BAT in cement industry

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Environment and Climate Regional Accession Network ECRAN

Content

- Cement industry
- Concerns
- Process
- Emissions
- Techniques for reduction
- BAT
- BAT conclusions

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Cement production

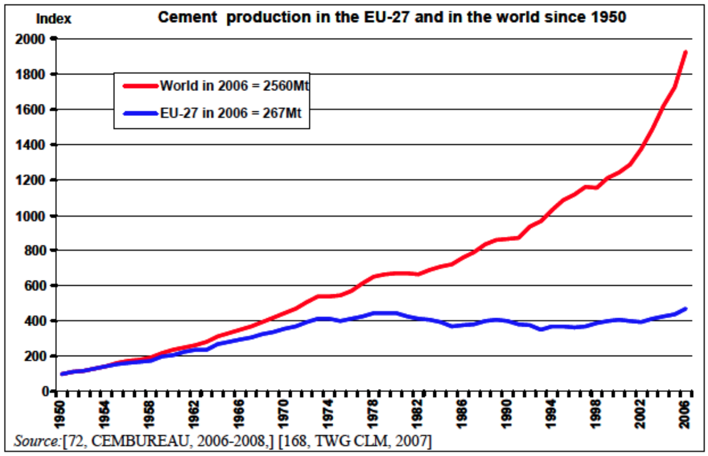

Figure 1.1: **Cement production in the EU-27 and globally from 1950 to 2006**

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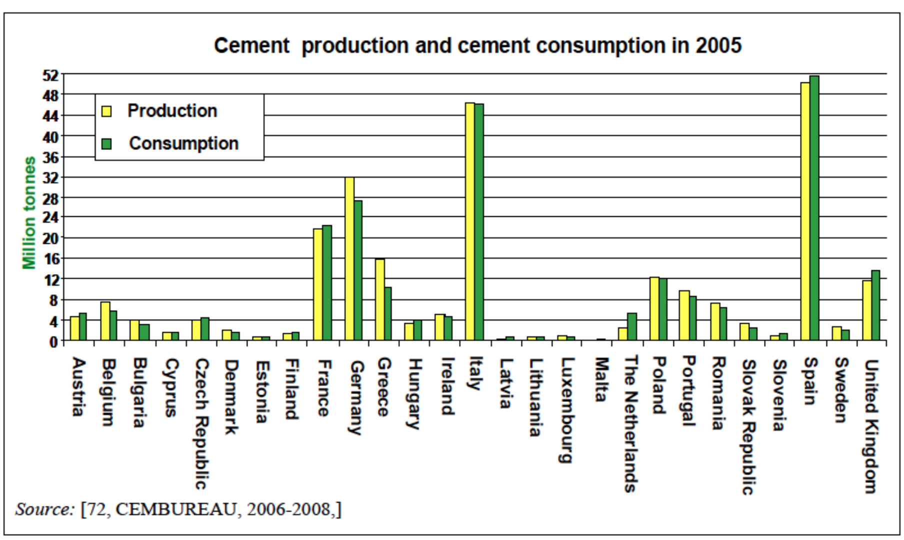

Figure 1.3 **Cement production inclusive of exported clinker and cement consumption in the EU 25**

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Impact of cement industry

Carbon dioxide emissions and climate change

- The concrete industry is one of two largest producers of carbon dioxide (CO_2), creating up to 5% of worldwide man-made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel.

Use of waste and waste fuel in production

- In 2011 the average fossil fuel replacement rate among EU Member States was 34.3%

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Sources of CO_2 emission

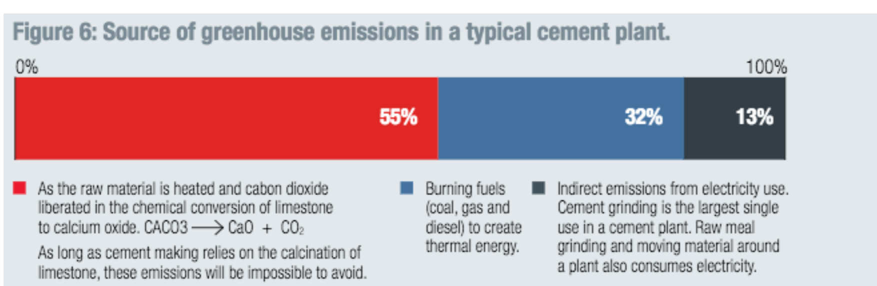

Figure 6: Source of greenhouse emissions in a typical cement plant.

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Major environmental issues

- Green house gasses
- Dust pollution
- Ecological concern arising from the degradation of mined-out areas
- Noise and transport pollution

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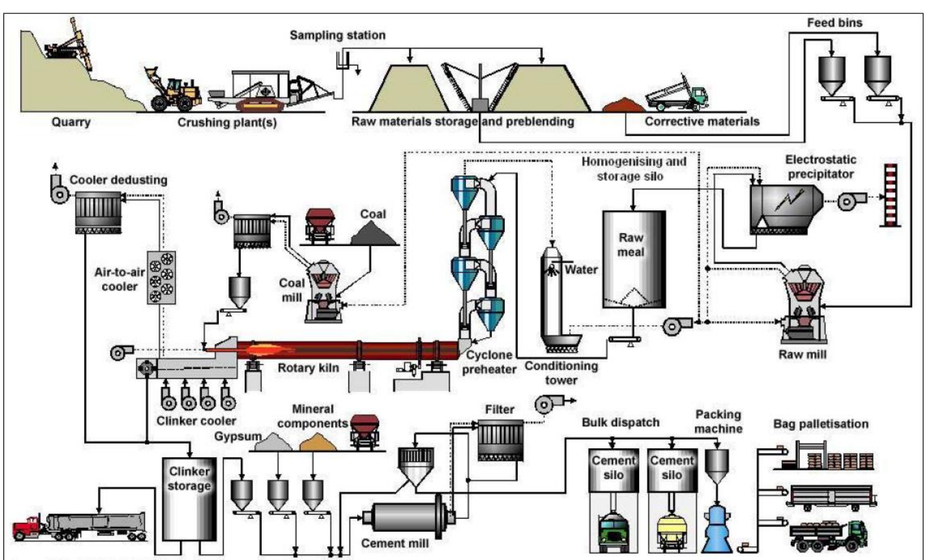
Manufacturing process



