



CEMBUREAU

Cement, concrete & the circular economy



THE ROLE OF CEMENT & CONCRETE IN THE CIRCULAR ECONOMY (EXECUTIVE SUMMARY)

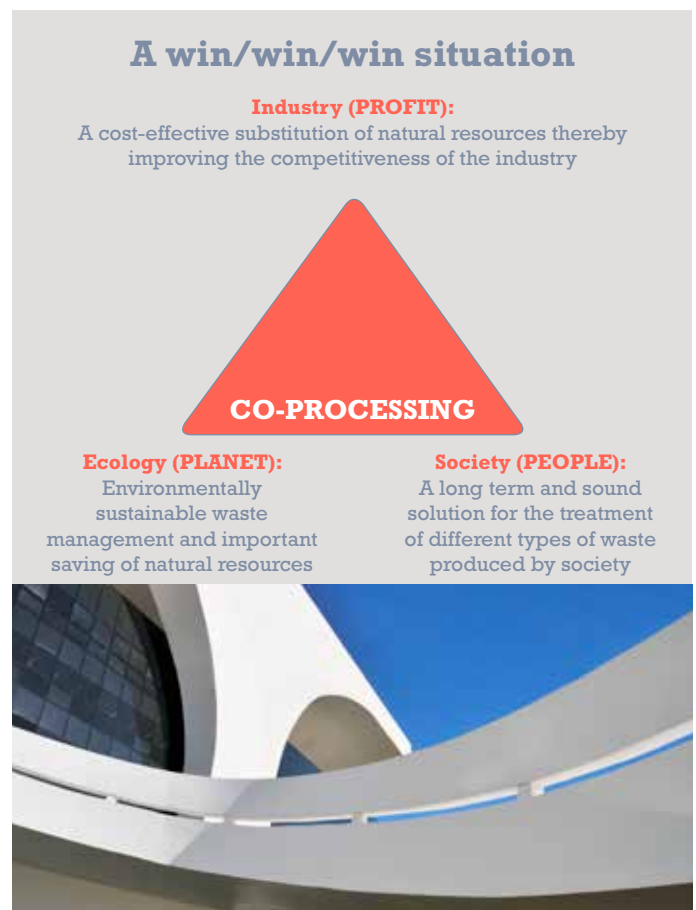
The cement and concrete industries have much to offer in terms of helping the EU achieve its circular economy goals. As the cement industry, we fully support any proposal which aims to make the most of Europe's resources, be they primary or secondary resources such as waste. In this respect, it is important that policymakers recognise and make the most of what is already taking place in many industries. As such, all forms of recycling should be encouraged whilst at the same time assessed in order to ensure that the best environmental, social and economic outcomes are achieved. On the one hand, this may mean that, in some instances, the best option could be to recycle a product back into the same product category. However, in other instances, it may be preferable to opt for an alternative recycling solution.

Thanks to material recycling in the cement industry, the mineral content of waste used as an alternative fuel serves as a raw material for the production of clinker, the main constituent in cement. In a nutshell, EU policy should:

- ◆ Foster the use of waste to achieve the EU targets set for waste recycling and resource efficiency.
- ◆ Material recycling from waste and fuel ashes should count towards recycling targets compliance for Member States.
- ◆ Leave open to Member States the range of waste treatment options for their assessment of the best technical feasibility, economic viability and environmental protection for waste streams.

According to the Commission's figures, approximately one third of all waste in Europe comes from construction and demolition. Only one third of that amount is recycled and it's not technical difficulties that prevent a higher recycling rate. It's market realities. Proof of that is that recycling rates greatly differ between European Member States with a 95% recovery rate in The Netherlands, for instance, against a European average of between 30% and 60%. As such, material producers in the construction industry need to work together and improve the collection and sorting of demolition waste and in creating an economically viable system encouraging its use.

In order to be truly sustainable, equal weight must also be given to each of the three pillars of sustainability. As such, it is crucial to look beyond the product and assess other economic costs or environmental impacts that can be generated. By way of an example, it would not make sense to transport concrete over long distances in order for it to be reused in a building when there is an option of recycling it in a different application locally (e.g. as road base).



