Toward a Sustainable Cement Industry in 2020

Improvement of the Environmental, Health & Safety Performance

Summary Report Substudy 10

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TNO – Environment, Energy and Process Innovation
TNO – Work and Employment
PricewaterhouseCoopers

Summary Report
Improvement of the EHS Performance

This summary report is based on a background document "Improvement of the EHS performance toward a sustainable cement industry" consisting of three parts:

I. Environmental aspects, prepared by TNO Environment, Energy and Process Innovation;
II. Improvement of the health and safety performance, prepared by TNO Work and Employment;
III. EHS management, prepared by PricewaterhouseCoopers.

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Contents

1 Overview

The background document concentrates on technical and managerial aspects of EHS control in the cement industry. It gives an overview of options for improvement toward a sustainable cement production in 2020. Energy consumption and use of alternative fuels and raw materials are included in this substudy.

Globally, the cement industry is in different stages of development. EHS issues and approach will depend on economical, managerial and technological possibilities in the local situation. Dependent on this local situation, the market etc. and starting from its own position with regard to technology, education and training of personnel and management approach, a cement plant has to select which option will be implemented to strengthen its position. These options can be larger or smaller changes in the plant, even a fundamentally new process, investments in new pieces of equipment, improvements in management systems, extra attention for specific problems etc. The cement industry is a very capital-intensive industry and large changes in equipment can only be introduced in a long-term investment scheme. Pay-back of these investments can take many years, even decades, and consequently large step improvements in a cement plant are only possible once in a long period. Furthermore, the introduction of new management systems should also be a gradually developing process in harmony with plant and local culture, educational backgrounds etc. Many of the intended changes will not, or not in first instance, be directed toward improvement of EHS issues. However, it may be anticipated, also from experiences in the past, that the EHS performance can and will improve gradually in time with the improvements in technological, managerial and educational plant operation and that additionally, many annual, small improvements will significantly improve the EHS performance in time. Therefore, in any stage of development and independent of its scale, a cement plant can initiate a process of continuous improvement of its EHS performance by paying attention to the EHS impact in all actions. This process of continuous improvement can be cost-effective and suited to the company's situation

Improvement of the following EHS issues requires the attention of the cement industry:

- reduction of emissions into the air. Historically SO_x, NO_x and dust emissions are high. The attention for heavy metals and dioxins increased after the introduction of waste materials as alternative fuels and/or raw materials (AFR). Since the start of the greenhouse debate, the CO_2 emission of the cement industry is of concern;
- reduction of the use of natural resources: energy, raw materials and fossil fuels;
- improvement of safety and health performance;
- introduction of EHS management systems for a systematic improvement of the EHS performance,
- in the long term, acceptance of a responsibility for product stewardship and product chain management including re-use and recovery of used products.

The cement process can also have a positive, environmental impact on society, especially on its waste management. Due to the specific nature of the process and the product, the cement industry is well suited for the cost-effective recovery of organic as well as inorganic materials: residues of other industrial operations or households. The recovery of these residues contributes to the desired saving of natural resources by the cement industry as well as to a cost-effective and sound waste management in society.

The priority in these EHS issues depends on the stage of development and the actual local impact of a cement plant:

- first reduce negative impacts on health of workers and neighbors by reducing concentrations of emitted substances, especially dust, in and around the plant;
- next, reduce the use of natural resources by the introduction of AFR
- for the long term, develop and introduce product-chain management.

This development in approach of EHS improvement will (have to) coincide with progress in process knowledge and the introduction of more advanced process technology and EHS management systems enabling responsible AFR use.

Many of these issues mentioned above are subject to a more or less autonomous improvement that is already ongoing and not directly or not only initiated for a sustainable development. To some extent, implementation of an EHS management systems, improvement of the safety and health performance, reduction of energy consumption and emissions are obvious issues for an industry aiming toward efficient and competitive production in an environment with growing prosperity.
Sustainable development is characterized by the awareness that a minimal, economic consumption of natural resources is an important course of action. Therefore, for the cement industry the use of AFR is currently an important issue in sustainable development; in future the emphasis could shift to the acceptance of a responsibility for product stewardship. Companies arrive at a point at which environmental gain is increasingly difficult to achieve within the company itself, but becomes easier to realize in the product chain of which the company is a part. In the long term, the focus of environmental attention will change: from a process-oriented approach to a process and product-oriented approach.

The development of the above-mentioned EHS issues toward sustainability is described below in connection with improving cement production technology. The report concludes with an overview of possible actions for the cement industry to improve its ESH performance.

2 Technology development

Globally, the cement industry is in different stages of technological development. Despite these differences it is possible for every clinker producing plants to gradually improve its level of technology (increasing the clinker production, energy usage reduction, emission reduction or process optimization) by making small or larger steps forward. This paragraph gives an overview of the progressively evolving production technology.

The cement industry is presently using two different technologies routes. Vertical kiln technology (shaft kilns) and rotary kiln technology. The rotary kiln technology, which requires a substantial investment, enables large-scale cement production. On the other hand, the vertical kiln technology is utilized by small-scale cement producers but application of this technology is still widespread, i.e. in China and India [1].

2.1 Vertical kiln technology

Due to a lack of actual information on its performance, this summary report deals with this plant type only in this chapter in a very limited way.

Basically in a shaft kilns fuel, mostly coal, and raw materials are ground and fed to the top of the kiln and air is introduced at the bottom. In most countries, this technology is replaced by rotary kiln plants enabling cement production at a larger scale, but for instance in India and China application is still widespread and will be widely applied during the next decades (next to small-scale rotary kilns). According to Chinese government, in 2015 the Chinese cement industry will produce 50 % of its cement production using shaft kiln technology [1].

With the nowadays-available technological improvement [2] as indicated below, it is possible to produce in shaft kilns cement with good quality, low energy usage and in an environmentally sound way comparable to the rotary kiln. The vertical kiln technology is suited to be used with old or new energy reduction techniques, emission control techniques and process operation controls described in this report.

However, on economic grounds, also due to the small production scale, implementation will often be unfeasible. Consequently, compared to moderately modern rotary kilns, emission levels of dust and organic components can be expected to be high. SO_x levels can be high depending on the sulfur concentrations in the raw materials and coal. Fundamentally, due to the air counter flow with the raw materials and fuel however, the process can be energetically sound. Shaft kilns in Germany in the early '80s are reported to have energy consumption down to 3 to 4 GJ/ton clinker, well comparable to rotary kilns [3]. However, average coal consumption of 250 kg/ton cement (approx. 7 GJ/ton) is reported for China, compared to 130 for small dry rotary kilns [1]. As a result, the cement industry in China contributes heavily to the country's emissions of dust, SO_x and NO_x and energy consumption.

Due to a lack of information, possible simple and cost-effective measures to improve the EHS performance of installations that are not to be replaced by modern plants, can only be tentatively suggested:

- filters for dust reduction in the flue gasses and measures for dust concentration reduction in the working areas;
- coal introduction below the kiln surface;

- selection of low sulfur materials if possible;
- introduction of health and environmental care systems including discussions with workers and management on EHS measures.

The suggested measures are directed toward a reduction of a negative impact on the environment and on workers safety and health. Possibly, some actions to save natural resources could be considered, such as:

- use of clean locally available biomass fuels, wood, organic residues;
- use of fly ash and slag for grinding with clinker or in the kiln.

The feasibility of these options will depend on local opportunities and the presence of sufficient process and product know-how. Due to the expected minimum of environmental measures, it is not recommended to use of non-clean materials, i.e. waste materials containing heavy metals, chlorine etc.

2.2 Rotary kiln technology

There exist four main cement production process routes – the dry, semi-dry, semi-wet and wet process, also for the rotary kiln technology. There is a strong tendency to replace wet systems by dry options. In the wet process it is easier to handle and to homogenize the raw materials, especially when the raw materials are wet and sticky. Nowadays, more advanced technologies are available to prepare homogeneous raw meals in a dry process. The main advantage of a modern dry process over the wet process is the far lower energy consumption, and consequently lower fuel costs. The wet process can still be the best choice but only under specific circumstances, for instance if the raw material is wet.

The text box below presents an overview of the technology development in the past with an expectation for the future. The 3 design levels presented can be described as follows:

I. level I design, representing a cement production plant type that still exists but is no longer built.
II. level II design, operation, representing a modern plant of the type that are built nowadays or during the next decade.
III. level III design, representing a future plant. Most elements are already demonstrated.

Technology development

Level I design

The level I design consists of a relatively simple dry process design, for instance with:

- Rotary kiln, with a satellite or grate cooler
- 2- or 4-stage suspension preheater
- Raw materials dryer
- Bag or ESP filter

This process design is already an improvement if compared to the wet cement process that will be gradually replaced unless it is applied on wet raw materials.

Level II design

The level II design is for instance a dry process including:

- a short rotary kiln;
- a grate cooler
- 4 to 6 stage suspension preheater/precalciner
- a raw materials dryer

improved bag or ESP filter.

Level III design

The level III design is a possible future clinker production process, at the moment it exists only on pilot scale. This alternative process [4], still under development, consist of a suspension preheater, a spouted bed granulating kiln, a fluidized bed sintering kiln, a fluidized bed quenching cooler and a packed bed cooler. But besides this fluidized bed clinker production process, the level II design can be combined with new or future technologies resulting in a level III process design, such as:

- SCR (NO_x) control [2]
- Staged combustion combined with SNCR [5]
- Model based Process Control
- Re-use of energy losses of the rotary kiln.