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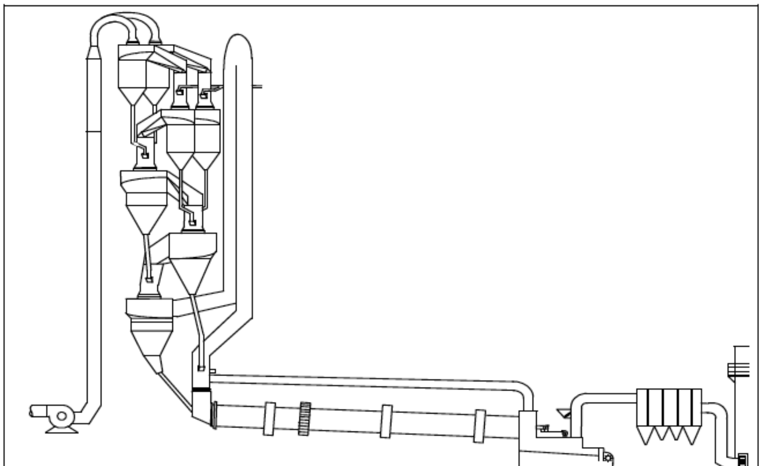
Preheater/precalciner/grate cooler kiln



Source: [72, CEMBUREAU, 2006-2008.]

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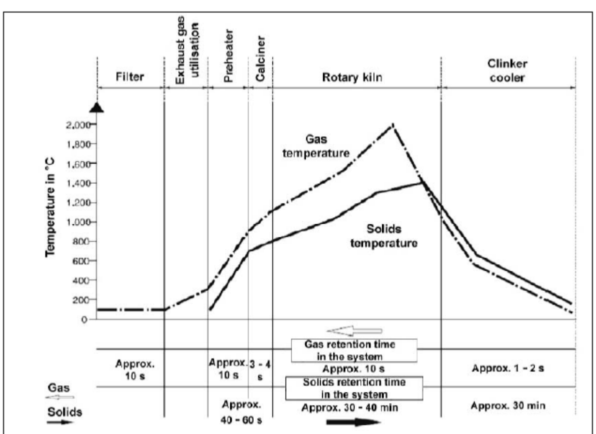
Gas and solids temperature profiles in a cyclone preheater kiln system



Source: [60, VDI 2094 Germany, 2003]

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Clinker Coolers

- Rotary coolers
- Tube coolers
- Planetary (or satellite) coolers
- Grate coolers
- Travelling grate coolers
- Reciprocating grate coolers
- Third generation of grate coolers

Source: [45, Schorcht, 2006] [90, Hungary, 2006]

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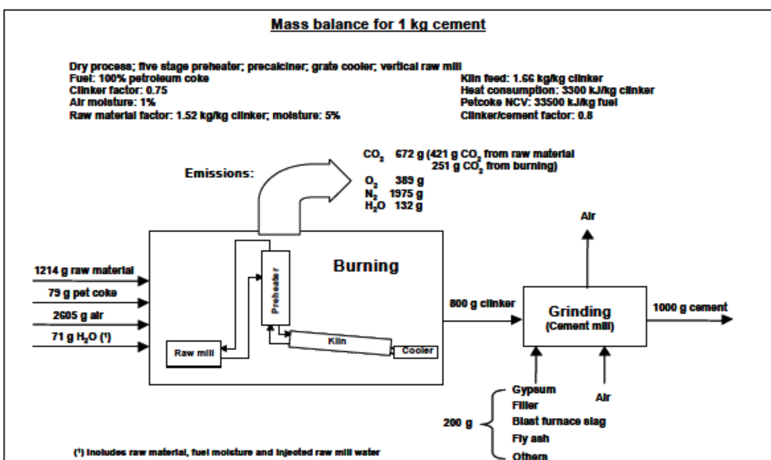
Mass balance – 1 kg cement



Source: [103, CEMBUREAU, 2006]

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Fuel consumption

Fuel consumption expressed as a percentage of heat generation by the cement industry in the EU-27

Type of fuel	Unit	2006
Coal (fossil)	%	18.7
Petcoke and coal (fossil)([1])	%	15.9
Fuel oil including HVFO([2])	%	3.1
Lignite and other solid fuels (fossil)	%	4.8
Natural gas (fossil)	%	1.0
Waste fuels	%	17.9

NB: Excluded: IE, CY, LT, SL
NB: Estimated: IT, PT, SE
([1]) reported by the EU-23+ members.
([2]) HVFO=highly viscous fuel oil.
Source: [72, CEMBUREAU, 2006-2008,], [168, TWG CLM, 2007]

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Table 1.8: Chemical analyses of raw materials and cement raw meal for the production of cement clinker

Components	Limestone, lime marl, chalk	Clay	Sand	PFA([1])	Fe source	Raw meal
	(mass %)					
SiO_2	0.5–50	33–78	80–99	40–60	0.5–30	12–16
Al_2O_3	0.1–20	7–30	0.5–7	20–30	0.2–4	2–5
Fe_2O_3	0.2–5.9	4.0–15	0.0–4	5–15	50–93	1.5–2.5
Mn_2O_3	0.02–0.15	0.090	0.051	0.127	0.1–4	0.0–0.5
Fe_2O_3 and Mn_2O_3	0.1–10	2–15	0.5–2		19–95	≤ 2
CaO	20–55	0.2–25	0.1–3	2–10	0.1–34	40–45
MgO	0.2–6	0.3–5	0.3–0.5	1.0–3	0.5–7	0.3–5
K_2O	0–3.5	0.4–5	0.2–3	1–5	0.1–1	0.1–1.5
Na_2O	0.0–1.5	0.1–1.5	0.0–1	0.2–1.5	0.1–1	0.1–0.5
SO_3([2])	0.0–0.7	0.0–4	0.0–0.5	0.0–1	0–3	0–1.5
Cl	0.0–0.6	0.0–1	Traces		0.0–0.5	0.0–0.3
TiO_2	0.0–0.7	0.2–1.8	0.0–0.5	0.5–1.5	0.0–3	0.0–0.5
P_2O_5	0.0–0.8	0.0–1.0	0.0–0.1	0.5–1.5	0.0–1	0.0–0.8
ZrO_2		0.02				
$CaCO_3$	96					
Loss on ignition (CO_2 + H_2O), LOI 950([3])	2–44	1–20	≤ 5	6.74	0.1–30	32–36

