GLASS INDUSTRY

SYNOPSIS SHEET

PREPARED IN THE FRAMEWORK OF EGTEI

1 Activity description and EGTEI contribution – summary

The sector of glass production includes the manufacturing of flat glass, container glass, and glass fibres, as well as the production of commodity glass (TV screen, lighting) and domestic glassware. The production of flat, container, fibre and commodity glass is dominated by large multinational companies, whereas the manufacture of table and decorative ware is mainly composed of small- and medium sized enterprises. Unlike the production of technical glass, domestic glass production is characterized by a great diversity of products and processes, including hand forming of glass. [1]
Manufacturing techniques vary from small electricity heated furnaces to cross-fired regenerative furnaces in the flat glass sector, producing up to 700 tonnes per day.
The total production of the glass industry within the EU in 1996 was estimated at 29 million tonnes, an indicative breakdown is given in the table below.

Table 1.1: Approximate sector based breakdown of glass industry production [2]

Sector	% of Total EU production (1996)
Container glass	60
Flat glass	22
Continuous filament glass fibre	1.8
Domestic glass	3.6
Special glass	5.8
Mineral wool	6.8

The major environmental challenges for the Glass Industry are emissions to air and energy consumption. Glass making is a high temperature, energy intensive activity, resulting in the emission of combustion products and the high temperature oxidation of atmospheric nitrogen, i.e. sulphur dioxide, carbon dioxide, and oxides of nitrogen. Furnace emissions also contain dust, which arises mainly from the volatilisation and subsequent condensation of volatile batch materials. It is estimated that in 1997 the Glass Industry emissions to air consisted of: 9000 tonnes of dust; 103500 tonnes of NO_x; 91500 tonnes of SO_x; and 22 million tonnes of CO_2 (including electrical generation). This amounted to around 0.7 % of total EU emissions. Total energy consumption by the Glass Industry was approximately 265 PJ. [2]

This sector was not considered as an individual sector in the previous NOx and SO_2 version of RAINS [3, 4], and **EGTEI has been able to develop an approach for representing this sector and to estimate costs of reduction techniques**. **The methodology for this sector was developed in close cooperation with the European Association of the Glass Industry ["COMITE PERMANENT DES INDUSTRIES DU VERRE" (CPIV)] and with experts from UBA Berlin, ADEME and SCHOTT GLASS.**

The representative unit used is the ton of glass melted (t of glass melted). Two reference installations (RI) have been defined depending on the fuel burned. The first uses natural gas and the second heavy fuel oil.
EGTEI defines different abatement measures. However, as for dust, the glass group of experts agreed that it would not be relevant to distinguish between bag filters and ESP. **Only one "deduster"** was defined. For NOx abatement measures, **a primary measure and a secondary measure** allowing to achieve different abatement emission levels have been defined. The SO_2 emissions are mainly depending on the concentration of sulphur in the raw material and in the fuel burned. That is why the expert group has defined **a dry scrubber** for the reference installation burning natural gas. For the other reference installation, **fuel switch and the use of a dry scrubber** are proposed.
EGTEI provides default emission factors (EF) with abatement efficiencies, investments and variable and fixed operating costs (OC) as well as unit costs (€/t pollutant abated and €/activity unit) for the different abatement measures.
National experts only need to collect **6 country specific parameters** (wages, electricity, ammonia price, catalyst cost, lime cost and extra cost of low sulfur fuel) and **6 country and sector specific parameters** (activity level, fuel consumption and the different pollutant emissions). EGTEI provides default costs for country and specific parameters which can be used if no better data exist. Knowing the 6 sector specific parameters then allows to properly describe the sector and to calculate the application rate of each abatement technique.

Recently, the specific glass sector “IN_GLASS” has been introduced in the new RAINS modules. In the future however, new technological developments should be considered by EGTEI to continuously update the background document and hence the representation of the glass sector.

2 Representation of the sector in RAINS[1]

In the RAINS model of the year 2003, which has been used for elaborating the background document, the RAINS sector “PR_GLASS” represented the production of glass in the PM module [5]. In the SO_2 and the NOx modules [3, 4], the glass production was aggregated in the RAINS sector “IN_OC”(Industry_Other Combustion).

