

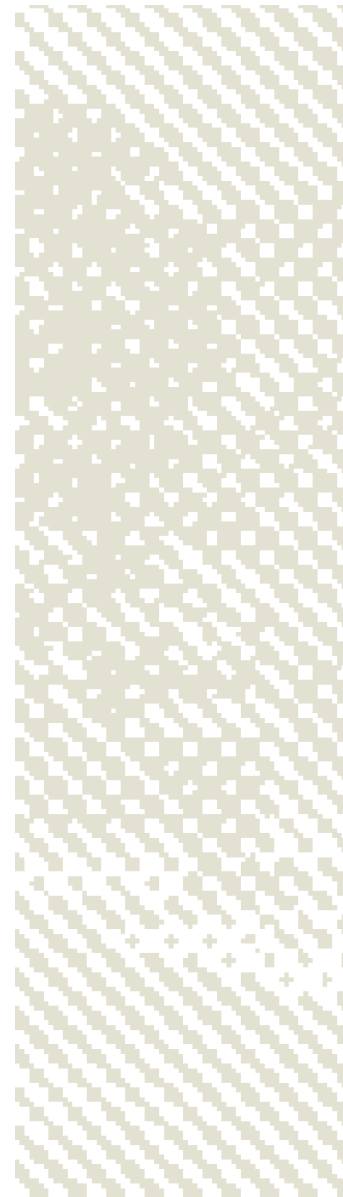


SUSTAINABLE CEMENT PRODUCTION

CO-PROCESSING
OF ALTERNATIVE FUELS
AND RAW MATERIALS
IN THE EUROPEAN CEMENT
INDUSTRY

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EXECUTIVE SUMMARY

Cement is an essential product, providing society with what it needs in terms of safe, comfortable housing and reliable modern infrastructure.

Co-processing in the cement industry is the optimum way of recovering energy and material from waste. It offers a safe and sound solution for society, the environment and the cement industry, by substituting non renewable resources with societal waste under strictly controlled conditions.

The co-processing of alternative fuels provides a solution in terms of reducing fossil fuel dependency as well as a contribution towards the lowering of emissions. The use of alternative raw materials also has numerous benefits, including a reduced need for quarrying and an improved environmental footprint of such activities. Substitution of clinker in cement is an example of the positive contribution of the European cement industry to resource management.

The use of alternative materials in the cement industry lowers global CO₂ emissions and does not have a negative impact on production process emissions, nor on the environmental and technical quality of the final product.

Furthermore, co-processing in the cement industry is carried out in a safe and sound manner, thus not affecting the health & safety of its workers or neighbourhood.

A WIN/WIN/WIN SITUATION

Industry (PROFIT):

A cost-effective substitution of natural resources thereby improving the competitiveness of the industry

CO-PROCESSING

Ecology (PLANET):

Environmentally sustainable waste management and important saving of natural resources

Society (PEOPLE):

A long term and sound solution for the treatment of different types of waste produced by society

AVERAGE EU SUBSTITUTION RATES:

- ▶ Alternative fuels: 18%
- ▶ Alternative raw materials: 5%
- ▶ Alternative constituents: 12%

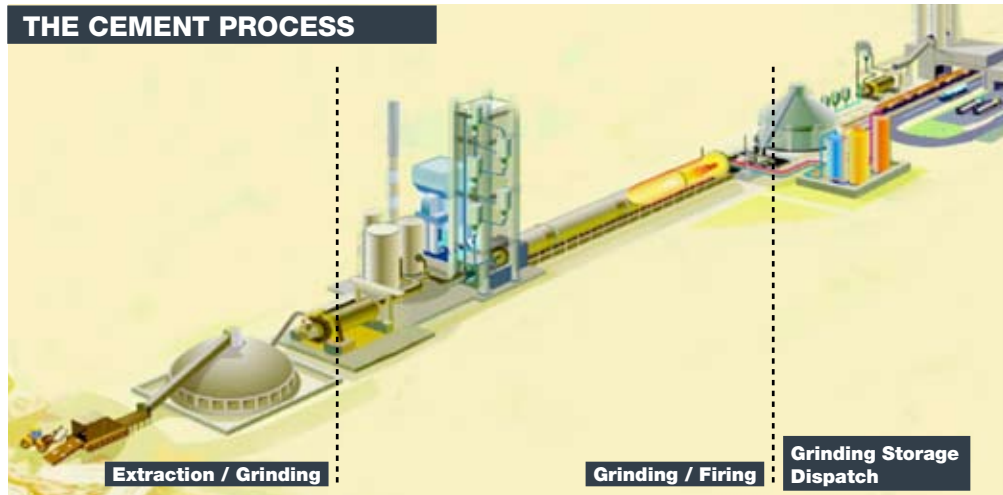
1 Cement and concrete manufacturing: the process

