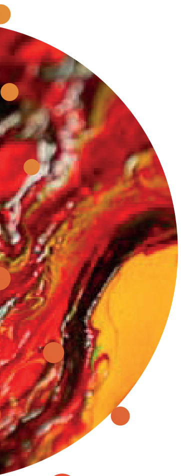
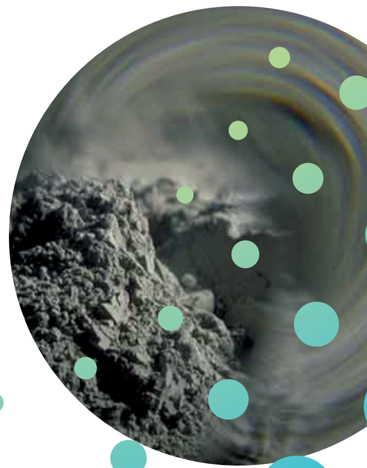
Cement Sustainability Initiative (CSI)





Guidelines for Co-Processing Fuels and Raw Materials in Cement Manufacturing

wbcsd






Contents

1 Introduction

1.1 The Cement Sustainability Initiative (CSI)

Cement is the most widely used building material in the world, with nearly 450 kilograms of cement being consumed yearly per capita. Making cement is an energy- and resource-intensive process, with both local and global impacts. Recognizing this, several cement companies initiated the Cement Sustainability Initiative (CSI) in 1999 as a member-sponsored program of the World Business Council for Sustainable Development (WBCSD).

Today, the CSI is a global effort by 24 major cement producers with operations in more than 100 countries who believe there is a strong business case for the pursuit of sustainable development. Collectively these companies account for about one-third of the world's cement production and range in size from large multinational companies to smaller local producers.

General information on the CSI may be found on the project website: www.wbcsdcement.org.

1.2 Background

The growth of the world population and the increase in average income are the main drivers behind the projected increases in waste generation worldwide. In parallel, various forms of waste are increasingly considered as resources that should be used in industrial processes. In order to avoid the loss of valuable resources and to safeguard precious land, the landfilling of waste is increasingly being prohibited or viewed as an option of last resort. While improvements to landfilling practices are being pursued in many developing countries, awareness is increasing that landfilling should be considered a temporary measure while developing a more resource-efficient waste management solution.

Simultaneously, the need for construction materials, such as cement, is rising due to population increases, growing economies and the trend towards urbanization. Cement production takes place worldwide, and in general close to where people are living and producing waste. This provides a local option for waste management. Concrete is a sustainable product (long-lasting, energy efficient in buildings, recyclable) even taking into account the energy-intensive component of cement in its production.

Considering increasing waste production on the one hand and the resource demands of the cement process on the other hand, cement companies started in 1979 to look at waste as a source of raw material and energy. Step by step, the use of waste by cement companies is now making a considerable contribution to the waste management system in many countries. The use of cement kilns for waste recovery – termed co-processing – should be situated in the waste hierarchy in between recycling and energy recovery. Where waste materials cannot be managed technically or economically by prevention and reduction, reuse and recycling, the cement manufacturing process provides a more ecologically sustainable solution compared to landfill or dumping, thanks to full energy and material recovery in the process (see figure 1, section 1.4).

Cement plants play a vital role in communities, conserving natural resources by utilizing waste for its production while at the same time recovering the energy content of the materials. Co-processing is a term used to refer to the use of suitable waste materials in manufacturing processes for the purpose of energy and resource recovery and the resultant reduction in the use of conventional fuels and raw materials through substitution.
The co-processing of waste by cement plants is a service that the cement plants can provide to their communities for the mutual benefit of both the plants and the communities: the cement plant can receive a reliable local supply of fuel or material that replaces natural resources; the community can benefit from a more ecological local solution that avoids the large capital expense of incinerators and waste-to-energy plants or the resource inefficiencies associated with landfills.

1.3 Why a Version 2 of the CSI guidelines?

Producing cement consumes both large quantities of raw materials and fuel, and produces substantial CO_2 emissions. The use of alternative fuels and raw materials in cement manufacturing can reduce the amount of conventional fuels and virgin raw materials needed, and thus reduce the overall environmental impact of the operations. These alternative materials can be either waste or by-products from other processes. While there are benefits to be gained from using such materials in the cement industry as alternative fuels or raw materials, some waste streams are not suitable for this purpose.

In keeping with this understanding, CSI member companies committed under the CSI *Agenda for Action*, published in 2002, to using waste materials only where it can be done safely, without harm to employees, neighbors and the environment or manufacturing process, and by maintaining the high quality of products. Building upon the principles of respecting the waste hierarchy, industrial ecology, and careful integration into local resource management infrastructures, in 2005 the CSI published its first set of guidelines for the responsible use of conventional and alternative fuels and raw materials in cement kilns.

This revised version of the *Guidelines for Co-Processing of Fuels and Raw Materials in Cement Manufacturing* provides a technical overview of key issues and guiding principles relating to the responsible selection and use of fuels and raw materials in the cement industry, in view of technology developments and the evolution of stakeholder expectations in recent years. This guidance draws on the experience gained since the first guidelines were published. It is not meant to be an all-encompassing compendium on the use of waste in the cement manufacturing process, but rather outlines the most important principles and procedures which must be undertaken in the responsible use of co-processing in cement manufacturing.

These guidelines should therefore be used in conjunction with other internationally recognized guidance documents, most notably:

- United Nations Environment Programme (UNEP) – Basel Convention *Technical guidelines on the environmentally sound co-processing of hazardous waste in cement kilns*[1]
- The guidelines issued by the Conference of the Parties to the Stockholm Convention[2]
- European Commission Reference Document on Best Available Techniques (BREF)[3]
- Other cement manufacturing specific guidance documents such as the Holcim- GTZ Guidelines[4] and SINTEF reports[5] provide other useful information on co-processing in the cement industry.[6]

The largest volume substances emitted during the production of cement are particulate matter (dust), oxides of nitrogen, sulphur dioxide, carbon dioxide and carbon monoxide. Trace quantities of volatile organic compounds, acid gases, some trace metals, and organic micro pollutants may also be emitted. While cement kilns typically operate at steady conditions (excluding startup and shutdown), naturally occurring changes in raw materials and fuels composition can produce small day-to-day variations in emissions.

Target audience

These guidelines provide a practical reference for cement companies and their stakeholders, helping them understand and identify responsible and sustainable approaches to the selection and use of fuels and raw materials.

We aim for the guidelines to be equally helpful to all cement companies and public bodies and widely distributed and used, particularly in countries and regions where specific requirements have not yet been fully identified. However, these guidelines are not meant to, and cannot,replace or supersede local, national or international requirements which must be followed.

Prior to finalizing these revised guidelines, the CSI consulted various stakeholder groups from industry, non-governmental organizations (NGOs), academia and regulatory bodies to solicit feedback on the quality and consistency of the document. Very valuable input was received and has been integrated as much as possible. We would like to thank all those who have taken time to respond to us with their specific comments. They have helped us to improve the quality of this document.

1 UNEP – Basel Convention Secretariat. Technical Guidelines on the Environmentally Sound Co-processing of Hazardous Wastes in Cement Kilns. Available from http://www.basel.int/TheConvention/Publications/TechnicalGuidelines/tabid/2362/Default.aspx.

2 Secretariat of the Stockholm Convention on Persistent Organic Pollutants. 2007. Guidelines on Best Available Techniques and Provisional Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants: Cement Kilns Firing Hazardous Waste. Expert Group on Best Available Techniques and Best Environmental Practices, United Nations Environment Programme. Available at http://chm.pops.int/Implementation/BATBEP/Guidelines/tabid/187/Default.aspx.

3 European Integrated Pollution Prevention and Control Bureau. 2010. Reference Document on Best Available Techniques in the Cement, Lime and Magnesium Oxide Manufacturing Industries. European Commission, Joint Research Centre, Institute for Prospective Technological Studies. Available at eippcb.jrc.ec.europa.eu/reference/BREF/clm_bref_0510.pdf.

4 Holcim-GTZ. 2006. Guidelines on Co-processing Waste Materials in Cement Production. The GTZ-Holcim Public Private Partnership.

5 SINTEF. 2009. Requirements for Co-processing of AFR and Treatment of Organic Hazardous Wastes in Cement Kilns.

SINTEF. 2009. Guidelines for Co-processing. Published in Proceedings of «China International Conference on the Utilization of Secondary Materials and Fuel in Building Materials Industry".

6 Further reference information can be found on the CSI website: http://www.wbcsdcement.org/index.php/key-issues/fuels-and-materials.

Principles

With the aim of assisting cement companies in designing their own strategies to contribute to sustainable development, the first version of the CSI guidelines introduced principles for member companies on how they would select and use fuels and raw materials in the future. The principles introduced in 2005 are still valid and are repeated and enhanced below:

- Maintain an economically vibrant industry, delivering profit to shareholders, rewarding employees, and contributing to local communities through employment, taxes and community activities.
- Comply with laws, regulations and standards relating to safety, health, environment and quality where they currently exist, and contribute to the improvement of the regulations and policies dealing with waste management in the country.
- Continue to deliver high-quality, competitively priced goods and services that meet our customers' needs and the strictest product standards. We will develop new cement products in response to society's changing social, environmental and economic needs.
- Make the health and safety of those involved in and affected by the production of cement paramount in decision-making. Design installation, transport, handling and operating procedures to protect the health and safety of employees, contractors and local communities.
- Be recognized as attractive employers and work to build relationships of trust with the communities in which we operate.
- Evaluate our choices within the broader context of sustainable resource management. We will seek to recover the mineral components and energy content of waste and by-products of other industrial, agricultural or municipal processes in our operations to replace conventional fuels and raw materials where possible and appropriate.
- Be involved in the waste management infrastructure of the countries in which we operate. We will be prepared to respond quickly to changes in the supply of waste and by-product resource streams, in particular where more sustainable options for their use emerge.
- Seek to use alternative fuels and raw materials as efficiently as possible by using the recommended co-processing techniques and practices, and by continuously improving our process management systems.
- Use common principles for monitoring, managing and reporting impacts in key areas, in particular health and safety, carbon dioxide and other airborne emissions, and material substitution rates.
- Continuously monitor and improve our safety, health, environment and quality management practices, and train employees in the policies and procedures relevant to their roles. We will pay particular attention to maintaining strong management practices in countries where few health, safety, environment or quality regulations currently exist.
- Engage in constructive dialogue with stakeholders, and make decisions regarding the use of conventional and alternative fuels and raw materials in an open, transparent and accountable way.
- Collect data to continuously improve our understanding of the impacts of our operations and report regularly on our performance.

