CEMENT INDUSTRY

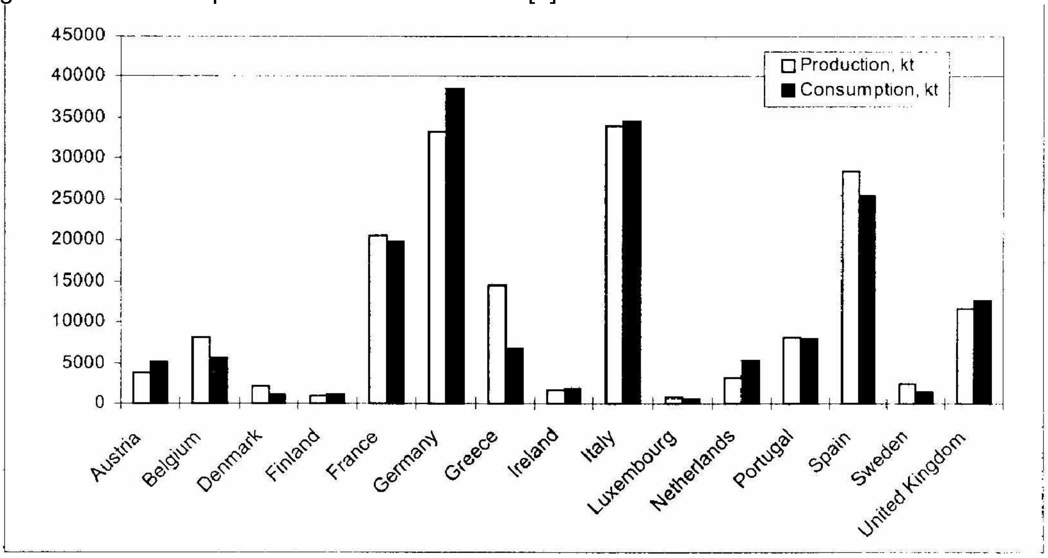
SYNOPSIS SHEET

Prepared in the framework of EGTEI

1 Activity description and EGTEI contribution – summary

Cement is a hydraulic binder which reacts with water to form calcium silicate hydrates. Different types of cement are known. The term “Portland cement” generally refers to a cement which consists completely or predominantly of cement clinker. Portland slag cement, Portland pozzolona cement etc. consist of a clinker and a ground additive. Additives used in cement production are for example fly ash and residues from iron and steel production. [1]
In 1995 cement production in the European Union totalled 172 million tonnes and consumption 168 million tonnes. 23 million tonnes of cement were imported and 27 million tonnes exported. These figures include trade between EU countries. [2]

Figure 1.1: Cement production in the EU 1995 [2]



The production of cement is carried out in several stages including:

- preparation of the raw materials (crushing, grinding, drying, homogenisation)
- burning of the raw material mixture to produce cement clinker
- preparation of the other cement components
- grinding and mixing of the cement components.

This sector was not considered as an individual sector in the previous NOx and SO_2 version of RAINS [3, 4], but was aggregated with the lime production to form the RAINS sector “IN_PR_CELI”. In the PM module, the “PR_CEM” sector represents the production of cement. **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 Cement Association (CEMBUREAU), with the Association Technique de l'Industrie des Liants Hydrauliques (ATILH) and with expert from ADEME.**

The representative unit used is the ton of clinker (t of clinker). One reference installation (RI) has been defined.
EGTEI defines different abatement measures. However, as for dust, the cement 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 splitted the Reference Installation in three installations according to their initial level of unabated SO_2 emission factor. As abatement measure, **absorbent injection** and **wet scrubber** have been defined.
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 have to collect **5 country specific parameters** (wages, electricity, ammonia price, catalyst cost, lime cost and limestone cost) and **country and sector specific parameters** (activity

level, fuel consumption and characteristics, and the different pollutant emissions). EGTEI provides default costs for country specific parameters which can be used if no better data exist.
The specific sector of cement “PR_CEM” has now been introduced in the new RAINS models. In the future however, any new technology which could be developed, should be considered by EGTEI in the background document to continuously improve the representation of the sector and the capacity of EGTEI to describe new technologies.

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_CEM” represented the production of cement in the PM module. In the SO_2 and the NO_x module, the cement production was aggregated with the lime production in the RAINS sector “IN_PR_CELI”.

3 Status of EGTEI

EGTEI has developed an approach for representing the cement sector and estimating costs of reduction techniques. The methodology for this sector was developed in close cooperation with the **European Cement Association (CEMBUREAU), with the Association Technique de l’Industrie des Liants Hydrauliques (ATILH) and with expert from ADEME**. 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 cement 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.]

The expert group on cement proposes to use **one** reference installation for the whole cement sector and not to take into account the different processes (wet, dry…).

Table 4.1: Reference Installation

Reference Code	Technique	Capacity [t/d]	Lifetime [a]	Plant factor [h/a]
01	Average capacity installation	1,100	35	7,680

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

4.2.1 Dust abatement techniques

For this specific pollutant, the expert group on cement has considered one single abatement option called “deduster” (efficient ESP equivalent to bag filter).