The main component of cement is **clinker**. Clinker is produced from raw materials, such as limestone and clay, which are crushed, homogenised and fed into a rotary kiln. The clinker burning takes place at a material temperature of 1450°C which is needed to form the new compounds. Clinker consists mainly of calcium-, silicium-, aluminium- and iron-oxides.

The next phase is handled in a cement grinding mill. Gypsum and other additional materials (such as blast furnace slag, coal fly ash, natural pozzolanas, limestone, etc.) are added to the clinker. All constituents are ground leading to a fine and homogenous powder: **cement**.

In **concrete** production, cement, aggregates and other suitable materials are mixed with water. When water is added to cement, it reacts and forms a glue which binds together the other main constituents of concrete.

**CEMENT IS AN
ESSENTIAL PRODUCT,
PROVIDING SOCIETY
WITH WHAT IT NEEDS
IN TERMS OF SAFE
AND COMFORTABLE
HOUSING AND
RELIABLE MODERN
INFRASTRUCTURE**



WORKING TOGETHER TO SOLVE AN IMPORTANT SOCIETAL PROBLEM

In 1999, an urgent solution for the treatment of thousands of tonnes of animal meal and fat from potentially contaminated animal products was required in Belgium. At the time, there was major public concern about this potential health hazard. The federal authorities identified the co-processing of the contaminated meat & bone meal in the cement industry as the best way of resolving this crisis. Belgian plants were, therefore, requisitioned to treat a large amount of potentially contaminated animal meal. This process provided a safe and environmentally sound solution as it allowed for the complete destruction of the contaminants in the kiln, as well as reducing emissions as a result of **fuel substitution**.

➤ **More information:** www.febelcem.be

A similar situation arose in Italy in 2001. Italian cement plants, in agreement with the public authorities, were requisitioned to treat a large amount of potentially contaminated meat & bone meal.

2 Co-processing: from waste management to resource management

The European cement industry is committed to ensuring that society has sufficient cement to meet its needs, whilst at the same time reducing its fuel and raw material requirements and subsequent emissions. Use of waste materials in the cement industry, also referred to as co-processing, contributes towards achieving these objectives. Co-processing is the substitution, in industrial processes, of primary fuels and raw materials with suitable waste materials.

The co-processing of waste in the cement industry provides a maximum substitution of non renewable materials. The decision on what type of waste can be finally used in a certain plant cannot be answered uniformly. As a basic rule, waste accepted as an alternative fuel and/or raw material must give an added value for the cement kiln in terms of the calorific value of the organic part and the material value of the mineral part. Some alternative materials will often meet both of these requirements, making it difficult to formulate general criteria regarding the materials which are co-processed in the cement industry.

Due to the characteristics of the production process, the cement industry is capable of co-processing:

- + alternative fuels, which have a significant calorific value (e.g. waste oils);
- + alternative raw materials, the mineral components of which mean they are suitable for the production of clinker or cement (e.g. contaminated soil)
- + materials that have both a calorific value and provide mineral components (e.g. paper sludge, used tyres)

USE OF SOLID WASTE

The treatment of municipal, commercial and some industrial waste reduces the need for landfilling of organic and recyclable waste. In Austria, cement plants started to use solid waste (made up of recyclable plastics, paper, textiles and composite materials) in 1993. All nine cement plants in Austria use solid waste to a certain extent. In addition, several companies are working in partnership with waste management companies in order to build pre-treatment facilities to provide alternative fuels which meet cement process specifications.