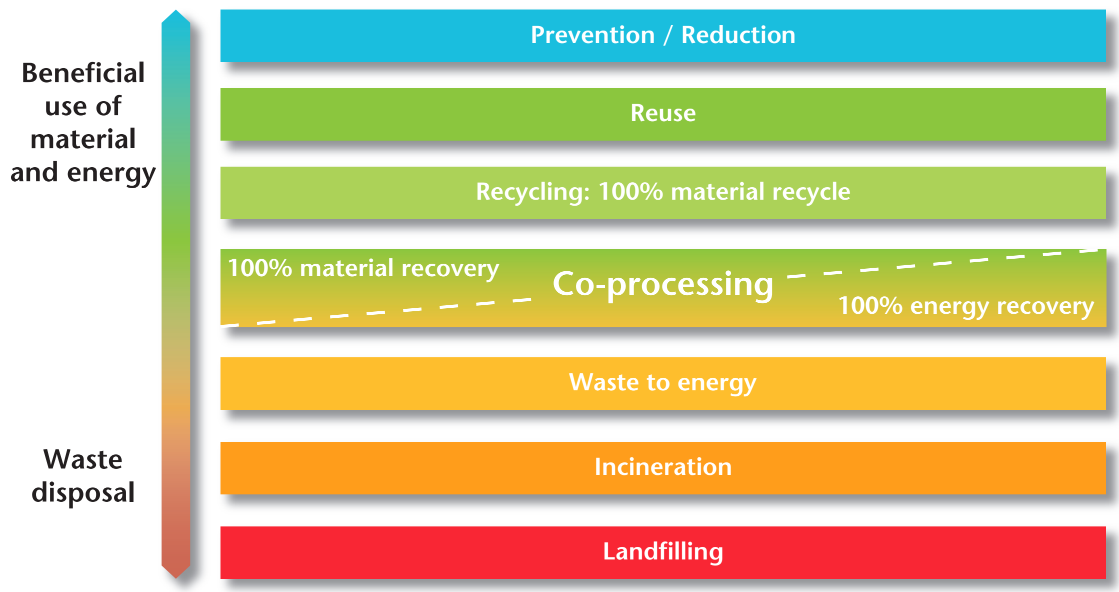
1.4 Contribution of co-processing to waste management

Governments, municipalities, companies and agricultural organizations that are faced with decisions on how to manage their waste are guided by the waste hierarchy in conjunction with economic value. Co-processing of waste in the cement industry is an advanced and innovative recovery process whereby energy is recovered and the non-combustible part of the waste is reused as raw materials.

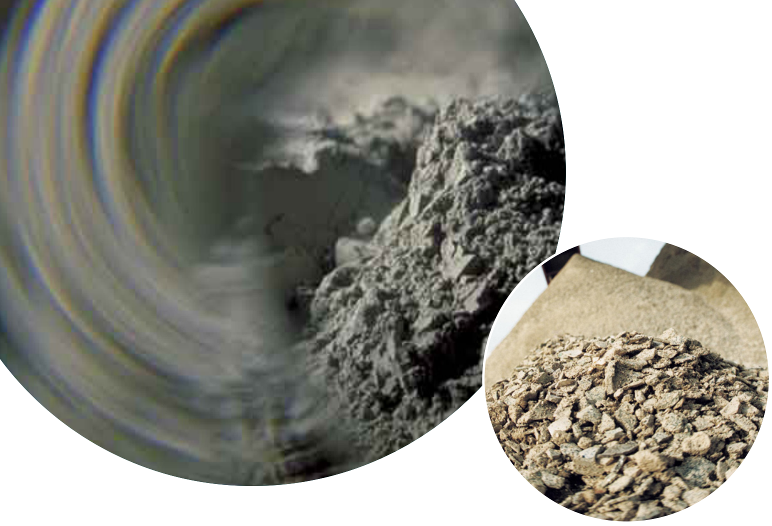
Waste prevention and reuse options followed by recycling are more and more demanded by society. The co-processing of wastes in a cement kiln is a mix of recycling and thermal recovery. The mineral portion of the waste is reused during the process and replaces virgin raw materials. At the same time, the energy content of the waste is very efficiently recovered into thermal energy, thus saving conventional fuels. Therefore, in the waste hierarchy co-processing generally has a position just below recycling as it is more beneficial than incineration with energy recovery.

A well balanced and accepted waste management system should be developed by cement plants in conjunction with all relevant local stakeholders. Co-processing development must be accompanied by a clear,consistent and transparent dialogue with: neighbors, employees (unions), customers, national regional and local authorities, NGOs, and waste generators. The dialogue with the stakeholders must be based on several key issues relevant for co-processing, including environmental impact, health and safety, transportation impacts, quality management of the alternative resources, impact on process and cement quality, reporting and public information, and needs or requirements of the community.

Figure 1: Co-processing in the waste hierarchy



1 Introduction



2 Cement manufacturing technology and co-processing of materials derived from waste

2.1 What is cement?

The first step in making cement is to heat limestone with small quantities of other materials (such as clay, sand and iron) to 1,450°C in a kiln, a process which requires large amounts of fuel. The resulting hard intermediate product is called clinker, which is ground with a small amount of gypsum into a powder to make ordinary Portland cement (OPC). Blending additional constituents, such as coal fly ash, additional limestone, pozzolana (a naturally occurring volcanic ash), and blast furnace slag with the clinker creates blended cements with different properties depending on the materials added. OPC and blended cements are the most commonly used types of cement.

Clinker contains the oxides of calcium (CaO), aluminium (Al_2O_3), silica (SiO_2) and iron (Fe_2O_3). When the primary ingredients (SiO_2, CaO and Al_2O_3) are mapped on a phase diagram (see figure 2), it is easy to see how OPC, clinker and other materials are related to these basic mineral elements. Changing the final composition can impact the properties of the cement produced its reactivity, strength and setting time.

Cement must conform to the strict building standards set for it. Consequently, the manufacturing process itself must be closely monitored and controlled to obtain clinker and cement that meet these standards. The appendix on guidance in co-processing at the end of this report discusses good operating and management practices in more detail.

Figure 2: Chemical composition of cement and mineral components

2.2 Thermal characteristics of a cement kiln

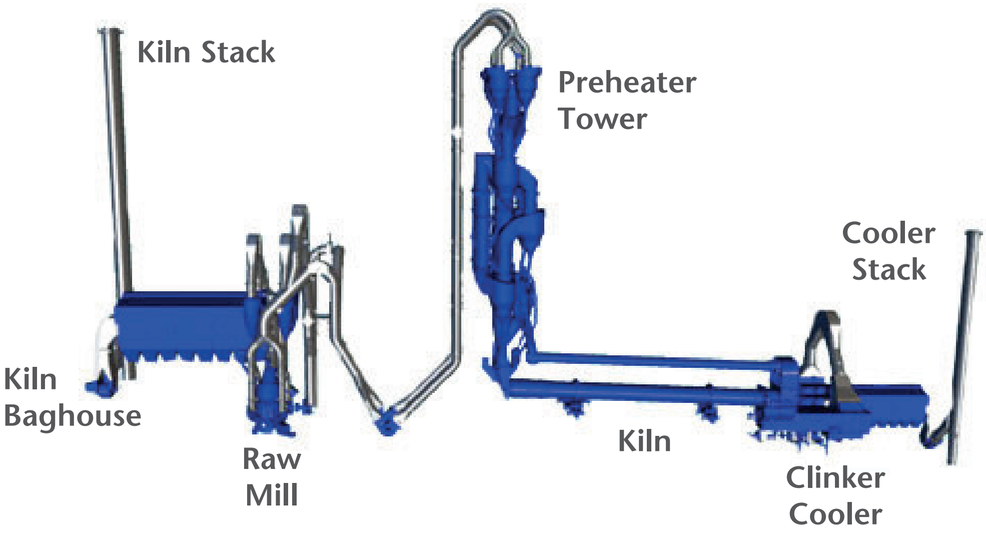
A cement plant consumes 3,000 to 6,500 mega joules (MJ) of thermal energy per tonne of clinker produced, depending on the raw materials and the process used.

Most cement kilns today use coal and petroleum coke as primary fuels, and to a lesser extent natural gas and fuel oil. As these fuels burn they provide energy, and some leave fuel ash containing silica and alumina compounds (and other trace elements). These combine with the raw materials in the kiln, contributing to the structure of the clinker and forming part of the final product. Energy use is the largest component of production cost, typically accounting for at least 30-40% of the total.

Two key processes take place in the cement kiln system. The first is the calcination process whereby the main ingredient, limestone (calcium carbonate), is heated to disassociate into lime (calcium oxide) and carbon dioxide in order for it to chemically react with other oxides. The calcination process occurs between 850°C and 950°C and, depending on the process, can occur in the kiln or in a specialized calciner, or in the lower section of a preheater.

The second key process in the kiln system is sintering. This is where the calcium oxide binds with the oxides of silica, aluminum and iron as they are heated in a kiln to about 1,450°C and form the intermediate product clinker.

Figure 3: Cement kiln system schematic



2.3 Cement kiln suitability for processing waste

The European Integrated Pollution Prevention and Control Bureau (EIPPCB)[7] has identified several features specific to a cement kiln system that result in the destruction of organic pollutants because of high temperatures and a sufficiently long retention time. This results in typically lower dioxins/furans (a family of toxic substances that all share a similar chemical structure) and volatile organic compounds (VOC) linked to fuel from cement kilns and lower heavy metal emissions compared to other methods of thermally processing the waste. Typically, emission limits for these combustion-related compounds are **the same or lower than those for waste incinerators.**

- Kilns operate at high temperatures, where the process requires: 2,000°C or higher in the flame of the main burner, 1,450°C in the material to make clinker, and 1,000 to 1,200°C in the calcination zone.
- The typical residence time of combustion gases in the kiln is more than five seconds at a temperature higher than 1,000°C. By contrast, gas residence time in a typical incinerator is two seconds. Residence time for solid materials varies from 20 minutes to an hour depending on the cement process.
- The process takes place under oxidizing conditions with good mixing conditions, assuring good combustion and avoiding the generation of carbon monoxide (CO) and other deleterious compounds.
- The thermally consistent conditions in a kiln guarantee the complete destruction of organic components in the waste, provided that the waste is introduced in accordance with the recommendations sections 2.5 and 4.7 in this report.
- Waste materials in the kiln are in contact with a large flow of alkaline (basic) materials that neutralize potential acid off-gases from combustion.

7 See the Official Journal of the European Union, L 100, volume 56, 9 April 2013, ISSN 1977-0677, available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:100:FULL:EN:PDF.

- Any inorganic mineral residues from combustion – including most heavy metals* – are trapped in the complex matrix of the clinker and cement.
- Complete combustion and the trapping of mineral residues mean that in most cases there is no ash residue from the process.**
- Cement kilns are often fitted with waste heat recovery and power generation systems. Such systems do not alter the emission profile of the cement kiln, including the formation of dioxin/furan or VOC emissions.

*Some volatile heavy metals (e.g. mercury (Hg), cadmium (Cd), thallium(Tl)) are not completely immobilized in this way; so their content in raw and/or waste materials must be assessed and controlled.

**Excess chlorine or alkali which may be in some virgin materials may produce cement kiln dust or bypass dust which must be removed, recycled or disposed of responsibly.

2.4 Turning waste into a source of raw material and fuel

The cement industry has many opportunities to replace a portion of the virgin natural resources it uses with waste and by-products from other processes. These may be used as raw materials, fuels, or as constituents of cement, depending on their properties.