The Fluidized Bed Clinker production process can reduce production costs and can achieve a further reduction in energy consumption.

The levels II and III design, more advanced when compared to the level I design, can include additional process integrated and end-of-pipe solutions for the further reduction of emissions. Examples of these techniques are summarized in the text box below.

In the past decade, a wide range of technological options for emission reduction is developed and demonstrated. Examples of such techniques to ensure control of the emissions of the clinker production process are [2]:

- Low-NOx Burners (NOx Control)
- Multi-Stage Combustion (NOx Control)
- SNCR (NOx Control)
- Precalciner
- Addition of Slaked Lime (SO2 Control)
- Circulating Fluidized Bed Absorber (SO2 Control)
- Wet Scrubber (SO2 Control)
- Adsorption on Activated Coke (SO2, VOC and Heavy Metals Control)
- Increasing Oxygen Concentration at Kiln Inlet (VOC Control)

3 Fuels

3.1 Fuel consumption

In this section the emphasis will be on the use of alternative fuels: waste materials and renewable biomass derived fuels. The fuels most used are coal/coke and natural gas; see Table 3-1 and Figure 3-1. From the figure it can be seen that alternative fuels, i.e. mainly wastes are taking up app. 10% of the fuel input. Depending on local circumstances, the fuel input of a cement factory can be completely different from what is shown.

Table 3-1 Thermal energy sources in the cement industry [6]

	Europe	Australia	Canada	US
	%	%	%	%
coal	36	45	51,9	66,0
petcoke	39	11	13,5	16,6
Petroleum products	7	1	7,1	1,1
gas	2	37	21,9	7,3
alternative	10	6	5,5	9,0
lignite	6	0	0,0	0,0
Total	100	100	100	100

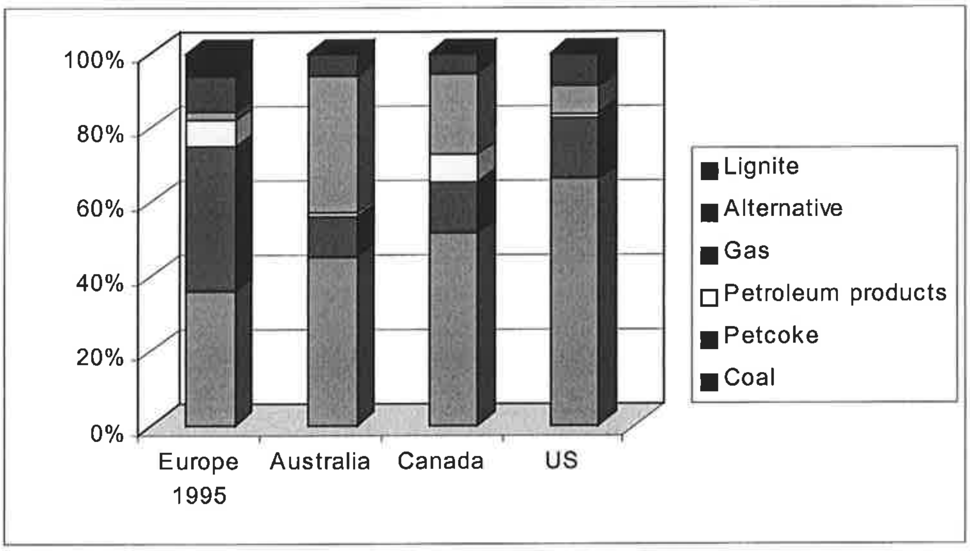

Figure 3-1 Thermal energy sources in the cement industry [6]

The total energy consumption of the cement industry world wide in 1994 was 6600 PJ [7]. Cement production worldwide increased with approximately 3% per year, leading to 20% growth in 2000 since1994. According to the World Resources Institute the world energy consumption in 1999 was about 400000 PJ; with a worldwide 1999 capacity of 1600 Gton, an average energy consumption of 4.5 GJ/ton, the total energy consumption of the cement industry is estimated at 7200 GJ thus equaling 1.8% of the world energy consumption. [7]

The fuels most used are coal/coke and natural gas; see Table 3-1. Depending on local circumstances, the fuel input of a cement factory can be completely different from what is shown. From Figure 3-1 it can also be seen that alternative fuels, i.e. mainly wastes are taking up app. 10% of the fuel input.

3.2 Fundamental aspects of alternative fuels

The cement industry is a highly energy intensive industry and energy cost of cement production are substantial; thermal energy and power account each for about 15 % of the total manufacturing cost of cement. In China, energy costs accounted for roughly 40% of the total manufacturing cost of cement in the early 1990s [1]. As a consequence, there is an economic drive, prior to an environmental one, for a reduction of energy consumption and the associated cost. As a consequence, energy consumption in Europe for instance is reduced in the last decades, especially by the introduction of more advanced technologies by about 30 %. Further reduction of energy costs is realized by the utilization of low cost fuels in the thermal process such as coal residues and pet coke. Following this line, the next step is the introduction of other waste materials.[1]

Fundamentally, the combustion process in the cement kiln offers several important features in favor of (waste) combustion, if compared to specialized waste combustion facilities:

- high combustion temperatures of 1800 °C to 2000 °C in the gas phase;
- long residence times at high combustion temperatures (over 1100 °C);
- the alkaline conditions and the intensive mixing are in favor of the adsorption of most metals, SO_x and Cl from the gas phase. This internal gas cleaning can result in low emission figures from the waste;
- the clinker reactions and the melt, occurring at 1450 °C, enable incorporation of ashes and, in particular, chemical binding of metals to the clinker. In this way, the cement process can immobilize these metals in the environment.

There is ample literature and experience on the technical aspects of waste recovery in the cement industry that shows that, within the technical limits, it is possible to recover waste in a cement kiln within appropriate environmental limits. However, in dealing with waste, some technical limitations have to be taken into account such as for instance

- volatile metals Hg, Tl, Cd are not well entrapped and materials containing these metals should not be used unless additional measures are taken to prevent emissions;
- inorganic wastes containing volatile organics cannot be fed into the cold kiln side to possible VOC emissions occurring without special measures.

In any case environmental performance must be monitored and controlled with more attention when using AFR. Continuous measuring of emissions is a prerequisite when using AFR

Nevertheless, atmospheric emissions from the cement industry when using AFR are heavily debated for two major reasons: general awareness of public when incinerating waste and emission concentrations of a cement plant are expected to be higher than a modern waste incinerator. However, several investigations show that, with proper precautionary measures, emissions from the cement kiln do not increase when substituting fossil fuel by AFR. Furthermore, that dioxin emissions are within the same limits that hold for modern waste

[1] The use of slag and fly ash for cement production from clinker after the kiln is also important for energy reduction and discussed in another chapter.

incinerators unless waste added to the raw meal and fed in cold kiln end. This is further discussed in the chapters on emissions.

The application of wastes in the cement industry, as fuel or as raw material, can be of benefit for both the cement industry and the waste management in the region. The advantage for the cement industry and for society is the opportunity for savings on fossil fuel and raw materials consumption and costs, contributing to a more sustainable production. Possible advantages for waste management (and for society) are the use of an existing facility, making it superfluous to invest in new waste combustion facilities, as well as the recovery of energy and materials incorporated in the waste, which is one of the aims of a waste management policy. Waste management costs are reduced, recovery is optimal and natural resources are saved. This conclusion is not correct for all wastes. Waste prevention and re-use should not be frustrated by low processing costs for waste. This may require a more detailed assessment to study the impact of processing a waste in the cement industry, e.g. by Life Cycle Analysis, and to decide between recovery in the cement industry and re-use or prevention.

A prerequisite is the existence of a waste policy aiming at waste recovery and environmentally sound disposal. Especially when an infrastructure for waste processing is to be developed in countries with an emerging waste policy, the cement industry can be optimally placed in the waste management system. When there is already an existing infrastructure for waste management (e.g. with incinerators for household, industrial and hazardous wastes), the cement industry will be confronted with a competition for waste and possibly by protective measures of authorities. Traditionally, in many industrialized countries, the infrastructure for waste management is initiated and managed by public bodies. The cement industry entering the waste market has to show and to develop its competence and prove that wastes can be used as alternative fuels by the cement industry in a responsible, safe and environmentally sound way in a discussion with public authorities, existing waste companies and NGO's, neighbors etc. These discussions were/are especially vehement in the case of hazardous waste processing.

Following from these discussions, also some important non-technical aspects can be formulated that have to be taken into account for the acceptance of alternative fuels:

- a clear code of conduct, the cement manufacturer should state its policy on the use of (hazardous) wastes and other alternative fuels, including an overview of acceptable and non-acceptable materials, to show how he wants to ensure workers health and safety and an environmentally sound practice.
  Some cement companies also destroy waste water and wet sewage sludge. This practice clearly increases specific energy consumption. This cannot be called alternative fuels for saving raw materials. This is waste disposal. It is acceptable if no better environmental and energetic solutions exist – as a service to society but communication should be transparent.