([1]) Pulverised fly ash.
([2]) Total content of sulphur, expressed as SO_3.
([3]) LOI 950 = loss on ignition.
Source: [60, VDI 2094 Germany, 2003], [81, Castle Cement UK, 2006], [90, Hungary, 2006], [103, CEMBUREAU, 2006]

Why waste in cement production?

• maximum temperatures of approx. 2000°C (main firing system, flame temperature) in rotary kilns
• gas retention times of about 8 seconds at temperatures above 1200°C in rotary kilns
• material temperatures of about 1450°C in the sintering zone of the rotary kiln
• oxidising gas atmosphere in the rotary kiln
• gas retention time in the secondary firing system of more than 2 seconds at temperatures of above 850 °C; in the precalciner, the retention times are correspondingly longer and temperatures are higher
• solids temperatures of 850°C in the secondary firing system and/or the calciner
• uniform burnout conditions for load fluctuations due to the high temperatures at sufficiently long retention times
• destruction of organic pollutants due to the high temperatures at sufficiently long retention times
• sorption of gaseous components like HF, HCl, SO2 on alkaline reactants
• high retention capacity for particle-bound heavy metals
• short retention times of exhaust gases in the temperature range known to lead to 'denovo-synthesis' of PCDD/F
• complete utilisation of fuel ashes as clinker components and hence, simultaneous material recycling (e.g. also as a component of the raw material) and energy recovery
• product-specific wastes are not generated due to a complete material utilisation into the clinker matrix; however, some cement plants in Europe dispose of bypass dust
• chemical-mineralogical incorporation of non-volatile heavy metals into the clinker matrix

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Typical waste in cement production

Fly ash	Blast furnace slag	Silica fume
Iron slag	Paper sludge	Pyrite ash
Spent foundry sand	Soil containing oil	
Artificial gypsum (from flue-gas desulphurisation and phosphoric acid production)		
Source: [8, CEMBUREAU, 2001], [91, CEMBUREAU, 2006]		

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Waste by chemical composition

Example list of wastes used as raw materials classified by their chemical composition and used in cement kilns in the EU-25

Raw material group	Examples of wastes used as raw materials
Ca group	Industrial lime (waste limestone) Lime slurries Carbide sludge Sludge from drinking water treatment
Si group	Spent foundry sand Sand
Fe group	Blast furnace and converter slag Pyrite ash Synthetic hematite Red mud
Al group	Industrial sludge
Si-Al-Ca group	Fly ash Slags Crusher fines Soil
S group	Industrial gypsum
F group	CaF_2 Filter sludge
Source: [76, Germany, 2006], [91, CEMBUREAU, 2006], [103, CEMBUREAU, 2006]	

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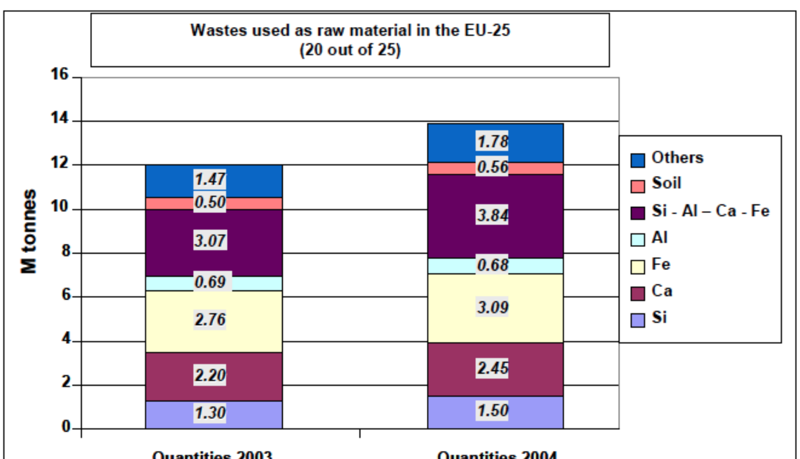
Waste as raw material in EU



Source: [74, CEMBUREAU, 2006]

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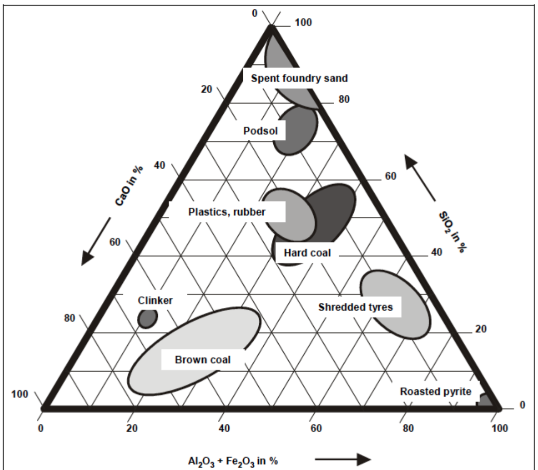
Constituents of raw materials and fuels



Source: [76, Germany, 2006]

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Types of wastes used as fuels

Group Nr.(1)	Types of waste fuels (hazardous and non-hazardous)
1	Wood, paper, cardboard
2	Textiles
3	Plastics
4	Processed fractions (e.g. RDF)
5	Rubber/tyres
6	Industrial sludge
7	Municipal sewage sludge
8	Animal meal, fats
9	Coal/carbon waste
10	Agricultural waste
11	Solid waste (impregnated sawdust)
12	Solvents and related waste
13	Oil and oily waste
14	Others