Alternative fuels and raw materials must meet quality specifications in the same way as conventional fuels and raw materials. Their use should follow the good practices discussed in appendix 1, Standard Procedures for Co-Processing, of this document.

(i) Alternative raw material use

Selected waste and by-products containing useful minerals such as calcium, silica, alumina and iron can be used as raw materials in the kiln, replacing raw materials such as clay, shale and limestone.

(ii) Alternative fuel

Selected waste and by-products with recoverable calorific value can be used as fuels in a cement kiln, replacing a portion of conventional fuels, like coal, if they meet conditions outlined in section 4.

In most cases, a specific pre-processing of the waste will be carried out in order to economically provide an engineered alternative fuel for the cement process, which usually includes a homogenization process with the target of ensuring a uniform source with near constant thermal properties. After the pre-processing, the alternative fuel produced keeps the status of the input wastes and is managed by waste regulations.

(iii) Alternative raw material and fuel

Because some materials have both useful mineral content and recoverable calorific value, the distinction between alternative fuels and raw materials is not always clear. For example, sewage sludge has a low but significant calorific value, and the ash from its combustion contains useful minerals for the clinker matrix.

For this specific case, these wastes must be treated as a fuel and processed in a high-temperature environment where the organic phase is completely destroyed.

(iv) Waste or by-product cement additives

These materials can be used with clinker to produce different types of cement. They may help to control the setting time of the cement (synthetic gypsum); they may have cementitious properties in their own right (blast furnace slag); or they may affect the consistency of the cement mortar. The use of these alternative constituents is extremely important in reducing the environmental impact of cement production. They can reduce the quantity of energy-intensive clinker required for each tonne of cement, further reducing CO_2 emissions per tonne.

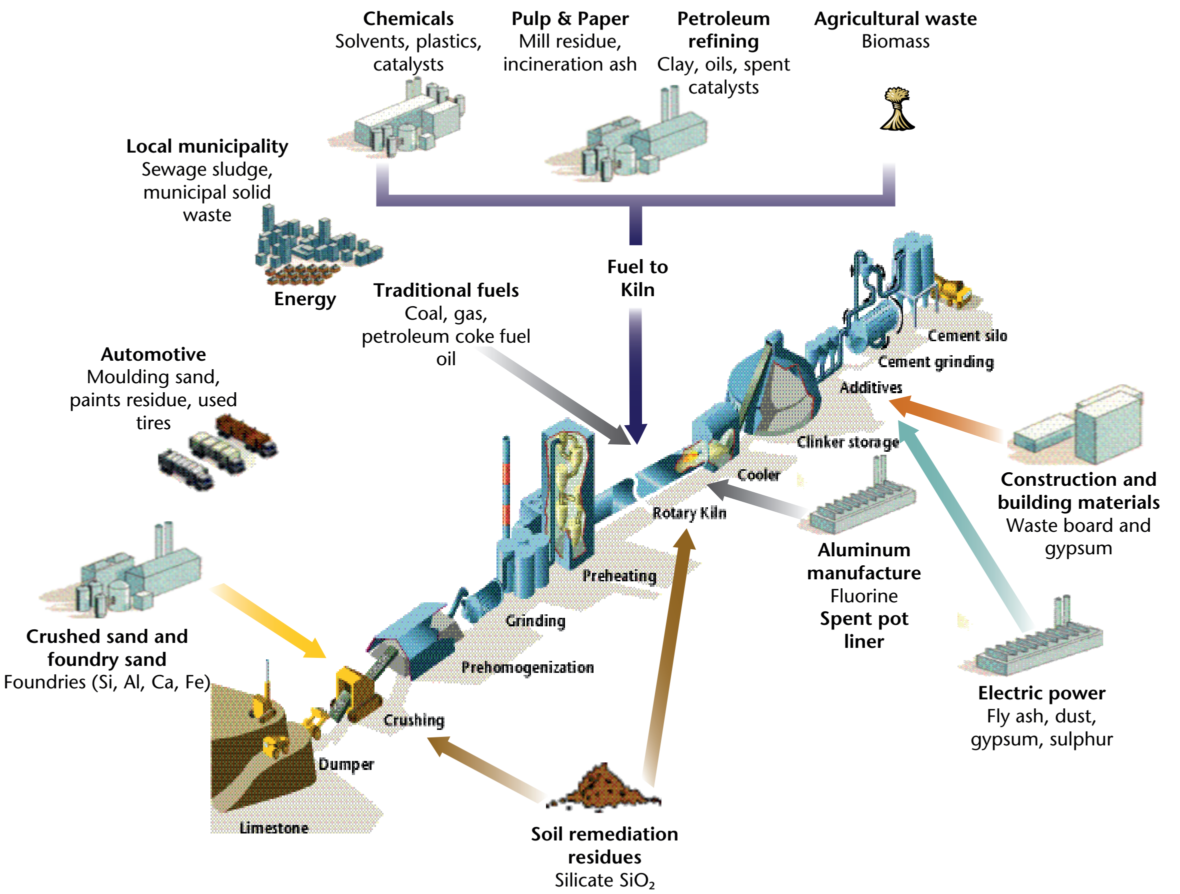
(v) Pre-processing of waste materials for the cement manufacturing process

The key to safe use of waste-derived fuels is understanding the consistency of the fuel utilized in the kiln; pre-processing of the waste is the methodology used to assure both the quality (what is in the waste-derived fuel) and the consistency of the fuel.

2.5 Feeding points for waste materials into the cement manufacturing process

Given the differences in temperature between different parts of the process, it is important that waste fuels and raw materials be introduced through an appropriate installation at the correct points in the process to ensure complete combustion or incorporation and to avoid unwanted emissions. For example, raw materials with volatile organic components may be introduced in the cement kiln at the main burner, in mid-kiln, in the riser duct, or at the precalciner. They should not be introduced with other raw materials, except where tests demonstrate that this will have no effect on gas emissions. Therefore, in most cases, a specific additional installation needs to be built to input these materials into the system.

Figure 4: Examples of feeding alternative fuels and raw materials



3 Selection of fuels and raw materials

3.1 Considerations for cement manufacturers

In the selection of alternative fuels and raw materials, the following variables should be considered.

3.1.1 Kiln operation

- Alkali, sulfur and chloride content: Excessive inputs of these compounds may lead to build-up and blockages in the kiln system. Where these cannot be captured in the cement clinker or kiln dust (CKD), a bypass may be required to remove excess compounds from preheater/precalciner kiln systems. High alkali content may also limit the recycling of CKD in the kiln itself.
- Heating (calorific) value: The key parameter for the energy provided to the process.
- Water content: Overall moisture content (of alternative and conventional fuels and/or raw feed materials) may affect productivity, efficiency and also increase energy consumption.
- Ash content: The chemical composition of the ash needs to be monitored to ensure that the final composition of the raw mix meets the necessary requirements for clinker production.
- Stability of operation (for example, duration and frequency of unplanned shutdowns (CO trips)) and the waste's state (liquid, solid), preparation (shredded, milled) and homogeneity.

3.1.2 Emissions

- Organic content: Organic constituents are associated with CO2 emissions and may result in CO, total organic carbon (TOC) and dioxin/furan emissions if waste is fed through unsuitable points or during unstable operating conditions. Should such conditions occur, the feeding of the alternative fuels must immediately stop until the process again becomes stable.
- Chloride content: Chlorides may combine with alkalis to form fine, difficult to control particulate matter. In some cases, chlorides have combined with ammonia present in the limestone feed. This may produce a visible detached plume of fine particulate with a high ammonium chloride content.
- Metals content: The non-volatile behavior of most heavy metals allows most of them to pass straight through the kiln system and be incorporated into the clinker. Introduced volatile metals will partly be recycled internally by evaporation and condensation until equilibrium is reached, with a very small portion being emitted in the exhaust gas. Thallium and mercury and their compounds are highly volatile, as are, to a lesser extent, cadmium, lead, selenium and their compounds. Dust control devices can only capture the particle-bound fraction of heavy metals and their compounds; therefore, emissions of the gaseous species must be controlled.
- Kiln gas bypass exhaust gas can be released from either a separate exhaust stack or from the main kiln stack in systems equipped with an appropriate bypass. The same air pollutants are found in both the main and kiln gas bypass stacks. Where an alkali bypass system is installed, appropriate control of the exhaust to atmosphere also needs to be provided on the bypass exhaust, similar to that required for the main exhaust stack.
- High sulfur content in raw materials, fuel and waste may result in the release of sulfur dioxide (SO_2).

3.1.3 Clinker, cement and final product quality

The production of cement requires rigorous control of the chemistry of the main ingredients: CaO, SiO_2, Fe_2O_3, and Al_2O_3, as well as other minor constituents such as sulfites (SO_3), potassium oxide (K_2O), sodium oxide (Na_2O), titanium dioxide (TiO_2) and phosphorous pentoxide (P_2O_5). Alternative raw materials and fuels must be used in quantities and proportions with other raw materials in order to achieve the desired balance of material composition in the kiln product, clinker. Significant work has been carried out by various groups, including industry, universities, research centers and governments, to understand the effect alternative fuels and materials have on the final concrete product.

Specifically, many stakeholders are concerned that some constituents contained within some wastes that are recovered for use as either raw materials or fuel could influence the concrete or be released from the cement product or concrete. This concern is heightened as concrete is a major component of residential construction and is often used in pipes. This is not a new question, and the topic has been the subject of numerous research studies over the last 20 years and more. Aggressive testing carried out by NSF/ANSI Standard 61[8] (a third party certification process for drinking water pipes in the United States) has shown that metals in the cement become bound in the concrete calcium-silicate structure and in this form do not leach from the product. Similar results have been reported in many other reports by the Association Technique de l'Industrie des Liants Hydrauliques,[9] Construction Technology Laboratories,[10] Forschungsinstitut der Zementindustrie,[11] Cembureau,[12] the European Committee for Standardization,[13] and others. [14]

There is substantial evidence that cement manufactured from the types of waste recommended in these guidelines does not change the performance or characteristics of the cement or concrete; high levels of some minor components can affect cement performance, and the manufacturer needs to take care that specific thresholds are not exceeded.

8 Colucci M., P. Epstein, B. Bartley. 1993. A Comparison of Metal and Organic Concentrations in Cement and Clinker Made with Fossil Fuels to Cement and Clinker Made with Waste Derived Fuels. NSF International. Ann Arbor, MI. March 1993.

9 Germaneau B., B. Bollotte, C. Defossé. 1993. "Leaching of Heavy Metals by Mortar Bars in Contact with Drinking and Deionized Water". Association Technique de l'Industrie des Liants Hydrauliques (ATILH). Paper for the Portland Cement Association Symposium – Concrete in the global environment.10 March 1993.

10 Kanare H., P. West. "Leachability of Selected Chemical Elements from Concrete". Construction Technology Laboratories, Inc. Paper for the Portland Cement Association Symposium – Concrete in the global environment. March 1993.Portland Cement Association.