3 Status of EGTEI

EGTEI has developed an approach for representing the glass sector and estimating costs of reduction techniques. The methodology used for this sector was developed in close cooperation with the European Association of the Glass Industry [“COMITE PERMANENT DES INDUSTRIES DU VERRE” (CPIV)] and with experts from UBA Berlin, ADEME and SCHOTT GLASS. The background document is available on the website of EGTEI : http://www.citepa.org/forums/egtei/egtei_doc-Proc-fer-n-fer.htm.

4 Methodology developed within EGTEI to represent the sector

4.1 Definition of reference installations

[General remark: The representation of the very heterogeneous glass sector is based on a significantly simplified approach (compromise) - for modelling purposes only. Data proposed for pollutant concentrations or emission factors or any other value are not supposed to be presented as regulatory or limit values.]

With regard to the economic assessment and the availability of data, the glass group proposes to simplify to a maximum extend and to use only **one** reference technology (melting furnace) for the whole glass sector.
For the development of the database software, two reference installations with different kinds of fuels have to be considered. The first uses natural gas and the second uses heavy fuel oil. Table 4.1 presents the RI considered.

Table 4.1: Reference Installations

Reference Code	Technique	Fuel	Capacity [t/d]	Lifetime [a]	Plant factor [h/a]
01	Average capacity installation	Natural gas	170	8	8,760
02	Average capacity installation	Heavy fuel oil	170	8	8,760

4.2 Definition of emission abatement techniques and proposed techno-economic data

4.2.1 Dust abatement techniques

For this specific pollutant, the glass group of experts agreed that it would not be relevant to distinguish between bag filters and electrostatic precipitators.

Table 4.2.1.1: Abatement Measures for dust

[1]The latest modified versions of the RAINS modules have not been considered. Here we refer to the RAINS model of the year 2003

Secondary Measure Code	Description	Lifetime (a)	Emission factor TSP (mg/Nm³)	Emission factor TSP (g/t of glass melted)	Emission factor PM10 (mg/Nm³)	Emission factor PM2.5 (mg/Nm³)
00	None	-	250	725	250	250
01	Deduster	10	10	29	10	10

Remark: the dust particles size is smaller than 2.5 µm.

Table 4.2.1.2: Investments and Operating costs for dust abatement

Description	Investment (k€)	Fixed Operating costs (%/a)	Variable Operating costs (€/t)	Total Operating costs (€/t)	Cost per tonne TSP abated (€/t)	Cost per tonne of glass melted (€/t)
None	-	-	-	-	-	-
Deduster	900	4	1.25	1.83	5,204	3.62

4.2.2 NOx abatement techniques

For NOx abatement measures, a primary measure and a secondary measure allowing to achieve different abatement emission levels have been defined.

Table 4.2.2.1: NOx abatement measures

Description	Efficiency (%)	Emission factor (mg/Nm³)	Emission factor (kg/t of glass)
None	-	2,800	8.12
Primary technologies	65	1,000	2.9
Primary + Secondary technologies	82	500	1.45

Table 4.2.2.2: Investments and Operating costs for NOx abatement measures

Description	Investment (k€)	Fixed Operating costs (%/a)	Variable Operating costs (€/t)	Total Operating costs (€/t)	Cost per tonne of NOx abated (€/t)	Cost per tonne of glass melted (€/t)
None	-	-	-	-	-	-
Primary technologies	330	4	0.15	0.36	218	1.15
Secondary technologies	525	4	1.06	1.2	1,879	2.72

4.2.3 SO_2 abatement techniques

The SO_2 emissions are mainly depending on the concentration of sulphur in the raw material and in the fuel burned.