(1) Each grouping spans several EWC listings, see Table 6.1 in Section 6.2.1

Source: [74, CEMBUREAU, 2006], [168, TWG CLM, 2007]

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Criteria for use of waste

- calorific value from waste material
- material value from waste material

Figure 1.7: Hazardous waste – impregnated sawdust

Source:[168, TWG CLM, 2007]

Figure 1.8: Specially prepared waste fuel based on, e.g. paper, plastics, textiles

Source:[81, Castle Cement UK, 2006]

Figure 1.9: Specially prepared household waste used as fuel in cement kilns

Source:[82, CEMEX Rugby UK, 2006]

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Calorific values for different types of wastes used as fuels in the EU-27

Examples of types of waste fuels (hazardous and non-hazardous)	Examples of calorific values (MJ/kg)
Wood	Approx. 16
Paper, cardboard	3 – 16
Textiles	up to 40
Plastics	17 – 40
Processed fractions (RDF)	14 – 25
Rubber/tyres	approx. 26
Industrial sludge	8 – 14
Municipal sewage sludge	12 – 16
Animal meal, fats	14 – 18, 27 – 32
Animal meal (carcase meal)	14 – 21.5
Coal/carbon waste	20 – 30
Agricultural waste	12 – 16
Solid waste (impregnated sawdust)	14 – 28
Solvents and related waste	20 – 36
Oil and oily waste	25 – 36
Oil-shale based fuel mix (85 – 90 % oil-shale)	9.5
Sewage sludge (moisture content > 10 %)	3 – 8
Sewage sludge (moisture content < 10 to 0 %)	8 – 13
Source: [75, Estonia, 2006] [168, TWG CLM, 2007] [180, Mauschitz, 2004]	

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Consumption of waste used as fuel

in EU-27 cement kilns in 2003 and 2004

Group No(1)	Type of waste	Types of waste fuels – Quantities in 1 000 tonnes – 2003 – Hazardous	Non-hazardous	2004 – Hazardous	Non-hazardous
1	Wood, paper, cardboard	0.000	214 991	1 077	302 138
2	Textiles	0.000	19 301	0.000	8 660
3	Plastics	0.000	354 070	0.000	464 199
4	RDF	4 992	570 068	1 554	734 296
5	Rubber/tyres	0.000	699 388	0.000	810 320
6	Industrial sludge	52 080	161 660	49 597	197 720
7	Municipal sewage sludge	0.000	174 801	0.000	264 489
8	Animal meal, fats	0.000	1 313 094	0.000	1 285 074
9	Coal/carbon waste	1 890	137 213	7 489	137 013
10	Agricultural waste	0.000	73 861	0.000	69 058
11	Solid waste (impregnated sawdust)	164 931	271 453	149 916	305 558
12	Solvents and related waste	425 410	131 090	517 125	145 465
13	Oil and oily waste	325 265	181 743	313 489	196 383
14	Others	0.551	199 705	0.000	212 380
Total		975 119	4 502 435	1 040 247	5 133.353

(1) Each grouping spans several EWC listings, see Table 6.1 in Section 6.2.1

Source: [74, CEMBUREAU, 2006]

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Substitution of waste fuels for cement production in EU-23+ countries

Country	Permitted capacities for waste fuels (t/yr) – National range(1)	National average	Amount of waste fuels used (t/yr) – National range(1)	National average	Percentage of heat release (%) – Hazardous waste – National range(1)	National average	Non-hazardous waste – National range(1)	National average
Austria(2)	10 000–35 000	-	9 500–39 000	30 000	30–45	12	15–50	35
Belgium, Netherlands, Luxembourg	-	-	58 500–402 000	138 930	0–25	11	21–30	24
Czech Republic	90 000(3)	-	-	40 000	0–40	15	0–100	37
Denmark, Finland, Sweden, Norway, Ireland	300 000(3)	-	22 000–120 000	75 000	2–20	15	24–35	32
Estonia, Latvia, Poland, Hungary	15 000–380 000	125 000	8 000–67 369	27 271	13.4–14	13.7	16–26.1	17.5
France	125 000–265 000	-	300–113 000	37 374	0–41.2	14	0.4–52	14.6
Germany	-	-	218 157(3)	56 857	0–25	5.2	76(3)	43.6
Greece, Portugal, Romania, Slovenia	20 000–500 000	20 506	640–60 000	9 196	0–3.8	0.7	0.4–15.6	2
Italy	5 000–115 000	28 000	5 300–90 600	13 100	1.3–21	12	0.9–37	11.3
Spain	8 800–100 000	43 000	2 000–36 000	15 500	0–27.8	4.8	2–25	8.5
United Kingdom	25 000–788 400	182 337	0–55 960	24 086	0–27.6	6	0–40	7.8

Note: Figures are aggregated from EU-23+ countries' replies
(1) Minimum – maximum
(2) Only 2004 figures
(3) Maximum
Source: [168, TWG CLM, 2007] [178, CEMBUREAU, 2008]

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Emissions to air

- oxides of nitrogen (NOx) and other nitrogen compounds
- sulphur dioxide (SO2) and other sulphur compounds
- dust
- total organic compounds (TOC) including volatile organic compounds (VOC)
- polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD and PCDF)
- metals and their compounds
- hydrogen fluoride (HF)
- hydrogen chloride (HCl)
- carbon monoxide (CO).

