Final Background Document

on the sector

Glass Industry

Prepared in the framework of EGTEI

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Combustion in the Glass industry

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 technical glass production, domestic glass production is characterized by a great diversity of products and processes, including hand forming of glass. [2]

Manufacturing techniques vary from small electricity heated furnaces in the ceramic fibre sector 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 (excluding ceramic fibres and frits), an indicative breakdown is given in the table below.

Table 0.1: Approximate sector based breakdown of glass industry production [1]

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 products of combustion 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. [1]

1 General information

1.1 Introduction

SNAP CODE: 03 03 14/15/16/17 - **NFR**: 3c
Sector activity unit: tonne of glass melted

Table 1.1: relevant pollutants in the sector

SO_2	NO_x	PM	VOC	NH_3
x	x	x	-	-

1.2 Data currently used in the RAINS model

At its present stage of development, the RAINS sector “PR_GLASS” represents the production of glass in the PM module. In the SO_2 and the NOx module, the glass production is aggregated in the RAINS sector “IN_OC”(Industry_Other Combustion). But in future, the RAINS sector “IN_GLASS” will be added to the SO_2 and NOx modules (as done in the PM module). [3, 4]

1.2.1 Control options for PM

Table 1.2: Unabated emission factors used in the RAINS model for glass production [kg/t glass produced] This table is not correct the dust emissions or concentrations for the glass industry reference installation are much smaller. **Total dust emission is about 0,4 kg/ton molten glas**

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Sector	RAINS Code	Unit	$PM_{2.5}$	Coarse[(1)]	PM_{10}	$>PM_{10}$	TSP
Glass production	PR_GLASS	[kg/t glass produced]	2.96	0.13	3.09	0.16	3.25
Glass production	*PR_GLASS*	*[kg/t glass melted]*(2)	*2.52*	*0.11*	*2.63*	*0.14*	*2.76*

(1): coarse particles: (> 2.5 and < 10 microns)

(2) : for a correction factor between the melted and produced capacity of 0.85.This line was introduced by EGTEI in order to relate to capacity of melted glass as in the whole document .

The RAINS model includes several end-of-pipe control options for the glass industry, particularly fabric filters and electrostatic precipitators. [4]

Table 1.3: Applied emission abatement techniques for PM in the RAINS model

Abatement technique	Unit	Emission factor for PM2.5	Emission factor for PM10	Emission factor for TSP
No control	g/t	2957	3087	3250
Cyclone	g/t	2070	2109	2125
ESP1 (1field)	g/t	207	213.7	218.4
ESP2 (2 fields)	g/t	118.3	119.5	119.6

ESP3P (3 fields and more)	g/t	29.57	29.64	29.90
Fabric filter	g/t	29.57	29.64	29.57

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

1.2.2 Activities for some countries

The baseline for the EU-15 energy pathway is the PRIMES model.

Table 1.4: Activity for some countries of the EU-15 (Mt of glass produced)

Country	**1990**	**1995**	**2000**	**2005**	**2010**
Belgium	0.75	0.76	0.75	0.71	0.74
France	3.95	4.21	4.49	4.85	5.39
Italy	3.32	3.95	4.22	4.45	4.90
Germany New Länder	1.53	1.97	2.05	2.29	2.46
Germany Old Länder	3.57	4.59	4.77	5.33	5.73
Spain	1.65	1.82	2.20	2.12	2.52
United Kingdom	2.67	2.96	2.55	2.69	3.31
…					

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

2 Definition of reference installation/process

[General remark: The representation of the very heterogeneous glass sector is based on a significantly simplified approach (compromise) - for modeling 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 installation (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. This only means that it is necessary to know the consumption of each kind of fuel in order to obtain the breakdown of each reference installation versus the quantity of fuel consumed.

Considering statistics of the BREF document on glass, the melting capacity of the reference furnace (C_{ref}) could be defined in the following way:

$$\boxed{C_{ref} = (\text{Sector production at the EU level / number of furnaces}) \cdot (1/F_c)}$$

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 could be a relevant order of magnitude for this correction factor (expert estimate).

Table 2.1: Estimate of EU furnace types in 1997

Type of furnace	**Number of units**	**Melting capacity (t/y)**	**Average melting capacity (t/d)**
End-fired	265	13 100 000	135
Cross-fired	170	15 300 000	250
Oxygen	30	1 200 000	110
Total	**465**	**29 600 000**	**170**

Source: [1].

Many of the sectors within the Glass Industry utilise large continuous furnaces with **lifetimes** up to **eight years**.

Table 2.2: Reference installations

Reference Code	**Technique**	**Fuel**	**Capacity [t/d]**	**Lifetime [a]**	**Operational hours per year [h/a]**
01	Average installation	Natural gas	170	8	8760
02	Average installation	Heavy fuel oil	170	8	8760

Remark on the relationship between pollutant concentration (C) in mg/Nm^3 and pollutant emission expressed in specific mass flow (F_s) in kg per tonne of glass produced.

A conversion factor F_{conv} needs to be introduced:

$$\boxed{C \times F_{conv} = F_S}$$

For the glass industry, the different concentrations are expressed for a reference oxygen content of 8% and dry gases in the whole document.

Each furnace (type) has a specific conversion factor, but an average conversion factor for the whole glass industry is proposed by the glass group. For the determination of F_{conv}, we weigh the conversion factor [from mg/Nm³ to kg/t of glass melted] for each sector of glass with the percentage of total EU production (1996):

Sector	Share of total EU production (1996)*	Conversion factors (10^{-3})**	Weighed conv. factor (10^{-3})
Flat glass	0.22	**3.5**	(0.22 · 2.5=) 0.55
Container glass	0.6	**2.25**	1.5
Continous filament glass fibre	0.018	4.5	0.081
Domestic glass	0.036	**3.5-4**	0.09
Special glass	0.058	??	0.1595
Mineral wool	0.068	2	0.136
Total glass			**2.5165**

*Source: BREF document on the Glass manufacturing sector (October 2000) Conversion factors are not correct comparing float with container glass, **the BREF is not correct in these values!**

**Expert estimate

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The BREF document mainly considers high level technology; therefore, to be more realistic with regard to the actual park of plants, the value is increased by 15%:

$F_{conv} = 2.52 \cdot 10^{-3} \cdot 1.15 = 2.9 \cdot 10^{-3}$

3 Dust emission

For this specific pollutant, the glass group of experts agreed that it would not be relevant to distinguish between bag filters and electrostatic precipitators.
In addition, the group has decided to propose emission levels which should be considered in the database:

An uncontrolled emission level (expert estimate):
Current proposal concerning concentration range: around 200 - 250 mg / $Nm^3 = C_{uncdust}$

chosen concentration: 250 mg/Nm³

Emission level after dedusting according to a common efficiency for bag filters and electrostatic precipitators (efficiency of 96%;expert estimate)
Current proposal concerning concentration range: around 5 - 30 mg / Nm^3

chosen concentration: 10 mg/Nm³

Table 3.1: Abatement Measures for dust

Primary Measure Code	Description	Lifetime (a)	Emission factor (mg/Nm³)	Emission factor (g/t of glass melted)
00	None		250	725
01	Deduster	10	10	29

Table 3.2: Investments and Operating costs

Measure Code	Description	Efficiency[(1)](%)	Investment (k€)	Fixed Operating costs (%/a)	Variable Operating costs (k€/t/a)
00	None		0	0	0
01	Deduster (ESP or bag filter)	96	900	4	See table 3.4

[(1)] theoretical efficiency, because in order to protect the filter it is necessary to additionally inject an absorbent which is captured by the filter, thus, real efficiency is even higher (around 99 %).