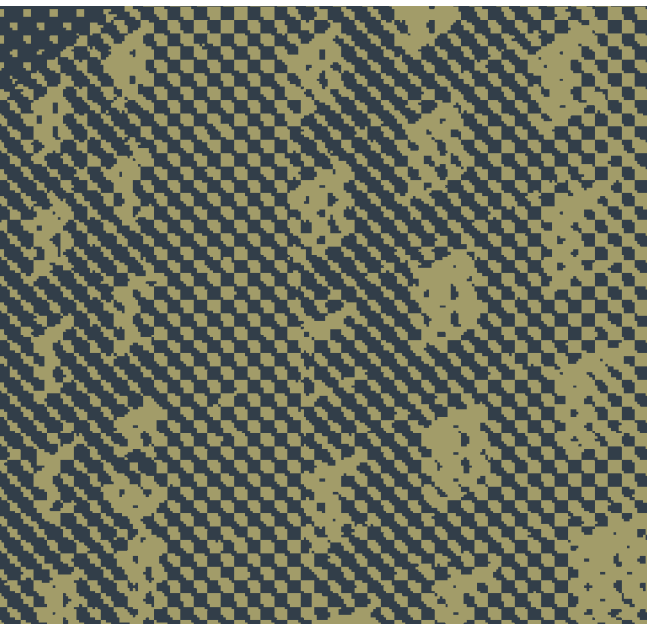
The Austrian cement industry started to co-process tyres as early as 1980.

However, not all waste materials can be co-processed in the cement industry. Several factors must be taken into consideration when deciding on the suitability of the materials. These include the chemical composition of the final product (cement) as well as the environmental impact of the cement production process. Examples of waste which is not suitable for co-processing in the cement industry include nuclear waste, infectious medical waste, entire batteries and untreated mixed municipal waste.

An adequate quality control system is strictly adhered to for all the materials used. This ensures that they are co-processed in an environmentally safe and sound manner, safeguarding the:

- + health & safety of the workers in the plant and the people living in the neighbourhood;
- + environmental impact of the production process;
- + high quality of the final product;
- + correct and undisturbed functioning of the production process;

The alternative materials used by the cement industry are derived exclusively from selected waste streams. They usually require pre-treatment (e.g. drying, shredding, blending, grinding or homogenisation) and an appropriate Quality Assurance. Pre-treatment is, therefore, an integral part of the "recovery" operation. Waste is often prepared for use as an alternative fuel by outside suppliers and waste-treatment experts.



The co-processing of waste has been recognised as a recovery operation under EU legislation. Recovery operations in cement plants are carried out in compliance with the provisions of both the Directives on the Incineration of Waste and Integrated Pollution Prevention and Control (IPPC), and are recognised as a Best Available Technique (BAT).

CASE LAW

Case C-228/00. Judgment of the Court (Fifth Chamber) of 13 February 2003. European Commission v. Germany

Ruling: A ruling delivered by the European Court of Justice holds that using waste as a fuel in cement kilns should be classified as recovery.

It should be borne in mind that the degree of co-processing in Europe varies from country to country as a result of:

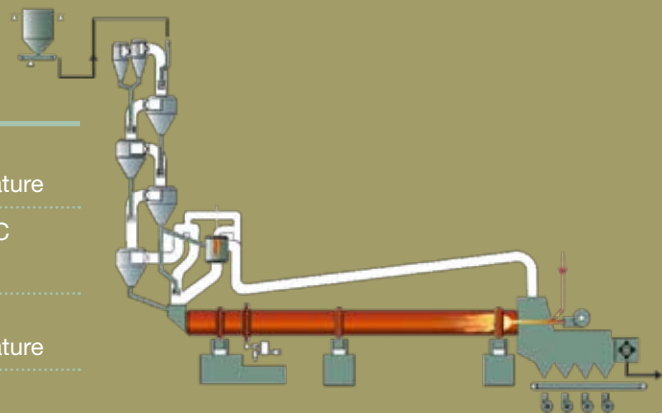
- + national regulation/waste management
- + experience (in the cement industry)
- + market and local conditions

The use of alternative resources in certain European countries is low and has a clear potential for growth. The European cement industry is, therefore, keen to collaborate in developing this further.