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Data of emissions ranges from European cement kilns

Reported emissions from European cement kilns([1])			
Pollutant	**mg/Nm^3**	**kg/tonne clinker**	**tonnes/year**
NO_x (as NO_2)	145–2040	0.33–4.67	334–4670
SO_2	Up to 4 837([2])	Up to 11.12	Up to 11 125
Dust	0.27–227([3])	0.00062–0.5221	0.62–522
CO	200–2000([4])	0.46–4.6	460–11 500
CO_2	-	Approx. 672 g/t_{cement}	1.5456 million
TOC/VOC	1–60([5])	0.0023–0.138	2.17–267
HF	0.009–1.0	0.021–2.3 g/t	0.21–23.0
HCl	0.02–20.0	0.046–46 g/t	0.046–46
PCDD/F	0.000012–0.27 ng I-TEQ/Nm^3	0.0276–627 ng/t	0.0000276–0.627 g/year
Metals([6])			
Hg	0–0.03([7])	0–69 mg/t	0–1 311 kg/year
∑ (Cd, Tl)	0–0.68	0–1 564 mg/t	0–1 564 kg/year
∑ (As, Sb, Pb, Cr, Co, Cu, Mn, Ni, V)	0–4.0	0–9 200 mg/t	0–9 200 kg/year

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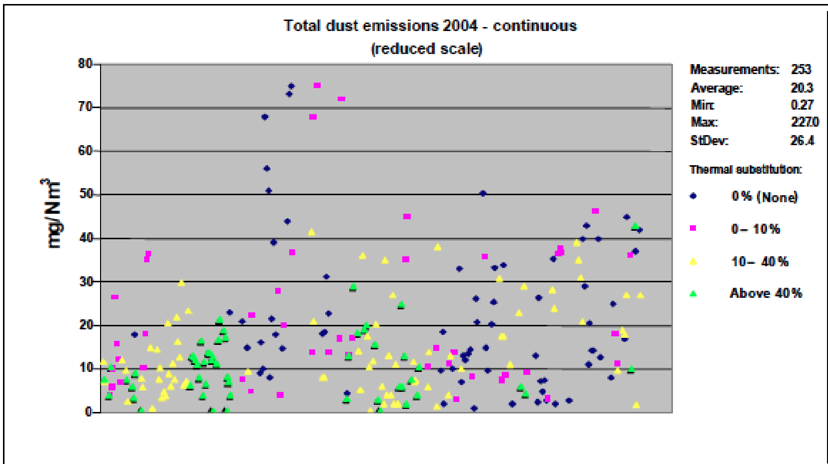
Emission values - dust measurements

in the clean gas from 253 rotary kilns in the EU-27 and EU 23+ countries



Source: [97, CEMBUREAU, 2007]

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Overview of techniques for controlling dust in the cement production process

Measure/technique	Applicability	Emissions data(1)		Cost (2)	
		mg/Nm³ (3)	kg/tonne(4)	Investment Million EUR	Operating EUR/t clinker
Electrostatic precipitators	All kiln systems, clinker coolers, cement mills	<10–<20 <10–<20 <10	0.02–0.05 0.02–0.05 0.02	2.1–6.0 0.8–1.2 0.8–1.2	0.1–0.2 0.09–0.18 0.09–0.18
Fabric filters	All kiln systems, clinker coolers, mills (raw material, cement, coal mills)	<5 <5 <10	0.01 0.01 0.02	2.1–6.0(5) 1.0–1.4(5) 0.3–0.5(5)	0.15–0.35 0.1–0.15 0.03–0.04
Hybrid filters	All kiln systems, clinker coolers, cement mills	<10–20	0.02–0.05		
Diffuse dust abatement	All plants	-	-	-	-

(1) Emissions data can be found in the corresponding paragraph of this section
(2) Cost for reducing the emissions to 10–30 mg/Nm³, normally referring to a kiln capacity of 3 000 tonne clinker per day and initial emissions of up to 500 g dust/Nm³
(3) For kiln systems normally referring to daily averages, dry gas, 273 K, 101.3 kPa and 10 % O_2
(4) kg/tonne clinker: based on 2 300 m³/tonne clinker
(5) Depends on the filter medium used, see Table 1.32, by separation efficiencies of higher than 99.9 %

Example of system types used for dust extraction

Types of systems and operational data for dust reduction			
Parameter	**Unit**	**ESPs**	**Fabric filters**
Year of construction		1962–2004	1999–2005
Pressure loss	hPa	1–8	10–12 (2) (1)
Temperature	°C	90–190	90–160(2)
Electric energy demand	kWh/t clinker	1–4	0.1–0.2
Fan power demand	kWh/t clinker	0.15–1.2	1.5–1.8
Total energy demand	kWh/t clinker	1.15–5.2	1.6–2.0
Amount of filter dust and dust extraction			
Parameter	**Unit**	**Compound operation**	**Direct operation**
Amount of filter dust	kg/t clinker	54–144 (1 718)(1)	80–200 (10–70)(1)
Dust extraction	kg/t clinker	0–35	0–66 (165)(1)

(1) Values in brackets refer to extreme values that have been reported in some individual cases.
(2) 240 °C was reported by using glass fibres with a PTFE membrane.
Source: [76, Germany, 2006], [103, CEMBUREAU, 2006]

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Investigation on fine dust distribution

in total dust from German cement kilns

Emissions source		Total dust concentration(1) (mg/Nm^3)	Fine dust fraction (%)			Fine dust concentration (mg/Nm^3)		
			< 2.5	< 10	> 10	< 2.5	< 10	> 10
			µm					
Kiln (ESP)(2)	Kiln flue-gas after ESP	15.4	51	87	13	7.9	13.4	2.9
Clinker cooler (ESP)	Clinker cooler flue-gas after ESP	14.0	68	99	1	9.5	13.9	≤ 0.1
Cyclone preheater (ESP), direct mode(3)	Kiln flue-gas after ESP	2.3	84	97	3	1.9	2.2	≤ 0.1
Cyclone preheater (ESP), combined mode(4)	Kiln flue-gas after ESP	4.8	66	97	3	3.2	4.7	≤ 0.1

(1) Total dust measured with filter sampler measurements (plane filter device), size segregation with cascade impactors
(2) Lepol kiln, now shut down
(3) Mill off
(4) Mill on
Source: [117, Germany, 2000]

Dust reduction techniques

along with reduction efficiencies according to the RAINS model

Technique	Reduction efficiency (%)		
	Total particulate matter	PM_{10}	$PM_{2.5}$
Cyclone	74.4	52.86	30
ESP 1	95.8	94.14	93
ESP 2	98.982	97.71	96
ESP 3	99.767	99.51	99
Fabric filter	99.784	99.51	99
Wet scrubber	98.982	97.71	96
Source: [172, France, 2007]			

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Techniques for reducing NOx emissions used in the cement industries in the EU-27 and EU-23+ countries