- ✓ **Investments**

To determine the investment of the deduster, an average between investment of ESP or bag filter is taken into account.
It turns out to be difficult to find information on investments, that is why the cost data from the BREF document is taken in this case.

The table below shows indicative capital and operating costs for ESP for varying sizes of furnaces and exhaust gas, including acid gas scrubbing. The figures given may vary by plus or minus 15 % for capital costs and 30 % for operating costs, depending on a number of site-specific factors. For installations that do not require acid gas scrubbing the capital costs will be approximately 30 % lower and operating costs 30 - 40 % lower [1]. But to protect the filter it is necessary to inject an absorbent which is captured by the filter.

Instead of this lesser measure, a reaction tower can sometimes be used.

Table 3.3: Cost of ESP with acid gas scrubbing [1]

Size tonnes/day	Gas volume flow Nm³/h	Capital cost (x1000) Euro
50 t/d Container	6,400	565
100 t/d Container	11,120	875
300 t/d Container	23,000	1,420

Determination of the gas volume flow V_{gas} for the reference installation:
$V_{gas} = F_{conv} \cdot 10^6 \cdot (\text{Capacity})$
$= 2.9 \cdot 10^{-3} \cdot 10^6 \cdot (170/24)$
$= 20{,}500$ Nm³/h

Thus, following the values from table 0.8 and a respective linear regression (Capital cost = $50 \cdot V_{gas} + 270{,}000$), the investment for an ESP with acid gas scrubbing is around 1,300,000 Euro. Considering that for installations that do not require acid gas scrubbing, the capital costs will be approximately 30 % lower, the investment for an ESP is around **900,000 Euro**.

For **bag filters**, in general, investment costs are lower than for electrostatic precipitators but operating costs are higher. However, as competition in the abatement equipment industry increases the costs of bag filters and ESPs are getting closer particularly for large gas volume flow.

Thus, the investment of the reference deduster is assumed to be around 900,000 Euro.

- ✓ **Variable Operating costs**

Variable Operating costs are defined as the costs depending on the level of production. Parameters for variable operating costs depend on the type of measure (technology) installed.

In general, the number of electrostatic precipitators used in the glass industry is much larger than for bag filters and therefore, to determine the operating cost of the deduster, **the operating cost of ESP** are taken.

The following paragraph shows the common parameters and prices needed for the calculation of the variable costs.

Electricity cost $\lambda^e \cdot c^e \cdot 10^{-3}$ [k€/**t**]

- λ^e: additional electricity demand (= new total consumption – old total consumption) [kWh/**t**]
- c^e: electricity price [€/kWh]

In France, the share of the electricity cost for the dedusting in the cost of the glass production is around 6 Francs per tonne of glass melted. [11]

Thus, $\lambda^e \cdot c^e \cdot 10^3 = 6/6.56 \cdot 10^{-3}$

$\lambda^e = 6\cdot10^{-6}/6.56/0.0569$
$= 16.1$ kWh/**t**

$c^e = 0.0569$ €/kWh (value for France)
$\lambda^e = 16.1$ kWh/**t**

Labour cost $\lambda^l \cdot c^l$ [k€/**t**]

- λ^l: labour demand [person-year/**t**]
- c^l: wages [k€/ person-year]

The average number of personnel for the deduster *and* the desulphurisation plant is around 0.75 person/year. [11]

Thus, the annual personnel costs attributed to the deduster are:

$AC_{PERS} = 0.75\cdot c^l\cdot I_{deduster} /(I_{deduster}+I_{desulphurisation})$

Thus $\lambda^l = 0.75$/Capacity ·900,000/(900,000+300,000)
$= 9.07\cdot10^{-6}$ person-year/**t**

$c^l = 37.234$ k€/ person-year (value for France)
$\lambda^l = 9.07\cdot10^{-6}$ person-year/**t**

Dust disposal cost $\lambda^d \cdot c^d \cdot ef_{unabated} \cdot \eta / 10^3$ [k€/**t**]

- $ef_{unabated}$: unabated emission factor of pollutant [t pollutant/**t**]
- λ^d: waste by-product disposal [t/ t pollutant removed]
- c^d: specific dust disposal cost [€/t]
- η: removal efficiency (= 1 - $ef_{abated}/ef_{unabated}$)

For the considered techniques and efficiencies, there is **no waste by-product disposal** accounted for. This is not correct, several furnaces have to dispose there filtered dust and have to pay high amounts for disposal (Euro 150,- to 600,- per ton ,depending of way of disposal).

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$\lambda^d = 0$ t/ t TSP removed

Table 3.4: Parameters needed to calculate variable Operating costs for primary deduster

	$ef_{unabated}$ [t Dust/t]	η	λ^d [t/t dust removed]	λ^e [kWh/t]	c^e [€/kWh]	λ^l [person-year /t]	c^l [k€/person-year]	**Variable Operating costs** (€/t)
Deduster	$725\cdot10^{-6}$	96	0	16.1	0.0569	$9.07\cdot10^{-6}$	37.234	**1.25**

4 NOx emission

According to a similar approach as for PM, the expert group discussed several emission levels which should be considered in the database:

An uncontrolled emission level (expert estimate):
Current proposal concerning concentration: around 2800 mg / Nm^3

An average emission level using primary measures (expert estimate):
Current proposal concerning concentration: 600 - 1400 mg / Nm^3

average concentration: 1000 mg/Nm^3

An average emission level using in addition secondary measures (SCR, SNCR), or techniques like oxy-firing or Reburning (expert estimate):
Current proposal concerning concentration: 500 mg / Nm^3

Comment: with additional measures (SNCR + oxyfiring or SCR), it is possible to reach lower concentrations (concentration: 250 mg/Nm^3 this would be a world record and not all furnaces equipped with oxy-firing or SCR/SNCR can always operate at world record conditions!). No: **maybe 350 – 400 mg/Nm^3**

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Table 4.1: Abatement Measures for NO_x

Measure Code	**Description**	**Efficiency (%)**	**Emission factor (mg/Nm³)**	**Emission factor (kg/t of glass)**
00	None	-	2800	8.12
01	Primary technologies	65	1000	2.9
02	Primary + Secondary technologies	82	500	1.45

Table 4.2: Investments and Operating costs

Description	**Lifetime (a)**	**Investment (k€)**	**Fixed Operating costs** (%/a)*	**Variable Operating costs** (k€/t)
None		0	0	0
Primary technologies	8	330	4	See chapter 4.1
Secondary technologies	10	**650**	4	See table 4.9

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*: The fixed Operating costs only depend on the capacity – or size - of the installation, i.e. on the investment, and they are expressed as a **percentage of the plant investment** [%/a]. Investment costs for secondary technologies is too low, monitoring & piping costs to be included.