SETTING THE POLITICAL SCENE

Circular economy & the Energy Union Strategy

The cement industry is supportive of the aims of the European Commission concerning the circular economy¹ and promotes the recognition afforded to the material recycling which occurs at the same time as energy recovery in cement production. The sector also supports the promotion of industrial symbiosis and the recognition of energy recovery as a waste management solution for non recyclable waste. The need for sorting systems for construction & demolition waste, is another area welcomed by the cement industry. Furthermore the cement industry welcomes the Energy Union Strategy² which aims to ensure that Europe has access to secure, affordable and climate-

friendly energy. With this in mind, the energy recovery from waste through co-processing in the cement industry has a relevant role to play across the EU-28 Member States, as by using waste as a fuel, the cement industry contributes towards security of energy supply, which is fully in line with the Energy Union Strategy. Against this backdrop, the following publication provides an overview of why the cement and concrete industry is central to the circular economy and what can be done to leverage the opportunities. It also demonstrates how the sector fits perfectly with many of the European Union's policy objectives, in terms of security of energy supply.

THE STORY OF CEMENT & CONCRETE MANUFACTURE

What is cement?

Cement is a fine, soft, powdery-type substance, mainly used to bind sand and aggregates together to make concrete. Cement is a glue, acting as a hydraulic binder, i.e. it hardens when water is added. Everyone knows the word cement, but it is often confused with concrete or mortar. Cement is a key ingredient in both concrete and mortar, and it is always mixed with other materials before use:

- ◆ Cement mixed with water, sand and aggregates forms concrete, which is what the vast majority of cement is used for.
- ◆ Cement mixed with water, lime and sand forms mortar.

Cement and concrete have been used to build durable structures for quite some time. The Coliseum in Rome, completed in 80 AD, is a good example of how a concrete structure can withstand time. The cement used by the Romans was produced using locally available raw materials, chalk and volcanic ash heated in open fires. The modern version of cement, called Portland cement, was developed back in the early 19th century and has been improved ever since. Common cements in Europe are specified by the European standard EN 197-1. There are also a number of special cements, such as supersulfated cements, very low heat cements and calcium aluminate cements.

Cement manufacture

The cement-making process can be divided into two basic steps:

- ◆ Clinker (the main constituent of cement) is first made in a kiln with gas up to 2000°C, which heats raw materials such as limestone (calcium carbonate) with small quantities of other materials (e.g. clay) to 1450°C. During this process, known as calcination, the calcium carbonate (limestone) is transformed into calcium oxide (lime), which then reacts with the other constituents from the raw material to form new minerals. This near-molten material is rapidly cooled to a temperature of 100 - 200°C.
- ◆ Clinker is then ground with gypsum and other materials to produce the grey powder known as cement.

What is concrete?

Concrete is a mixture of cement, water, aggregates and a small amount of ingredients called admixtures. It is the most commonly used manmade material in the world, its production equivalent to almost three tonnes of concrete per person, per year, twice as much as all other materials put together, including wood, steel, plastics and aluminium.

Aggregates make up approximately 60-75% of the mixture by volume and cement and water make up the rest. Aggregates are usually inert materials like gravel, crushed stone, sand or recycled concrete. The type of aggregate selected depends on the application of the concrete. Thanks to the special binding properties of cement, concrete is a very resilient, durable material that can bear heavy loads and resist environmental extremes. The vast majority of cement is used to make concrete.