Table 4.2.3.1: SO_2 abatement measures

Measure Code	Abatement technique	Efficiency (%)	Emission factor (mg/Nm³)	Emission factor (kg/t)
Reference Installation 01				
00	-	-	600	1.74
01	Dry scrubber 50%	50	300	0.87
Reference Installation 02				
00	-	-	4,200	12.2
01	Low Sulphur HF	57	1,800	5.2
02	Low Sulphur HF + Dry scrubber 20%	20	1,400	4.1

Table 4.2.3.2: Investments and Operating costs for SO_2 abatement measures

Description	Investment (k€)	Fixed Operating costs (%/a)	Variable Operating costs (€/t)	Total Operating costs (€/t)	Cost per tonne of SO_2 abated (€/t)	Cost per tonne of glass melted (€/t)
Reference Installation 01						
None	-	-	-	-	-	-
Dry scrubber 50%	300	4	0.414	0.607	1,384	1.2
Reference Installation 02						
None	-	-	-	-	-	-
Low Sulphur HF	0	0	X(1)	X(1)	X(1)	X(1)
Dry scrubber 20%	300	4	0.233	0.426	983	1.02

(1): depending on country specific data

5 Country specific data to be collected

Different types of country specific data have to be collected to give a clear picture of the situation in each Party. EGTEI proposes default values for the economic parameters which can be modified by the national expert if better data are available.
For the glass activity, country specific economic parameters are used to calculate variable operating costs. They are presented in table 5.1 as default costs proposed by EGTEI (these costs are entered only once in the ECODAT database tool).

Table 5.1: Country specific costs

Parameters	Default costs provided by EGTEI	Country specific costs
Electricity [€/kWh]	0.0569	To be provided by national experts
Wages [€/h]	37,234	To be provided by national experts
Ammonia price [€/t_{NH3}]	400	To be provided by national experts
Catalyst cost [k€/m³]	15	To be provided by national experts
Lime cost [€/t_{lime}]	100	To be provided by national experts
Extra cost of low S fuel [€/GJ/%S]	0.255	To be provided by national experts

Default data have been used to calculate variable and annual abatement costs presented in tables 4.2.1.2; 4.2.2.2, 4.2.3.2.
Information concerning activity levels from 2000 to 2020 as well as the description of the control strategy is also necessary (these data can be directly entered in the database ECODAT). A full specification of the work to be done by national experts is provided in the general EGTEI methodology.

In order to make collection of data as easy as possible, a methodology is described in the background document, based on the consumption of fuel [6].

Table 5.2: Fuel consumption for each RI and total amount of glass melted

PARAMETER	2000	2005	2010	2015	2020
Natural gas consumption in the whole glass sector [TJ]					
Heavy fuel oil consumption in the whole glass sector [TJ]					
Total quantity of glass melted in the whole glass sector [t]					

This data allows to calculate the activity level of each RI.
Table 5.3: Activity levels for Reference Installations (t glass melted / year)

RIC	2000	2005	2010	2015	2020

01					
02					
Total	Calculated automatically by the ECODAT tool				

Remark: for the glass industry, specific emission levels are in fact linked to the melting capacity. The production capacities and the melting capacities slightly differ, and a correction factor (F_c) needs to be used: 0.85 has been proposed by experts for this correction factor.

Table 5.4: Correction factor for the melting/production capacities

	Default data (mean)	**User input (mean)**
Fc	0.85	To be provided by national expert

National experts can also modify - in a range of ± 10% - the default unabated emission factor proposed by EGTEI to represent the reference situation of the glass industry for all Parties.

Table 5.5: Unabated emission factor [kg/ t glass melted]

Pollutants	**Default data mean**	**User input mean**
EF NO_x	8.12	To be provided by national expert
EF PM_{TSP}	0.725	To be provided by national expert
EF PM_{10}	0.725	To be provided by national expert
EF $PM_{2.5}$	0.725	To be provided by national expert
Reference installation 1		
EF SO_2	1.74	To be provided by national expert
Reference installation 2		
EF SO_2	12.2	To be provided by national expert

6 Application rate and applicability of each abatement technique

The national experts are kindly asked to provide for each abatement technique its application rate and its applicability in 2000, 2005, 2010, 2015, 2020. If a national expert has this information at hand, he can fill in the different tables described in paragraphs 6.1, 6,2 and 6.3.
If not, a methodology is described in the background document [6] and an Excel sheet can be downloaded from the website of EGTEI http://www.citepa.org/forums/egtei/egtei_doc-Proc-fer-n-fer.htm to help calculating the application rate.