Variable Operating costs are defined as the costs depending on the level of production. Parameters for variable operating costs depend on the type of measure (technology) installed. The following tables show the common parameters and prices needed for the calculation of the variable costs and the investments.

4.1 Costs for primary technologies

- ✓ **Investments**

Table 4.3: Investments induced by combustion modification in the glass manufacturing sector [10]

Production Capacity [Mg/d]	Investment [€]
600	920,000
350	540,000
50	230,000

For a Production capacity of 145 Mg/d (melting capacity·Fc = 170 Mg/d ·0.85), the investment is around **330,000 Euro**, following the values from Table 0.12 and a linear regression (Investment =1240·Production capacity +150,000).

✓ **Variable Operating costs**

Labour cost $\lambda^1 \cdot c^1$ [k€/**t**]

- λ^1: labour demand [person-year/**t**]
- c^1: wages [k€/ person-year]

The number of additional personnel for the primary measure unit is taken here as 0.25 [11]

Thus, the annual personnel costs are:

$AC_{PERS} = 0.25 \cdot c^1$

Thus λ^1 = (0.25)/ Capacity

= 0.25/(170·365)

= $4.03 \cdot 10^{-6}$ person-year/**t**

$\lambda^1 = 4.03 \cdot 10^{-6}$ person-year/**t**
c^1 = 37.234 k€/ person-year (value for France)

4.2 Costs for secondary technologies

✓ **Investments**

To determine the investments of secondary technologies, the SCR and SNCR technologies are chosen. An average between them is taken into account for characterizing the investment of the secondary measure.

Table 4.4: Investments for the SNCR process at a glass production plant [1]

Production Capacity [Mg/d]	Investment [€]
50	190,000
100	280,000
300	450,000

For a production capacity of 145 Mg/d, the investment is around **300,000 Euro**, according to the values from the Table 0.13 and a linear regression (Investment = 985·Production capacity +160,000).

Table 4.5: Investments for the SCR process at a glass production plant [1]

Production Capacity [Mg/d]	**Investment [€]**
50	430,000
100	615,000
300	1,000,000

For a production capacity of 145 Mg/d, the investment for a SCR is around 670,000 Euro, according to the values from the Table 0.14 and a linear regression (Investment = 2,200·Production capacity +350,000). **Is this with the required monitoring of NOx and NH3 concentrations? Then you should add 75,000 EURO extra!**

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Considering that **the catalyst cost** is taking into account in the variable Operating cost and that its investment is around **120,000 Euro** (see the calculation in the paragraph "Catalyst replacement cost" for the SCR in the chapter "Variable Operating cost"), **the investment for the SCR** without catalyst is around **550,000 Euro**.

✓ Variable Operating costs

In this case, to determine the operating cost, the SNCR and SCR technologies are considered. The different costs are the following:

SNCR

Electricity cost $\lambda^e \cdot c^e / 10^{-3}$ [k€/**t**]

- λ^e: additional electricity demand (=new total consumption – old total consumption) [kWh/**t**]
- c^e: electricity price [€/kWh]

λ^e = 5 kWh/**t** [12]
c^e = 0.0569 €/kWh (value for France)

Ammonia cost $\lambda^s \cdot c^s \cdot ef_{unabated} \cdot \eta / 10^3$ [k€/**t**]

- $ef_{unabated}$: unabated emission factor of pollutant [t pollutant/t]
- λ^s: specific sorbents demand (e.g. NH_3) [t_{NH3}/t pollutant removed]
- c^s: sorbents price [€/tonne]
- η: removal efficiency (= $1 - ef_{abated}/ef_{unabated}$)

$\lambda^s = \lambda^m \cdot \lambda^M$
with:
λ^m: NH_3/NOx (mol/mol) ratio
λ^M: NH_3/NOx (mol weight/mol weight) ratio

$\lambda^s = 3 \cdot (17/46)$
$= 1.11$

$ef_{unabated} = 8.12\ t_{NOx}/t$
$\lambda^s = 1.11\ t_{NH3}/t\ NO_x$ removed
$c^s = 400$ €/t_{NH3} (ammonia pur)
$\eta = 50$ %

Labour cost $\lambda^l \cdot c^l$ [k€/**t**]

- λ^l: labour demand [person-year/**t**]
- c^l: wages [k€/ person-year]

The number of additional personnel for the SCR unit is taken here as 0.25 [11]

Thus, the annual personnel costs for the SCR process are:

$AC_{PERS} = 0.25 \cdot c^l$

Thus $\lambda^l = (0.25)/ \text{Capacity}$

$= 0.25/(170 \cdot 365)$

$= 4.03 \cdot 10^{-6}$ person -year/**t**

$\lambda^l = 4.03 \cdot 10^{-6}$ person-year/**t**
$c^l = 37.234$ k€/ person-year (value for France)

Table 4.6: Parameters needed to calculate variable Operating costs for SNCR

	$ef_{unabated}$ [t NOx/t]	η	**λ^s [t/t NOx removed]**	**c^s [€/t]**	**λ^e [kWh/t]**	**c^e [€/kWh]**	**λ^l [person-year/t]**	**c^l [k€/person-year]**	**Variable Operating costs** (€/t)
SNCR	$2.9 \cdot 10^{-3}$	50	1.11	400	5	0.0569	$4.03 \cdot 10^{-6}$	37.234	**1.08**

SCR

Electricity cost $\lambda^e \cdot c^e / 10^{-3}$ [k€/**t**]

- λ^e: additional electricity demand (= new total consumption – old total consumption) [kWh/**t**]
- c^e: electricity price [€/kWh]

$\lambda^e = 5$ kWh/**t** [12]
$c^e = 0.0569$ €/kWh (value for France)

Ammonia cost $\lambda^s \cdot c^s \cdot ef_{unabated} \cdot \eta / 10^3$ [k€/**t**]