¹ Closing the loop - An EU action plan for the Circular Economy

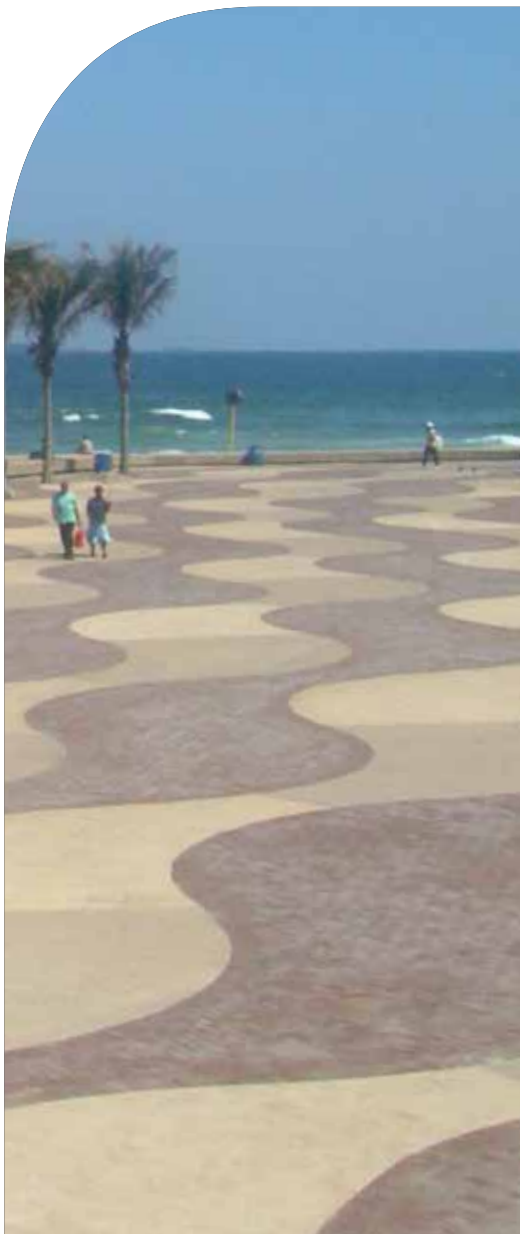
² A European Energy Union

CLINKER PRODUCTION & 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. The use of waste materials in the cement industry, also referred to as co-processing, contributes towards achieving these objectives. Co-processing is the use of waste as raw material, or as a source of energy, or both to replace natural mineral resources (material recycling) and fossil fuels such as coal, petroleum and gas (energy recovery) in industrial processes. The co-processing of waste in the cement industry provides a maximum substitution of non renewable materials. The cement industry uses waste which is, in principle, non recyclable due to a number of factors, including:

- ◆ Recycling it is not always economically viable
- ◆ There can be an insufficient market for the recycled product
- ◆ Recycling could, in fact, not be the best ecological option (eg, it could increase the CO₂ footprint)



The main raw materials used in cement production have traditionally been limestone and clay, both of which are abundantly available. However, as mentioned, it is possible to replace part of the raw materials used in cement production with waste and by-products from other industrial processes. Selected waste and by-products containing useful elements such as calcium, silica, alumina and iron can be recycled as raw materials in the kiln, replacing natural substances.

In recent years, about 5% of raw materials used in the production of clinker in Europe consisted of recycled material and ashes from fuel, totalling about 8 million tonnes per year. Examples of recycled materials include contaminated soil, waste from road cleaning and other iron-, aluminium-, and silica-containing wastes or by-products, such as coal fly ash and blast furnace slag. The chemical suitability of recycled materials is important to ensure that they provide the necessary constituents for the formation of clinker.

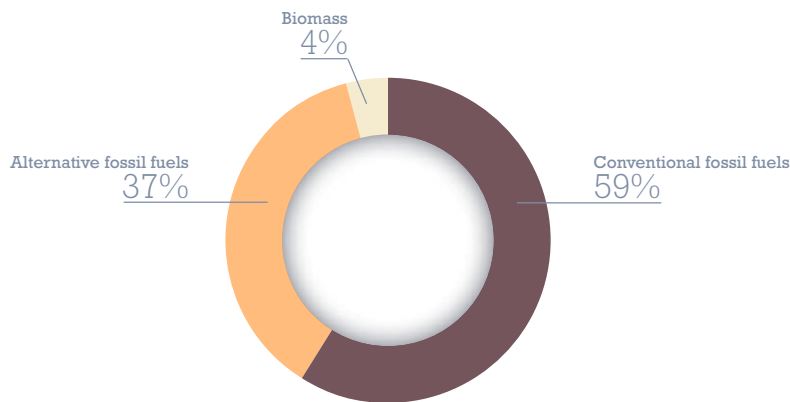
The use of alternative raw materials offers numerous benefits, including a reduced need for quarrying and lower CO₂ emissions if the alternative materials are already decarbonated, as in the case of ashes from lignite or coal, blastfurnace slag, concrete crusher sand, aerated concrete meal and fractions from demolition waste.

