7.11 Lime production

7.11.1 Coverage

This category covers the lime production and the use of lime kiln in lime industry. It does not cover the lime kiln integrated in other industrial process such as in paper industry.
The emissions from lime plants which cause greatest concern are dust (TSP) emissions. Lime production process is also a source of nitrogen oxides (NO_x) and sulphur dioxide (SO_2) emissions. These emissions mainly arise from the limestone calcining process. [9]

7.11.2 Emission sources

The lime is produced by a heating process. Calcium or magnesium carbonate is heated to form carbon dioxide and lime. During this process, NO_x, SO_2 and dust are emitted.
Different techniques are used for lime production. The choice of the technique depends on the quantity of lime to be produced and the size of the feed stones.

Most of used furnaces are based on either the shaft or the rotary design. All of these designs incorporate the concept of three zones: the **preheating** zone where limestone is heated to 800°C, the **calcining** zone where the combustion takes place and enable the formation of lime at over 900°C, and the **cooling** zone where lime is cooled. The lime which exits from the cooling process is called quicklime (CaO).

Some rotary and fluidised bed kilns, are operated in connection with separate preheaters.
Quicklime from the cooling process is screened and fines particles, less pure, are removed. The screened quicklime is then crushed and classified to control the grading of the products.
Slaked lime can also be produced. It includes hydrated lime, milk of lime and lime putty. Hydrated lime is produced from quicklime using a hydrator. Milk of lime and lime putty are produced by slaking of lime in excess of water. Batch and continuous slakers are used for this operation. [9].

7.11.3 BAT, Associated Emission Levels (AEL)

If not stated otherwise, emission levels given in this section are expressed on a daily average basis and standard conditions of 273 K, 101.3 kPa, 11% oxygen and dry gas.

SO_2:

In lime production, SO_2 emissions are influenced by the sulphur content of the fuel used during the combustion process. SO_2 emissions also depend on the design of kiln and the required sulphur content of the lime produced. The main measure to reduce SO_2 emissions is the use of free sulphur fuel or fuel with low sulphur content. There is no secondary measure considered in the current BAT to reduce SO_2 emissions. Absorbent addition techniques are available, but not currently applied.
SO_2 from the flue-gases of kiln firing processes can be reduced by using process optimisation measures/techniques to ensure an efficient absorption of sulphur dioxide, i.e. efficient contact between the kiln gases and the quicklime.
As no BAT emission levels are available, typical SO_2 emissions from lime production are presented in the following table. [9].

Table 1: Associated SO_2 emission levels with BAT to reduce emissions in lime Industry. [7]

Emission source	Techniques	Associated emission level with BAT (mg/Nm^3) [1]
Parallel flow regenerative kiln (PFRK), annular shaft kiln (ASK), mixed feed shat kiln (MFSK), other shaft kiln (OSK) and preheater rotary kiln (PRK)	Combination of: process optimisations to ensure an efficient absorption of SO_2, use of fuel with low sulphur content and using absorbent addition techniques	<50 – 200
Long rotary kiln (LRK)		< 50 – < 400

[1]The level depends on the initial SO_X level in the exhaust gas and on the reduction measure technique used

NO_x:

In lime production, NO_x emissions are influenced by different parameters: the type of fuel, the type of combustion, the combustion air-ratio and the flame temperature. Those parameters depend on the quality of lime to be produced and the design of kiln.
Both primary and secondary measures can be used in order to reduce NO_x emissions. Primary measures include:

- Process optimization: smoothing and optimising the plant operation and/or homogenisation of the fuel and raw material feedings.
- Burner design: NO_x emissions can be minimised by the operation of special low NO_x burners. These burners are useful for reducing the flame temperature and thus reducing thermal and (to some extent) fuel derived NO_x. The NO_x reduction is achieved by supplying rinsing air for lowering the flame temperature or pulsed operation of the burners. Low NO_x burners are only applied to rotary kilns.

Secondary measure that can be applied is:

- Selective non catalytic reduction (SNCR): in the selective non-catalytic reduction (SNCR) process, nitrogen oxides (NO + NO2) from the flue-gases are removed by selective non-catalytic reduction and converted into nitrogen and water by injecting a reducing agent into the kiln which reacts with the nitrogen oxides. The reactions occur at temperatures of between 850 and 1020 °C, with the optimal range is typically between 900 to 920 °C. In lime manufacturing, SNCR is applicable to preheater rotary kilns (Lepol grate). For vertical kilns, it is technically not yet feasible to carry out an SNCR treatment since the temperature of the flue-gas is far below 200 °C. In long rotary kilns, the application of the SNCR technology is not practical as the zone with the optimal window of temperatures is located within the rotating part of the kiln. Being an emerging technique in the lime industry, SNCR is currently only applied in one plant in Europe.