- $ef_{unabated:}$ unabated emission factor of pollutant [t pollutant/t]
- λ^s: specific sorbents demand (e.g. NH_3) [t_{NH3}/t pollutant removed]
- c^s: sorbents price [€/tonne]
- η: removal efficiency (= 1 - $ef_{abated}/ef_{unabated}$)

with: $\lambda^s = \lambda^m \cdot \lambda^M$
λ^m: NH_3/NO_x (mol/mol) ratio
λ^M: NH_3/NO_x (mol weight/mol weight) ratio

$\lambda^s = 1.05 \cdot (17/46)$
$= 0.39$

$ef_{unabated} = 8.12$ t_{NOx}/t
$\lambda^s = 0.39$ t_{NH3}/t NO_x removed

c^s = 400 €/t_{NH3} (ammonia pur)
η = 50 %

Catalyst replacement cost ($\lambda^{cat} \cdot ci^{cat} \cdot pf / lt^{cat}$) [k€/**t**]

- λ^{cat}: catalyst volume (per unit of installed capacity) [m^3/**t**]
- ci^{cat}: unit costs of catalysts [k€/m^3]
- lt^{cat}: life time of catalyst [10^3 hrs]
- pf: operational hours per year [10^3 hrs]

For a gas volume flow of 50,000 Nm³/h, the catalyst volume is around 20 m³ in the Euroglas plant at Hombourg/France. [13]
Thus, for a gas volume flow of 20,500 Nm³/h (calculated for the reference installation in the chapter 0.4), λ^{cat} is around 8.2 m^3 of glass melted.

ci^{cat} = 15 k€/m^3 for glass plant
$\lambda^{cat} = 1.32 \cdot 10^{-4}$ m^3/**t**
lt^{cat} = 5 years = $43.8 \cdot 10^3$ hrs
pf= 8760 h

The investment for the catalyst I_{cat} is:
$I_{cat} = \lambda^{cat} \cdot ci^{cat} \cdot$capacity
$= 8.2 \cdot 15 \cdot 170 \cdot 365$
= 120,000 Euro

Labour cost $\lambda^l \cdot c^l$ [k€/**t**]

- λ^l: labour demand [person-year/**t**]
- c^l: wages [k€/ person-year]

The number of additional personnel for the SCR unit is taken here as 0.25. [11]

Thus, the annual personnel costs for the SCR process are:

$AC_{PERS} = 0.25 \cdot c^l$

Thus λ^l = (0.25)/ Capacity

$= 0.25/(170 \cdot 365)$

$= 4.03 \cdot 10^{-6}$ person-year/**t**

$\lambda^l = 4.03 \cdot 10^{-6}$ person-year/**t**
c^l = 37.234 k€/ person-year (value for France)

Table 4.7: Parameters needed to calculate variable Operating costs for SCR

$ef_{unabated}$ [t NOx/t]	η	λ^s [t/t NO_X removed]	c^s [€/t]	λ^e [kWh/t]	c^e [€/kWh]	λ^l [person-year/t]	c^l [k€/person-year]	λ^{cat} [m³/t]	ci^{cat} [k€/m^3]	lt^{cat} [10^3 hrs]	Variable Operating costs (€/t)
$2.9 \cdot 10^{-3}$	50	0.39	400	5	0.0569	$4.03 \cdot 10^{-6}$	37.234	$1.32 \cdot 10^{-4}$	15	43.8	**1.06**

✓ **Conclusion**

In the glass industry, the costs are closer to the costs of the SCR process. To obtain the cost of the secondary measures, the following shares are taken into account:
90 % of SCR
10 % of SNCR.
According to this repartition, the different costs of the NO_x secondary measures are the following:

Table 4.8: Investments and Operating costs of the secondary measures

Description	**Lifetime (a)**	**Investment (k€)**	**Fixed Operating costs** (%/a)	**Variable Operating costs** (€/t)
None		0	0	0
Secondary technology	10	525	4	1.06

Table 4.9: Parameters needed to calculate variable Operating costs for secondary measure

$ef_{unabated}$ [t NO_X/t]	η	**λ^s [t/t NO_X removed]**	**c^s [€/t]**	**λ^e [kWh/t]**	**c^e [€/kWh]**	**λ^l [person-year/t]**	**c^l [k€/person-year]**	**λ^{cat} [m³/t]**	**ci^{cat} [k€/m³]**	**lt^{cat} [10^3 hrs]**
$2.9 \cdot 10^{-3}$	50	0.46	400	5	0.0569	$4.03 \cdot 10^{-6}$	37.234	$1.19 \cdot 10^{-4}$	15	43.8

How is oxy-firing accounted for (investment & operating costs??
Extra costs (interest and writing off of investment & operational & oxygen compared to air firing), is roughly 5 to 10 euro per tonne glass. The investment & operational costs can be very diverse depending on glass type, existing situation (new or existing plant), etc.

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5 SO_2 emission

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

The expert group on glass has proposed a methodology to handle this pollutant:

5.1 Gas firing

The expert group has discussed several emission levels which should be considered in the database:

An uncontrolled emission level (expert estimate):
Current proposal concerning concentration range: around 500 - 600 mg / Nm^3.
Chosen concentration: 600 mg / Nm^3 (Is higher for float glass furnaces!!)
For float glass furnaces (natural gas fired) : 750-1000 mg/Nm^3. This emission originates from the sulphate in the batch.
For oil fired float glass furnace: (750-1000) + 1200 mg SO_2 /Nm^3 per 1 % sulphur in fuel oil.
For container glass furnaces (natural gas fired): 400-600 mg SO_2/Nm^3
Remark: The complete recycling of filter dust, including the sulphated waste, is often considered to be a reasonable environmental and economic option, where it is technically

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possible. With closed loop filter dust recycling, the SO_2 uncontrolled emission levels observed today, are generally significantly higher than the mentioned 600 mg/Nm³ for natural gas firing . [1]

An average emission level taking into account for a dry scrubbing an abatement rate of 50% (expert estimate):
Current proposal concerning concentration range: around 300 - 400 mg / Nm^3
Chosen concentration: 300 mg / Nm^3 (Is probably too low for float glass)

Mis en forme

Table 5.1: Abatement Measures for SO_2

Measure Code	Abatement technique	Emission factor (mg/Nm³)	Emission factor (kg/t)
00	-	600	1.74
01	Dry scrubber 50%	300	0.87

Table 5.2: Investments and variable Operating costs

Measure Code	Description	Removal efficiency (%)	Lifetime (a)	Investment (k€)	Fixed Operating costs (%/a)*	Variable Operating costs (k€/t/a)
00	None	-	-	0	0	0
01	Dry scrubber	50	10	300	4	See table 5.3

*: The fixed Operating costs only depend on the capacity – or size - of the installation, i.e. on the investment, and they are expressed as a **percentage of the plant investment** [%/a]

✓ **Investments**

It is difficult to find information on the investment of this technique. In the BREF document [1], the costs for scrubber systems in combination with ESPs are given (see Table 5.9: Cost of ESP with acid gas scrubbing)

The investment for an ESP is around 900,000 Euro (1,300,000 with acid gas scrubbing). Thus a dry scrubber costs around 400,000 Euro. But following some experts estimates [11], the **investment for a dry scrubber** rather is around **300,000 Euro**.