- the cement industry should show clearly that it uses alternative fuels to save natural resources and to recover waste and therefore contributes to sustainable development. Several methods are developed. Figure 3-2 shows the main elements of a method proposed by Holcim [8]:

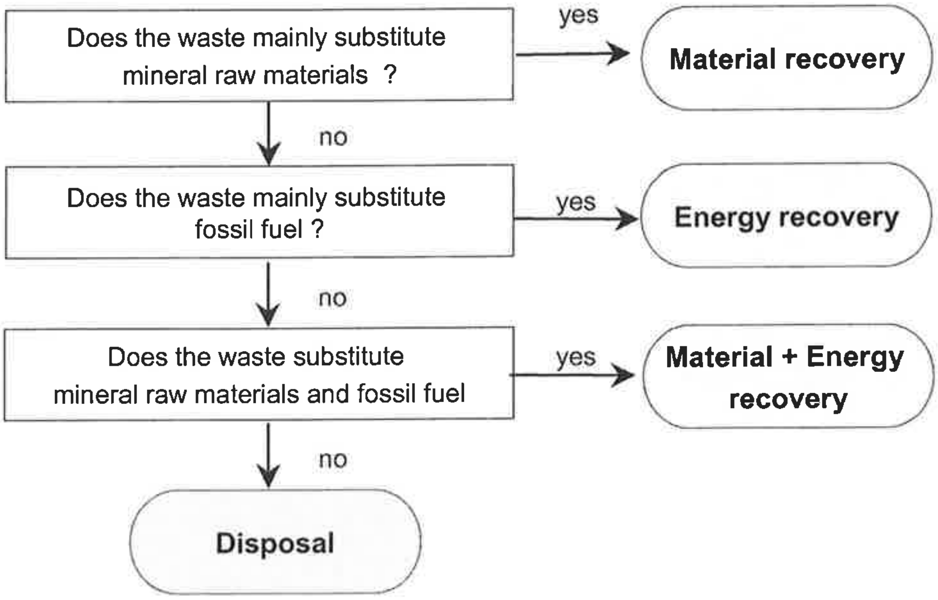

Figure 3-2 Holcims proposal to distinguish between disposal and recovery [8]

- combustion of waste materials in cement kilns can be economically attractive and become competitive with more expensive recycling processes that are higher in the waste management hierarchy: this could hold for plastics and spent oils. Life Cycle Analysis and Costing methods can show the optimum solutions that can depend on locally different infrastructure for waste. This aspect is not within the scope of this sub study;
- hazardous waste processing often is a small-scale activity, which does not comply with the handling of bulk materials in a cement factory. For these wastes, it is attractive to have specialized companies that prepare a standard fuel for cement kilns from a variety of hazardous wastes. The specialization ensures capable state-of-the-art handling and know-how with regards to hazardous waste processing. This is practiced by many cement companies that receive their fuel trough these specialized companies, in which they sometimes actively participate;
- an important objection against the use of heavy metal containing wastes in the cement industry is that it causes the distribution of metals throughout the economic environment. Immobilization of metals in cement occurs but leaching of metals from cement products into the environment will occur to some extent. Immobilization of metals generally is well investigated, but the behavior of some metals that are not well-immobilized and metal behavior during the second life of building materials (i.e. after recycling) are probably unproblematic but need more systematic attention. The subject is no part of this (sub)study and will not be elaborated here. However, the example of animal meal shows that mistakes in this respect, be it in one country or one company, can have far-reaching consequences for others. Animal meal recovery for animal food in the UK resulted in the BSE problem and consequentially to a ban on the use of animal meal for this purpose throughout the EU. In-depth research on cement quality, especially on leaching and a clear policy on waste recovery can help to prevent the same for waste recovery in the cement industry.

3.3 Alternative fuels

"Traditional" alternative fuels

Some cement companies have gathered much experience and know-how with regard to the handling of alternative fuels. Cembureau states [9] that in 1995 10 % of the thermal energy consumption originates from alternative fuels, equivalent to 2,5 Mton coal. Many plants in the US and Canada also use alternative fuels Table 3-2 and Table 3-3 give an overview [10,11]. Websites of cement industries in Middle-and South-America and Asia indicate their growing interest in alternative resources for raw materials and fuel.

Well-known examples of alternative fuels are:

- pet coke, coal residues, tires: materials that are accepted as alternative fuels;
- industrial or household sewage sludge: accepted, but its energy content originates from a drying process elsewhere;
- hazardous sludges as paint sludge, to be processed to solid fuels for the cement industry e.g. by mixing with saw dust;
- waste wood, impregnated wood;
- liquid hazardous wastes, spent oil and solvents, blended to a mixture with homogeneous properties.

Plants operating at 40 % alternative fuel are reported [12]. CEMEX is planning to realize a kiln that realizes 100 % substitution using pet coke [13]. These alternative fuels mentioned can already be considered as technically proven. Their properties and handling methods are well known. Their availability and attractiveness depend on the local environmental legislation and waste management structures.

Very special fuels are animal fat and animal meal. Due to a ban on the use of meal for cattle food there are large residues that have to be incinerated. In for example France and the Netherlands [14], the cement industry was even asked by the government to do so.

Table 3-2 Distribution of fuel consumption (US cement plants, [10,11])

	1972	1995	1999
Coal and Coke	36.1%	70.4%	74.1%
Natural Gas	45.1%	10.7%	6.5%
Petroleum Products	12.2%	1.0%	1.0%
Electricity	6.6%	10.0%	10.3%
Wastes	0.0%	7.9%	7.7%
Total Fuel	100.0%	100.0%	100.0%

* Based on MJ's consumed

Table 3-3 Waste Fuel Summary (US cement plants, [10,11])

United States	1990	1995	1999
Total Plants Reporting	76	90	93
Plants using Waste Fuel	25	48	51
Percent	33	53	55
Types of Wastes Fuels Utilized **			
Tire Derived	9	23	35
Waste Oil	5	9	8
Solvents	4	2	12
Hazardous	2	2	
Waste Derived Liquid	8	11	
Other Solid Waste			11
Other	14	22	6

* Waste Fuel Categories redefined
** Plants may use more than one type of waste fuel

New options from household waste
Options that are demonstrated on a practical scale but are relatively new are [15]:

- energy rich waste fractions separately collected from households, of mixed nature (e.g. paper/plastic fractions) or homogeneous e.g. only plastics
- energy-rich fractions mechanically separated from household waste or industrial, office wastes with equal composition, rich in paper and plastics.

The heating value of these fuels will be in the order of 15 MJ/kg, approximately 50 % of the value for regular fuels. These mixed paper and plastic fractions originate from offices and households in addition to paper fractions that are separately collected and recycled in the paper industry.

The examples given below and other projects are described in the study “Fuel and Energy Recovery” [15] which is directed to the production of alternative fuels from non-hazardous waste. A high estimate of the total <u>potential</u> energy value of these wastes for the European Union amounts to 30 Mton oil equivalent per year. A typical case is the production of fuel as pellet or fluff and its use. A very special case is the use of a circulating fluid bed gasifier at the Rüdersdorfer cement works (see box below) [16].

For waste management, the production of fuels for industrial installations or power plants has the advantage that existing combustion plants can be used and that, generally, the fuel production cost are lower than waste combustion costs in a dedicated installation and the energy efficiency can be higher.

The economics of these types of fuel for the cement industry or not clear. A prudent assumption would be that in regions where the erection of municipal waste combustion installations is considered, the co-combustion of this fuel fraction in cement kilns could be of benefit for both parties. The costs of producing these fuels by mechanical separation (sieving, wind sifting) or separate collection systems from municipal or similar wastes will be lower than the processing costs in a municipal waste combustion installation. Waste combustion costs can amount to in the order of $100 per ton. Fuel production costs are in the order of $ 50 per ton.

The new kiln 5 at Rüdersdorfer cement works was the first in the world to be equipped with a circulating fluid bed gasifier for the utilization of secondary material. The produced gas is burnt in the calciner. The burnt-out ash is processed in the raw mill as a component in the production of raw meal. Thus elegantly the problem is solved of alternative raw materials with a high organics content that prohibits feeding at the cold end of the kiln with other raw materials.
Secondary materials used are oil-contaminated soils, scrap wood and a "lightweight" fraction consisting of waste paper and plastic not suited for reuse.
At the entrance of the kiln a bypass is installed to remove chlorides and SO_3 enabling the use of secondary fuels with 1.5 % by mass Cl, and keep any coating formation under control..

The "lightweight" fractions used as secondary fuels are specific lightweight production wastes, residues from the sorting process and wastes from collection systems which, because of heir seize, impurities, are no longer suitable for material utilization. The main constituents of these fractions are paper, cardboard, plastics, film and wood. A certification procedure and a monitoring system assure the quality of the secondary fuels.

Extensive emission measurements with 25 % substitute fuels showed no significant effect compared to a situation without secondary fuels.
CO_2 inertization is applied for the gasifier (as well as for the coal silos). If due to a sudden malfunction the gas can be no longer discharged, the air supply is interrupted and CO_2 is introduced at several points from a high-pressure storage tank.

"Use of secondary materials at Rüdersdorfer cement works", ZKG 52(1999), 596-607 & [16]

3.4 Renewable fuels

The use of renewable fuels and power can contribute to the reduction of greenhouse gas emissions. The International Panel on Climate Change (IPCC) does not consider energy from fossil waste to be renewable. The inventory rules in the Kyoto protocol do not take into account emissions from the biomass part of waste but include emissions from materials of fossil origin such as plastics and spent oils.