Table 6: Input parameters needed to calculate application rates

PARAMETER	**2000**	**2005**	**2010**	**2015**	**2020**
Natural gas consumption in the whole glass sector [TJ]					
Heavy fuel oil consumption in the whole glass sector [TJ]					
Total quantity of glass produced in the whole glass sector [t]					
E_{NOx} Emission of NOx [t]					
E_{SOx} Emission of SO2 [t]					
E_{dust} Emission of Dust [t]					

6.1 Dust abatement measures

Table 6.1: Application rate and applicability for dust abatement measures

Description	Application rate in 2000 [%]	Application rate in 2005 [%]	Applicability [%]	Application rate in 2010 [%]	Applicability [%]	Application rate in 2015 [%]	Applicability [%]	Application rate 2020 [%]	Applicability [%]
None									
Deduster			100		100		100		100

6.2 NOx abatement measures

Table 6.2: Application rate and applicability for NO_x abatement measures

Description	Application rate in 2000 [%]	Application rate in 2005 [%]	Applicability [%]	Application rate in 2010 [%]	Applicability [%]	Application rate in 2015 [%]	Applicability [%]	Application rate in 2020 [%]	Applicability [%]
None									
Primary technologies			100		100		100		100
Secondary technologies			Dust application rate		Dust application rate		Dust application rate		Dust application rate

6.3 SO_2 abatement measures

Table 6.3: Application rate and applicability for SO_2 abatement measures

Description	Application rate in 2000 [%]	Application rate in 2005 [%]	Applicability [%]	Application rate in 2010 [%]	Applicability [%]	Application rate in 2015 [%]	Applicability [%]	Application rate in 2020 [%]	Applicability [%]
Reference installation 1									
None									
Dry scrubber 50 %			Dust application rate		Dust application rate		Dust application rate		Dust application rate
Reference installation 2									
None									
Low S heavy fuel			100		100		100		100
Dry scrubber 20 %			Dust application rate		Dust application rate		Dust application rate		Dust application rate

7 Relevance of EGTEI information for Integrated Assessment Modelling (IAM)

In the previous version of the NO_x and SO_2 RAINS modules [3, 4], the glass sector was not represented as a separate sector. It was considered as part of “Industry_Other Combustion”. Thus, emission factors, abatement techniques and costs considered were not specific to this sector and it was very difficult to define a reduction scenario. For this reason the sector was identified as a priority sector at the beginning of the EGTEI work.
EGTEI now provides an approach to specifically consider the glass sector. The approach has been developed in close cooperation with industry. The category “IN_GLASS” has now been introduced in the new RAINS modules. But before IIASA can start more structural adaptation of the modules, more complete sets of country specific data are required.

8 Perspective for the future

In the future, new production technologies which could gain relevant market shares should be considered by EGTEI in the background document to continuously develop the representation of the sector.

9 Bibliography

[1] Technical background documents for the actualisation and assessment of UN/ECE protocols related to the abatement of the transboundary Transport of nitrogen oxides from stationary sources, DFIU, 1999.

[2] Reference document on Best Available Techniques in the Glass Manufacturing Industry, IPPC, December 2001, http://eippcb.jrc.es/pages/FActivities.htm

[3] Nitrogen oxides emissions, abatement technologies and related cost for Europe in the RAINS model database, IIASA, 1998. http://www.iiasa.ac.at/~rains/reports/noxpap.pdf

[4] Sulfur emissions, abatement technologies and related cost for Europe in the RAINS model database, IIASA, 1998. http://www.iiasa.ac.at/~rains/reports/so2-1.pdf

[5] Modelling Particulate Emissions in Europe, A framework to Estimate Reduction Potential and Control Costs, IIASA, 2002. http://www.iiasa.ac.at/rains/reports/ir-02-076.pdf

[6] Background document on the sector of the glass industry prepared in the framework of EGTEI, http://www.citepa.org/forums/egtei/egtei_doc-Proc-fer-n-fer.htm

ANNEXE: Example of data collection and use of EGTEI data – Case of France

A. Country specific data collection and the scenario CLE developed

The French national expert has been able to complete ECODAT for the glass sector with the help of the European Glass Association (CPIV). This proves that the country specific representation of the glass sector following the EGTEI approach can be done with manageable effort.