✓ **Variable Operating costs**

The different costs for the dry scrubber are the following:

Lime cost: $\lambda^s \cdot c^s \cdot ef_{unabated} \cdot \eta / 10^3$ [k€/**t**]

- $ef_{unabated}$: unabated emission factor of pollutant [t pollutant/**t**]
- λ^s: specific lime demand (e.g. NH_3) [t/t pollutant removed]
- c^s: lime price [€/t]
- η: removal efficiency (= 1 - $ef_{abated}/ef_{unabated}$)

with: $\lambda^s = \lambda^m \cdot \lambda^M$
λ^m: Ca/S (mol/mol) ratio
λ^M: $Ca(OH)_2/SO_2$ (mol weight/mol weight) ratio

$\lambda^s = 3 \cdot (74/64)$
$= 3.47\ t/t_{SO2\ removed}$

$ef_{unabated} = 1.74 \cdot 10^{-3}\ t_{SO2}/\mathbf{t}$
$\eta = 50\ \%$
$\lambda^s = 3.47\ t/t_{SO2\ removed}$ (with Ca/S (mol/mol) ratio = 3)
$c^s = 100$ €/t (value for France)

Waste disposal cost $\lambda^d \cdot c^d \cdot ef_{unabated} \cdot \eta / 10^3$ [k€/**t**]

- $ef_{unabated}$: unabated emission factor of pollutant [t pollutant/**t**]
- λ^d: demand for waste disposal [t/ t pollutant removed]
- c^d: specific waste disposal cost [€/t]
- η: removal efficiency (= 1 - $ef_{abated}/ef_{unabated}$)

For the considered technique and efficiency, there is **no waste by-product disposal.** This is not realistic, many glass furnaces cannot recycle the filter dust and have to taker disposal costs into account.
Depending on way of external disposal (recuperation/recycling or landfill) EURO 150,- to 600,- per ton

Mis en forme
Mis en forme

$\lambda^d = 0$ t/ t TSP removed

Labour cost $\lambda^l \cdot c^l$ [k€/**t**]

- λ^l: labour demand [person-year/t]
- c^l: wages [k€/ person-year]

The average number of personnel for the deduster *and* the desulphurisation plant is around 0.75 person/year. [11]

Thus, the annual personnel costs for the dry scrubber are:

$AC_{PERS} = 0.75 \cdot c^l \cdot I_{desulphurisation} / (I_{deduster} + I_{desulphurisation})$

Thus $\lambda^l = 0.75/\text{Capacity} \cdot 300{,}000/(900{,}000+300{,}000)$
$= 3.02 \cdot 10^{-6}$ person-year/**t**

$c^l = 37.234$ k€/ person-year (value for France)
$\lambda^l = 3.02 \cdot 10^{-6}$ person-year/**t**

Table 5.3: Parameters needed to calculate variable Operating costs for dry scrubber 50%

	$ef_{unabated}$ [t SO_2/t]	η	**λ^s [t/t SO_2 removed]**	**c^s [€/t]**	**λ^d [t/t SO_2 removed]**	**λ^l [person - year/t]**	**c^l [k€/ person - year]**	**Variable Operating costs** (€/t)
Dry scrubber	$1.74 \cdot 10^{-3}$	50	3.47	100	0	$3.02 \cdot 10^{-6}$	37.234	**0.414**

5.2 Liquid fuel firing

The expert group estimated several emission levels which should be considered in the database:

An uncontrolled emission level (expert estimate):

Current proposal concerning concentration: around 4200 mg / Nm^3

This level has been proposed considering a liquid fuel containing around 3% of Sulphur and, in addition, 600 mg/Nm^3 generated by sulphates introduced with the raw materials.

A first stage of emission control corresponding to the current EU situation (expert estimate):

Current proposal concerning concentration: around 1800 mg / Nm^3

This level has been proposed considering a liquid fuel containing around 1% of Sulphur and in addition 600 mg/Nm^3 generated by sulphates introduced with the raw materials.

A second stage of emission control taking into account an average abatement rate by dry scrubbing of 20% from a reference situation described in the first stage (expert estimate)

Current proposal concerning concentration: around 1400 mg / Nm^3

Table 5.4: Abatement Measure for SO_2

Measure Code	**Abatement technique**	**Emission factor (mg/Nm³)**	**Emission factor (kg/t)**
00	-	4200	12.2
01	Low S heavy fuel oil	1800	5.2
02	Dry scrubber 20%	1400	4.1

Table 5.5: Investments and variable Operating costs

Measure Code	**Description**	**Removal efficiency (%)**	**Investment (k€)**	**Fixed Operating costs (%/a)***	**Variable Operating costs (k€/t/a)**
00	None	-	0	0	0
01	Low Sulphur HF	-	0	0	See table 5.6
02	Dry scrubber	20	300	4	See table 5.7

*: The fixed Operating costs only depend on the capacity – or size - of the installation, i.e. on the investment, and they are expressed as a **percentage of the plant investment** [%/a]

Variable Operating costs are defined as the costs depending on the level of production. Parameters for variable operating costs depend on the type of measure (technology) installed. The following tables show the common parameters and prices needed for the calculation of the variable costs.