11 Thielen G., G. Spanka, W. Rechenberg. 1993. "Leaching characteristics of cement bound materials containing organic substances and inorganic trace elements". Forschungsinstitut der Zementindustrie, Düsseldorf, Germany. Paper for the Portland Cement Association Symposium – Concrete in the global environment.

12 Cembureau. 2005. "Trace Elements Leaching from Concrete and the Use of Alternative Resources". 22 Feb. 2005.

13 European Committee for Standardization (CEN). 1999. A study of the characteristic leaching behavior of hardened concrete for use in the natural environment. Report of the Technical Committees CEN/TC51 and CEN/TC 104. Final Draft, 59p.

14 Hazelton P., B. Murphy. 2007.Interpreting Soil Test Results – What do all the numbers mean? New South Wales Department of Natural Resources. CSIRO Publishing:Sydney.

3.2 Employee health and safety

Ensuring healthy and safe working conditions for employees and contractors is fundamental to good corporate social responsibility and is one of the most important issues for the cement industry. Following up on commitments made in its agenda for sustainable development, the CSI published good practice guidelines on safety procedures in the cement industry based on experience and focused on previously identified fatality and injury causes. Among other health hazards, these guidelines address the handling of alternative fuels.

The CSI guidance document, Health and Safety in the Cement Industry: Examples of Good Practice, is available at www.wbcsdcement.org/safety. The publication Employee Safety in the Cement Sector: A Guidebook for Measuring and Reporting, which presents a standard for measuring, monitoring and reporting on health and safety performance that CSI members agreed to implement, is also available.

The anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers are the fundamental principles of occupational risk assessment and management. It is recommended that a health and safety program be designed applying a precautionary approach to identify, evaluate and control hazards, and, when applicable, provide for emergency response for hazardous waste operations. Conducting a job safety analysis or hazard and operability study are approaches that can be used to identify hazards and potential exposures, along with appropriate control practices and techniques. An analysis of environmental risks and impacts arising from the use of all raw materials and fuels should be performed.

Adequate documentation and information on safe material handling, operating procedures and easily understood safety and emergency instructions should be provided in advance by facility management to ensure the workforce is knowledgeable about hazards and safety measures put in place for worker protection. This information can often be found in the material safety data sheet (MSDS) and information coming from the waste producers. It is essential that employees, regulatory authorities and local emergency responders (e.g. fire departments) have timely information on the contingency measures set up by individual facilities. Particularly, emergency plans and procedures should be established well before the start-up of any operations involving hazardous waste, and reviewed periodically thereafter in response to new or changing conditions or information.

As is general practice, the use of personal protective equipment (PPE) to reduce exposure to hazards should be limited to situations where engineering and administrative controls are not practicable or effective in reducing exposure to acceptable levels. The protection given by the use of PPE should be adequate to ensure employee health and safety based on current industry standards, however PPE alone should not be relied on to provide protection against hazards, but should be used in conjunction with safeguards, engineering controls and sound manufacturing practices.

Facilities should develop and implement appropriate documented training programs for employees and contractors to be effectively trained to a level determined by their job function and responsibility.

4 Recommended techniques and practices for cement co-processing

4.1 Collection and transport of waste and by-products

Where there are no specific regulations, hazardous wastes and other wastes should be packaged, labeled and transported in conformity with generally accepted and recognized international rules and standards, taking due account of relevant internationally recognized practices. Under the Waste Framework Directive (WFD)[15] in the European Union (EU), the mixing of hazardous waste during collection and transport is allowed only under specific conditions and where collectors and carriers have obtained a permit to do so.

Only fully qualified and licensed transporters who are conversant with and conform to the applicable legal requirements should be used in order to avoid accidents and, in particular, incidents due to the incompatibility of poorly labeled or poorly characterized waste or by-products being mixed or stored together.

Companies proposing to import wastes have to take into account the importing country's obligations under national law and the applicable international control regimes concerning transboundary movements of wastes, most notably the Basel Convention, whose secretariat is administered by the United Nations Environment Programme (UNEP), and the Organisation for Economic Co-operation and Development (OECD) Council Decision C(2001)107/FINAL, as amended. EU Member States are also obliged to comply with the European Community Regulation on shipments of waste.[16] The Basel Convention and the European Community Regulation concern international movements of waste, whether destined for disposal or recovery, whereas the OECD Decision only concerns movements of wastes destined for recovery operations within the OECD area. All of the instruments operate subject to a range of administrative controls by the countries implementing them.

Under the Basel Convention, before transboundary shipments of hazardous wastes can be allowed to take place by the country of export, the existence of a legally binding contract between the waste generator and the receiver must be verified. The Convention also requires a confirmation from the receiver when the operation has taken place, according to the terms of the contract, as specified in the notification document.

4.2 Acceptance of alternative fuels and raw materials

All candidate alternative fuels and alternative raw materials should be identified by source prior to acceptance. The materials should be pre-screened to ensure the receiving facility is fully aware of the composition of the materials, including their mineral composition, level of organic material and heavy metal composition, and that the composition meets the plant's pre-determined acceptance criteria. It is recommended that a qualification form be completed by the waste producer. It is also recommended that the relationship between the producer and the cement plant be defined by a written contract.

The acceptance criteria should be reviewed (and updated) on a regular basis in accordance with local regulation, and in cases where there are no regulations, at least annually.

Suitable protocols should be developed and implemented governing the delivery and reception of alternative fuels and raw materials on the site. The documents accompanying the materials should be checked in order to determine their compliance with the conditions agreed with the customer and the regulations. In case of non-compliance, appropriate protocols should exist and be communicated to the customer and implemented.

The storage of alternative fuels and raw materials should take into account health and safety, firefighting, and local conditions, and comply with all applicable regulations.

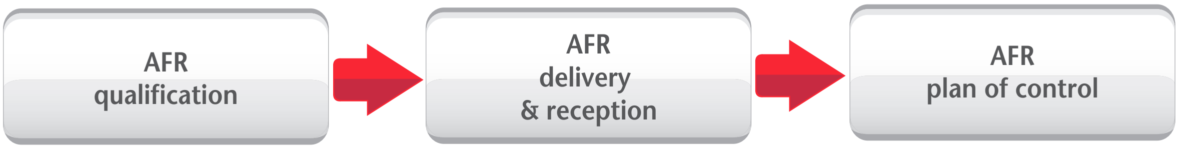
The plan of control of the site should be extended to include alternative fuels and raw materials. Suitable parameters to monitor quality for the purposes of environmental control should be selected and agreed upon with the customer and monitored at a suitable frequency.

It is recommended that an environmental and quality management system (EQMS) be implemented on the site. EQMS should include suitable procedures, instructions, processes and a plan of control to manage the alternative fuels and raw materials (AFR) on the site.

15 Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives.

16 Regulation (EC) N°1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste (Official Journal of the European Union No. L 190, 12.7.2006, page 1 (with amendments)). See http://ec.europa.eu/environment/waste/shipments/legis.htm.

Figure 5: AFR process



The use of alternative raw materials and fuels with high levels of heavy metals can have the potential to impact on either the environment or the product (clinker) quality. In regards to environment, it is usually recommended that the heavy metals content be limited to:

Hg + Cd + Tl < 100 ppm

Cu< 1,000 ppmfor long and Lepol kilns, < 3,000 ppm for pre-calciner kilns

As + Ni + Co + Se + Te + Cr + Pb + Sb + Sn + V < 10,000 ppm

Cr < 150 ppm / fraction material (loss free basis) in raw mix.

The analytical equipment needed to perform the necessary tests (e.g. mercury, other heavy metals, organic compounds, etc.) to support screening and acceptance of alternative raw materials and alternative fuels should be available either internally or at an accessible external lab. Analyses must be made by a lab equipped for the required tests, with equipment that is regularly checked and calibrated and which is the subject of a regular audit (certification or internal audit).

Full traceability of the waste streams is recommended:

- Through identification protocol and supply chain procedures
- Through regular audit of the equipment and procedures
- Through notification to the authorities according local regulations.

Mercury, as a volatile metal, is rarely trapped in the cement clinker and is either reported to the stack gas where it can be removed or is condensed within the kiln dust. Without a method to remove mercury from the kiln system (such as dust shuttling), all the mercury in the raw materials and fuels will be emitted in the stack gas. Therefore, without a mercury removal system, it is extremely important to limit the mercury input from fuels and raw materials; it is thus recommended to limit mercury in alternative fuels and raw materials to a level less than:

Maximum[A] average ppb[B] mercury in specific alternative raw material < 100 / fraction of alternative raw material in raw mix (loss free basis)

Maximum[A] average ppb mercury in specific alternative fuel < alternative fuel LHV [C](GJ/t-fuel) * 100 / kiln fuel consumption (GJ/t-kk) * AFR %

A at least 80% of samples should be below this value

B ppb: parts per billion (10^{-9}) or mg/ton

C LHV: lower heating value

Although these limits can be used as a quick screen for alternative raw materials and fuels, when there are multiple input streams that may contain mercury and in cases where mercury abatement is utilized, it is necessary to perform a mass balance that can be used to predict the influence of various fuels, raw materials and abatement methods on stack emissions of mercury.

4.3 Responsible use of biomass

The use of biomass as a fuel in cement plants represents an opportunity to both lower the greenhouse gas impact of fuels and to contribute to the local economic development of communities around the cement plants. The responsible use of biomass as a fuel requires the cement plant to ensure that these opportunities are utilized in ways that are positive for people and the planet. All biomass activities should be carried out in full compliance with local and national regulations.

First, the entire supply chain associated with biomass production, transportation and use should be positive (produce less greenhouse gas – GHG) compared to conventional fuels. The production of biomass should be done in a way that does not adversely affect biodiversity, including protected and rare species. Biomass production should be protective of soil and air quality, and water (both ground and surface) quality and quantity.

Biomass for fuel production should never compete with food supply and the subsistence of communities. The cement plant must ensure that the biomass supply chain and use does not endanger local food supplies (dramatically increase food cost) or communities where the use of biomass is essential for subsistence (for example: heat, medicines, building materials, etc.).

Lastly, transparency with stakeholders is vital. This not only includes a dialogue about how the biomass project might impact the community, but in the context of biomass, this extends to respect for local populations, particularly in relation to working conditions and property rights. Whenever it is necessary to purchase land on which there are already inhabitants, this should be done with the free prior informed consent of existing inhabitants.

4.4 Commonly restricted waste

Although both conventional fuels and raw materials may be substituted in part by waste of suitable composition, the quality of the clinker and cement products must be maintained and the products must not be misused as a sink for heavy metals. Waste, which owing to its chemical composition, material properties or potential hazards, may influence the safety or operation of a cement plant, or whose use in a cement plant would lead to significant additional environmental impact, should not be co-processed in cement plants. It is therefore necessary to specify quality requirements for the waste employed, and in certain cases to restrict the use of certain wastes. As a consequence, the following is a list of waste materials that should not be considered for co-processing in cement plants:

- Radioactive waste from the nuclear industry
- Electrical and electronic waste (e-waste)
- Whole batteries
- Corrosive waste, including mineral acids
- Explosives and ammunition
- Waste containing asbestos
- Biological medical waste
- Chemical or biological weapons destined for destruction
- Waste of unknown or unpredictable composition, including unsorted municipal waste
- Waste raw materials with little or no mineral value for the clinker (i.e. heavy metal processing residues).

