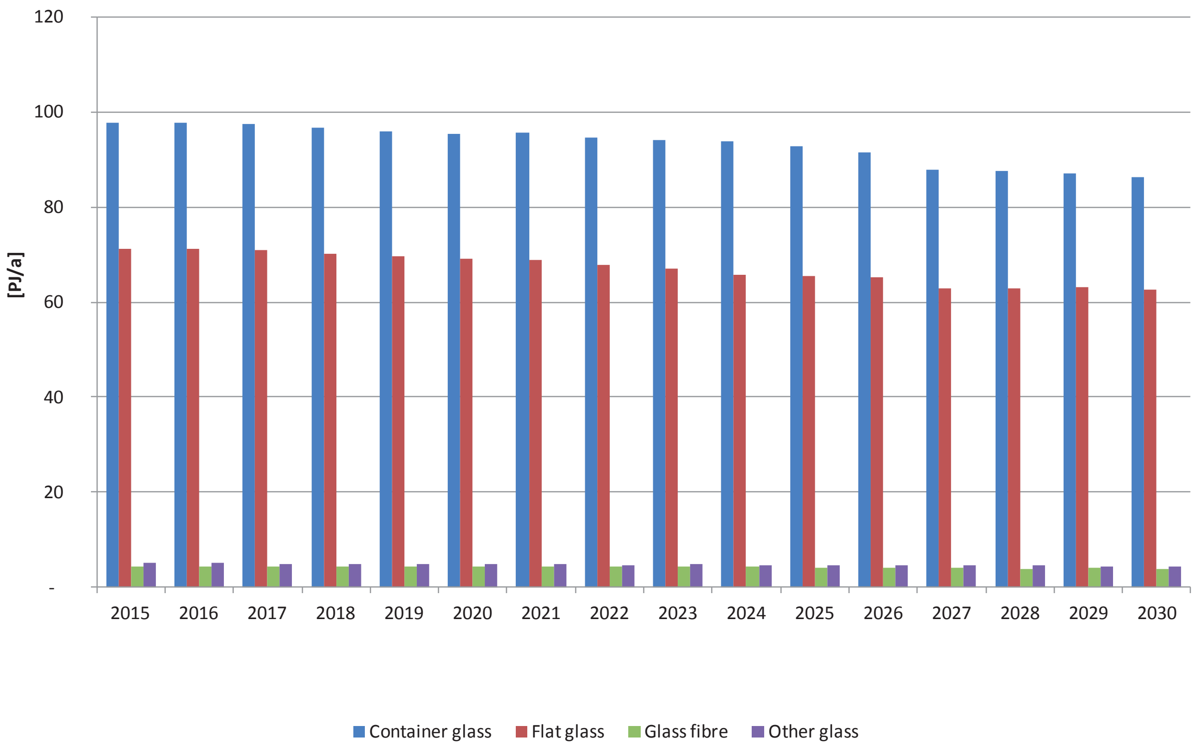

Figure 8. Development of total energy demand in different glass sectors with all effects considered [PJ/a] (source: own calculation).

Conclusions and outlook

The aim of this paper was to design and apply a model to determine the future impact of EEM for industrial furnace processes at the example of the European glass industry and to analyse its results. For this purpose, a detailed bottom-up model combining the information of individual plants with aggregated techno-economic information was designed and applied to various sectors of the European Class industry. With the model it is possible to estimate the current and future energy demand and the CO_2-emissions.

For the European glass industry the energy demand and the CO_2-emissions have been calculated using the developed model. The analysis of the modelling results indicate that the overall energy demand decreases by 12 % to 157 PJ/a in 2030 while production largely remains constant. With regard to the analysis of future energy demand, the impact of aging of glass furnaces has been found to be a very relevant factor when it comes to analysing the future energy demand. Its impact can easily off-set the effect of important energy efficiency options. Likewise, a broader use of cullet, where applicable could help to considerably contribute to the overall savings, as well.

Further assessments of other industrial furnaces would be useful to provide a more comprehensive picture on how the energy demand of all types of industrial furnaces in Europe. Sectors that could be assessed as well are for example the ceramics sectors or the production of ferrous and non-ferrous metal products. A considerable challenge is gathering stock data for setting up such models. For the European glass industry this proved to be a difficult task. It is expected that equal difficulties must be faced in other sectors.

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