Country and sector specific economic parameter

Country specific parameter costs have been defined from costs encountered in the medium size industry which are monthly published by official French statistic organizations.

Table A.1: French specific parameter costs

Parameters	French specific costs
Electricity [€/kWh]	0.0569
Wages [€/h]	37,234
Ammonia price [€/t_{NH3}]	400
Catalyst cost [k€/m³]	15
Lime cost [€/t_{lime}]	100
Extra cost of low S fuel [€/GJ/%S]	0.255

Activity level

The activity level can be introduced directly or be calculated on the basis of the energy consumption of each reference installation. The French expert has used the methodology described in the background document to determine the application rates and activity levels. For this determination, the calculation required some input information such as:

- E_{NOx}: Emission of NOx in the sector per year
- E_{dust}: Emission of Dust in the sector per year
- E_{SO2}: Emission of SO_2 in the sector per year
- Natural gas consumption in the whole sector
- Heavy fuel oil consumption in the whole sector
- Total quantity of glass produced in the whole glass sector

Table A.2: The 6 input parameters needed to calculate application rates and activities level in the case of France

PARAMETER	1990	1995	2000	2005	2010	2015	2020	2025	2030
Natural gas consumption in the whole glass sector [PJ]	21.95	23.01	26.83	28.96	29.21	30.68	30.93	31.17	31.40
Heavy fuel oil consumption in the whole glass sector [PJ]	18.88	22.90	18.66	19.31	19.47	18.41	18.56	18.70	18.84
Total quantity of glass produced in the whole glass sector [Mt]	4.98	5.49	6.00	6.50	6.67	6.83	7.00	7.18	7.36
E_{SOx} Emission of SO2 [t]	29.61	25.59	18.50						
E_{NOx} Emission of NOx [t]	21.12	17.25	14.71						
E_{dust} Emission of Dust [t]	3.47	2.46	2.31						

Knowing the fuel consumption (table A.2) and assuming that the specific energy consumption for gas and heavy fuel oil is the same, the activity level of each RI can be determined as presented in the following table:

Table A.3: Activity levels on Reference Installations (Mt of glass melted / year)

RIC	1990	1995	2000	2005	2010	2015	2020	2025	2030
Natural Gas	3.15	3.24	4.16	4.59	4.71	5.02	5.15	3.15	3.24

Heavy fuel oil	2.71	3.22	2.90	3.06	3.14	3.01	3.09	2.71	3.22
Total	5.86	6.46	7.06	7.65	7.85	8.04	8.24	5.86	6.46

Table A.4: Correction factor for the melting/production capacities

	Default data	French input
Fc	0.85	0.85

Unabated emission factor

Default emission factors are adapted to the French situation.

Table A.5: Unabated emission factor [kg/ t glass melted]

Pollutants	Default data (mean)	French input (mean)
EF NO_x	8.12	8.12
EF PM_{TSP}	0.725	0.725
EF PM_{10}	0.725	0.725
EF $PM_{2.5}$	0.725	0.725
Reference installation 1		
EF SO_2	1.74	1.74
Reference installation 2		
EF SO_2	12.2	12.2

Current legislation control scenario (CLE)

Knowing these different input parameters, with the help of the Excel sheet available on the website of EGTEI (http://www.citepa.org/forums/egtei/egtei_doc-Proc-fer-n-fer.htm), the application rate and the applicability of each abatement technique have been determined for the years 1990 until 2000.
For the years 2005 until 2020, the regulatory constraints have been taken into account. For the glass sector, it has been considered that from 2007 the national regulatory constraint will be implemented in France and that in 2015 all the French installation will have a deduster. Thus, it was possible to calculate the application rate in 2010 by making an extrapolation between the years 2005 and 2015, assuming that in 2005 the application rate was the same as in 2000.