Table 4.2.1.1: Abatement Measures for dust

Measure Code	Description	Lifetime (a)	Emission factor (mg/Nm³)	Emission factor (g/t of clinker)
00	None	-	56,520	130,000
01	Deduster	10	20	46

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

Table 4.2.1.2: Investments and Operating costs for dust

Description	Investment (k€)	Fixed Operating costs (%/a)	Variable Operating costs (€/t)	Total Operating costs (€/t)	Cost per tonne TSP abated (€/t)(1)	Cost per tonne of clinker (€/t) (1)
None	-	-	-	-	-	-
Deduster	1,625	4	0.346	0.531	8	1.10

(1): Case of France

Remark:
The mentioned costs are for the treatment of raw emissions (without any abatement techniques already installed). But in most cases the plant has already implemented a dedusting equipment (ESP or bag filter). Then the specific cost (C_{Dust}) would be derived from the cost mentioned in tables 4.2.1.1 and 4.2.1.2 to be divided by the marginal mass of pollutant avoided (obtained by the difference between the initial situation (average current concentration or specific mass emission for the whole sector) and the final one (concentration or specific mass emission fixed in the BAT range)). For more details see the background document.

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

Measure Code	Description	Efficiency (%)	Emission factor (mg/Nm³)	Emission factor (g/t of clinker)
00	None		1,400	3,220
01	Primary technologies	25	1,050	2,415
02	Primary + Secondary technologies	72	400	920

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)(1)	Cost per tonne of clinker (€/t)(1)
None	-	-	-	-	-	-
Primary technologies	250	4	0.0264	0.0548	199	0.16
Secondary technologies	600	4	0.569	0.638	740	1.11

(1): Case of France

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 and also on the technology used to produce cement. For this specific pollutant, it has been decided to split the reference installation in three categories to make the economic evaluation. Each category is depending on the unabated emission factor, as described in the table 4.2.3.1.

Table 4.2.3.1: SO_2 abatement measures

Measure Code	Level of initial emission	Unabated emission factor (mg/Nm³)	Abatement technique	Abated emission factor (mg/Nm³)
00	A	< 400		< 400
01	B	1,000	Absorbent injection	< 400
02	C	1,600	Wet scrubber	< 400

Table 4.2.3.2: Investments and Operating costs for SO_2 abatement measures

Description	Investment (k€)	Fixed Operating costs (%/a)	Variable Operating costs (k€/t/a)	Total Operating costs (€/t)	Cost per tonne of NOx abated (€/t)(1)	Cost per tonne of clinker (€/t)(1)
None	-	-	-	-	-	-
Absorbent injection	200	4	0.698	0.721	573	0.791
Wet scrubber	5,500	4	0.606	1.31	1144	3.16

(1): Case of France

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 cement 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
Lime cost [€/t_{lime}]	100	To be provided by national experts
Limestone cost [€/$t_{limestone}$]	20	To be provided by national experts

French 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.

Table 5.3: Activity levels for Reference Installations (t clinker / year)

RIC	Description	2000	2005	2010	2015	2020
01	Level A: < 400 mg/Nm³					
02	Level B: 400 –1,200 mg/Nm³					
03	Level C: > 1,200 mg/Nm³					
Total		Calculated automatically by ECODAT				

<u>Remark</u>: for the cement industry, specific emission levels are in fact linked to the clinker capacity. The production capacities and the clinker capacities slightly differ, and a correction factor (F_c) needs to be used: 0.8 could be a relevant order of magnitude for this correction factor (expert estimate).

Table 5.4: Correction factor for the melting/production capacities

	Default data (mean)	User input (mean)
Fc	0.80	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 cement industry for all Parties

Table 5.5: Unabated emission factor [kg/ t clinker]

Pollutants	Default data	User input)
EF NOx	3.22	
EF PM_{TSP}	130	

EF PM_{10}	-	
EF $PM_{2.5}$	-	
Reference installation 1		
EF SO_2	Country specific data	
Reference installation 2		
EF SO_2	Country specific data	
Reference installation 3		
EF SO_2	Country specific data	

The fuel consumption and its characteristics are also to be collected in order to subtract the fuel consumption of the sector to the total energy scenario.

Table 5.6: Fuel consumption of each fuel burned in the cement industry (GJ/year)

	2000	**2005**	**2010**	**2015**	**2020**
Natural gas					
Heavy fuel oil					
Waste					
Solid fuels					
Biomass					
….					

Table 5.7: Fuel characteristics of each fuel burned in the cement industry

	S content [wt-%]	Lower heat value [GJ/t]
Natural gas		
Heavy fuel oil		
Solid fuels		
Waste		
Biomass		
…		

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 the 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 on the website of EGTEI http://www.citepa.org/forums/egtei/egtei_doc-Proc-fer-n-fer.htm to help to calculate the application rate.