The cement industry should consider starting a discussion on the sustainable or renewable character of fossil wastes. It is without discussion that their use saves fossil fuels and therefore their use is furthered (depending on exact composition) in many countries but on the other hand a CO_2 emission is attributed to their use. For the cement industry as well as for the society itself, it could be most attractive when the cement industry would concentrate on waste materials independent of their origin, be it fossil or renewable. The cement kiln is the industrial plant that is most suited for the incineration of those wastes that have no better use and have to be disposed of. There will always be a demand for waste incineration capacity and an, economically as well as environmentally, attractive option is the use of cement kilns.

Though energy from fossil waste is not renewable, it is stated in the brochure "Alternative Fuels in the Cement industry" [17]:

- The use of waste as alternative fuels also contributes towards a lowering of emissions such as greenhouse gases by replacing the use of fossil fuels with materials that would otherwise have to be incinerated with corresponding emissions and final residues.

The incorrect suggestion that fossil waste combustion also reduces greenhouse gas emissions was also put forward in the discussions with representatives of most cement industries. For a discussion on this point, it is referred to the substudy on greenhouse gas emissions. Despite the fact that AFR of fossil origin is not renewable, it can contribute to some extent to a reduction of the CO_2-emission because it has a lower CO_2-emisionfactor (in ton CO_2/GJ energy) if it substitutes coal.

Options for undisputedly renewable fuels are indicated below. Some examples of renewable fuels are:

- (waste) wood;
- the biomass part of the fuels derived from municipal waste sewage sludge;
- organic wastes from the food industry, households;
- agricultural residues such as straw, bagasse, olive , cotton residues...
- forest residues: residues from commercial wood production such as branches;
- energy crops as miscanthus, eucalyptus, willow or perennial grass: crops specially grown for energy purposes.

The heating value of these fuels can be in the order of 15 MJ/kg, approx. 50 % of the value for fossil fuels. Some biomass can be used directly such as a waste wood. Other types will need pretreatment before they can be applied. Several technologies are under development to produce a more easy to handle fuel:

- rapid pyrolysis produces a liquid with a heating value like the biomass;
- gasification produces a low calorific gas containing H_2, CO_2 and CO;
- HTU (Hydro Thermal Upgrading) produces a high calorific heavy crude-like product from (wet) biomass.

Generally, relatively to other fuels, biomass fuels will be lower in sulfur, but higher in chlorine content.

In a report of the Dutch Energy Agency [18], estimates are given of the global availability of biomass for energy production. Table 3-4 is a summary of the results. This is a long-term estimate (2050) and the indicated ranges express the high uncertainty. To realize the high figures for biomass production in agriculture a strong effort to restructure agricultural production systems is imperative. In the study, the cost of energy from eucalyptus grown in Nicaragua are estimated at 2 $/GJ (current coal price approx. 1.5 $/GJ). These energy crops are relatively expensive energy sources.

Table 3-4 Biomass production estimates for 2050 [18]

Biomass category	Description	Energy potential	Remarks
I. Biomass growth on current farmland	Intensification of agriculture worldwide anticipated	0- 870 EJ	Conflict with food production should be avoided; restructuring of agriculture needed for high production
II. Biomass growth on marginal grounds	Low productivity growth	60 –150 EJ	Low productivity can result in high cost
III. Use of biomaterials	Biomass production needed for materials	minus 40- minus 150 EJ	This demand for biomass decreases the availability for energy
IV. Residues of food production	From sugar, rice, corn production etc.	15 EJ	Part of these residues will be needed for soil fertilization
V. Forest residues	Residues from wood production such as branches	14-110 EJ	Part of these residues will be needed for sustainable forests management
VI. Manure	Use of dry manure	5 – 55 EJ	Highly uncertain
VII. Organic wastes	Development depends on consumption level, prosperity	5 – 50 EJ	Higher supply if use of bio-materials is increased.
Total		40- 1100 EJ (200-700 EJ)	Between brackets moderate vision in a world using biomass for energy on a large scale.

At present the world fossil fuel consumption amounts to 407 ExaJoule (EJ, 10^9 GJ). For 2050, Shell scenarios [33], see Table 3-5, indicate a world energy consumption of 850–1120 EJ/year of which respectively 10 or 11 % originates from biomass.

Table 3-5 Shell scenarios for energy sources in 2050 [33]

Scenario	2000	2050 Dynamics as usual	2050 Spirit of the coming age
Fossil fuel	345	540	701
Other (nuclear, hydro)	59	71	148
Biofuels	0	52	108
Other renewables	4	191	164
Total	407	852	1121

On short term, for the cement industry the following sources or renewable energy could be important; waste wood, sewage sludge and fuels from municipal and comparable wastes.

Especially the latter category could be of growing interest in developed countries. Organic wastes from the food industry can be used as cattle food and are in that case hardly attractive for the cement industry.

Agricultural residues can be attractive dependent on the local situation and infrastructure for collection. Table 3-6 contains estimates of actual production figures derived from FAO-statistics. Many crop residues will be used for energy already.

Table 3-6 Production, residue quantity and energy content of important crops in 1997 (data on wet biomass) [19]

	Production (10^{12} ton)	Residue (10^{12} ton)	Energy content (10^{15} GJ)
corn	586	586	9
wheat	610	793	12
rice	573	802	12
sugar cane	1241	534	8
coconut	46	46	0.7
cotton	56	17	0.25

Energy crops can be attractive in special local situations. If the regular fuel can only be obtained at high cost due to transportation barriers and land and labor are cheap. Socio-economically, local projects for biomass growth can be of interest for developing regions stimulating local employment and business and diminishing imports.

If the cement industry would consider the use of renewable fuels, the cement industry could face competition by other potential users. In many industrialized countries organic wastes and residues are becoming of growing importance as sources for energy. For instance, in the Netherlands, coal fired power stations have intentions to substitute up to 20 % of the energy value of their coal by biomass in 2010 to reduce their greenhouse gas emissions and are testing all kinds of biomass such as sewage sludge, waste wood. The Netherlands energy policy is aiming at approx. 4.5 % energy from biomass in 2020. Local sources for available biomass are not sufficient and therefore studies on biomass imports and energy growth outside the Netherlands (in warm climates as Nicaragua or in Estonia) are conducted. These studies deal with growth of biomass in these regions followed by transportation and conversion for energy production in Europe

If this trend is developing on an international scale during the next decades, the interest of many parties in the economically attractive sources of renewable energy will increase as well as the competition to obtain them.

For the cement industry as well as for the society itself, it could be most attractive to concentrate on waste materials independent of their origin, be it fossil or renewable. The cement kiln is the industrial plant that is most suited for the incineration of many wastes that cannot be prevented or re-used and have to be disposed of. Therefore, the cement industry should work toward a situation in which waste incineration in cement kilns is accepted as a sustainable operation despite of the CO_2 emission. The cement industry should develop a clear situation in which only wastes are accepted that can be recovered in the cement kiln within environmental limits.

4 Energy consumption

Over the last decade, the process of clinker making has improved from the long dry process kiln with an energy consumption of up to 5000 kJ/kg clinker to the (now state of the art) dry, multistage cyclone preheater and precalciner kilns with an energy consumption of 3000 kJ/kg. As the theoretical thermal energy consumption amounts to approx. 2000 kJ/kg it is generally believed that in kiln fuel consumption, technology has gone as far as it can in reducing energy consumption; losses in the exhaust gases and shell radiation cannot be reduced anymore economically. A study by the European Commission in 1993 [20] concluded that the potential further savings that might be made in the EU cement sector amounts to about 2.2%. Although this may be true for a number of up-to-date plants, the majority is still using more than the target value: e.g. in the US and Canada the plants with preheater and precalciner use 4000 kJ/kg clinker [21].

Electrical energy consumption in up-to-date plants also has been reduced to a target value of 90-110 kWh/ton cement and only minor improvements are possible. Electrical energy consumption for future plants is expected to increase by the growing use of alternative materials (AM) such as slag and fly ah, requiring more grinding energy; this of course should be more than) offset by reduced energy consumption in clinker production. The background document gives a detailed overview of energy saving measures.

Now the energy consumption in clinker making at modern cement plants cannot be brought further down economically; further major reduction should be achieved by the use of alternative materials (AM).

Table 4-1 Future characteristics of cement production

Level III plant	
Thermal energy consumption (MJ/kg clinker)	3
Use of fly ash and slag (% of cement production)	20
Thermal energy consumption (MJ/kg cement)	2.4
Power consumption (kWh/kg cement)	100

In the substudy report on Climate Change, it is calculated that, as a worldwide average, approximately 13 % addition of alternative materials in blended cements is achievable (with large regional variations). Assuming 20 % addition after the kiln the energy perspective for cement production is shown in Table 4-1

In the framework of sustainable development not only the use of AM's should be mentioned but also ongoing research to close the cement cycle, i.e. concrete and masonry rubble coming from demolition is (thermally) treated and used again in cement and/or brick production. Results of this research are expected to become available in a few years.

5 Emissions and emission reduction

The emissions of the cement industry that require most attention are emissions into the air from the cement kiln. Waste water discharge is usually limited to surface run off and cooling water and causes no substantial contribution to water pollution. The storage and handling of fuels is a potential but easy to control source of contamination of soil and groundwater. The contribution of gaseous emissions released from the production of cement to total emissions in countries of the CORINAIR90[2] inventory is shown Table 5-1.

Table 5-1 Contribution to total emissions of the CORINAIR90 inventory.