The decision on what type of waste can be 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. 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)
- ◆ materials which have a significant mineral component (e.g. industrial slags)
- ◆ materials that have both a calorific value and provide mineral components (e.g. used tyres and industrial sludges)

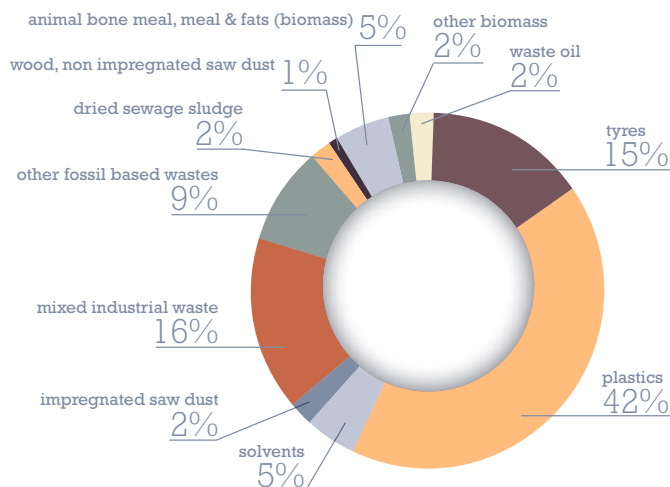
Breakdown of fuels

Thermal Energy Consumption by fuel type 2014



Breakdown of alternative fuels

Alternative fuels breakdown 2014



It has been estimated that by 2050, 40% of kiln energy will come from traditional sources, i.e. coal (30%) and petcoke (10%), while 60% of kiln energy could potentially be provided by alternative fuels of which 40% could be biomass. This fuel mix would lead to an overall decrease of 27% in fuel CO₂ emissions.

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 clinker production process. Examples of waste which is not suitable for co-processing in the cement industry include nuclear waste, infectious medical waste, and entire batteries. 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
- ◆ high quality of the final product
- ◆ correct and undisturbed functioning of the production process
- ◆ environmental impact of the production process.



Characteristics of co-processing in the cement industry

Clinker is manufactured by heating raw materials inside the main burner of a kiln to a temperature of 1450°C, which is hotter than lava flowing from a volcano! The flame reaches temperatures of 1800°C. The material remains at 1200°C for 12-15 seconds at 1800°C for 5-8 seconds (also referred to as residence time). These characteristics of a clinker kiln offer numerous benefits and they ensure a complete destruction of organic compounds, a total neutralization of acid gases, sulphur oxides and hydrogen chloride. Furthermore, heavy metal traces are embedded in the clinker structure and no by-products, such as ash of residues, are produced.



The legislative framework needs to recognise these new waste management options, such as material recycling in the cement industry, as contributing to the EU and Member State recycling targets.



What makes co-processing unique?

In addition to combining both energy recovery and material recycling, co-processing in the cement industry is unique in that dedicated waste pre-treatment facilities have been established in order to treat the waste prior to sending it as a fuel to cement plants. 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. On the one hand, these facilities provide a constant supply of waste which allows the cement industry to control the clinker production process and ensure clinker quality. At the same time, these pre-treatment facilities also separate the waste and ensure that any waste which can be recycled is sent for recycling.

Why is energy recovery important?

By using waste as a fuel, the cement industry contributes towards security of energy supply, which is fully in line with the recently published Energy Union Package. In the cement industry, energy recovery:

- ◆ contributes to the lowering of CO₂ emissions
- ◆ makes the cement industry less dependent on imported fossil fuels
- ◆ reduces the amount of waste sent to landfill

In 2014, the European cement industry used an energy equivalent of about 15.8Mt of coal, a non renewable fossil fuel, for the production of 172Mt of cement. Alternative fuels, including waste biomass, constituted 41% of this total across Europe, saving about 6.5Mt of coal.

Furthermore, co-processing offers a high potential for the cement industry to reduce global CO₂ emissions. In 1990, the percentage of non-renewable energy gained by the use of waste as a fuel was 3%. In 2014, it stood at 37%, resulting in 18Mt of avoided CO₂ emissions each year. CO₂ emissions from waste biomass are climate neutral. 14% of the alternative fuels used by the European cement industry consist of biomass from waste, such as meat & bone meal and sewage sludge. This could be developed further provided biomass remains accessible.