Individual facilities may also exclude other materials depending on the local raw material and fuel chemistry, the infrastructure and the cement production process, the availability of equipment for controlling, handling and feeding the waste materials, and site-specific health, safety and environmental issues.

4.5 Incinerator ash

Cement plant operators are often asked to consider the use of incinerator ashes as alternative raw material. Commercial incinerators or waste-to-energy plants produce two categories of incinerator ash:

- Incinerator fly ash from the boiler and the gas treatment
- Bottom ash from the unburnable portion of the waste feedstock.

Incinerator fly ash is a mixture of the volatile pollutants (i.e. chlorine, sulfur and volatile metals) captured with lime or other inorganic absorbents. This composition of waste incinerator fly ash is therefore usually not compatible for usage in cement kilns without additional pretreatment.

Bottom ashes are pretreated to extract portions which can be recycled in the steel industry. The remaining portion is composed of inert material polluted with unburned organics, alkalis and residual metals. Analyses from several countries have demonstrated that the composition of the bottom ashes is not stable and is highly dependent on the input waste composition (which is typically highly variable) and the conditions of operation of the incinerator (which varies according to the calorific value of the wastes). Due to the composition and the variability of the constituents, the usage of bottom ashes in the cement process as alternative raw materials (ARM) is often inappropriate and not recommended. Before using incinerator ash as a raw material in any industrial operation, an in-depth analysis of the variability of the composition over a long period of time (including the starting and stopping periods of the incinerator) should be performed. The impacts on cement quality, process and emissions must be well evaluated. Whatever the composition, bottom ash must be considered as a waste and therefore follow the waste procedure protocols with a systematic monitoring of the composition.

4.6 Pre-processing

The co-processing of waste in the cement industry as a substitute fuel or raw material source usually requires that waste feed stocks be pretreated or pre-processed (for example, through sorting, shredding, grinding, blending or mixing, among others) to produce a uniform waste stream. The quality assurance of these processes is driven by the need to meet the specifications (for example, limits on contaminants such as chlorine and heavy metals) which are set by the receiving facility to produce clinker and cement according to specific standards, while guaranteeing that environmental standards are being met. For optimum operation, cement kilns require uniform waste material flows in terms of quality and quantity. Although for certain wastes this can only be achieved by pre-processing, in some cases, for example used oil or tires, wastes may be used “as-delivered” without further processing.

Pre-processing in general can be defined as those operations that lead to homogenization of the chemical composition and/or physical characteristics of the wastes. This is carried out with the aim of adapting a waste to suit a selected treatment operation, and as such, pre-processing should only be carried out because it is a technical requirement from the cement plant operator to guarantee a homogeneous and stable feedstock, and not to circumvent waste acceptance criteria. Pre-processing should produce a waste that complies with chemical and physical specifications that are fixed by the end users.

While pre-processing involving the blending and mixing of different hazardous and non-hazardous waste streams may be required to guarantee a homogeneous feedstock that meets certain specifications for use, the blending of hazardous wastes should not be conducted with the intention of reducing contamination levels or hazardous characteristics in order to meet certain limit values or to bypass legal requirements. In general, the pre-processing of waste entailing blending or mixing of waste (either with other categories of hazardous waste or with other waste, substances or materials) is generally permissible providing:

– The mixing operation is carried out by a facility which is qualified to perform the operation. Treatment operations must be undertaken in a way that ensures that only intentional, non-accidental mixing operations are conducted.

– The adverse impact of the waste management on human health and the environment is not increased, and waste management is carried out without endangering human health, without harming the environment and, in particular: without risk to water, air, soil, plants or animals; without causing a nuisance through noise or odors; and without adversely affecting the countryside or places of special interest.

In relation to mixing or blending, the European Commission's *Reference Document on Best Available Techniques for the Waste Treatment Industries* defines the best available techniques as the following:

– Have and apply mixing/blending rules oriented to restrict the types of wastes that can be mixed/blended together in order to avoid increasing pollution emissions of downstream waste treatments.

– Ensure that the collection/mixing of packaged waste only takes place under instruction and supervision and is carried out by trained personnel. For certain types of wastes, collection/mixing needs to be carried out under local exhaust ventilation.

– Apply a suitably sized extraction system to provide the required airflow to control gaseous emissions from, among others, pretreatment areas and mixing/reaction tanks. Alternatively, provide separate systems to treat vent gases from specific tanks.

– Consider carrying out the mixing and blending operations in closed areas with appropriate atmosphere control systems for the preparation of solid waste fuel from hazardous waste.

The extent of waste processing will depend on the type of material being processed and the requirements of the end user; although operations like mixing and homogenization can improve feeding and combustion behavior, it can involve risks and should be carried out according to a prescribed preparation. To ensure that the use of waste and by-products does not detract from smooth and continuous kiln operation, product quality, or a facility's environmental performance, a constant quality and feed rate of alternative fuels and raw materials is necessary. To this end, the following basic principles for pre-processing should be adhered to:

– The chemical and physical quality of the alternative fuels and raw materials shall meet any specifications or standards ensuring environmental protection, protection of the process, and quality of the material produced.

– Energy and mineral contents must remain stable to allow optimal feed in the kiln.

– The physical form must allow safe and proper handling, storage and feeding.

General tidiness and cleanliness should be applied to enhance the working environment and to allow potential operational problems to be identified in advance. The main elements that should be considered are: systems to identify, locate and store wastes received according to their risks; the prevention of emissions from operating equipment; effective wastewater management; and effective preventive maintenance.

The following are certain core principles that a pre-processing facility should conform to:

– The pretreatment facility must have a permit related to waste treatment.

– The alternative fuels produced from hazardous wastes should be considered as hazardous wastes (even if the hazardous wastes are mixed with non-hazardous wastes) and they should keep the corresponding waste status.

– The operation must be managed by professional team under quality, health and safety procedures.

– Pre-processing of waste through mixing cannot be used to change the classification or chemical acceptance according to regulations of the waste or the material.

– The traceability of the waste streams must be applied in the process.

– The qualification process of the input waste must include the determination of the final destination of the wastes.

– A waste processing plan should be maintained that includes quality specifications for the processed waste.

– Quality control and testing procedures must be incorporated into the waste processing plan to ensure that the waste-derived fuel meets its specifications. Such specifications should include the characteristics and variability of the materials, including the requirements of sections 3.1, 4.2 and 4.3 here within.

4.7 Kiln operation

The general principles of good operational control of the kiln system using conventional fuels and raw materials should also be applied to the use of waste or by-products. In particular, all relevant process parameters should be measured, recorded and evaluated systematically; this should cover free lime in the clinker, and excess oxygen, carbon monoxide levels and total hydrocarbon (THC) emissions in the stack gas.

To ensure optimal kiln performance, alternative fuels and raw materials should be fed to the cement kiln through appropriate feed points, in adequate proportions and with proper waste quality and emission control systems. The feed point should be selected according to the nature (and, if relevant, hazardous characteristics) of the materials used. Feeding to the kiln must also ensure exposure to sufficient temperature, sufficient retention time, sufficient mixing conditions, and sufficient oxygen.

Alternative fuels with highly stable molecules, such as highly chlorinated organic compounds, should be introduced at the main burner to ensure complete combustion due to the high combustion temperature and the long retention time available at this location. Other feed points may be appropriate only after test results prove high destruction and removal efficiency rates.

Alternative raw materials with volatile organic components (over 5,000 mg/kg) should not be introduced with other raw materials in the process unless tests have shown that undesired emissions at the stack do not occur.

Mineral inorganic wastes free of organic compounds can be added to the raw meal or raw slurry preparation system or blended/interground with the clinker.

4.8 Emissions control and monitoring

Cement plants emit a range of pollutants that are subject to regulation and control. Emissions measurement, monitoring and reporting contributes to understanding, documenting and improving the industry's environmental performance. A lack of credible and easily understandable emissions information can lead to local concerns about plant operations.

The monitoring and reporting of emissions should be carried out according to permit specifications and regulatory requirements, or, where these do not exist, as a minimum as defined in the latest version of the CSI Guidelines for Emissions Monitoring and Reporting in the Cement Industry. These guidelines stipulate that kilns should be equipped with devices that continuously monitor oxygen, carbon monoxide, particulate, SO_2, NOx, dust and THC emissions, as well as conducting periodic measurement tests for heavy metals and dioxins/furans. In 2005, the CSI published its first emissions measurement and reporting protocol to provide a common framework for all CSI members. The guidelines were updated in 2012 to take into account the experience gained during implementation and evaluation of the first guidelines and the development of the regulatory framework in the years since. The guidelines are available from: www.wbcsdcement.org/emissions.

Guidance on best available techniques and provisional guidance on best environmental practices for the prevention or minimization of the formation and subsequent release of unintentional persistent organic pollutants (POPs) from cement kilns co-processing hazardous waste has been published by the Stockholm Convention Secretariat.[17] The guidelines describe primary measures considered to be sufficient to achieve low emissions levels for PCDDs/PCDFs (dioxins/furans) (below 0.1 ng I-TEQ/Nm3) in flue gases for new and existing installations. Where these options do not lead to performance down to these low levels, secondary measures are cited, which are usually installed for the purpose of controlling pollutants other than unintentionally formed POPs, but that may also lead to a simultaneous reduction in emissions of chemicals listed in annex C of the Stockholm Convention. With regard to maximum emission limits for other pollutants, pertinent national legislation should apply. In relation to mercury in particular, as limiting the amount of mercury in the waste does not ensure low mercury air emissions from the kiln, the Basel Convention Technical Guidelines recommend that an emission limit value for mercury be in place.

4.9 Communications and stakeholder involvement

The provision of information through media sources and stakeholder involvement through public meetings and advisory committees, among others, should be ongoing activities for a cement plant. Communication and involvement work together to develop good relationships between companies and the communities they impact.

In developing a general approach to stakeholder involvement, a clear understanding of the objectives and a reasonable timescale for involvement are essential. Cement plants should be prepared to commit the necessary resources, be willing to find mutually beneficial outcomes, and be prepared to accept that even the best engagement process may fail to achieve consensus. Operators planning on using waste, and hazardous waste in particular, should be prepared to address public and employee concerns over possible impacts, providing all necessary information to allow stakeholders to understand the use of the wastes in cement manufacturing while illustrating the measures that would be implemented to avoid adverse impacts.

Advice for the design of communication programs so that they include more engagement with stakeholders may be found in the *Communication and Stakeholder Involvement Guidebook for Cement Facilities*,[18] developed under the direction of the Battelle Memorial Institute as part of the Toward a Sustainable Cement Industry project commissioned by the WBCSD. The guidebook's goal is for cement companies to have a stable and productive relationship with the communities in which they operate. It first describes a general approach to basic communication and stakeholder involvement programs. Then it presents specific tools for implementing an overall communication program. Finally, the guidebook describes scenarios under which a cement plant may need to increase its communication and stakeholder involvement program.