Source-activity	Contribution to total emissions [%]							
	SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
Cement	0.8	2.3	<0.1%	<0.1%	0.2	2.1	0.3	-
Power plants >300 MW	85.6	81.4	10.2	5.5	16.8	79.0	35.7	2.4
Incineration of Domestic or Municipal Wastes	0.1	0.2	<0.1%	<0.1%	0.2	0.4	-	-

0 = emissions are reported, the exact value is below the rounding limit (0.1%)
- = no emissions are reported

Though the data are not up-to-date and present European data only, it indicates clearly the relative importance of the cement industry's contribution to emissions into the air: the contribution is significant but not the most important one. Important missing information is the emission data concerning dust, metals and dioxin (short for polychlorinated dibenzodioxins and dibenzofurans (PCDDs and PCDFs)) emissions. A comparison of some emission limit values for different countries is shown in Table 5-2.

Table 5-2 Comparison of emission limits of several regions in the world, (in mg/Nm^3 10 vol% O_2 unless otherwise stated).

	EU	USA	Australia	Brazil	China
dust	30	0.15 [kg/Mg dry feed]	100	77	100
NO_x	800(existing plants) 500(new plants)	-	940	-	-
Hg	0.05	0.12	3	0.04	-
Dioxin [ng TEQ/ Nm^3]	0.1	0.2	0.11	-	-
HCl	10	130 ppmv	200	1.8 kg/h	-

Table 5-3 shows differences in emission limit values for waste combustion plants, power stations and cement kilns. Cement kiln limits hold for waste co-incineration; the power plant values hold in the absence of waste . If waste is co-incinerated in a power plant, their is a

[2] CORINAIR 90 is a study of emissions of air pollutants in Europe, initiated by the European Environment Agency Task Force. The study has attempted to produce a complete, consistent and transparent emission inventory for eight pollutants, information about which are derived from 31 countries/regions, namely the twelve EU countries, five EFTA-5 countries, ten PHARE countries and also Croatia, Malta and the former East Germany..

mixing rule to calculate an average value between waste incinerator values and the presented values.

Table 5-3 Emission limits for power plants and cement plants in Europe, both with an energy input equal to 100 MW_{th} (values in [mg/Nm^3 at 10 vol% O_2] unless otherwise stated)

Component	Power Plant [3] (100 MW_{th})	Waste incinerator	Cement Plant
Dust	22	10	30
SO_x	620	50	50[(4)]
NO_x	300	500	500 (new plants) 800 (existing plants)
Cd+Tl	0.035	0.05	0.05
Hg	0.035	0.05	0.05
Sb+As+Pb+Cr+ Co+Cu+Mn+Ni+V	0.35	0.5	0.5
Dioxin	0.073 ng/Nm^3 10 vol% O_2	0.1 ng/Nm3 10 vol% O2	0.1 ng/Nm^3 10 vol% O_2

With an increasing interest of the European cement industry for waste recovery, the emission limit value for cement plants have evolved in the direction of the values for waste incineration plants as is shown in Table 5-4.

Table 5-4 Evolution of emissions and emission limit values (column with actual data is indicative, values in [mg/Nm^3 at 10 vol% O_2] unless otherwise stated).

Pollutant	Actual before 1994 mg/Nm^3	EU Directive 1994 mg/Nm^3	EU Directive 2000 mg/Nm^3
PM (dust)	20-200	50	30
NO_x	500-3000	800	500 (new plants)
			800 (old plants)
SO_2	10-2500	400	50 [4)]
TOC	10-500	10	10 [4]
CO	500-2000	500	- [4]
Cl	25	30	10
Dioxins	0-10	n.a.	0.1 (ng/Nm^3)
HM Class 1[5]	0.3	0.2	0.1
HM Class 2[6]	0.3	1	0.5 (HM 2+3)
HM Class 3[7]	0.3	5	

[3] Emission limit values for power plants for SO_2 decrease with increasing capacity of 100 – 300 MW_{th} for power plants. A 100 MW_{th} cement kiln would produce approx. 2700 ton/day cement

[4] The competent authority in cases may authorize exemptions when TOC and SO_2 do not result from the incineration of waste fuels. The competent authority can set emission limit values for CO.

[5] Heavy metals class 1 : Cd, Tl and Hg

[6] Heavy metals class 2 : As, Co, Ni, Se, Te

[7] Heavy metals class 3 : Sb, Cr, Cu, Mn, Sn, Pb, V, Zn

In general, actual permitted emission levels can be lower than the emission limit values depending on local situation such as geographical and climatological conditions, background concentrations from other sources. Although it is of course necessary that the cement industry complies with emission standards, the concentrations of pollutants at ground level (immission concentrations) are ultimately the most important [23].

In many countries, protective immission standards are set; examples are given in Table 5-5.

Table 5-5 Immission standards in Germany[1], the UK[2], NL[2] EU[2], and from WHO[2] [23]

Component	Units	Germany	UK	NL	EU	WHO
Dust	µg/m^3	40	150	40	50	
SO_2	µg/m^3	10	50	40-60	20	50
NOx	µg/m^3	20	40	25	40	40
Hg	ng/m^3	50				
Cd	ng/m^3	0.4				5
As	ng/m^3	0.23				
Pb	ng/m^3	100		500	500	500
Benzene	ng/m^3	200		1000	5000	
Dioxins	fg/m^3	5				

[1] Proposed standards, [2] Annual means; WHO: GV's=Guideline values

The table only lists a few examples of yearly values; there are also hourly values, daily (24 h) values etc. (As can be seen from the table) values differ considerably from country to country. Dispersion models can calculate the concentration distribution at ground level taking into account local atmospheric conditions. The background document gives a simplified example of how these models indicate the contribution of a cement plant to local pollution and provide a basis for a more detailed analysis of the environmental and health impact of a cement plant.

National policies regarding specific environmental pollutants can be another factor with influence on emissions. In Switzerland for instance, an 800 mg NO_x/Nm^3 emission limit for individual plants still stands to ensure that local increases in NO_x emissions do not occur. However, on a national level the total annual flux of level of NO_x is also an important parameter in the environmental policy. As a result, the Swiss cement industry reached an agreement with the government to reduce its total annual NO_x emission with 20 % in 2009 (compared to 1996 NO_x emissions and clinker production level) [24]. Interesting in the chosen approach is that the industry is allowed some flexibility in their method of achieving the targets. Annual NO_x emissions targets have been developed for the industry and are linked to clinker production, see Figure 5-1. The cement industry can choose the most cost-effective investment scheme to reach the target by choosing the most attractive investment option.

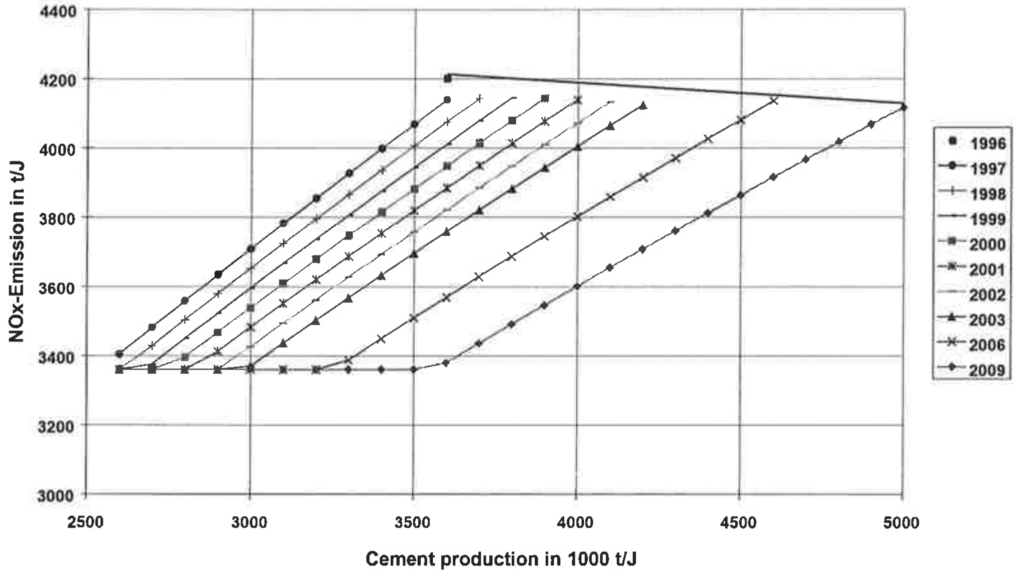

Figure 5-1 Annual NO_x emission targets by the Swiss Cement Industry [24]

When the market is buoyant and clinker production is increased, investment in NOx abatement measures is more economically feasible. During depressed market conditions, investment in NOx abatement is less affordable for the industry.

To reach the local emission limit values, the cement industry has a good record of achieving its goals with cost-effective process improvements and without the enormous end-of-pipe abatement equipment that is applied in industrialized countries in specialized waste incinerators or, to a les extent, by power stations. This is caused:

- first by inherent process conditions: the lime has excellent absorption properties;
- secondly by improved process configurations, as described earlier;
- and thirdly by increased process know-how and development of process integrated measures such as calciners.

With respect to the third point, it is believed that further progress in this direction of cost effective emission reduction is possible by introduction of new model based control techniques.

Most important equipment for emission control is the dust filter. Many metals, SO_x, Cl are strongly adhered to the dust particles. With the latest dust filters dust concentrations down to 10 mg/Nm^3 are achieved [25]. Lowering the filter temperature can also help in achieving low Hg, Tl and Cd levels.