Cost of low-sulphur fuel [k€/t]

Extra cost of low S fuel oil (1 % S) · (sulphur content of the old fuel-sulphur content of the new fuel)

Table 5.6: Cost of low-sulphur fuel

	Extra cost of low S fuel oil (1 % S) k€/t/%S	**Sulfur content of the old fuel**	**Sulfur content of the new fuel**
Cost of low-sulphur fuel	Country-specific parameter	3 %	1%

<u>Dry scrubber 20%</u>

The different costs for the dry scrubber are the following:

<u>Lime cost</u>: $\lambda^s \cdot c^s \cdot ef_{unabated} \cdot \eta / 10^3$ [k€/**t**]

- $ef_{unabated}$: unabated emission factor of pollutant [t pollutant/**t**]
- λ^s: specific lime demand (e.g. NH_3) [t/t pollutant removed]
- c^s: lime price [€/t]
- η: removal efficiency (= 1 - $ef_{abated}/ef_{unabated}$)

with: $\lambda^s = \lambda^m \cdot \lambda^M$
λ^m: Ca/S (mol/mol) ratio
λ^M: $Ca(OH)_2/SO_2$ (mol weight/mol weight) ratio

$\lambda^s = 1 \cdot (74/64)$
$= 1.16$ t/$t_{SO2\ removed}$

$ef_{unabated} = 5.2 \cdot 10^{-3}$ t $_{SO2}$ /**t**
$\eta = 20$ %
$\lambda^s = 1.16$ t/$t_{SO2\ removed}$ (with Ca/S (mol/mol) ratio = 1)
$c^s = 100$ €/t (value for France)

<u>Waste disposal cost</u> $\lambda^d \cdot c^d \cdot ef_{unabated} \cdot \eta / 10^3$ [k€/**t**]

- $ef_{unabated}$: unabated emission factor of pollutant [t pollutant/**t**]
- λ^d: demand for waste disposal [t/ t pollutant removed]
- c^d: specific waste disposal cost [€/t]
- η: removal efficiency (= 1 - $ef_{abated}/ef_{unabated}$)

For the considered technique and efficiency, there is **no waste by-product disposal.** <u>Not realistic for all furnaces!!, see before.</u>

Mis en forme

$\lambda^d = 0$ t/ t TSP removed

<u>Labour cost</u> $\lambda^l \cdot c^l$ [k€/**t**]

- λ^l: labour demand [person-year/t]

- c^l: wages [k€/ person-year]

The average number of personnel for the deduster and the desulphurisation plant is around 0.75 person/year. [11]

Thus, the annual personnel costs for the dry scrubber are:

$\mathrm{ACPERS} = 0.75 \cdot c^l \cdot I_{desulphurisation} /(I_{deduster}+I_{desulphurisation})$

Thus $\lambda^l = 0.75/\mathrm{Capacity} \cdot 300{,}000/(900{,}000+300{,}000)$

$= 3.02 \cdot 10^{-6}$ person-year/**t**

$c^l = 37.234$ k€/ person-year (value for France)
$\lambda^l = 3.02 \cdot 10^{-6}$ person-year/**t**

Table 5.7: Parameters needed to calculate variable Operating costs for dry scrubber 20%

	$ef_{unabated}$ [t SO_2/t]	**η**	**λ^s [t/t SO_2 removed]**	**c^s [€/t]**	**λ^d [t/t SO_2 removed]**	**λ^l [person - year/t]**	**c^l [k€/ person - year]**	**Variable Operating costs** (€/t)
Dry scrubber	$5.2 \cdot 10^{-3}$	20	1.16	100	0	$3.02 \cdot 10^{-6}$	37.234	**0.233**

6 Emission abatement techniques and costs

6.1 NO_x abatement techniques

Table 6.1: Abatement Measure and emission factors for NO_x

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Measure Code	**Description**	**Lifetime (a)**	**Efficiency (%)**	**EF (kg/t)**	**EF CI %**	**Q**
00	None	-	-	8.12		3
01	Primary technologies	8	65	2.9		3
02	Primary + Secondary technologies	8	82	1.45		3

Table 6.2: Investments and Operating costs

Description	**Investment (k€)**	**EF CI %**	**Q**	**Fixed Operating costs** (%/a)	**EF CI %**	**Q**	**Variable Operating costs** (€/t)	**EF CI %**	**Q**	**Total Operating costs** (€/t)	**EF CI %**	**Q**
None	0	-	-	0	-	-	0	-	-	0	-	-
Primary technologies	330		3	4		3	0.15		3	0.36		3
Primary + Secondary technologies	855		3	4		3	0.124		3	1.57		3

Table 6.3: Parameters needed to calculate variable Operating costs

Description	λ^e [kWh/t]	λ^s [t/t NO_x removed]	λ^l [person-year/t]	λ^{cat} [m³/t]	lt^{cat} [10^3 hrs]
None		-	-	-	-
Primary technologies	-	-	$4.03 \cdot 10^{-6}$	-	-
Primary + Secondary technologies	5	0.46	$8.06 \cdot 10^{-6}$	$1.19 \cdot 10^{-4}$	43.8

6.2 Dust abatement techniques

Table 6.4: Abatement Measures and emission factors for dust

Supprimé : 4

Primary Measure Code	Description	Lifetime (a)	EF PM_{TSP} (g/t)	EF CI %	Q	EF PM_{10} (g/t)	EF CI %	Q	EF $PM_{2.5}$ (g/t of glass melted)	EF CI %	Q
00	None	-	725		3	n.i.		3	n.i.		3
01	Deduster	10	29		3	n.i.		3	n.i.		3

n.i.: no information

Table 6.5: Investments and Operating costs

Description	Investment (k€)	EF CI %	Q	Fixed Operating costs (%/a)	EF CI %	Q	Variable Operating costs (€/t)	EF CI %	Q	Total Operating costs (€/t)	EF CI %	Q
None	0			0			0			0		
Deduster	900		3	4		3	1.25		3	1.83		3

Table 6.6: Parameters needed to calculate variable Operating costs

	λ^d [t/t dust removed]	λ^e [kWh/t]	λ^l [person-year/t]
None	-	-	-
Deduster	0	16.1	$9.07 \cdot 10^{-6}$

No fugitive emission in the process are considered.

6.3 SO_2 abatement techniques

6.3.1 Liquid fuel firing

Table 6.7: Abatement Measure for SO_2

Measure Code	Abatement technique	Lifetime (a)	Removal efficiency (%)	Emission factor (kg/t)	EF CI %	Q
00	-	-	-	12.2		3
01	Low S heavy fuel oil	-	57	5.2		3
02	Low S heavy fuel oil + Dry scrubber 20%	10	67	4.1		3

Table 6.8: Investments and variable Operating costs

Description	**Investment (k€)**	**EF CI %**	**Q**	**Fixed Operating costs (%/a)**	**EF CI %**	**Q**	**Variable Operating costs (k€/t)**	**EF CI %**	**Q**	**Total Operating costs (€/t)**	**EF CI %**	**Q**
None	0		3	0		3	0		3	0		3
Low Sulphur HF	0		3	0		3	$X^{(1)}$		3	$X^{(1)}$		3
Low Sulphur HF + Dry scrubber	300		3	4		3	$2.33 \cdot 10^{-4} + X^{(1)}$		3	$0.426 + X^{(1)}$		3

$X^{(1)}$: Variable Operating costs for the low S heavy fuel oil depending from country-specific data

Table 6.9: Parameters needed to calculate variable Operating costs

	λ^s **[t/t SO₂ removed]**	λ^d **[t/t SO₂ removed]**	λ^l **[person-year/t]**
None	-	-	-
Low Sulphur HF	-	-	-
Low Sulphur HF + Dry scrubber	1.16	0	$3.02 \cdot 10^{-6}$