It is recommended that companies and facilities develop and implement a stakeholder engagement program and policy that includes specific reference to the use of fuels and raw materials. Such a program should identify the main stakeholders, their roles, needs and expectations, and should provide opportunities to address their concerns and to respond appropriately. Additionally, as agreed in the CSI Agenda for Action, each member company will report on their progress in developing stakeholder engagement programs, and will report progress on key issues to relevant stakeholders.

17 Secretariat of the Stockholm Convention, op. cit., pp.31-38.

18 Hund, G., J. Engel-Cox, K. Fowler, T. Peterson, S. Selby and M. Haddon, M. 2002. Communication and Stakeholder Involvement: Guidebook for Cement Facilities. Battelle Memorial Institute and Environmental Resources Management (ERM) Ltd. Commissioned by the World Business Council for Sustainable Development. Available at http://www.wbcsdcement.org/pdf/battelle/stakeholder_guide.pdf

5 Performance indicators and reporting guidelines

5.1 Key performance indicators

Key performance indicators (KPI) provide a measure of how companies are moving toward more eco-efficient use of fuels and raw materials. The measures below are the ones that CSI member companies have committed to report on. KPIs have also been agreed upon by CSI member companies for other key areas identified in the CSI Charter, including those for emissions monitoring and employee health and safety.

5.1.1 Air emissions

– Refer to CSI *Guidelines for Emissions Monitoring and Reporting in the Cement Industry*

5.1.2 Energy KPIs

– **Specific heat consumption for clinker production:** total heat consumption of kilns divided by the clinker production, in mega joules per metric tonne of clinker (MJ/t)

– **Alternative fuel rate (kiln fuels):** energy contained in consumed alternative fuels divided by the total heat consumption of kilns (%)

– **Biomass fuel rate (kiln fuels):** energy contained in consumed biomass fuels and biomass content of mixed fuels divided by the total heat consumption of kilns (%)

Specific heat consumption, alternative fuel rate and biomass fuel rate are defined according to the latest version of the *Cement CO_2 and Energy Protocol*, published by the CSI in May 2011. The guidance document, the Excel spreadsheet, and the Internet Manual, the three of which comprise the protocol, may be downloaded from www.cement-co2-protocol.org/v3.

5.1.3 Raw material KPI

– **Alternative raw materials rate:** consumption of alternative raw materials, as a percentage of total raw materials for cement production (calculated on a dry basis)

– **Clinker/cement (equivalent) factor:** calculated based on total clinker consumption and cement production (%)

The clinker/cement factor is defined according to the latest version of the *Cement CO_2 and Energy Protocol.*

Example – Alternative raw materials rate:

Raw materials for clinker production for an example kiln, per year:

	Conventional raw materials		Alternative raw materials		
	High limestone	Low limestone	Fly ash	Iron additive	Slag
Wet basis	1,136,175 t	1,305,950 t	68,674 t	11,473 t	7,053 t
Moisture	9.6 %	10.2 %	20.7 %	9.9 %	5.8 %
Dry basis	1,027,102 t	1,172,743 t	54,458 t	10,337 t	6,644 t

Total conventional raw materials: 2,199,845 t/a

Total alternative raw materials: 71,439 t/a

Raw materials for blended cement

	Conventional raw materials		Alternative raw materials		
	High limestone	Low limestone	Fly ash	Slag	Synthetic gypsum
Wet basis	50,000 t	120,000 t	150,000 t	400,000 t	230,000 t
Moisture	9.6 %	7.5 %	0.2 %	5.4 %	4.5 %
Dry basis	45,200 t	111,000 t	149,700 t	378,400 t	219,650 t

Total conventional raw materials: 156,200 t/a

Total alternative raw materials: 747,750 t/a

Alternative raw materials rate:

$$\frac{71{,}439 + 747{,}750}{2{,}199{,}845 + 71{,}439 + 156{,}200 + 747{,}750} = 25.8\%$$

5.2 Reporting

The indicators and reporting periods are determined according to the accounting rules and consolidation criterion set in the most current version of the *Cement CO_2 and Energy Protocol.*

5.2.1 Which installations are covered?

A company can choose one of the following options to set the organizational boundaries for reporting:

- Equity share approach
- Control approach (operational or financial)
- A combination of both.

These approaches are briefly summarized in the current version of the *Cement CO_2 and Energy Protocol.*

A company should clearly state in its public reporting which method it applies and the exact scope of what is reported.

A new or acquired entity/facility/installation will need to comply with this protocol at the latest the second year following the year the clinker was first produced or the year it was acquired. A closed or sold entity/facility/installation may be excluded from this protocol for the whole year of their closure or divestiture.

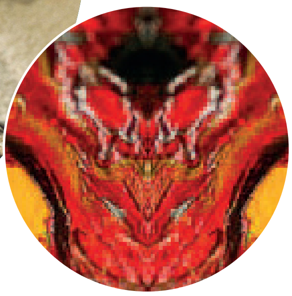
5.2.2 Reporting frequency

The KPI values have to be reported by each company individually on an annual basis. Companies can make their own decisions about which documentation will be used for the reporting (e.g. an environmental or sustainability report, website, etc.).

Reporting emissions can be based on financial years, rather than calendar years. This can help to reduce reporting costs and causes no problems provided that it is done consistently over time, with no gaps or overlaps. Any changes in the reporting year should be clearly indicated. Permit requirements and local regulations need to be complied with.

5.2.3 Performance values

As agreed in the CSI Agenda for Action, each CSI member company will establish, publish and report on their individual values for each KPI.



6 Glossary

Term	Definition
Alternative Fuel:	All other fuels that are not conventional fuel, including waste and biomass.
Blending:	Process or technique required in most waste materials treatment operations due to the heterogeneous nature of waste in order to guarantee a homogeneous and stable feedstock of the wastes that will be finally processed. Although it is a particular case of mixing (see definition of "mixing"), the term "blending" is used more for mixing liquids than for solids, except for mixing a solid into a liquid.
Bottom ash:	By-product typically produced as a residue from coal-fired power plants and that can be used as an alternative raw material for clinker production as it has quite variable physical (particularly grain size distribution), chemical and engineering characteristics not fulfilling a specification identical to fly ash. While fly ash is light enough to be carried up with the flue gases, and ideally trapped in filters before reaching the environment, bottom ash forms clinkers on the wall of the furnace, with the clinkers eventually falling to the bottom of the furnace. See a separate definition for waste incinerator bottom ash below.
Blast furnace slag:	A processed by-product of iron production in blast furnaces that is usable as a cement extender. Iron blast furnace slag (different from steel slag) is usually used for this purpose.
By-product:	A substance or object resulting from a production process where the primary aim of the production process is not to produce that item (i.e. a production residue). A by-product can be used directly in normal industrial practice without requiring chemical transformation; it fulfills all relevant product, environmental and health protection requirements and will not lead to adverse environmental or human health impacts.
CEMBUREAU:	The European Cement Association, the representative organization of the cement industry in Europe, based in Brussels.
Conventional fuel:	Coal, petroleum coke, petroleum oil (including high viscosity fuel) and natural gas.
Co-processing:	The use of suitable waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution.

Eco-efficiency: A concept first used by the WBCSD that combines economic and environmental performance to create products with greater value added and lower environmental impact. It is a management tool used to encourage companies to become more competitive, innovative and environmentally responsible.

End-of-waste status: Certain specified waste that ceases to be waste when it has undergone a recovery operation, including recycling, and complies with specific criteria. The assigning of end-of-waste status depends on each country's criteria based in specific legislation.

Fly ash: A by-product with binding properties typically produced as a residue from coal-fired power plants and that can be used as a cement extender. It is carried in the flue gases of power plants and collected in particle removal systems (electrostatic precipitators or fabric filters). See also waste incinerator fly ash.

Homogenization: Process or technique required in most waste material treatment operations due to the heterogeneous nature of waste, in order to guarantee a homogeneous and stable feedstock of the wastes, basically to get an adequate and homogeneous calorific value for those waste materials that will be processed in the end (see also mixing and blending).

Industrial ecology: A concept based on improving industrial efficiency by imitating natural ecosystems. Its aim is to prolong the useful life of raw materials and reduce the environmental impact of industrial activity by closing the cycle of materials, making one activity's waste another's raw material.

Mixing: Process or technique required in most waste material treatment operations due to the heterogeneous nature of waste, in order to guarantee a homogeneous and stable feedstock of the wastes that will be processed in the end. The term "mixing" is used more for solid or semi-solid waste materials (e.g. pasty materials).

Pozzolana: A mineral admixture that acts a supplement to standard Portland cement hydration products to create additional binder in a concrete mix. It can be either natural when occurring in nature or artificial when obtained by thermally activating clays.

Sustainable development: "Development that satisfies present needs without compromising the ability of future generations to satisfy their own needs", as first defined in the report *Our Common Future* published by the United Nations Brundtland Commission in 1987.

Waste: Any substance or object which the holder discards or is required to discard.

Waste incinerator bottom ash: The incombustible solid residue left after treating waste in an incinerator.

Waste incinerator fly ash: The material collected in the gas treatment control device of a waste incinerator and/or boiler.

Waste management: The collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker.

7 Acronyms and abbreviations

AFR	alternative fuels and raw materials
ARM	alternative raw materials
CKD	cement kiln dust
CSI	Cement Sustainability Initiative
BAT	best available techniques
BREF	European Commission Reference Document on Best Available Techniques
EIPPCB	European Integrated Pollution Prevention and Control Bureau
EQMS	environmental and quality management system
EU	European Union
GHG	greenhouse gas
GJ	giga Joule
H&S	health and safety
HSE	health, safety and environment
kg	kilogram
kk	clinker
KPI	key performance indicator
LHV	lower heating value
mg	milligram
MJ	mega Joule
MSDS	material safety data sheet
NGO	non-governmental organization
OECD	Organisation for Economic Co-operation and Development
OPC	ordinary Portland cement
ppb	parts per billion
POP	persistent organic pollutant
PPE	personal protective equipment
SEP	stakeholder engagement plan
SHEQ	safety, health, environment and quality
t	metric ton
THC	total hydrocarbon
TOC	total organic carbon
UNEP	United Nations Environment Programme
VOC	volatile organic compounds
WFD	Waste Framework Directive of the European Union
WPDS	waste package data sheet

8 Elements and compounds

Al_2O_3	aluminum oxide
As	arsenic
CaO	calcium oxide
Cd	cadmium
CO	carbon monoxide
CO_2	carbon dioxide
Co	cobalt
Cr	chromium
Cu	copper
Fe_2O_3	iron oxide
Hg	mercury
K_2O	potassium oxide
N	nitrogen
Na_2O	sodium oxide
Ni	nickel
NOx	nitrogen oxides
P_2O_5	phosphorous pentoxide
Pb	lead
Sb	antimony
Se	selenium
SiO_2	silicate
Sn	tin
SO_2	sulfur dioxide
SO_3	sulfite
Te	tellurium
TiO_2	titanium dioxide
Tl	thallium
V	vanadium

Appendix: Guidance for co-processing

These checklists offer general guidance for the responsible use and handling of alternative raw materials and fuels. They describe good practice in the different areas of site operations. Sites holding an operating permit from local authorities specifying conditions of operation should aim for full compliance.