Use of wastes has resulted in a discussion on dioxin formation in cement kilns. Measurements by the VDZ [26] show that none of the 45 reporting kilns exceed the emission limit value of 0.1 ng TEQ/Nm^3, see Figure 5-2. Figure 5-2shows the result of the average values, most of them far below the emission limit; in 4 cases no dioxins could be detected. There is no distinction between waste and no-waste using kilns. Taiheiyo Cement Corporation [27] reports average dioxin/furan emission measured in 18 kilns below the limit of 0.1 ng TEQ/Nm^3 for in total 18 cement kilns. The average value is 0.0066 ng TEQ/Nm^3 with a deviation of 0.0.083ng-TEQ/ Nm^3; total annual emission amounts to 0.5g-TEQ/year [27].

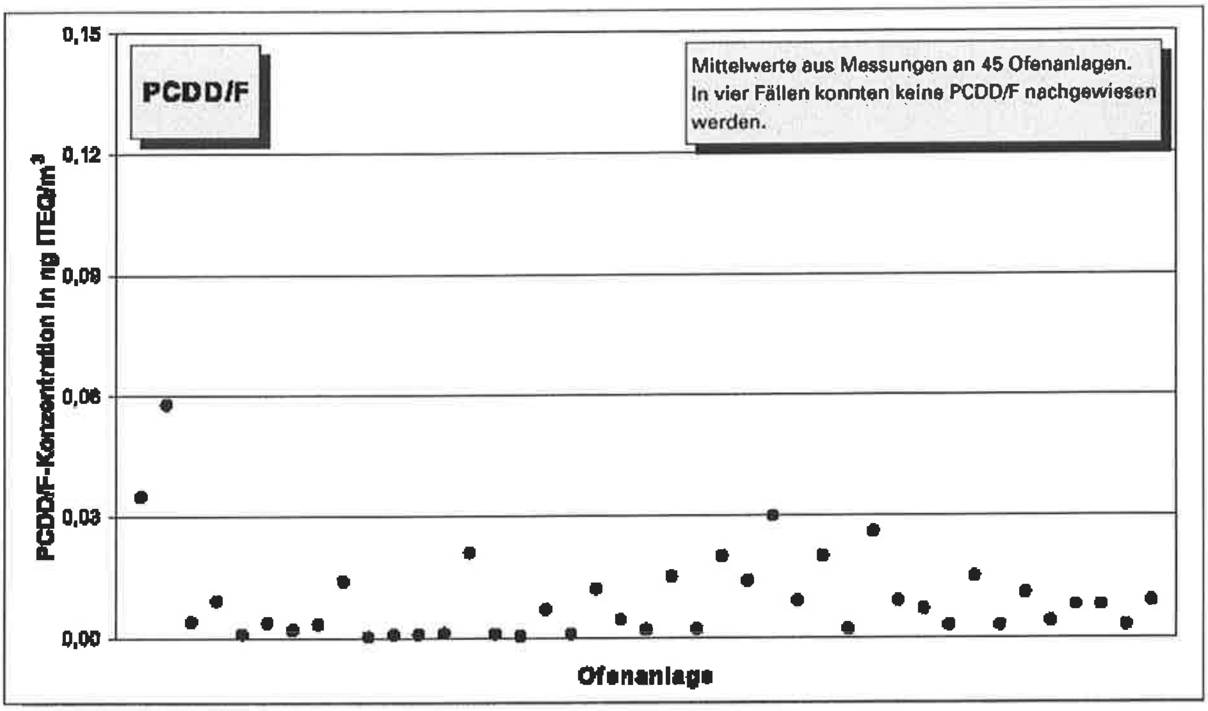

Figure 5-2 Dioxin emissions of 45 cement kilns in Germany [26]

These results show that dioxin emissions can be controlled without additional measures with proper process control and that high dioxin concentrations measured in the past can be avoided. It is believed that problems only occur in specific situations, i.e. in wet kilns with high organic content in the raw materials combined with production of low alkali cements. In that case specific technological measures could be necessary.

Despite all options to avoid exceeding emission limits by proper process and dust control, there is a tendency toward application of additional abatement techniques, summarized in section 2.2, in general especially for the control of NO_x emissions. Other end-of pipe solutions (scrubbers, coal filters) are more and more introduced to solve local immission problems occur due to geographical (presence of mountains) and climatological conditions.

6 Cost-benefit aspects of improved EHS performance

The development toward an improved EHS performance is not only a cost factor, but also has beneficial aspects. Sometimes these are hardly to quantifiable but often there also clear proceeds and saving that enable profitable investments in sustainable development.

For example, CEMEX has modified a cement kiln by introducing calciner technology to enable burning of 100 % pet coke [13]. By investing $ 1.6 million in its calcinations process, CEMEX has reduced energy consumption and emissions, saving the company $ 2.3 million per year. CEMEX also estimated the benefits of its improved safety and health policy. In 4 years, it realized a decrease in the accident rate in cement operation of 63%. This represents about 492 lost time injuries avoided in our 40 cement plants. The economical impact for this improvement represents around 5 US million dollars.

It should also be emphasized once more that from experiences in the past it may be anticipated, that the EHS performance can and will improve gradually in time with the improvements in technological, managerial and educational plant operation and that additionally, many annual, small improvements can and will significantly improve the EHS performance in time. Therefore, in any stage of development and independent of its scale, a cement plant can initiate a process of continuous improvement of its EHS performance by paying attention to the EHS impact in all actions and looking for, be it small, annual steps in this direction.

In section 1.1 it was stated that many of the identified EHS issues are subject to a more or less autonomous improvement that is already ongoing and not directly or not only initiated for a sustainable development. To some extent, implementation of an EHS management systems, improvement of the safety and health performance, technology improvement with a reduction of energy consumption and emissions are obvious issues for an industry aiming toward efficient and competitive production in an environment with growing prosperity. Costs and benefits associated with these developments can hardly be attributed to sustainable development.

Sustainable development is characterized by the awareness that a minimal, economic consumption of natural resources is an important course of action. For the cement industry this includes the use of AFR and on longer term also the acceptance of a responsibility for product stewardship. Currently, AFR implementation, in particular from waste or residues, is a central issue in sustainable development.

In this case cost factors are clear; for instance investments have to be made for the preparation of wastes, the infrastructure for transportation and storage and feeding equipment into the kiln. Additionally, investment could be necessary in emission reduction equipment and make it attractive to reduce emissions beyond compliance with regular limits. As an example, installation of activated coal filters would not only reduce VOC emissions but also open the option of processing AFR containing high concentrations of mercury.

Benefits, lower fuel and raw materials costs, are depending on current fuel costs and existing alternative disposal or recovery options for the AFR. These are high in industrial countries but will be considerably lower in countries with an emerging waste market. Cost for hazardous waste combustion in industrialized countries can amount to over 250 $/ton, depending on composition. For municipal waste, combustion costs can be in the order of 100 $, while production of municipal waste derived fuel costs in the order of 50 $/ton. In both cases an attractive margin can be realized to justify the considerable investments needed.

The availability of agricultural residues strongly depends on local circumstances. Possibly, they could be obtained at around zero cost from processing industries.

For the short term, energy crops will generally be too expensive and will only be considered in a world in which the control of the climate change problem has become a more prominent factor or in very specific situations (high fuel costs, no other options).

Use of alternative materials such as slag and fly ash require additional effort in acquiring and grinding energy.

In the next future, companies can arrive at a point at which environmental gain is increasingly difficult to achieve within the company itself, but becomes easier to realize in the product chain of which the company is a part. In the long term, the focus of environmental attention will change: from a process-oriented approach to a process and product-oriented approach. Product recycling, development of stronger products enabling saving in cement use are technical options arising from chain management that can further reduce the use of natural resources. This subject is not in the scope of the study.

7 Safety and health performance

7.1 Risks and exposure

The background document EHS performance shows that several risks are involved with the production of cement. Health risks include: dust and temperature exposure, contact with allergic components and toxic substances. Safety risks include: noise exposure, falling, burns, explosion and transportation. Main topics in the cement industry are:

- Improvement of incidence rates;
- Respiratory diseases caused by dust;
- Contact with allergic and toxic components.

Accident rates reported by the larger cement companies [32] show a decrease over the last years. However, lethal accidents still happen. Economic consequences of incidents leading to absence from work can be large and can be used as an incentive for prevention. CEMEX estimates the economic impact of the improvement in accident rate s at 5 million dollars.

In the chemical industry awards are rewarded for local companies, which perform with zero accidents per million working hours, whereas an accident rate target is normally set at 0.5 or 1% (0,5 - 1 accidents per 100 employees), a figure that is only within reach for the frontrunners in the cement industry. For comparison, see the text box with information presented by CEMEX [28].

The cement industry, historically has reported incidence rates higher than others industries, as example is attached a comparative table of this rates in USA in 1999.