CO-PROCESSING IN THE CEMENT INDUSTRY PROVIDES THE OPTIMUM WAY OF RECOVERING ENERGY AND MATERIAL FROM WASTE. ADDITIONALLY IT OFFERS A SAFE AND SOUND SOLUTION FOR SOCIETY, THE ENVIRONMENT AND THE CEMENT INDUSTRY BY SUBSTITUTING NON RENEWABLE RESOURCES WITH SOCIETAL WASTE UNDER STRICTLY CONTROLLED CONDITIONS

THE AVANTAGES OF CO-PROCESSING

Characteristics	Temperature and time
Temperature at main burner	>1450°C: material >1800°C: flame temperature
Residence time at main burner	>12-15 sec and >1200°C > 5-6 sec and > 1800°C
Temperature at precalciner	>850°C: material >1000°C: flame temperature
Residence time at precalciner	> 2-6 sec and >800°C



- + Excess of oxygen during and after combustion
- + Complete destruction of organic compounds
- + Total neutralisation of acid gases, sulphur oxides and hydrogen chloride, by the active lime in the kiln load, in large excess to the stoichiometry
- + Embedding of the traces of heavy metals in the clinker structure with very stable links (metallic silicates formation)
- + No production of by-products such as ash or liquid residue from gas cleaning

Total recovery of energy and mineral content of waste (raw material and fossil fuel saving). The technical characteristics are compliant with European Directives, i.e, the Waste Incineration Directive.

> Alternative fuels: Saving of non renewable fossil fuels

In 2006, the European cement industry used an energy equivalent of about 26Mt of coal, a non renewable fossil fuel, for the production of 266Mt cement. Alternative fuels constituted 18% of this across Europe, saving about 5Mt of coal.

In terms of using waste as an alternative fuel in the cement industry, there are two characteristics of particular importance: burning conditions (high temperature with a long residence time and oxidising atmosphere) and a natural alkaline environment of raw materials. These conditions are particularly favourable for insuring a high level of destruction of polluting substances such as dioxins and furans. Indeed, the SINTEF¹ report states that "with material temperature at approximately 1450°C and kiln gas temperatures up to 2000°C, long residence time up to 8 seconds, or more, insures complete pyrolysis or breakdown of organic waste".

In the cement plant, dedicated facilities are built to receive, store and inject the alternative fuels, often complemented by waste pre-treatment facilities. These facilities take into account the characteristics of the alternative fuel and the specific regulation related to the handling of waste (especially in terms of health & safety).

Energy provided by co-processing is entirely used in the clinker manufacturing process. The calorific content may vary depending on the waste used. However, it is not only the calorific value which counts as the mineral content of the waste (ash) can also be used as an alternative raw material in clinker production, meaning no residues are generated.



Co-processing of used tyres: a long lasting success story

The clinker burning process offers the possibility of a simultaneous energy and material recovery of the individual components of the tyres. The high calorific value of the rubber is used to substitute primary fuels and the inert ingredients (mainly iron and alumina) substitute the raw materials. Moreover, if the natural raw material does not contain enough iron, the use of tyres helps directly to meet the desired product requirements. Based on the long lasting, successful experience in the co-processing of tyres, Germany has put tyres on a list of materials suitable for the clinker burning process. It should be noted that tyres contain a significant amount of biogenic carbon (about 27% due to the content of natural rubber), thus leading to a direct reduction of fossil fuel related CO₂. Depending on where they are fed into the kiln, tyres can also deliver a significant contribution to the reduction of nitrogen oxide emissions.

CO-PROCESSING ALTERNATIVE FUELS PROVIDES A SOLUTION IN TERMS OF REDUCING FOSSIL FUEL DEPENDENCY AS WELL AS A CONTRIBUTION TOWARDS A LOWERING OF EMISSIONS

¹ Formation and Release of POPs in the Cement Industry. Second edition. SINTEF 26 January 2006

> **Alternative raw materials: Substitution of natural virgin resources**

In 2006 about 5% of the raw materials used in the production of clinker consisted of alternative raw materials, totalling about 14.5Mt/ year.

Alternative raw materials can be used to replace the traditional raw materials extracted from quarries, such as clay, shale and limestone, which are used in the kiln. Examples of alternative raw materials include contaminated soil, waste from road cleaning and other iron-, aluminium-, and silica-containing wastes, such as coal fly ash and blast furnace slag. The chemical suitability of alternative raw materials is important to ensure that they provide the necessary constituents for the formation of clinker.

**THE USE OF ALTERNATIVE RAW MATERIALS PROVIDES
NUMEROUS BENEFITS, INCLUDING A REDUCED NEED FOR
QUARRYING AND AN IMPROVED ENVIRONMENTAL FOOTPRINT OF
SUCH ACTIVITIES**

> **Cement: Substitution of clinker with alternative constituents**

Cement in Europe must be manufactured according to the harmonised standard EN 197-1 which clearly indicates the 27 common cements according to their main constituent. As mentioned, the main component of cement is clinker. Depending on availability, part of the clinker can be replaced with alternative constituents. Two major examples are granulated blast furnace slag, a by-product of the iron manufacturing process, and fly ashes, one of the residues generated from the combustion of coal.