Table A.6: Application rate for dust abatement measures (scenario CLE)

Description	Application rate in 1990 [%]	Application rate in 1995 [%]	Application rate in 2000 [%]	Application rate in 2005 [%]	Application rate in 2010 [%]	Application rate in 2015 [%]	Application rate 2020 [%]	Application rate 2025 [%]	Application rate 2030 [%]
None	80.89	50.57	42.89	42.89	21.44	0	0	0	0
Deduster	19.11	49.43	57.11	57.11	78.56	100	100	100	100

The same methodology has been used as for the determination of the application of the deduster. In the case of NOx, with application of the regulatory constraints, the application rate in 2015 achieves 40% for Primary measure and 60% for Secondary measures.

Table A.8: Application rate for NO_x abatement measures (scenario CLE)

Description	Application rate in 1990 [%]	Application rate in 1995 [%]	Application rate in 2000 [%]	Application rate in 2005 [%]	Application rate in 2010 [%]	Application rate in 2015 [%]	Application rate 2020 [%]	Application rate 2025 [%]	Application rate 2030 [%]
None	13.51	0	0	0	0	0	0	0	0
Primary technologies	86.49	84.27	43.72	43.72	40	40	40	40	40
Primary technologies + Secondary technologies	0	15.73	56.28	56.28	60	60	60	60	60

The same methodology has been used as for the determination of the application of the deduster. It is important to note the dry scrubbing requires the implementation of a deducting process and then the application rate of the dry scrubber for the installation burning gaseous fuel can be derived from those of the deduster.

Table A.10: Application rate for SO_2 abatement measures (scenario CLE)

Description	Application rate in 1990 [%]	Application rate in 1995 [%]	Application rate in 2000 [%]	Application rate in 2005 [%]	Application rate in 2010 [%]	Application rate in 2015 [%]	Application rate 2020 [%]	Application rate 2025 [%]	Application rate 2030 [%]
Reference installation 1									
None	80.89	50.57	42.89	42.89	21.44	0	0	0	0
Dry scrubber 50 %	19.11	49.43	57.11	57.11	78.56	100	100	100	100
Reference installation 2									
None	55.46	20.40	0	0	0	0	0	0	0
Low S heavy fuel	44.34	79.60	45.96	42.89	21.44	0.00	0.00	0.00	0.00
Low S heavy fuel + Dry scrubber 20 %	0	0	54.04	57.11	78.56	100	100	100	100

B. Trends in emissions and total costs for the CLE scenario

Data shown in the table below are directly provided by ECODAT and based on input parameters defined in chapter A.
Table B.1 presents NOx. SO_2 and TSP emissions from 1990 to 2030 for the CLE scenario.

Table B.1: Trends in emissions in the CLE scenario

	1990	1995	2000	2005	2010	2015	2020	2025	2030
CLE scenario									
SO_2 emission (t)	29.61	25.59	18.50	19.70	18.67	16.73	17.15	17.58	18.02
NOx emission (t)	21.12	17.25	14.71	15.96	15.93	16.33	16.74	17.16	17.59
TSP emission (t)	3.47	2.46	2.31	2.51	1.40	0.23	0.24	0.24	0.25

Table B.2: Annual cost of emission reductions obtained with CLE scenario [kEuros/y]

	1990	1995	2000	2005	2010	2015	2020	2025	2030
CLE scenario									
SO_2 reduction measures	5,709	12,501	14,721	15,650	17,090	17,885	18,357	14,706	16,960
NOx reduction measures	4,967	8,780	16,495	17,873	19,044	19,505	19,990	14,216	15,672
TSP reduction measures	3,449	9,835	12,418	13,456	18,994	24,763	25,379	18,049	19,897

Source: **RAINS PM Web** tool (http://www.iiasa.ac.at/~rains/cgi-bin/rains_pm)