Industry (SIC Code)	Lost Workday Cases	Days Away from Work
Oil & Gas Extraction (13)	0.43	3
Coal Mining (12)	0.73	12
Chemical & Allied Products (28)	0.87	5
Textil Mill Products (22)	1.49	7
Concrete, gypsum and plaster products (327)	1.64	35
Paper & Allied Products (26)	2.19	26
Lumber & Wood Products (24)	2.48	19
Metal Minning (10)	2.70	58
Cement Hydraulic (324)	2.86	69
General Building Contractors (15)	3.49	21
Rubber & Miscellaneous Plastic products (30)	5.19	30

In 1997, CEMEX has formulated a target for their safety performance of 1 %. It reports a 63 % decrease in the accident rate (number of accidents per employee) over the period 1997-2000, from 4.4 % to 1.6 % [28]. This accounts for 40 cement plants located in 10 countries. Their operations in Costa Rica and Egypt are brought up to CEMEX's standards. Both showed an improvement by decreasing their accident rates by 50% and 61% in 2000, respectively, in comparison with the first half of the year. Of the 40 cement plants, 4 facilities operated with zero accidents (CEMEX Spain's Lloseta and Tenerife plants, CEMEX Colombia's Santa Rosa plant, and CEMEX Venezuela's Guayana plant), while 12 other achieved an accident rate of less than 1% [28].

Accident frequencies of 42 (Austria), 16 (Germany) and 11 (France) per million working hours can be considered as relative high.

Ciments Calcia, part of the Italcementi Group, shows a decrease in frequency rate from 29,8 to 13,7 over a period of 12 years (1987 – 1999), whereas the last 6 years the figures are stable and no further improvement has been achieved. It has formulated a safety program with, for 2001, an objective of a frequency rate below 10,0. Interesting is that Ciments Calcia regards unsafe acts as the main cause of injuries. They consider management responsible for the improvement of the working conditions in such a way that no unsafe acts can be made and responsible for the development of safety awareness of the employees.

The Japan Cement Association reports the frequency rate of the manufacturing industry in 2000 at 1.10 with a strength rate (number of lost days / total labor hours x 1000) of 0.13.

Due to the process incidents and accidents with burns are rare but happen. A study in Egypt over the period 1991-1995 shows that 155 accidents occurred on a population of 3200. The total number of working days lost was 4,776 with a mean of 31 days per case. This study can be seen as a warning to take in consideration the safety measures in the cement process where workers can come in contact with hot clinker or cement powder.

Exposure to dust can cause respiratory diseases. A study in 1998 report that dust levels ranging from 26–114 mg/m^3 have been recorded in quarries and cement works [29], whereas the U.S. Federal respirable dust standard limits exposure to 2.0 mg/m^3 for an 8-hour working shift. In an individual case at sieving was 384 mg/m^3 reported. In modern factories using the wet process are the upper short time values occasionally 15 – 20 mg/m^3. When the dust contains silica components, regulations are stricter due to the known carcinogenity of (crystalline) silica. In the USA a study showed that in the industry of cement, concrete, gypsum and plaster products, 17.9% of the 252 samples exceed the PEL (Permissible Exposure Limit) of silica. These data for the cement industry should give enough suspicion to be very cautious on the subject of dust, especially dust containing (crystalline) silica.

Important to notice are the contact with allergic components and with toxic substances. Many substances can be considered to be allergic inducing components. In the cement industry, chromate components have to be an issue of concern because of its use, toxicity and known effect to cause cancer. Replacing chromium VI with chromium III is a good measure but the industry should try to prevent as much contact with chromium as possible.

Thallium is a highly toxic substance, which is used in additives in cement factories. Three studies in the 1980s showed that the thallium intake by cement workers were up to 6 times higher as normal intake, measured by the workers' urinary thallium concentrations [30]. The recommendation is to take action to diminish the intake.

7.2 Toward an occupational safety & health management system

Four phases can be distinguished in the development in the field of safety, health and environment management (the Safety Transition Model© [31]):

1. ad hoc: in this phase the survival of the fittest is the underlying principle of an attitude towards safety and health issues in which action is taken when things go wrong;
2. systemization: now the company understands the problems related to safety and health and formulates a policy to tackle these problems;
3. management system: in this phase management takes responsibility for safety and health by implementing a management system through which safety and health are linked with decision making and work processes;
4. pro-active: here a company strives for continuous improvement of safety and health which is regarded as important as finance and production.

It is considered that the large companies in the cement industry are already in phase 3 of introducing and implementing a safety, health and environment management system; many other companies will in phase 1 or 2.

CEMEX has implemented a program which consist of a safety management system with elements as:

- top management commitment (policy, CEO direct involvement), EHS steering committee);
- corporate standards (OSH corporate manual, auditing criteria, risk management standards);
- indicator system (Intranet system for indicator and accident report, quarterly safety indicators report);
- company infrastructure (with EHS-coordinators per country with operations, intranet EHS conversation network, EHS annual meeting & report, use of Intranet system for indicator and accident report, periodic working meetings via video conference);
- sharing best practices among plants.

Their emphasis on "Fostering a safety culture" will lead them into phase 4 in which safety, health & environmental issues are of same importance as financial results and the focus will be on reducing and eliminating the risks.

A safety management system helps a company to comply with health and safety targets, norms and regulations. It helps also to make safety and health a day-to-day business: in all operations the consequences for safety and health are taken into account. The cement industry will achieve a better OSH-performance when companies develop and implement such a safety and health management system. Several elements are required for a structural approach toward improvement in safety & health performance:

- The level of safety education and the commitment of the management of the facility to reduce and prevent accidents;
- Management responsibility for the improvement of the working conditions;
- Management responsibility for the development of safety awareness of the employees;
- Training of personnel to diminish unsafe acts;
- Commitment by workers and their superiors for measures to prevent contact with substances;
- Implementing measures to prevent contact with substances in the following order:
  1. eliminating the source or the substances;

2. diminishing the use of it;
3. collective measures such as central air exhausting;
4. individual measures such as personal air refreshing;
5. personal protection equipment.

An outline of an OSH management system is described in the background document.

Currently there is a co-operation project (the Cement Safety Task Force) in which large cement producers such as Holcim, Lafarge, Italcementi, Cemex and Siam participate. The aim is to learn from shared information. The participants are analysing information and developing recommendations - working out what kind of actual actions will be taken across the industry. This task force is a good example of the increasing awareness within the larger companies that sustainable business cannot be achieved without attention to and action on safety and health issues. This can be considered as a typical phase 3 –moving towards phase 4- activity: the management system is in place, the commitment is tangible and now best practices can be exchanged to enhance the effectiveness of the efforts.

However, not all companies are involved. The involved companies are the 'frontrunners' who explore alternative ways to make business safer, but with the risk of increasing the gap between them and the followers.

Implementation of the OSH management system is a first step towards improvement of the safety and health performance. The action program can consist of a time bound plan in which the OSH management system is developed and implemented within 10 years all over the world. Verification by third parties can be an integral part of the program. After that, the industry is in phase 3 regarding the Safety Transition Model.

7.3 Development toward an inherently safer production

Phase 4 in the presented model includes transport of the best practices throughout industry and safety and health thinking into day-to-day operations, decisions and changes. Understanding the basic risk factors underlying accidents and near-misses are a necessity to achieve improvement of the safety and health performance. An active program of analyzing and controlling these factors should be implemented. An inherent safety and health approach can be the solution to realize the philosophy 'there's no risk'. A major factor in the realization of this inherent safer and healthier process is the exchange of best practices for safer operation and the implementation with all stakeholders.

Technical installations seem static, but they usually develop gradually. Changes in technical installations are made regularly and sometimes these changes are more substantial. Throughout time, gradual changes may lead to a substantially different installation. Every change does, however, not only form a potential threat to safety, but is in principle also a potential *opportunity* for the introduction of inherent safer elements in the plant. This potential is hitherto hardly exploited systematically in safety management, but can be a key element in growing towards a sustainable industry in 2020.

For example, the existing processes can be optimized using the existing knowledge on all fields of operation. Therefore, to achieve an inherent safer and healthier process it will be necessary to involve employees for determining which risks and problems can be eliminated best using these principles. They know the existing risks and problems and their knowledge can be used to implement the inherent safe design principles.

To achieve an inherent safer and healthier process, it will also be necessary to exchange best practices among the companies to reduce the risks. It is recommended to start a pilot with the most persistent risk involved, e.g. analyzing and controlling the main basic risk factors leading to accidents or preventing workers from inhalating dust with silica components.

8 The role of EHS management

8.1 EHS management in corporate strategy

Current EHS management systems in the cement industry show large differences between different countries. This is caused by the fact that EHS management is mainly driven by national regulations. Being in full compliance with (inter)national legislation is the main objective of most EHS management strategies. In western countries EHS management is predominantly based on the ISO 14001 standard, and to a much smaller extent on EMAS. The introduction and full implementation of integrated EHS management systems is considered essential for state-of the-art operation.

Some companies start embedding EHS issues in their corporate strategy. In leading cement companies, a sound EHS strategy is seen as an important element of guaranteeing the continuity of the company. EHS issues become more and more strategic issues and reach the agenda of top management of the cement industry.

Many companies have difficulties in producing EHS management information. As a consequence, it is commonly accepted that it is difficult to assess EHS performance - especially at an aggregated level – and to produce management information. To achieve this, there is an urgent need for KPIs addressing EHS management issues in cement industry.

Sustainability is rewarded at the stock exchange, as investors (just like other stakeholders) estimate the value of a company not only in financial terms. There is a shift occurring in business thought. Environmental issues are moving from 'being a liability' to 'becoming an opportunity'.

A related issue for multinationals is to move towards working according to the same standards worldwide, for instance by implementing a firm-wide code of conduct in which (among other things) environmental codes for employees and safety and health issues are addressed.