**SUBSTITUTION OF CLINKER IN CEMENT IS AN
EXAMPLE OF THE POSITIVE CONTRIBUTION
OF THE EUROPEAN CEMENT INDUSTRY TO
RESOURCE MANAGEMENT**

3 Co-processing's contribution to CO₂ emission reduction

Co-processing offers a high potential for the cement industry to reduce global CO₂ emissions. Without co-processing, the wastes and by-products which make up these materials would have to be incinerated or landfilled² with corresponding greenhouse gas emissions.

In 1990, the percentage of energy gained by the use of waste as a fuel was 3%. In 2006, it stood at about 18%, resulting in a reduction of 8Mt of CO₂ emissions each year whilst saving about 5Mt of coal.

CO₂ emissions from biomass are climate neutral. More than 20% of the alternative fuels used by the European cement industry consist of pure biomass, such as meat & bone meal and sewage sludge. This could be developed further provided biomass remains accessible. In addition, the alternative fuels used in the cement industry contain a high level of biomass due to its content of e.g. wood or paper fractions.

TACKLING INDUSTRIAL WASTE: CEMENT KILNS VERSUS INCINERATORS – AN ENVIRONMENTAL COMPARISON

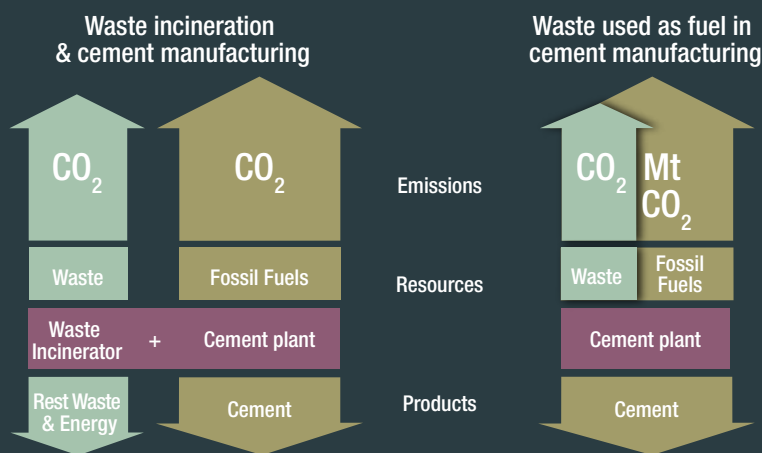
A study conducted by the Netherlands Organisation for applied Science Research (TNO) compared the environmental impacts of using waste as an alternative fuel and raw material in the cement industry, and burning waste in hazardous waste incinerators while recovering electricity and steam. This assessment took into consideration the complete life-cycle of the different waste streams and all the environmental impact categories (Life-cycle assessment). It concluded that, for the vast majority of environmental impacts, using industrial waste as alternative fuels in the cement industry was better for the environment than treating them in waste incinerators.

Source: Summary by Greenfacts.

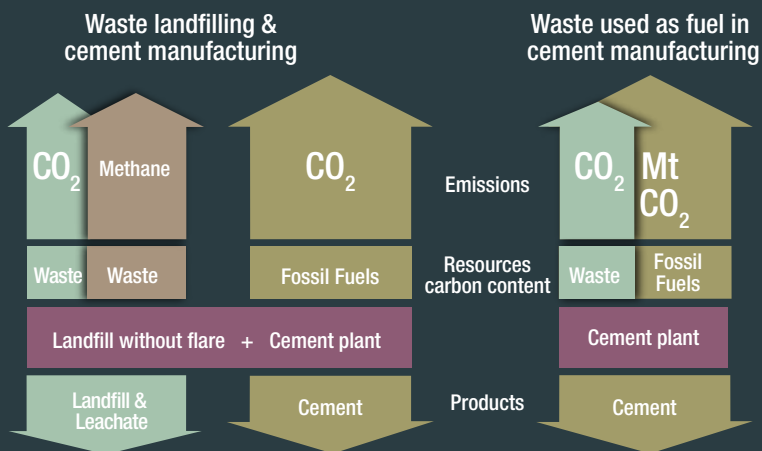
➤ **More information:**
www.coprocessing.info

The CO₂ emissions of manufacturing cement result from the production of the intermediate product, clinker. Reducing the clinker content reduces, therefore, the energy and carbon intensity of the cement produced.