Table 6.1: Input parameters needed to calculate application rates

PARAMETER	**2000**	**2005**	**2010**	**2015**	**2020**
Activity levels for Reference Installation 01 (t clinker / year)					
Activity levels for Reference Installation 02 (t clinker / year)					
Activity levels for Reference Installation 03 (t clinker / year)					
E_{NOx}: NOx Emission [t]					
E_{dust}: Dust Emission [t]					

SO_2 Emission of the Reference Installation 01 before treatment [t]					
SO_2 Emission of the Reference Installation 01 after treatment [t]					
SO_2 Emission of the Reference Installation 02 before treatment [t]					
SO_2 Emission of the Reference Installation 02 after treatment [t]					
SO_2 Emission of the Reference Installation 03 before treatment [t]					
SO_2 Emission of the Reference Installation 03 after treatment [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									

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									
Reference installation 2									
None									
Injection absorbent			Dust application rate		Dust application rate		Dust application rate		Dust application rate
Reference installation 3									
None									
Wet scrubber			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 NOx and SO_2 RAINS model [3, 4], the cement sector was not represented as a separate sector. It was aggregated with the lime production in the sector "IN_PR_CELI". 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 work.
EGTEI now provides an approach to specifically consider the cement sector. The approach has been developed in close cooperation with industry. The category "PR_CEM" 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 technology 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] Emission control at stationary sources in the federal republic of Germany, Volume 1 and 2, DFIU, 1996.
[2] Reference document on Best Available Techniques in the Cement and Lime Manufacturing Industries.
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 cement 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 not been able to complete totally ECODAT for the cement sector, but with the help of the Association Technique de l'Industrie des Liants Hydrauliques (ATILH) he introduces all the information for NOx and PM emissions. For SO_2 emissions, more information is needed and an inquiry will be done.

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
Lime cost [€/t_{lime}]	100
Limestone cost [€/t_{lime}]	20

Activity level

Table A.2: Clinker production in France (Mt of clinker / year)

RIC	1990	1995	2000	2005	2010	2015	2020	2025	2030
01	21.40	16.27	16.55	16.89	17.47	16.90	16.33	15.77	15.20

Table A.3: Correction factor for the melting/production capacities

	Default data mean	French input mean
Fc	0.8	0.8

Fuel characteristics

Table A.4: Fuel consumption (PJ/year)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
BC1	0	0	0	0	0	0	0	0	0
BC2	0	0	0	0	0	0	0	0	0
HC1	35.56	8.53	5.48	6.08	6.19	6.40	6.02	5.68	5.34
HC2	0	0	0	0	0	0	0	0	0
HC3	0	0	0	0	0	0	0	0	0
DC	17.78	21.93	27.41	24.94	24.13	24.96	23.49	22.14	20.82
HF1	6.96	1.83	1.83	1.82	1.86	1.92	1.81	1.70	1.60
HF2	10.82	17.66	9.74	7.91	6.19	6.40	6.02	5.68	5.34
GAS	1.55	0.61	0.61	0.61	0.62	0.64	0.60	0.57	0.53
OS1	0	0	0	0	0	0	0	0	0
OS2	4.64	10.35	15.84	19.47	22.89	23.68	22.28	21.00	19.75
Total	77.30	60.90	60.91	60.83	61.87	64.01	60.23	56.76	53.39

Table A.5: Fuel characteristics

	Sulphur content (%)	Heat values (GJ/t)
DC	5	32

OS2	1	17
HF1	2,97	39
HF2	3,5	39

Unabated emission factor

Default emission factors are adapted to the French situation.

Table A.6: Unabated emission factor [kg/ t clinker]

Pollutants	Default data	French input
EF NOx	3.22	3.22
EF PM_{TSP}	130	130
EF PM_{10}	-	-
EF $PM_{2.5}$	-	-
Reference installation 1		
EF SO_2	Country specific data	
Reference installation 2		
EF SO_2	Country specific data	
Reference installation 3		
EF SO_2	Country specific data	

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 cement sector, it has been considered that from 2007 the national regulatory constraint will be implemented in France and that in 2005 all the French installation will have a deduster.

Table A.7: 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	6.1	4.08	3.35	0	0	0	0	0	0
Deduster	93.90	95.92	96.65	100	100	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 2000 achieves 64% for Primary measure and 36% for Secondary measures.

Table A.9: 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	0	0	0	0	0	0	0	0	0
Primary technologies	67	69	64	64	64	64	64	64	64
Primary technologies + Secondary technologies	33	31	36	36	36	36	36	36	36

For SO_2 emissions, an inquiry is needed to determine the emission and activity of all reference installations. The table will be filled later.

Table A.11: 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 2									
None									
Injection absorbent									
Reference installation 3									
None									
Wet scrubber									

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

Data shown in the tables below are 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)	To be calculated								
NOx emission (t)	40.90	31.58	30.87	31.52	32.59	31.53	30.47	29.42	28.36
TSP emission (t)	3.850	2.307	2.119	1.10	1.14	1.10	1.06	1.02	0.99

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

	1990	1995	2000	2005	2010	2015	2020	2025	2030
CLE scenario									
SO_2 reduction measures									
NOx reduction measures	11,263	8,202	9,261	9,452	9,776	9,457	9,138	8,825	8,506
TSP reduction measures	22,104	17,167	17,595	18,579	19,217	18,590	17,963	17,347	16,720