These checklists are not to be used as an all-inclusive or exhaustive list of things to do in implementing alternative fuels or materials in a cement plant. Decisions must be made by each plant on a case-by-case basis within the broad framework of sustainable development considerations.

i. Guidance for the selection of fuels & raw materials

Operators should develop a fuels and/or raw materials evaluation & acceptance procedure based on the following:

- Have you prepared a sample of fuel or material from the supplier?
- Did you prepare a waste package data sheet (WPDS) for the fuel or material (including chemical & physical properties, health, safety and environment (HSE) considerations during sourcing, transport, handling & use, and a typical sample of the material)?
- Did you test the sample against WPDS specifications?
- Did you assess the impact of transport, unloading, storing & using the material on the health and safety (H&S) of employees, contractors and the community?
- Did you ensure that appropriate equipment and management practices are in place to address/mitigate these impacts?
- Did you select what personal protective equipment (PPE) must be used by employees to handle the fuel/material on-site safely?
- Did you assess the potential effect on plant emissions?
- Do you have the appropriate equipment and/or procedures needed to ensure no negative impacts on the environment?
- Did you assess potential impacts on process stability and quality of final product?
- Did you assess compatibility of new fuels and/or raw materials with those currently in use (i.e. sulfur, chlorine levels)?
- Did you determine what certifications (i.e. hazardous waste notifications under the Basel Convention) or materials analysis data the supplier must provide with each delivery (material safety data sheet - MSDS)?
- Did you assess whether each load should be tested prior to off-loading at the site?

Variables/parameters to consider/check in the selection of fuels and/or raw materials:

Kiln operation

- Chlorine, sulfur and alkali content (fuel or raw material)
- Water content (fuels or raw materials)
- Heat value (fuel)
- Ash content (fuel)
- Heavy metals (fuel or raw materials)
- Volatile content (fuel)

Clinker and cement quality

- Phosphate content
- Chlorine, sulfur and alkali content
- Chromium

Emissions

- Sulfides in raw materials
- Organic carbon in raw materials
- Heavy metals

ii. Compliance with regulations or company policy

- Did you identify all relevant laws, regulations, standards and company policies relating to safety, health, environment and quality control?
- Have you put appropriate equipment and/or management procedures in place to ensure continuous compliance?
- Are all employees and contractors aware of the relevant laws, regulations and standards, and know their responsibilities under them?
- If the safety, health, environment and quality (SHEQ) regulations of national, regional and local authorities are lacking in your regions, have you promoted the joint development of such regulations (on your own or with other cement companies)?

iii. Basic management systems

Personnel management

- Have you provided sufficient resources to operate and manage SHEQ systems efficiently?
- Are these resources adequately trained?
- Have you set up a system of continuous improvement, training & feedback?

Operational management

- Have you developed all H&S operation and maintenance procedures for workers and installations?
- Is a management system in place to ensure that operation & maintenance procedures are systematically reviewed following modifications to or new installations of equipment, fuels and raw materials (change management)?

Emergency procedures

- Are there robust emergency procedures on-site complying with relevant local regulations?

Stakeholder communications

- Is a stakeholder engagement plan (SEP) in place?
- Have you ensured adequate management systems are in place to monitor SEP performance and stakeholder feedback?

iv. Installation design

General design considerations

- Did you design operations to safeguard against all health and safety risks and against damaging the environment?
- Did you use appropriate procedures, and competent and qualified personnel to undertake or oversee such hazard and operability studies?
- Did you consider plant layout to ensure safe access for day-to-day operations, emergency escape routes & maintenance?
- Did you apply recognized standards to the design of installations and equipment?
- In case of retrofitting & modifications, did you thoroughly evaluate existing equipment from a safety and performance standpoint before resuming operations?
- Did you document modifications to installations & equipment and revise SHEQ systems appropriately?

Reception and storage of materials

- Have you secured appropriate permits for the storage of fuels and/or materials?
- Did you create suitable and safe systems to move fuel and/or materials from transportation to storage areas and vice versa?
- Did you consider SHEQ risks from spillage?
- Did you ensure that suitable vapor filtration and capture equipment are in place to minimize impact to the reception & storage points and surrounding areas from unloading activities?
- Do storage facilities fit their purpose?
- Do storage areas meet relevant safety and design codes?
- Have you considered all aspects of preventive fire controls & fire fighting?
- Have you put in place adequate dust control systems?
- Did you design your storage to maintain fuel and/or material quality?
- Did you design transfer & storage areas to manage and contain accidental spills into rainwater or firewater (avoiding contamination by the materials)?
- Does your storage for liquids have adequate secondary containment?
- Have you trained all reception & storage personnel adequately in fire fighting, incident prevention and emergency procedures?

Material handling and feed systems

- Have you designed handling & feeding systems appropriately for the fuel and/or raw materials used?
- Did you assess all risks from fugitive emissions?
- Did you consider all H&S aspects of handling & feeding, including delivery and on-site transport?
- Do you use appropriate vehicles and equipment to transport fuels and/or raw materials?
- Are all personnel involved in transportation adequately trained and qualified?
- Do the transport providers (external & internal) document maintenance and operator training?

- Do transporters comply with all local legal requirements regarding transportation of waste, fuels and/or materials (including hazardous, when applicable)?
- Have you considered all environmental and H&S aspects of transportation (i.e., spills, fire), including emergency plans?

v. Selection and reception of materials

- Did you select fuels and/or raw materials only after their supplier and their chemical & physical properties had been clearly identified?
- How do you ensure that all vehicles carrying fuels and/or raw materials are checked upon arrival at site and all necessary identifications performed (i.e. checking documents for compliance, etc.)?
- Do you weigh all such vehicles in and out of the site?
- Do you record all deliveries?
- How do you ensure that the fuels and/or materials delivered conform to the set specifications?
- Do you have systems in place to reject out-of-spec deliveries?
- Have you trained all personnel (including 3rd party vehicle drivers) on unloading, including health &safety and emergency instructions?
- Do you sample and analyze vehicle loads once on-site according to the frequency and protocol defined in your site control plan?

vi. Management for non-compliant deliveries of waste fuels and raw materials

- Have you prepared written instructions describing all measures to be implemented in case of non-compliance of delivered waste fuels and/or raw materials with agreed specifications?
- Did you make these available to your suppliers?
- Are all your personnel adequately trained in these instructions?
- Have you put systems in place to ensure their enforcement?
- Do you inform waste fuels and/or raw materials suppliers of every non-compliant delivery?
- Do you notify authorities in such cases (if needed in your permit)?
- Do you have alternative solutions for the disposal of rejected waste fuels and/or raw materials?
- Do you keep appropriate statistics of rejects and periodically review the performance and reliability of the waste fuels and/or raw materials producers accordingly?

Wvii. Management of quality control

- Did you develop a plan of control covering all fuels and/or raw materials entering, processed at, or produced at the site?
- Does the plan provide detailed instructions for sampling, personnel assignment, frequency of sampling and analysis, laboratory protocols and standards, calibration procedures and maintenance, and recording and reporting protocols?
- Does the plan include specifications for each fuel and/or raw material used?
- Have you allowed for adequate laboratory design, infrastructure, sampling and test equipment, including their maintenance?
- Do you carry out periodic inter-laboratory tests in order to check and improve the performance of the laboratory?
- Have you trained all quality control personnel according to their specific needs and to the nature of the fuels and/or raw materials used?

viii. On-site handling and storage

- Are written procedures and instructions in place for the unloading, handling and storage of the solid and liquid fuels and/or raw materials used on-site?
- Have you trained all relevant employees in these operating procedures?
- Is a system in place to regularly audit compliance with such procedures?
- Are storage facilities operated in such a way as to control emissions to air, water and soil?
- Have you clearly identified designated routes for vehicles carrying specified fuels and/or raw materials within the site?
- Are there appropriate signs indicating the nature of materials at storage, stockpiling and tank locations?

ix. Risks and safety tips for handling and storage of fuels

Solid fuels: coal and pet-coke

- Have you put adequate equipment and management procedures in place to deal with the risks of fire with auto-ignition for coal and explosion for given concentrations of oxygen and dust with an ignition source?
- Have you fitted fine coal and pet-coke silos with carbon monoxide and temperature monitoring systems, an explosion safety device, and an atmosphere control device such as CO2 inertization?

Liquid fuels: heavy oil and used oils

- Have you designed your equipment and procedures to address risks of fire and explosion, and leaks and spills from storage and handling areas that could contaminate soils and water tables?
- Are your oil storage and handling areas tight and fitted with secondary containments?

Scrap tires: whole and shredded

- Have you prepared for risk of fire?
- Have you taken precautions [for whole tires] related to the proliferation of mosquitoes and rodents?
- Are your storage halls fitted with water sprinkler systems?

Waste solvents

- Have you designed your equipment and procedures to address risks of fire and explosion, and leaks and spills from storage and handling areas that could contaminate soils and water tables?
- Are your solvent tanks and handling areas tight and with secondary containment?
- Are your tanks fitted with an explosion safety device?
- Have you made allowances for additional devices such as atmosphere control (e.g. N2 inertization) and temperature control (e.g. shell cooling), etc.?

Fuels derived from refuse

- Are your storage halls fitted with water sprinkler systems to prevent fires?
- Have you properly addressed the risks of fire with auto-ignition after temperature rises spontaneously, and explosion of vapors from the solvent fraction of the product?
- Have silos been fitted with carbon monoxide and temperature monitoring systems, an explosion safety device, and an atmosphere control device (e.g. CO_2 inertization)?
- Are your storage halls vented enough to control accumulation of solvent vapors and fitted with water sprinkler systems?

Meat and bone meal

- Have you addressed properly the risks of fire with auto-ignition after temperature rises spontaneously and explosion for given concentrations of oxygen & dust with an ignition source?
- Are your silos fitted with temperature monitoring systems and an explosion safety device?

General

- Do you maintain “good housekeeping” in all areas?
- Are your storage areas kept clear of uncontrolled combustible materials?
- Have you posted clear safety warnings, no smoking, fire, evacuation route, and any procedure signs at your installations?
- Have you installed an emergency shower and eye washing station, clearly marked and located near the storage of liquid alternative fuels?
- Have you put into place a fire protection system that is available at all times and meets all standards and specifications from local authorities?
- Are adequate alarms provided to alert all personnel about emergency situations?
- Is communications equipment (e.g. telephone) available and maintained at the site so that the site control room and the local fire department can be contacted immediately in case of a fire?
- Are all equipment grounded, and appropriate anti-static devices and adequate electrical devices selected (e.g. motors, instruments, etc.)?

x. Manufacturing operations

- Are written procedures and operating

instructions in place for the use of conventional and alternative fuels and/or raw materials?