THE USE OF WASTE & BIOMASS INSTEAD OF FOSSIL FUEL IN THE CEMENT INDUSTRY REDUCES EUROPEAN ABSOLUTE EMISSIONS



THE USE OF SOLID WASTE IN A CEMENT PLANT PREVENTS METHANE EMISSIONS IN A LANDFILL.



² Emissions from landfill consist of about 60% methane, a gas with a global warming potential 21 times that of CO₂.

4 No increased environmental impact from co-processing

Emissions from the cement kiln come from the physical and chemical reactions of the raw materials and from the combustion of fuels. The main constituents of the exit gases from a cement kiln are nitrogen from the combustion air, CO₂ from calcination and combustion, water from the combustion process and the raw materials, and excess oxygen. The exit gases also contain small quantities of dust, chlorides, fluorides, sulphur dioxide, NO_x, carbon monoxide, and still smaller quantities of organic compounds and heavy metals.

Impact of co-processing on kiln emissions:

- + Sulphur oxides – SO₂: Alternative fuels have no influence on total SO₂ emissions.
- + Nitrogen oxides – NO_x: Alternative fuels do not lead to higher NO_x emissions – in some cases, NO_x emissions can even be lower.
- + Total organic carbon – TOC: there is no correlation between the use of alternative fuels and emissions levels.
- + Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF): No difference has been found in dioxin emissions when alternative fuels are used.
- + Hydrogen chloride – HCl: HCl emissions vary irrespective of the fuel used.
- + Hydrogen fluoride – HF: There is very little difference in HF emissions when using alternative fuels.
- + Heavy metals: Emissions vary irrespective of the fuel used. However, nearly 100% of them remain either in the cement clinker matrix or the cement kiln dust as non leachable compounds. In any event, alternative fuels undergo a rigorous acceptance and inspection procedure before being used.
- + Dust: Dust emissions taken under both fuel regimes indicate no difference between the two.

In relation to the co-processing of alternative fuels, the installations meet the same standards as dedicated waste incinerators.

**THE USE OF SUITABLE
ALTERNATIVE MATERIALS
DOES NOT HAVE ANY
NEGATIVE IMPACT
ON EMISSIONS**

Sewage sludge: a multifaceted solution

Until recently, the only solution was to dump or use sewage sludge in agriculture. However, sewage sludge can now be used as both an alternative fuel and raw material in the clinker manufacturing process. It is important to note that there is a surplus of sludge, and therefore the need for alternative forms of processing is becoming all the more acute. The Netherlands and Spain are just two examples of countries where the cement industry is providing a solution for sewage sludge.

Since March 2000, the ENCI cement plant located in Maastricht (Netherlands) has been working together with the Limburg Purification Board, receiving pre-treated sewage sludge from their sewage water treatment plants (following further treatment in the Board's own thermal sludge dryers). Today, 80.000 tonnes of dried sewage sludge are co-processed annually in a kiln with a capacity of 865.000 tonnes of clinker per year.

In 2005, the cement sector in Catalonia (Spain) reached an agreement with the Catalan administration, trade unions and the local councils, to launch a trial to monitor the environmental behaviour of thermally dried sewage sludge from the Barcelona area as an alternative fuel in cement plants. The aim is to use more than 60.000 tonnes of dried sewage sludge every year as a petcoke substitute, providing a solution for the high amount of sewage sludge which cannot be used in agriculture.

5

Impact on cement quality

All cement produced in Europe must meet the applicable European standard, regardless of the materials used. Therefore, the cement industry carefully selects and monitors all intake materials.

Depending on the amount of alternative raw materials and fuels used, the concentration of individual elements in the final product may increase or decrease as a result of waste processing. However, this is of little consequence as these materials replace fossil fuels and/or raw materials composed of the same elements. As cement is blended with aggregates, e.g. gravel and sand for the production of concrete or mortar, it is the behaviour of these trace elements in the building material (concrete or mortar) which is ultimately decisive for evaluating the environmentally relevant impacts of waste co-processing in the clinker burning process on the quality of the product.