6.3.2 Natural gas

Table 6.10: Abatement Measure and emission factors for SO_2

Measure Code	**Abatement technique**	**Lifetime (a)**	**Emission factor (kg/t)**	**EF CI %**	**Q**
00			1.74		3
01	Dry scrubber 50%	10	0.87		3

Table 6.11: Investments and Operating costs

Description	**Investment (k€)**	**EF CI %**	**Q**	**Fixed Operating costs (%/a)**	**EF CI %**	**Q**	**Variable Operating costs (€/t)**	**EF CI %**	**Q**	**Total Operating costs (€/t)**	**EF CI %**	**Q**
None	0		3	0		3	0		3	0		3
Dry scrubber 50%	300		3	4		3	0.414		3	0.607		3

Table 6.12: Parameters needed to calculate variable Operating costs

	λ^s **[t/t SO₂ removed]**	λ^d **[t/t SO₂ removed]**	c^l **[k€/ person-year]**
None	-	-	-
Dry scrubber	3.47	0	37.234

7 Data to be provided by national experts for the completion of the database for their own country

The following tasks are required:

7.1 **Validation work**

For representing costs in this sector, the national expert were invited to comment on the methodology proposed by the Secretariat:

- Validation of investments provided and,
- Validation of the method of derivation of operating costs.

Or

- Provide other costs for the same combination of techniques and justify them.

7.2 Provision of specific data

Tables to be filled in by national experts:

7.2.1 Country specific data

Determination of country specific data to calculate variable costs (they are valid for all stationary sources and only have to be entered in the tool once)

Table 7.1**:** Country-specific data

Parameters	**Costs**
Electricity price [€/kWh]	
Wages [€/person-year]	
Ammonia price [€/t_{NH3}]	
Catalyst cost [k€/m³]	
Lime cost [€/t_{lime}]	
Extra cost of Low S fuel [€/GJ/%S]	

7.2.2 Activity level for Reference installations

Respective share (t glass melted/year) of the total activity level carried out on each reference installation in 2000, 2005, 2010, 2015, 2020.

Table 7.2**:** Activity levels for Reference Installations (t glass melted / year)

RIC	**2000**	**2005**	**2010**	**2015**	**2020**
01					
02					
Total	Calculated automatically by the tool				

- If no prevision on the structure of this sector is available (for 2005 to 2020), the proportions used in 2000 can be used. But total activity (t/y) should evolve.

- For helping to provide the information, please fill in the following table 7.3

Table 7.3**:** Gas/liquid fuel consumption (GJ/year) and total activity level (t glass melted / year) for each year

RIC	**2000**	**2005**	**2010**	**2015**	**2020**
Natural gas					
Heavy fuel oil					
Total activity level Na					

Thus, with these information, it is possible to know the activity level of each reference installation and to fill in table 7.2.

Activity level for Reference installation 1 = Natural gas consumption [GJ]·Quantity of glass melted divided by the natural gas and the heavy fuel oil consumption [GJ].

Activity level for Reference installation 2 = Heavy fuel oil consumption [GJ]·Quantity of glass melted divided by the natural gas and the heavy fuel oil consumption [GJ].

7.2.4 Correction factor for the melting/production capacities

Mise en forme : Puces et numéros

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 could be a relevant order of magnitude for this correction factor (expert estimate). For example, expert from Germany proposes 0.87.

Table 7.4: Correction factor for the melting/production capacities

	Default data mean	**User input mean**
Fc	0.85	

7.2.5 Unabated emission factor

Mise en forme : Puces et numéros

Table 7.5: Unabated emission factor [kg/t glass melted]

Pollutants	**Default data mean**	**CI %**	**User input mean**	**CI %**
EF NO_x	8.12			
EF PM_{TSP}	0.725			
EF PM_{10}	-			
EF $PM_{2.5}$	-			
Reference installation 1				
EF SO_2	1.74			
Reference installation 2				
EF SO_2	12.2			

7.2.3 Application rate and applicability

Respective percentage of reduction measures in 2000 for each reference installation as well as if possible, the percentage of use in 2005, 2010, 2015, 2020 and applicability according to the definition used in the RAINS model.

NO$_x$ abatement measures

Table 7.6: 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

- For helping to provide the information, use the following methodology.

Methodology to calculate the different application rate:

The different input parameter to determine the application rate are:

- ✓ E_{NOx}: Emission of NO$_x$ in a country (t per year) for the different years
- ✓ *Na*: Activity level (t of glass melted per year) for the different years (production capacity = melting capacity · 0.85)

Then, the sector situation may be defined by:

$$F_{s\ a\ NOx} = (E_{NOx}/N_a)$$

According this result, it is possible to calculate the different application rate:

F_{S1NOx}: Uncontrolled NO$_x$ emission level
F_{S2NOx}: NO$_x$ emission level implementing the DeNO$_x$ stage 1 technical option (primary measures - PM)
F_{S3NOx}: NO$_x$ emission level implementing the DeNO$_x$ stage 2 technical option (secondary measures - SM)

- ✓ If $F_{S1NOx} > F_{s\ a\ NOx} > F_{S2NOx}$, it can be considered that some primary measure may still be implemented on a given percentage of the production capacity.

The virtual application rate of primary measures $T_{1,NOx}$ is obtained by:

$$T_{1,NOx} = (F_{s\ a\ NOx} - F_{S1NOx})/(F_{S2NOx} - F_{S1NOx})$$

- ✓ If $F_{s\ a\ NOx} < F_{S2NOx}$ it may be considered that some secondary measures have already been implemented. In this case, it can be considered that the application rate concerning NO$_x$ primary measures is 100%.

The virtual application rate of secondary measures $T_{2,NOx}$ is obtained by:

$$T_{2,NOx} = (F_{s\ a\ NOx} - F_{S2NOx}) / (F_{S3NOx} - F_{S2NOx})$$

Dust abatement measures

Table 7.7: Application rate and applicability for dust abatement measures

Description	Application	Application	Applica	Application	Applica	Application	Applica	Application	Applica

	rate in 2000 [%]	rate in 2005 [%]	bility [%]	rate in 2010 [%]	bility [%]	rate in 2015 [%]	bility [%]	rate in 2020 [%]	bility [%]
None									
Deduster			100		100		100		100

- For helping to provide the information , use the following methodology.

Methodology to calculate the different application rate:

The different input parameter to determine the application rate T_{Dust} are:

- ✓ E_{Dust}: Emission of dust in a country (t per year) for the different years
- ✓ Na: Activity level (t of glass melted per year) for the different years (production capacity = melting capacity · 0.85).