Techniques for reducing/controlling NO_x emissions

Country		Flame cooling	Mineralised clinker	Staged combustion	SNCR	SCR
Belgium	BE	2			2	
Bulgaria	BG					
Czech Republic	CZ				2([1])	
Denmark	DK		2		1	
Germany	DE			7	33	1([2])
Estonia	EE					
Greece	EL			1		
Spain	ES		4	2	3+5 (pilot phase)	
France	FR	2		7	14+4([3])	
Ireland	IE			1	2([4])	
Italy	IT	2		7	16([2])	1([5])
Cyprus	CY					
Latvia	LV					
Lithuania	LT					
Luxembourg([1])	LU					
Hungary	HU				3	
Malta	MT					
Netherlands	NL				1	
Austria	AT	3		2	8([1])	
Poland	PL			9		
Portugal	PT	6			4	
Rumania	RO					
Slovenia	SI					
Slovakia	SK					
Finland	FI				2	
Sweden	SE				3	
United Kingdom	UK			1	9([6])	
Switzerland	CH	2	1	1	4	
Norway	NO					
Turkey	TR	1	1	2		

([1]) Scheduled for 2008
([2]) Reported to be in operation but reporting still lacking
([3]) Scheduled for 2008
([4]) Scheduled for commissioning in 2007
([5]) One plant has been in operation since the middle of 2006, second plant since 2007
([6]) Put into operation in 2007
Source: [85, CEMBUREAU, 2006]

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Abatement techniques for SO2 reduction used in the EU-27 and EU-23+ countries in 2008

Techniques for reducing/controlling SO_2 emissions				
Country		Absorbent addition	Wet scrubber	Activated carbon
Belgium	BE	2		
Bulgaria	BG			
Czech Republic	CZ	1		
Denmark	DK		2	
Germany	DE	11		
Estonia	EE			
Greece	EL			
Spain	ES			
France	FR	3		
Ireland	IE			
Italy	IT	1		
Cyprus	CY			
Latvia	LV			
Lithuania	LT			
Luxembourg	LU			
Hungary	HU			
Malta	MT			
Netherlands	NL			
Austria	AT	1	1	
Poland	PL			
Portugal	PT	3		
Romania	Ro			
Slovenia	SI		1	
Slovakia	SK			
Finland	FI			
Sweden	SE		1	
United Kingdom	UK		2	
Norway	NO			
Switzerland	CH	1	1	1
Turkey	TR			
	TOTAL	23	8	1

Source: [73, CEMBUREAU, 2006], [182, TWG CLM, 2008]

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Overview of techniques for controlling and reducing SO2

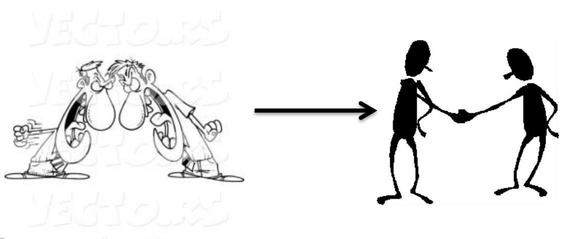
Measures/ techniques	Kiln systems applicability	Reduction efficiency	Emissions data		Cost	
			mg/Nm³ (¹)	kg/tonne (²)	Investment (million EUR)	Operating (EUR/t)
Absorbent addition	All	60–80 %	< 200–400(⁵)	0.23–0.92	0.2–0.3	0.1–0.4
Wet scrubber	All	> 90 %	< 10–300(⁴)	0.02–0.69	5.8–23(⁶)	0.5–2(⁶)
Activated carbon	Dry	Up to 95 %	< 50	< 0.11	15(³)	No info.

(¹) Normally refers to daily averages, dry gas, 273 K, 101.3 kPa and 10 % O_2
(²) kg/tonne clinker: based on 2 300 m³/tonne clinker
(³) This cost also includes an SNCR process, referring to a kiln capacity of 2 000 tonne clinker/day and initial emissions of 50–600 mg SO_2/Nm³, cost data from 1997
(⁴) The final achievable emission level is dependent on the initial SO_2 value prior to the installation of the wet scrubber and could be higher
(⁵) For an initial SO_x level of 1 200 mg/Nm³ (see Section 1.4.5.2.1)
(⁶) 2008

Best Available Technique (BAT)

Fundamental principle in the IE Directive

1) To protect and improve the environment!
2) To allow/urge/support operators I general to run and develop environmental effective production



BAT combines interests of environment and industry

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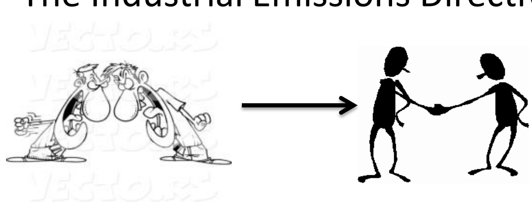
BAT

- What is the sense?
  - To ensure high environmental standards, allow competitive industry to operate and urge continuous improvement
- BAT Included firstly in IPPC directive 1994, now
- The Industrial Emissions Directive (2010/75/EU)



BAT combines interests of environment and industry

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Definition of BAT in the IED

***B**est*	Most effective in achieving a **high general level** of protection of the environment **as a whole**
***A**vailable*	Developed on a scale which allows implementation in the relevant industrial sector, under **economically and technically viable conditions**
***T**echniques*	**Both** the technology used and the way in which the installation is **designed, built, maintained, operated and decommissioned**

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Role of BAT conclusions in IED permitting

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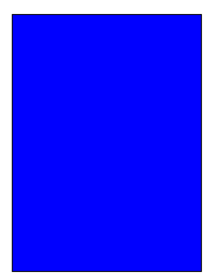
BAT are determined by a Technical Working Group steered by the JRC (EIPPCB) and documented in BREFs

'BAT conclusions' are secondary legislation



BAT conclusions are the reference for setting permit conditions

Permits to contain **emission limit values** (ELVs) to ensure that, under normal operating conditions, **emissions do not exceed BAT-associated emission levels (BAT-AELs)**