Heavy metal releases from concrete and mortar are low, as they remain firmly trapped in the product. Independent tests on concrete and mortar have shown that the leaching of heavy metal concentrations is noticeably below those prescribed, for instance, by national legislation. In addition, storage under different and partly extreme conditions has not led to any environmentally relevant releases.

THE CO-PROCESSING OF WASTE HAS NO NEGATIVE IMPACT ON THE ENVIRONMENTAL AND TECHNICAL QUALITY OF THE PRODUCT

6

Co-processing and health & safety

The European cement industry is committed to the health & safety of its workers and neighbours. As with all other fuels, raw materials and components, the necessary health & safety analyses have been conducted, with adequate procedures put in place, including personal protective equipment and storage facilities.

Secil-Outão case study

Intertox performed an extensive risk assessment of co-processing in Outão (Portugal) to estimate the potential hazards emissions may pose to both human health and the ecosystem. This assessment was based on the “worst case scenario”, simulating the effect of cumulative less favorable occurrences, in order to determine whether the emission levels would pose a risk to health and the environment. It concluded that co-processing is not expected to have any significant impact on the health of the local population or the local environment.

➤ **More information:** www.secil.pt

CO-PROCESSING IN THE CEMENT INDUSTRY DOES NOT HAVE A NEGATIVE IMPACT ON THE HEALTH & SAFETY OF ITS WORKERS OR SURROUNDING NEIGHBOURHOOD

7 Co-processing legislation & guidelines

Co-processing in the European cement is strictly controlled. Guidelines, such as the Guidelines for the Selection and Use of Fuels and Raw Materials in the Cement Manufacturing Process produced by the Cement Sustainability Initiative, provide practical guidance for cement manufacturers. In addition, legislation at European Union level also applies to the use of AFR in the European cement industry.

The UK's Committee on the Medical Effects of Air Pollution, (COMEAP) has stated that the burning of waste-derived fuels in cement kilns results in no changes in emissions that would be of significance to human health. Its latest (2008) report on Meat & Bone Meal, Processed Sewage Pellets, and Refuse Derived Fuel extended the 2005 review of waste tyres and substitute liquid fuels, and indicated that these findings were relevant to any combination of these fuels.

➤ **More information:**

<http://www.advisorybodies.doh.gov.uk/comeap/>

- + Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and repealing certain Directives
- + Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the Incineration of Waste.
- + Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning Integrated Pollution Prevention and Control (Codified version) - Incorporates and repeals the Council Directive 96/61/EC of 24 September 1996 concerning Integrated Pollution Prevention and Control and all its amendments (Directive 2003/35/EC (only Article 4 and Annex III), Directive 2003/87/EC (only Article 26), Regulation No 1882/2003 (only point (61) of Annex III) and Regulation No 166/2006 (only Article 21(2)) into a single "codified" text.
- + Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on Shipments of Waste.

This information is correct at the time of publication. For the latest information, please visit: www.cembureau.eu