Then, the sector situation may be defined by:

$$F_{s\ a\ Dust} = (E_{Dust}/N_a)$$

with: $F_{s\ a\ Dust} = F_{S2Dust} \cdot T_{Dust} + F_{S1Dust} \cdot (1 - T_{Dust})$

F_{S1Dust}: Uncontrolled dust emission level

F_{S2Dust}: Emission level after Dedusting

Then:

$$T_{Dust} = ((E_{Dust}/N_a) - F_{S1Dust}) \cdot (1/(F_{S2Dust} - F_{S1Dust}))$$

SO_2 abatement measures

Table 7.8: 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									
Low S heavy fuel			100		100		100		100
Dry scrubber 20 %			Dust application rate		Dust application rate		Dust application rate		Dust application rate
Reference installation 2									
None									
Dry scrubber 50 %			Dust application rate		Dust application rate		Dust application rate		Dust application rate

- For helping to provide the information, use the following methodology.

Methodology to calculate the different application rate:

As dry scrubbing requires the implementation of a dedusting process, the SO_2 emissions generated by the glass production using gaseous fuels may be assessed considering that there is no reason to have very different dedusting implementation rates for gas and liquid fuel firing and so using T_{Dust}.

SO_2 emitted with gas firing ($E_{\mathbf{SO2\ gas}}$) = Production of glass with gas firing · ($F_{S1SO2\ Gas} \cdot (1 - T_{Dust}) + F_{S2SO2\ Gas} \cdot T_{Dust}$)
with:

$F_{S1SO2\ Gas}$: Uncontrolled SO_2 emission level for gas firing
$F_{S2SO2\ Gas}$: SO_2 emission level implementing the $DeSO_2$ technical option for gas firing

SO_2 emitted with liquid fuel firing ($E_{\mathbf{SO2\ Lfuel}}$) is obtained by = $E_{\mathbf{SO2}} - E_{\mathbf{SO2\ gas}}$.

Then, for each kind of fuel, the different application rate can be calculated.

- *Natural gas*

$$\boxed{F_{s\ a\ SO2,gas} = (E_{SO2\ gas}/N_a)}$$

with: $F_{s\ a\ SO2,gas} = F_{S2SO2\ Gas} \cdot T_{SO2,gas} + F_{S1SO2\ Gas} \cdot (1- T_{SO2,gas})$

Then:

$$\boxed{T_{SO2,gas} = ((E_{SO2\ gas}/N_a) - F_{S1SO2\ Gas}) \cdot (1/(F_{S2SO2\ Gas} - F_{S1SO2\ Gas}))}$$

- *Heavy fuel oil*

The same methodology as for NO_x emissions is used to determine the application rate.

Glass industry

Summary list of parameters and data(National experts need data for at least 6 parameters)

	Parameter	Annotation	Unit	Type of data	Current proposal
1	Activity level 2000, 2005, 2010, 2015 and 2020	N_a	Tonnes per year	Input	-
2	Energy consumption 2000, 2005, 2010, 2015 and 2020	E_{cons}	GJ	Input	-
3	Gas/liquid fuel consumption 2000, 2005, 2010, 2015 and 2020	$E_{consgas}$ / $E_{consfuel}$	Percentage or GJ	Input	-
4	SO_2 (as SO_2) 2000	E_{SO2}	Tonnes per year	Input	-
5	NO_x (as NO_2) 2000	E_{NOx}	Tonnes per year	Input	-
6	Dust 2000	E_{Dust}	Tonnes per year	Input	-
	Reference melting capacity used for the economical assessment	C_{ref}	Tonnes per day	Fixed by the experts	170
	Sector production at the EU level	S_{prod}	Tonnes per day	BREF information	79,050
	Number of furnaces	N_{furn}	-	BREF information	465
	Correction factor	F_c	-	Fixed by the experts	0.85
7	Conversion factor between concentration and specific mass flow	F_{conv}	-	Fixed by the experts	$2.9 \cdot 10^{-3}$
8	Uncontrolled dust emission level	F_{S1Dust}	Kg / tonne of glass	Fixed by the experts	*0.725*
9	Emission level after Dedusting	F_{S2Dust}	Kg / tonne of glass	Fixed by the experts	*0.029*
10	Cost of the dedusting option per tonne of pollutant avoided	C_{Dust}	Euro/ tonne of glass	Evaluated by the experts	5,204
11	Uncontrolled NO_X emission level	F_{S1NOx}	Kg / tonne of glass	Fixed by the experts	*8.12*
12	NO_X emission level implementing the $DeNO_X$ stage 1 technical option (primary measures - PM)	F_{S2NOx}	Kg / tonne of glass	Fixed by the experts	*2.9*
13	NO_X emission level implementing the $DeNO_X$ stage 2 technical option (secondary measures - SM)	F_{S3NOx}	Kg / tonne of glass	Fixed by the experts	*1.45*
14	Cost of the DeNOx stage 1 technical option (PM) per tonne of pollutant avoided	C_{NOX1}	Euro / tonne NO_x abated	Evaluated by the experts	218
15	Cost of the $DeNO_X$ stage 2 technical option (SM) per tonne of pollutant avoided	C_{NOX2}	Euro / tonne NO_x abated	Evaluated by the experts	1,952
16	Uncontrolled SO_2 emission level for gas firing	$F_{S1SO2\ Gas}$	Kg / tonne of glass	Fixed by the experts	*1.74*
17	SO_2 emission level implementing the $DeSO_2$ technical option for gas firing	$F_{S2SO2\ Gas}$	Kg / tonne of glass	Fixed by the experts	*0.87*
18	Cost of the $DeSO_2$ technical option per tonne of pollutant avoided for gas firing	$C_{SO2\ GAS}$	Euro / tonne SO_2 abated	Evaluated by the experts	1,384
19	Uncontrolled SO_2 emission level for liquid fuel firing	$F_{S1SO2\ Lfuel}$	Kg / tonne of glass	Fixed by the experts	*12.2*
20	SO_2 emission level implementing the $DeSO_2$ stage 1 technical option	$F_{S2SO2\ Lfuel}$	Kg / tonne of glass	Fixed by the experts	*5.2*
21	SO_2 emission level implementing the $DeSO_2$ stage 2 technical option	$F_{S3SO2\ Lfuel}$	Kg / tonne of glass	Fixed by the experts	*4.1*
22	Cost of the stage 1 $DeSO_2$ technical option per tonne of pollutant avoided for liquid fuel firing	$C_{SO2\ LFUEL\ 1}$	Euro / tonne SO_2 abated	Evaluated by the experts	Specific national data
23	Cost of the stage 2 $DeSO_2$ technical option per tonne of pollutant avoided for liquid fuel firing	$C_{SO2\ LFUEL\ 2}$	Euro / tonne SO_2 abated	Evaluated by the experts	983

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