Why is material recycling important?

There is a large amount of waste which cannot be recycled back into the same product category. Fortunately, there are several other solutions available for this waste - and co-processing in the cement industry is one of them! Thanks to material recycling in the cement industry, the mineral content of waste used as an alternative fuel serves as a raw material for the production of clinker, the main constituent in cement.

It should be borne in mind that the level 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 and become an integral part of Member States waste management systems, thereby contributing to the EU Energy Union goals with steady and cost-effective energy security of supply from waste diverted from landfills.

Co-processing: A combination of energy recovery and material recycling

The cement industry specialises in the treatment of difficult waste streams and supports a ban on the landfilling of recyclable and recoverable waste.

- ◆ On the one hand, the cement industry is able to use waste as an alternative fuel (Energy Recovery), which reduces our recourse to primary fossil fuels – as well as reducing CO₂ emissions!
- ◆ On the other, the cement industry can recycle the mineral content of the waste as a raw material (Material Recycling) – thus reducing our dependence on virgin raw materials!

In accordance with the Waste Framework Directive, 'recycling' includes any operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. Given the above, material recycling in the cement industry is clearly a recycling operation. The material recycling component of co-processing contributes towards Member States compliance with EU recycling targets and should be recognised as such.



Poland: Co-processing as a waste management solution

The use of alternative fuels in the Polish cement industry began some 20 years ago. In order to gain public acceptance and recognition for co-processing as a waste management solution, the sector engaged early on in active dialogue with a broad range of stakeholders including NGOs, different levels of government, journalists, scientists and the waste sector. All relevant information concerning the co-processing of waste was made available and discussed with these stakeholders, with the aim of demonstrating the advantages of such a waste management solution and why cement kilns are the best option for such waste. As a result of this open dialogue, alternative fuels currently constitute 55% of the thermal energy of Polish cement plants. Refuse derived fuels and industrial waste account for 1.2 million tonnes of the 1.4 million tonnes of waste co-processed in the Polish cement industry today. The cement industry is currently looking at ways in which it could increase Poland's capacity to co-process to 1.7 million tonnes, which is the equivalent of around 10% of the municipal waste generated in Poland.

Waste heat recovery from clinker production

Overall, 99% of the energy produced is for heat needed for the mineral transformation into clinker (the cement-based product). In the cement industry the majority of waste heat emitted from a clinker kiln is normally used for the drying processes (raw material drying and grinding/milling, slag drying, sand drying, fuel drying and grinding).

In line with the Energy Efficiency Directive³ several Member States are working on the development of heating and cooling strategies based on an integrated approach which combines the use of waste heat from waste-to-energy incinerators for the production of steam and electricity or combined heat and power plants. In this regard, the employment of cogeneration plants for steam and electricity or of combined heat and power is, in principle, applied in cement manufacturing, with excess heat from clinker production being recovered for district heating. Examples of waste heat recovery from the cement industry for power generation can be found in Sweden, Germany and Denmark, and for hot water in Sweden and Germany.

³ 2012/27/EU

Tackling landfills

Regarding the landfilling of waste, CEMBUREAU believes that more should be done to ban the landfilling of recyclable and recoverable waste. Today, large disparities do exist between Member States with respect to their waste management performance. However, banning landfills would require capacity building to implement waste collection, separation and pre-treatment systems in order to be able to divert waste from landfill.

The cement industry has a clear role to play, as it can provide a solution for a certain amount of the waste currently being landfilled. There are currently around 210 kiln-operated cement plants distributed across the EU. Therefore, although EU funds could contribute to a reduction in landfilling by encouraging other waste treatment options, it is important to ensure that full use is made of existing waste management capacity. As such, existing cement plants that co-process waste should be taken in consideration as a waste treatment solution for residual waste from landfills before funding and developing unnecessary excessive capacity.

Co-processing in the cement industry: a very energy efficient waste management solution

Given that the cement industry consumes high quantities of energy, energy efficiency (both thermal and electrical) is a priority for the sector. In parallel to increasing the amount of alternative fuels used, the sector continues to invest in improving the energy efficiency of its kilns. Overall, the average energy efficiency of the cement industry across Europe ranges between 70-75%. For the most efficient installations currently in existence, this figure rises to 85%. Subject to improvements in terms of the processing of waste, the amount of waste co-processed in the cement industry could increase from 8 million tonnes (2012) to between 24 and 30 million tonnes, accounting for 10-15% of the high combustible waste generated in Europe.