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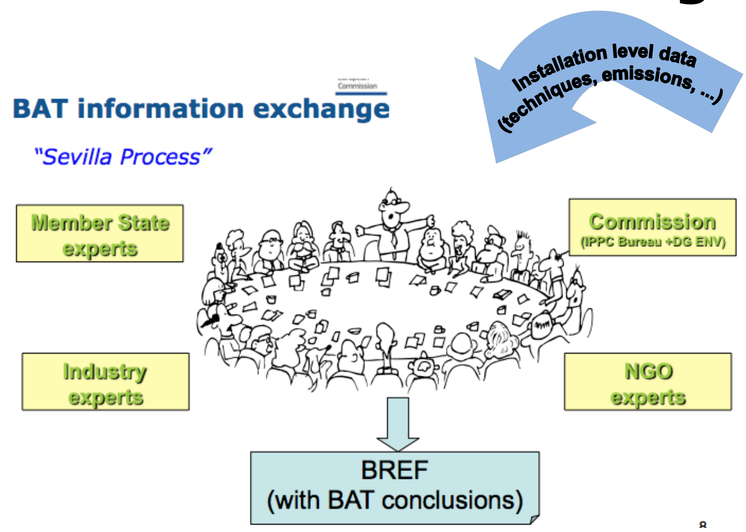
BAT information exchange



Content of BREF documents

Standard BREF structure:

1. Preface
2. General information
3. Process/techniques used
4. Consumption and emission levels
   Candidate BAT
5. BAT conclusions
6. Emerging techniques

Annexes

So far – 31 sectors covered with BREFs + 2 ref documents
http://eippcb.jrc.ec.europa.eu/reference/

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Production of Cement, Lime and Magnesium Oxide

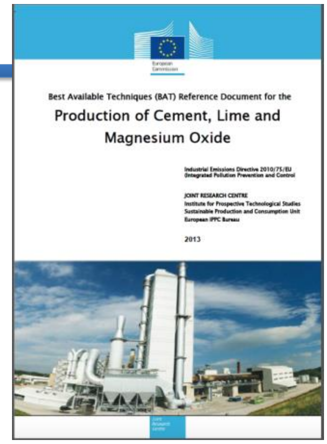
- BREF Note 2013 – 475 pages
- 69 BAT conclusions – 29 for cement industry pages

COMMISSION IMPLEMENTING DECISION

of 26 March 2013

establishing the best available techniques (BAT) conclusions under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions for the production of cement, lime and magnesium oxide

(notified under document C(2013) 1728)



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Other BREFs relevant

- Emissions from storage
- Energy efficiency
- Industrial cooling systems
- Waste incineration
- Large combustion plants

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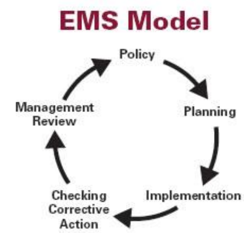
BAT conclusions – 29 articles

1 Environmental management systems (EMS)
2 Noise
3-5 General primary techniques and monitoring
6-10 Energy consumption and process selection
11-13 Use of waste
14-18 Dust
19-26 Gaseous compounds (NOx, Sox, CO, TOC, HCL HF) emissions
27-28 PCDD/F and metal emissions
29 Process losses/waste



Monitoring

5. BAT is to carry out the monitoring and measurements of process parameters and emissions on a regular basis and to monitor emissions in accordance with the relevant EN standards or, if EN standards are not available, ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality, including the following:

	Technique	Applicability
a	Continuous measurements of process parameters demonstrating the process stability, such as temperature, O_2 content, pressure and flowrate	Generally applicable
b	Monitoring and stabilising critical process parameters, i.e. homogenous raw material mix and fuel feed, regular dosage and excess oxygen	Generally applicable
c	Continuous measurements of NH_3 emissions when SNCR is applied	Generally applicable
d	Continuous measurements of dust, NO_x, SO_x, and CO emissions	Applicable to kiln processes
e	Periodic measurements of PCDD/F and metal emissions	
f	Continuous or periodic measurements of HCl, HF and TOC emissions.	
g	Continuous or periodic measurements of dust	Applicable to non-kiln activities. For small sources (<10 000 Nm^3/h) from dusty operations other than cooling and the main milling processes, the frequency of measurements or performance checks should be based on a maintenance management system.

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Energy consumption

6. In order to reduce energy consumption, BAT is to use a dry process kiln with multistage preheating and precalcination.

Table 4.1: BAT-associated energy consumption levels for new plants and major upgrades using dry process kiln with multistage preheating and precalcination

Process	Unit	BAT-associated energy consumption levels (1)
Dry process with multistage preheating and precalcination	MJ/tonne clinker	2 900 – 3 300 (2)(3)

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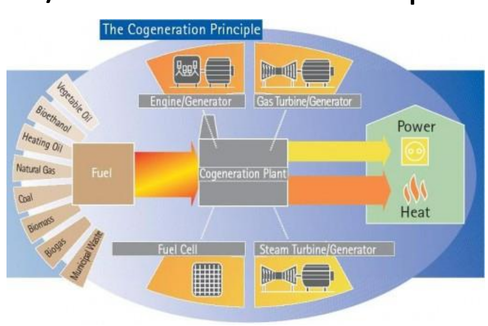
Cogeneration

9. In order to reduce primary energy consumption, BAT is to consider cogeneration/combined heat and power plants.



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Waste quality control

11. In order to guarantee the characteristics of the wastes to be used as fuels and/or raw materials in a cement kiln and reduce emissions, BAT is to apply

	Technique
a	Apply quality assurance systems to guarantee the characteristics of wastes and to analyse any waste that is to be used as raw material and/or fuel in a cement kiln for: I. constant quality II. physical criteria, e.g. emissions formation, coarseness, reactivity, burnability, calorific value III. chemical criteria, e.g. chlorine, sulphur, alkali and phosphate content and relevant metals content
b	Control the amount of relevant parameters for any waste that is to be used as raw material and/or fuel in a cement kiln, such as chlorine, relevant metals (e.g. cadmium, mercury, thallium), sulphur, total halogen content
c	Apply quality assurance systems for each waste load

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Dust emissions from kiln firing processes

17. In order to reduce dust emissions from flue-gases of kiln firing processes, BAT is to use dry flue-gas cleaning with a filter.