8.2 Performance based approach

Cement companies are moving towards a system of performance based *monitoring* of EHS issues. Performance based *management* of EHS issues is one (logical) step further, which is however not implemented yet. Management information systems on EHS issues are mostly operating locally and have no connections to the companies' ERP systems.

Once a set of KPIs has been developed that satisfactory covers the field of EHS management, performance objectives can be set and projects can be planned to achieve these objectives. Cement companies can then use internal and external benchmarking to achieve continuous improvement.

Traditionally, environmental performance metrics and reporting systems have been driven by localized regulatory compliance. As sustainability becomes a global business driver, the information system for sustainability will have to be global too. For most companies this means a serious upgrade of their current environmental data management systems, which - as stated - are most often local solutions without any connection to basic company information systems.

Activities like audits, permits and licenses, monitoring emissions, risk assessment, waste management, training and cost assessment prove to be very suitable for integration. Integrated applications enable companies to link EHS information with other business administration database systems - with this possibility they have been able to develop emission prevention standards that are higher than what is regulatory required.

Performance based management of EHS issues requires setting (and management aimed at achieving) clear and measurable objectives for the improvement of environmental, health & safety performance. This will also require the implementation of a sound EHS monitoring system that would enable monitoring and auditing – internal and external – of environmental performance at all operations and facilities.

Performance based management of EHS issues will also require a new approach towards embedding responsibilities within the organization, and in line with these responsibilities, a new approach towards staff performance appraisal systems. This will require training of all staff involved in EHS related activities. Achievements in the field of EHS performance will subsequently have to be rewarded in staff assessments and translated into improved career perspectives.

8.3 Stakeholder influence

The cement industry is very concerned about its reputation towards direct neighbors and other stakeholders. The cement industry is often regarded as a heavily polluting industry by (local) regulators, direct neighbors and (local) pressure groups. Therefore, optimizing stakeholder relations is of great importance. In general, cement industry is seen an industry that traditionally maintains a low profile culture and image, which will possibly make it more difficult to make the transition towards an industry that has adopted transparent stakeholder communication as one of its main features.

Some companies have started structuring the involvement of stakeholders by organizing regular meetings with community groups, in which neighbors and local authorities are represented. The main aim of these meetings is to inform the groups on the company's plans and acquire support for these plans.

Given the traditional generally low involvement in stakeholder communication in the past, the cement industry will have to achieve a change in company culture to realize an efficient and open dialogue with its stakeholders.

Effective stakeholder involvement will become a prerequisite to create competitive advantage. It is recommended to involve (groups of) stakeholders as much as possible in the process and operational aspects of EHS management. This will result in a constant check of current practice with stakeholder requirements, and will contribute to building a solid relationship with the stakeholders.

The Global Reporting Initiative (GRI) was developed with the aim to develop globally applicable guidelines for reporting on economic, environmental and social performance for corporations. This initiative offers a means for clear and comparable communication towards stakeholders and will also facilitate benchmarking of plants and companies.

8.4 Chain related EHS management issues

In the cement industry, EHS management issues are strongly related to the value chain. Several cement companies indicate (in their environmental reports) that they are working on improving EHS chain management. These efforts are mainly directed at chain analyses and other research, and disclosure of this information throughout the value chain.

EHS management will evolve further to chain related management. Sustainable building has been an issue in the building industry (and governmental institutions involved in building contracts / regulations) for several years. Attention for sustainability aspects in design, installation aspects and use of materials is anticipated to remain important in the coming years. The cement industry will therefore be challenged by the market to deliver a product that will have to live up to high quality standards and to high environmental standards.

Companies arrive at a point at which environmental gain is increasingly difficult to achieve within the company itself, but becomes easier to realize in the product chain of which the company is a part. The focus of environmental attention will change: from a process-oriented approach to a process and product-oriented approach. Several EHS issues, for instance the use of secondary fuels and the use of cement-containing fractions in the clinker kilns, are strongly related to the value chain.

Cement industry should make full use of possibilities the relations in the value chain offer to provide sustainable solutions. By optimizing interactions in the value chain, improvements can be achieved for instance with regard to logistical aspects, quality of resources and waste management. This could for instance be initiated by including environmental codes for contractors and other third parties in the code of conduct of the company.

Many industries have already responded to the focus on environmental aspects of products by governments and pressure groups. They are implementing concepts like 'ecodesign', 'product-oriented environmental care' and 'product stewardship'. With regard to the latter: as cement industry is a major player in the value chain of concrete building products, it should take full responsibility for product stewardship related to the people and planet effects of the use of cement. This implies a major responsibility on building an adequate data file around these issues and disclosing the data upstream into the value chain.

9 Options for an action plan toward a sustainable cement industry 2020

Technology development and environmental performance

1. The environmental performance as well as the quality of cement process and product have greatly improved during the last decade largely due to integrated process technological developments, including process control and research to enhance process know-how and understanding. For further, cost-effective improvement, process and product research and development, should have an important position in the cement industry to assure the environmental as well as the safety performance of the process and to minimize health effects.

2. Cement process bound emissions (due to the high process temperature, raw materials quality) such as dust, NO_x, SOx and /or VOC are often accepted to be higher than emissions from other industrial installations. For sustainable cement production, the cement industry should aim at a situation with a comparable emission limits.

3. The cement process has a relatively uniform production process globally applied on many hundreds of locations in many different companies. Furthermore, the cement process has inherent features (basic material, high temperatures, AFR options) for a good environmental performance. The cement industry could consider the option to enhance this performance and to become an industry with an excellent environmental record. Exchange of information and experience, monitoring, benchmarking, enhancement of process development are possible instruments.

4. Investigate for the long term, the option of co-operation with municipal and indusial waste combustion companies or technology suppliers to develop cement production processes based on these wastes.

Fuel use

1. State clearly that you want to use only wastes only in case of waste recovery and if processing is an environmentally sound practice. Define waste recovery using a clearly defined method. Other waste materials for instance only if requested by authorities. Develop a code of conduct for environmentally sound and safe performance.

2. In the Kyoto protocol, emissions from burning waste of fossil origin are considered to result in a CO_2 emission. Nevertheless, incineration of these wastes is environmentally attractive as they replace fossil fuels. The cement industry should discuss this apparent contradiction to ensure the sustainability of fossil waste that cannot be re-used or avoided. The cement kiln is an, environmentally as well economically, option attractive option for the incineration of many wastes.

3. Give priority to the use of renewable fuels derived from biomass and biomass waste. Sewage sludge, saw dust and waste wood are already used. Globally there is a large potential in agricultural and forest residues

4. Consider the use of wastes of AFR from municipal and similar (office, industrial) wastes. There is a huge potential. The fuel is partly renewable. Local sources can be explored and local waste management costs can be reduced. Economically less attractive than hazardous waste.

5. Enter early in emerging waste markets and in waste markets where specialized waste incineration is introduced to become optimally placed for the environmentally and economically attractive AFR material

6. Separate cement production from the fuel production. Fuel production from waste is a small-scale activity requiring other capabilities than needed in a cement production facility.

Alternative raw materials

1. Intensify co-operation with fly ash and slag producers to maximize the use of AR in the cement industry. Develop technology if necessary.

2. Investigate the role of cement standards in impeding maximum use of inorganic alternative raw materials. Consider redefining cement standards.

3. Consider for the long-term options to reuse potential raw materials in demolition waste to demonstrate responsible care in the building materials chain and to preserve resources.

OSH performance

1. Understanding the basic risk factors underlying accidents and near-misses are a necessity to achieve improvement of the safety and health performance. An active program of analyzing and controlling these factors should be implemented.

2. Implement a OSH management system with full commitment of top management and elements as:
   - top management commitment (policy, CEO direct involvement), EHS steering committee)
   - corporate standards (OSH corporate manual, auditing criteria, risk management standards)
   - indicator system (Intranet system for indicator and accident report, quarterly safety indicators report)
   - company infrastructure (with EHS-coordinators per country with operations, intranet EHS - conversation network, EHS annual meeting & report, use of Intranet system for indicator and accident report, periodic working meetings via video conference)
   - sharing best practices among plants.

3. For the long term, develop an approach toward Inherently Safe and Healthy Operation by creating a situation in which improving the S&H performance is considered as important as other objectives and which risk factors induced by human or system failure are systematically reduced.

EHS management

1. In order to reshape EHS management according to the enhanced requirements of stakeholders, a strong top corporate involvement will be required in EHS issues. This will facilitate a shift from short-term technical support to long-term strategic thinking in EHS management strategy.

2. Implementing a sound knowledge information system for EHS-issues will enable the monitoring and auditing of the progress made with regard to EHS issues. It is ideally linked or integrated to the ERP system that is in use. KPIs addressing EHS management issues are a prerequisite for performance based EHS management.

3. Effective stakeholder involvement will become a prerequisite to create competitive advantage. It is recommended to involve (groups of) stakeholders in the process and operational aspects of EHS management. The Global Reporting Initiative (GRI) can offer an opportunity to help shape EHS management and stakeholder communication.

4. As the cement industry is a major player in the value chain of concrete building products, cement industry should take its responsibility for product stewardship related to the use of cement.
   Many measures are directed towards the production process, but it might be more effective and sustainable to take measures in the chain. High strength cement, recycling and re-use of cement products are technical consequences of this approach.

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