CIRCULAR ECONOMY PRINCIPLES IN CEMENT PRODUCTION

Substitution of clinker with alternative constituents

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. Part of the clinker can be replaced with alternative constituents, depending on their availability. Two major examples are granulated blast furnace slag, a by-product of the steel manufacturing process, and fly ash, one of the residues generated from the combustion of coal.

- ◆ These constituents are defined in the European cement standard EN 197-1 “Cement - Part 1: Composition, specifications and conformity criteria for common cements”. In many cases, several main constituents are combined. On average, in CEMBUREAU member countries the use of cements with a lower clinker content has been growing steadily.
- ◆ At an equivalent performance level, the choice of a cement with a lower clinker content using materials with latent cementitious properties, provided that these materials are available locally, is currently seen as a choice that reduces the initial environmental impact of concrete construction.

New cements

In addition, innovative binder technologies not requiring the high temperature firing of limestone and silica materials are being researched. This research is at an early stage and significantly more time and work will be required to identify whether they are economically viable and suitable for the production of durable concrete.

CIRCULAR ECONOMY PRINCIPLE IN CONCRETE PRODUCTION

Concrete is made from natural materials which are generally abundant and locally available. In concrete manufacture, waste is prevented by the use reclaimed (un-hardened) concrete in ready-mixed concrete production. In addition, concrete can be recycled 100% at the end of its life. Furthermore, and depending on the cement type used, alternative materials such as fly ash, a by-product of coal-fired power plants, and ground granulated blastfurnace slag (GGBS) from steel production, can also be recycled in the concrete manufacturing process.

CONCRETE IN USE

Durability

Concrete is used in constructions like buildings, bridges, tunnels and dams for its strength, which grows over time, as it is not weakened by moisture, mould or pests. Its durability makes concrete a key material for sustainable construction. Indeed, concrete buildings can last 100 years and more and require very little maintenance. But why is this relevant? If we compare a building with a life span of 50 years to one with a life span of 100, almost twice as many resources and embodied CO₂ are associated with the building lasting 50 years, since it would need to be built twice in order to last the same length of time.

END-OF-LIFE?

100% recyclable!