Technique ([1])	Applicability
a. Electrostatic precipitators (ESPs)	Applicable to all kiln systems
b. Fabric filters	
c. Hybrid filters	
([1]) A description of the techniques is given in Section 4.5.1.	

BAT-associated emission levels
The BAT-AEL for dust emissions from flue-gases of kiln firing processes is <10 – 20 mg/Nm3, as the daily average value. When applying fabric filters or new or upgraded ESPs, the lower level is achieved.

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Diffuse dust emissions

14. In order to minimise/prevent diffuse dust emissions from dusty operations, BAT is to use one or a combination of the following techniques:

- Use a simple and linear site layout of the installation
- Enclose/encapsulate dusty operations, such as grinding, screening and mixing
- Cover conveyors and elevators, which are constructed as closed systems, if diffuse dust emissions are likely to be released from dusty material
- Reduce air leakages and spillage points
- Use automatic devices and control systems
- Ensure trouble-free operations
- Ensure proper and complete maintenance of the installation using mobile and stationary vacuum cleaning
- Ventilate and collect dust in fabric filters
- Use closed storage with an automatic handling system
- Use flexible filling pipes for dispatch and loading processes, equipped with a dust extraction system for loading cement, which are positioned towards the loading floor of the lorry

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NOx emissions

19. In order to reduce the emissions of NOx from the flue-gases of kiln firing and/or preheating/precalcining processes, BAT is to use one or a combination of the following techniques:

	Technique (¹)	Applicability
a	Primary techniques	
	I. Flame cooling	Applicable to all types of kilns used for cement manufacturing. The degree of applicability can be limited by product quality requirements and potential impacts on process stability
	II. Low NO_x burners	Applicable to all rotary kilns, in the main kiln as well as in the precalciner
	III. Mid-kiln firing	Generally applicable to long rotary kilns
	IV. Addition of mineralisers to improve the burnability of the raw meal (mineralised clinker)	Generally applicable to rotary kilns subject to final product quality requirements
	V. Process optimisation	Generally applicable to all kilns
b	Staged combustion (conventional or waste fuels), also in combination with a precalciner and the use of optimised fuel mix	In general, can only be applied in kilns equipped with a precalciner. Substantial plant modifications are necessary in cyclone preheater systems without a precalciner. In kilns without precalciner, lump fuels firing might have a positive effect on NO_x reduction depending on the ability to produce a controlled reduction atmosphere and to control the related CO emissions
c	Selective non-catalytic reduction (SNCR)	In principle, applicable to rotary cement kilns. The injection zones vary with the type of kiln process. In long wet and long dry process kilns it may be difficult to obtain the right temperature and retention time needed. See also BAT 20
d	Selective catalytic reduction (SCR)	Applicability is subject to appropriate catalyst and process development in the cement industry

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NOx - ELV

Table 2

BAT-associated emission levels for NO_x from the flue-gases of kiln firing and/or preheating/precalcining processes in the cement industry

Kiln type	Unit	BAT-AEL (daily average value)
Preheater kilns	mg/Nm³	< 200 – 450 (1) (2)
Lepol and long rotary kilns	mg/Nm³	400 – 800 (3)

(1) The upper level of the BAT-AEL range is 500 mg/Nm³, if the initial NO_x level after primary techniques is > 1 000 mg/Nm³.
(2) Existing kiln system design, fuel mix properties including waste and raw material burnability (e.g. special cement or white cement clinker) can influence the ability to be within the range. Levels below 350 mg/Nm³ are achieved at kilns with favourable conditions when using SNCR. In 2008, the lower value of 200 mg/Nm³ has been reported as a monthly average for three plants (easy burning mix used) using SNCR.
(3) Depending on initial levels and NH_3 slip.

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SOx emissions

21. In order to reduce/minimise the emissions of SOx from the flue-gases of kiln firing and/or preheating/precalcining processes, BAT is to use one of the following techniques:

	Technique (1)	Applicability
a	Absorbent addition	Absorbent addition is, in principle, applicable to all kiln systems, although it is mostly used in suspension preheaters. Lime addition to the kiln feed reduces the quality of the granules/nodules and causes flow problems in Lepol kilns. For preheater kilns it has been found that direct injection of slaked lime into the flue-gas is less efficient than adding slaked lime to the kiln feed
b	Wet scrubber	Applicable to all cement kiln types with appropriate (sufficient) SO_2 levels for manufacturing the gypsum

(1) A description of the techniques is provided in Section 4.5.3.

Table 4.4: BAT-associated emission levels for SO_x from the flue-gases of kiln firing and/or preheating/precalcining processes in the cement industry

Parameter	Unit	BAT-AEL (1) (2) (daily average value)
SO_x expressed as SO_2	mg/Nm³	<50–400

(1) The range takes into account the sulphur content in the raw materials.
(2) For white cement and special cement clinker production, the ability of clinker to retain fuel sulphur might be significantly lower leading to higher SO_X emissions.

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Process losses/waste

29. In order to reduce solid waste from the cement manufacturing process along with raw material savings, BAT is to:

	Technique	Applicability
a	Reuse collected dusts in the process, wherever practicable	Generally applicable but subject to dust chemical composition
b	Utilise these dusts in other commercial products, when possible	The utilisation of the dusts in other commercial products may not be within the control of the operator

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Group work - Questions

A) Energy (BAT conclusions 6-10)
- How do energy consumption comply/relate to with BAT?
- Sub questions (measurement, performance, monitoring, documentation, improvements – plans?)

Air (BAT conclusions - dust (14-18) other (19-28)
- Compliance with BAT for Dust, SOx, Nox others
- Sub questions (measurement, techniques, results, documentation, improvements – plans?)

B) Waste and raw materials (BAT conclusions 11-13 and 29)
- Use of waste and waste fuel in production? Waste reuse
- Sub questions (amount, permit conditions, control, results, improvement – plans?)

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