- Do they adequately cover start-up and shutdown of the kiln and actions to comply with set quality requirements of the product and emissions?
- Are all operators trained in these operating procedures, and is compliance with such procedures audited regularly?
- Arethe monitoring and reporting of emissions carried out according to national and local regulations and requirements?
- Isadequate personal protective equipment available to employees, contractors and individuals visiting the installation?

xi. Selection of feed point for alternative fuels and raw materials

- Has the feed point at which alternative fuels and/or raw materials are introduced into the kiln been selected according to the nature (and, if relevant, hazardous characteristics) of the alternative fuels and raw materials used?
- Do the waste materials contain organic components that can be volatilized into the adequately high temperature zones of the kiln before being burned in the main kiln burner, the precalciner burner, the secondary firing at the preheater, or the mid-kiln (for long dry and wet kilns)?
- Are wastes introduced to the kiln system continuously and with controlled flow?
- Are alternative fuels with highly stable molecules, such as highly chlorinated compounds (1% of halogenated organic substances, expressed as chlorine) introduced at the main burner to ensure complete combustion due to the high combustion temperature (>1,100°C) and the long retention time (note that other feed points are appropriate only where tests have shown high destruction and removal efficiency rates)?
- Are automatic systems in place to stop feeding waste when appropriate temperatures and residence times are not maintained or cannot be reached (at start-ups or shutdowns for instance), and whenever any emission limit value is exceeded?
- Are adequate tests performed to demonstrate that undesired emissions at the stack do not occur before introducing alternative raw materials with volatile organic components with other raw materials in the process?

xii. Process control for alternative fuels and raw materials

- Have you ensured the constant quality and feed rate of the alternative fuels and raw materials so as not to detract from smooth and continuous kiln operation, product quality, or the site's environmental performance?
- Do you constantly measure, record and evaluate all relevant process parameters, including free lime, excess oxygen, and carbon monoxide levels, and generally continue to follow all principles of good operational control of the kiln system?
- Have you assessed the impact of alternative fuels and/or raw materials on the total input of circulating volatile elements such as chlorine, sulfur or alkalis prior to acceptance?
- In case of operational troubles in the kiln system, have you defined procedures for input limits and operational set points individually for these components based on the process type and on the specific site conditions?
- Have you issued written instructions for start-up, shutdown or upset conditions of the kiln, describing conditions of use of alternative fuels and raw materials?
- Are your kiln operators trained adequately to understand these instructions?
- Have you set procedures to ensure that in most cases, waste fuels should not be used during start-up and shutdown of kilns, except where kiln temperatures are achieved to produce clinker that meets quality standards?
- Have you set procedures to ensure that waste fuels must not be used during failure of the air pollution control devices (e.g. filter or precipitator at the stack of the kiln)?

xiii. On-site security

- Are adequate systems and procedures in place to minimize the risk of unauthorized access to hazardous materials and explosives used on-site?

xiv. Emergency response plan

- Do you have an emergency response plan in place which:
- Identifies potential spill or contamination areas?
  - Defines clean-up procedures?
  - Identifies areas of high risk on-site or in the local community?

- Provides written instructions in the event of an emergency?
- Documents the equipment required in the event of an emergency?
- Assigns responsibilities to employees and local officials?
- Details emergency response training requirements?
- Describes reporting and communication requirements both within the company and with interested external stakeholders?

– Have you reviewed your emergency response plan jointly with the relevant external emergency services?

– Have you put systems in place to arrange emergency drills with the local community emergency response services to ensure a coordinated response under emergency conditions?

xv. Safety requirements

For more complete coverage of health and safety, please see the work of the Cement Sustainability Initiative's Task Force 3 on health and safety: www.wbcsdcement.org/safety.

Have you prepared safety and emergency instructions, such as safety data sheets?

– Are they available to employees and contractors in due time, clear and easily understandable?

– Are hazards relating to new materials reviewed with operating staff prior to using such materials in the facility?

– Have you conducted a job safety analysis to identify hazards and potential exposures, along with appropriate control practices and techniques?

– Is adequate personal protective equipment (PPE) available to employees, contractors and individuals visiting the installation? (PPE includes but is not limited to: helmet, glasses, gloves, hearing protection, safety shoes, respiratory protection, and other protective equipment specified in the safety data sheets)

– Is their use mandatory?

– Is automated handling equipment used wherever possible?

– Have all appropriate hygiene precautions (i.e. vaccinations) been taken for operators wherever a contact risk such as infection or skin irritation exists?

– Does maintenance work require authorization by plant management, and is it only carried out once a supervisor has checked the area and necessary precautions have been taken?

– Do you have special procedures, instructions & training in place for such routine operations as:
    - Working at height, including proper tie-off practices and use of safety harnesses?
    - Confined space entry where air quality, explosive mixtures, dust or other hazards may be present?
    - Total electrical lock-out, to prevent accidental reactivation of all types of electrical equipment undergoing maintenance?
    - "Hot works" (i.e. welding, cutting, etc.) in areas that may contain flammable materials?

– Are appropriate management systems in place (i.e. audits, consequence management, etc.) to ensure the enforcement of all H&S requirements?

xvi. Employee training in safety, health, environment and quality

– Have you developed and implemented appropriate documented SHEQ training programs for employees?

– Are all new employees trained during an induction process?

– Are such training programs given to contractors and, in some instances, suppliers?

– Has all the personnel reporting to work on-site for the first time been trained through a site-specific induction program?

– Are training records kept on file?

– Does the training program include:
    - General and job specific safety rules?
    - Safe operation of equipment?
    - Details of the site emergency response plan?
    - Procedures for handling alternative fuels and raw materials?
    - Use of personal protective equipment?

About the World Business Council for Sustainable Development (WBCSD)

The World Business Council for Sustainable Development (WBCSD), a CEO-led organisation of some 200 forward-thinking global companies, is committed to galvanising the global business community to create a sustainable future for business, society and the environment. Together with its members, the council applies its respected thought leadership and effective advocacy to generate constructive solutions and take shared action. Leveraging its strong relationships with stakeholders as the leading advocate for business, the council helps drive debate and policy change in favor of sustainable development solutions.

The WBCSD provides a forum for its member companies - who represent all business sectors, all continents and a combined revenue of more than $7 trillion - to share best practices on sustainable development issues and to develop innovative tools that change the status quo. The council also benefits from a network of 65+ national and regional business councils and partner organizations, a majority of which are based in developing countries.

www.wbcsd.org

About the Cement Sustainability Initiative (CSI)

The CSI is a global effort by 24 leading cement producers, with operations in more than 100 countries. Collectively, these companies account for around 30% of the world's cement production and range in size from very large multinationals to smaller local producers. All CSI members have integrated sustainable development into their business strategies and operations, as they seek strong financial performance with an equally strong commitment to social and environmental responsibility. The CSI is an initiative of the World Business Council for Sustainable Development (WBCSD).

www.wbcsdcement.org

www.wbcsdcement.org/fuels

Cement Sustainability Initiative

Disclaimer

This report is released in the name of the WBCSD. It is the result of a collaborative effort by members of the secretariat and executives from member companies participating in the Cement Sustainability Initiative (CSI). Drafts were reviewed among CSI members, so ensuring that the document broadly represents the majority view of this group. This does not mean, however, that every member company agrees with every word.

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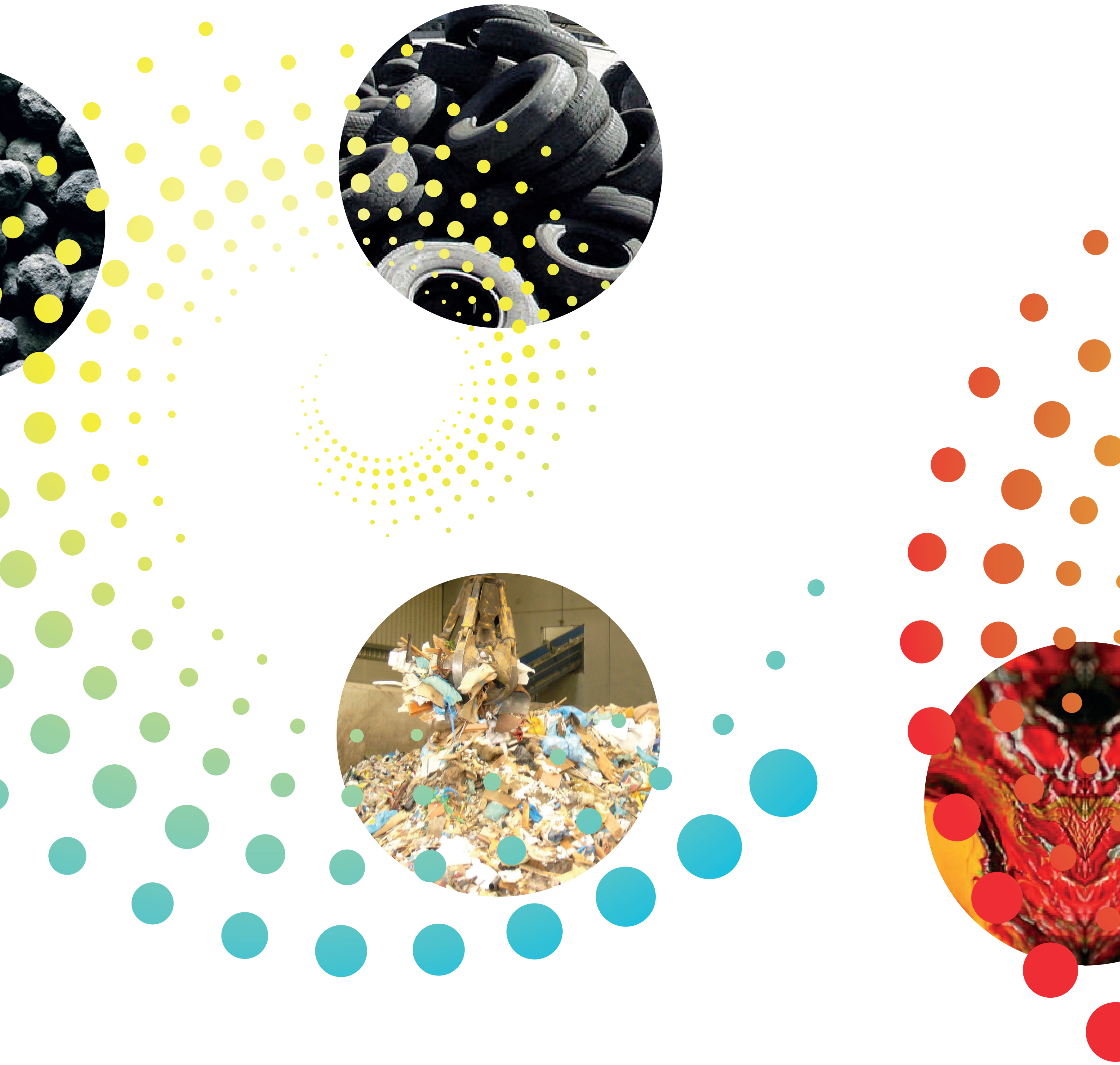

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