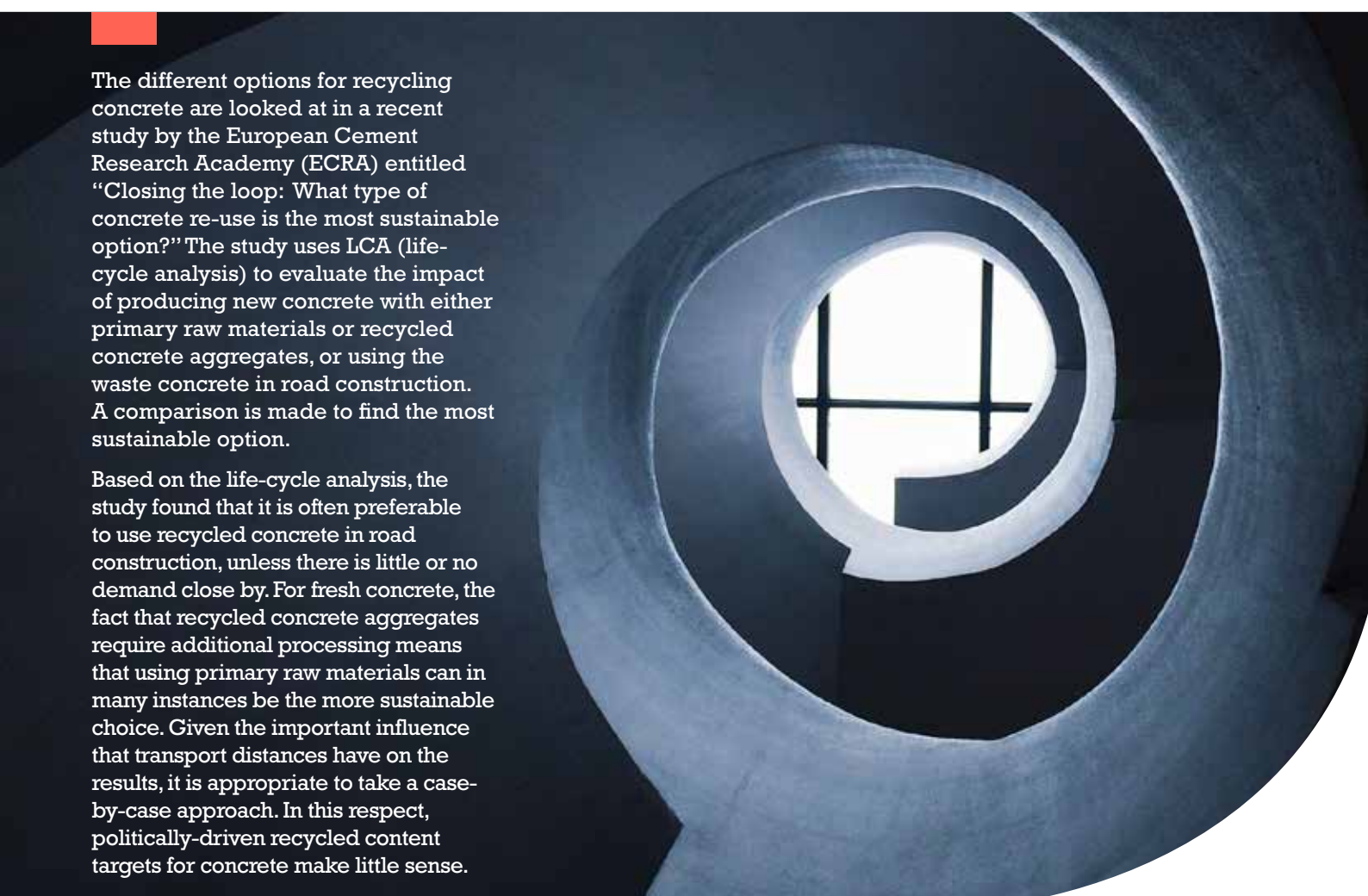
The impacts associated with the end-of-life of a building, such as disposal or recycling, must also be given due consideration. In this respect, about 450-500 million tonnes of construction and demolition waste (C&DW) is generated every year in Europe, at least a third of which is concrete. Fortunately for concrete, recycling is not technically difficult. Concrete can be 100% recycled after demolition.

Recycling concrete from C&DW offers two main benefits: it reduces our dependence on primary raw materials and reduces the amount of waste sent to landfill. There are two main ways in which recycled concrete is reused:

- ◆ As a recycled aggregate in new concrete
- ◆ As a recycled aggregate in road construction and earthworks.

The choice of application should be based on the optimum balance of sustainability, local availability and long-term technical performance (see box).

A third route for recycling concrete under development is the use of the fine particles from crushed concrete as a secondary raw material in clinker production.



The different options for recycling concrete are looked at in a recent study by the European Cement Research Academy (ECRA) entitled "Closing the loop: What type of concrete re-use is the most sustainable option?" The study uses LCA (life-cycle analysis) to evaluate the impact of producing new concrete with either primary raw materials or recycled concrete aggregates, or using the waste concrete in road construction. A comparison is made to find the most sustainable option.

Based on the life-cycle analysis, the study found that it is often preferable to use recycled concrete in road construction, unless there is little or no demand close by. For fresh concrete, the fact that recycled concrete aggregates require additional processing means that using primary raw materials can in many instances be the more sustainable choice. Given the important influence that transport distances have on the results, it is appropriate to take a case-by-case approach. In this respect, politically-driven recycled content targets for concrete make little sense.

HOW ARE WE CIRCULAR?

◆ The raw materials used to produce cement and concrete, primarily limestone and aggregates, are abundantly available. However, our industry makes strong efforts to reduce its recourse to these primary raw materials, both in its manufacturing process and in the use of its products, and this through the use of different types of waste streams from a variety of other industries. The cement industry is a key example of industrial symbiosis.