As no BAT emission levels are available, typical NO_x emissions from lime production process are presented in the following table. [9]

Table 2: Associated NO_X emission levels with BAT to reduce emissions in lime Industry. [7]

Emission source	Techniques	Associated emission level with BAT (mg/Nm^3)
Annular shaft kiln (ASK), parallel flow regenerative kiln (PFRK), mixed feed shat kiln (MFSK) and other shaft kiln (OSK).	Combination of: primary techniques (use of fuel with low nitrogen content, process optimisations, burner design (low NO_X burners), air staging (PRK)) and SNCR (lepol rotary kiln).	100 – < 350[1 2]
Long rotary kiln (LRK) Preheater rotary kiln (PRK)		< 200 – < 500[1 3]

[1]The higher ranges are related to the production of dolime and hard burned lime.
[2]For LRK and PRK zith shaft producing hard burned lime, the upper level is up to 800 mg/Nm^3.
[3]Where primary measures/techniques are not sufficient and where secondary measures/techniques are not available to reduce NOx emissions to 350 mg/Nm3, the upper level is 500 mg/Nm3, especially for hard burned lime.

Dust:
In lime production, the kiln and the post-cooling processes are the main sources of dust emissions. Fugitive emissions from handling and storage of materials are also significant.
Rotary kilns are generally equipped with ESP while shaft kilns and lime grinding plants are equipped with fabric filters to control dust emissions. Fabric filters should be equipped with burst bag detectors to indicate the need for maintenance.
Cyclones can also be used to reduce dust emissions but only as flue gases pre-cleaners. Cyclones are easy to operate and cost effective but do not retain effectively microparticles.
Flue gases from lime hydrating can be dedusted using wet scrubbers or fabric filters while flue gases from lime grinding can be dedusted using both cyclones and fabric filters.
The following table gives an overview of achievable dust emissions levels in lime manufacturing.

Table 3: Associated dust emission levels with BAT to reduce emissions in lime Industry. [9], [2],

Emission source	Techniques	Associated emission level with BAT (mg/Nm^3)[2]
Kilns	ESP	Dust: < 10 - 20
	Fabric filters	Dust: < 10
Dusty operations[1]	Fabric filter	Dust: <10
	Wet scrubbers (mainly used in hydrating plants)	Dust: < 10 – 20

[1]It has be noted that for small sources (<10000 Nm^3/h) a priority approach has to be taken into account.
[2]Values are given as the average over the sampling period (spots measurements, for at least half an hour)
[3]In exceptional cases where resistivity of dust is high, the BAT AEL could be higher, up to 30 mg/Nm^3, as the daily average value.

7.11.4 Emerging techniques

Considered emerging reduction techniques in lime production are:

- Fluidised bed calcinations to reduce SO_2 and NO_x emission levels.
- Absorbent addition (hydrated lime or sodium bicarbonate) to reduce SO2 emission levels. This process needs an optimised residence time to be effective.
- Ceramic filters to reduce dust emission levels. They are not currently used but their ability to reduce dust at high temperature makes this technique available.

7.11.5 Cost data for emission reduction techniques

As dust emissions are the emissions which cause the greatest concern, costs of reduction techniques are only presented for dust. [9], [2]. There are three main dedusting techniques used for lime kilns : fabric filters, electrostatic precipitators (ESPs) and wet scrubber.
Investments costs are affected by the size of the filter and the operating conditions. Therefore, a wide variation of investment costs exists. The main cost drivers are investments, maintenance and energy. The cost of dust reduction techniques are presented in the next table.

Table 4: Cost of techniques for controlling dust in lime Industry.

Technique	Applicability	Emission level		Cost [3]	
		mg/m[3] [1]	kg/tonne [2]	investment	operating
ESP	All kiln systems, milling plant, subsidiary processes	<10 – <20	0.015 – 0.1	0.6 – 3.9	>1.5
Fabric filter	All kiln systems	<10 – <20	0.015 – 0.15	0.25 – 1.7	>1.5
	Milling plant, subsidiary processes	<10 – <20	0.015 – 0.05		
Wet dust separator	All kiln systems, hydrating plants	10 – 30	0.06 – 0.25	-	-

[1] normally referring to daily averages, dry gas, 273 K, 101.3 kPa and 11% O_2, except for hydrating plants for which conditions are as emitted.
[2] kg/tonne lime based on 3 700 Nm^3/tonne of lime for rotary kilns with preheaters, 3 000 Nm^3/tonne of lime for annular shaft kilns and parallel flow regenerative kilns and 5 000 Nm^3/tonne for long rotary kilns
3 investment in 10^6 euros and operating cost in euros/tonne lime, referring to different kiln capacities.

7.11.6 References used in chapter 7.11

[1] Auswertung von staub- und Feinstaubemissionsdaten der Datenbank nordrhein-westfälisher Emissionserklärungen, LUA NRW, 2003.

[2] Background document: lime production, EGTEI, 2003.

[3] Comments from André Peeters Weem, Cees Braams, InfoMil, the Dutch Ministry of Environment, 12/2008.

[4] Comments from Maja Bernicke, Federal Environment Agency Germany, 12/2008.

[5] Comments from Gaston Theis, Swiss Federal Office for the Environment, 11/2008.

[6] "Compilation of the answers-to-questions-and proposal of EGTEI secretariat.doc",EGTEI, 02/2009.

[7] Reference document on Best Available Techniques in the cement and lime manufacturing industries, Final draft version, February 2009.

[8] "EGTEI-State of progress.doc", for WGSR, March 2009.

[9] Draft reference document on Best Available Techniques in the cement and lime, and magnesium oxide manufacturing industries, May 2009.

[10] Comments from Mira Tayah, IMA, May 2009.