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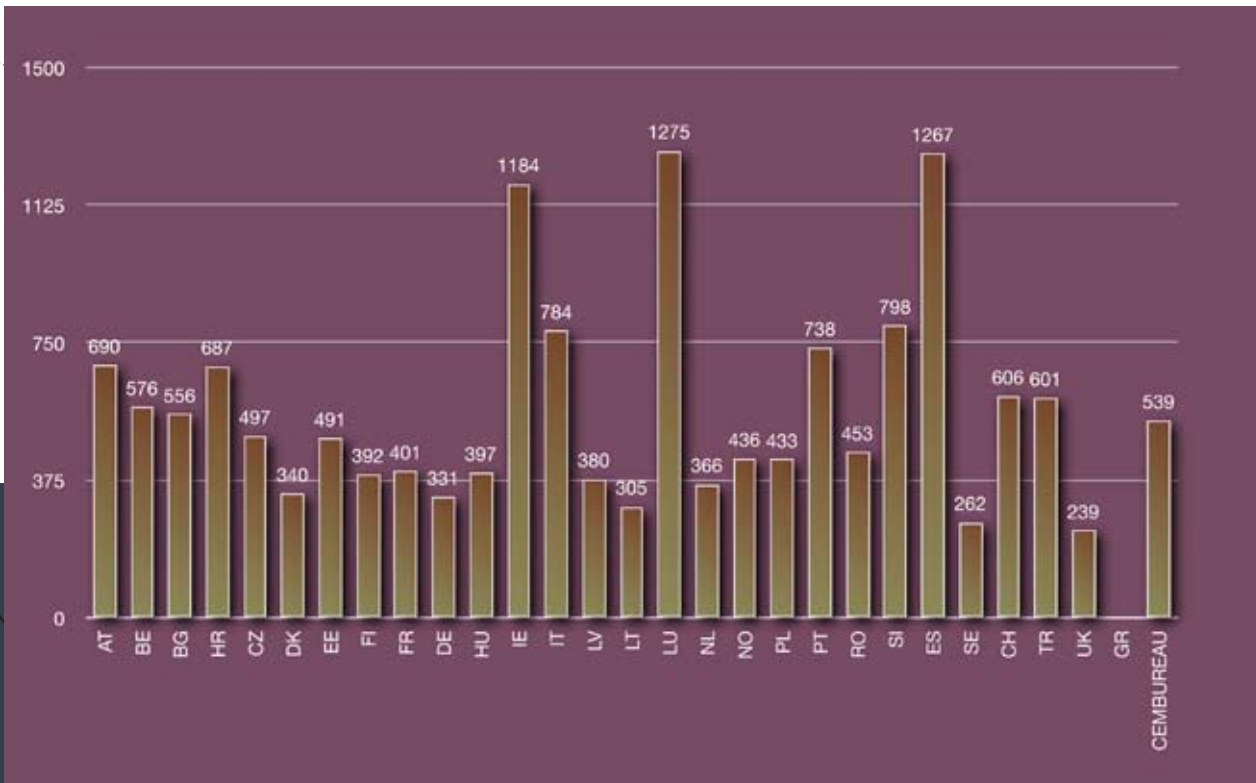
The European Cement Industry: an overview

Cement plays a key role in our lives: it is a basic material for all types of construction, including housing, roads, schools, hospitals, dams and ports, and may even be used in decorative items such as tables and bookcases.

Cement is a finely ground, non-metallic, inorganic powder, which, when mixed with water, forms a paste that sets and hardens. It's most important use is in the production of concrete, acting as the binder gluing the other key ingredients of concrete – sand and gravel. It typically makes up about 12% of the concrete mix.

Concrete is the second most consumed substance on earth after water and is an essential, virtually irreplaceable product used in the built environment. As a building material, it contributes positively towards the energy efficiency of buildings, and has excellent and proven fire resistance properties which deliver protection of life, property and the environment in the case of fire. In relation to adaptation to climate change, concrete also has much to offer in terms of flood prevention and resilience to adverse weather conditions.

**CEMBUREAU CEMENT CONSUMPTION 2007
PER CAPITAL / KG**

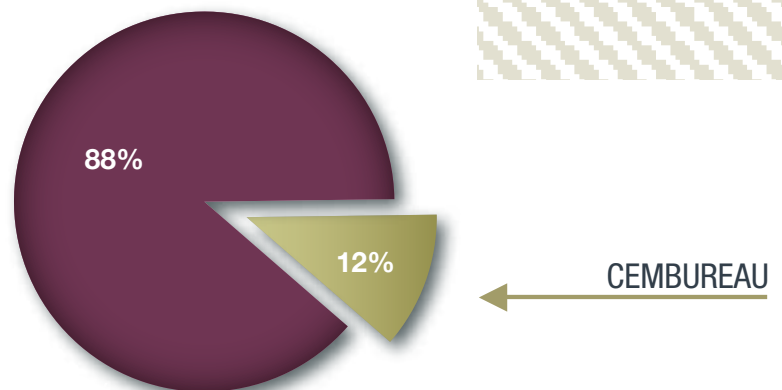


CEMENT IN EUROPE

CEMBUREAU, the European Cement Association based in Brussels, is the representative organisation of the cement industry in Europe. Currently, its Full Members are the national cement industry associations and cement companies of the European Union (with the exception of Cyprus, Malta and Slovakia) plus Norway, Switzerland and Turkey. Croatia is an Associate Member of **CEMBUREAU**.

In 2007, **CEMBUREAU** Members produced a total of 325Mt of cement. The average per capita consumption in the **CEMBUREAU** member countries in 2007 was 546kg. In the 27 Member States of the European Union, production reached an estimated 270Mt, accounting for nearly 10% of world production.

WORLD CEMENT PRODUCTION 2007 2.77 BILLION TONNES







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