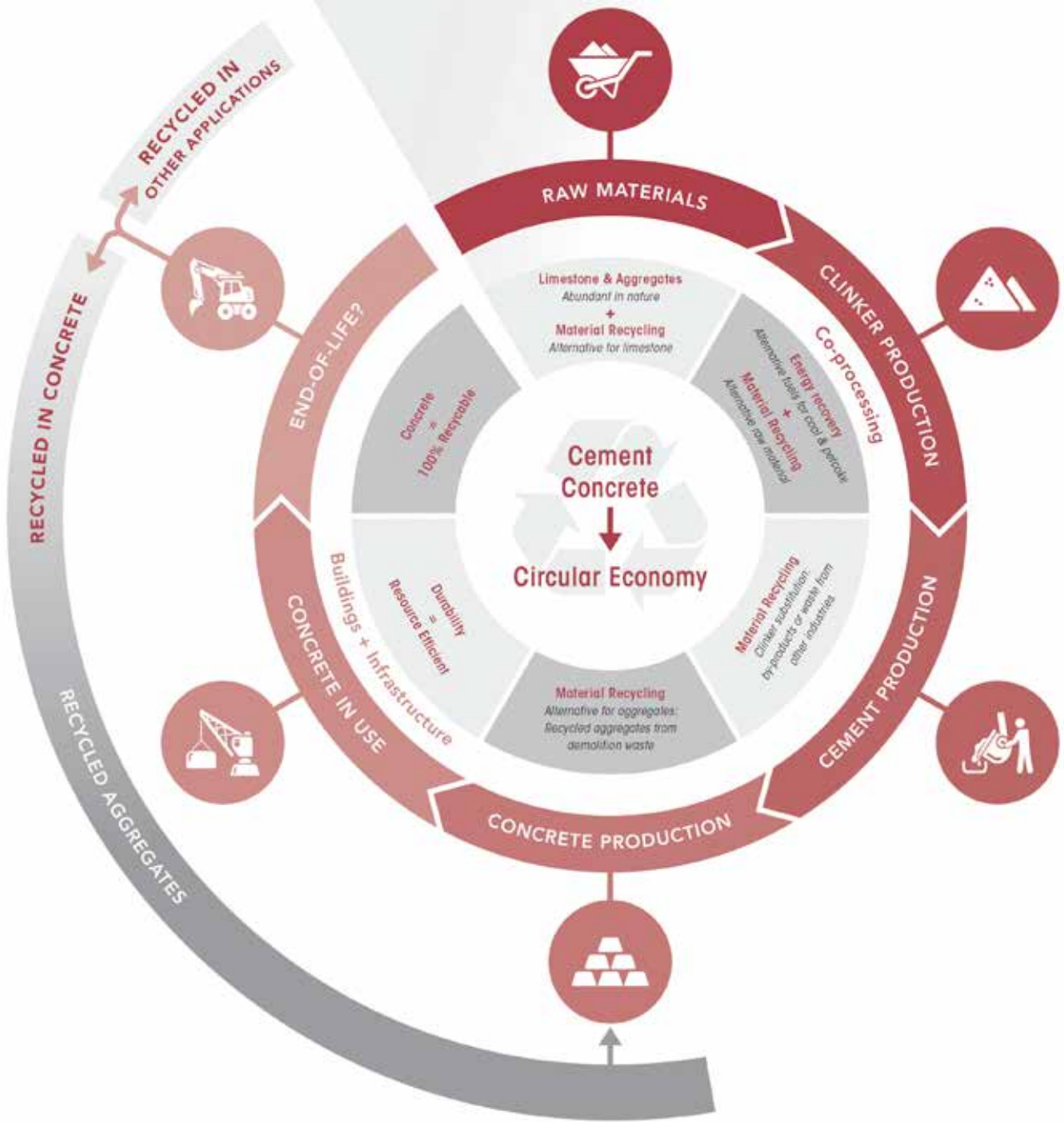
◆ When manufacturing clinker, the cement industry is able to use waste as a fuel instead of coal and petcoke. At the same time, the mineral content of waste is recycled as a raw material. We, in the cement industry, refer to this use of waste as an energy source and/or a raw material in industrial processes as 'co-processing'.

◆ Material recycling also occurs when making cement. Here, we replace part of the clinker with by-products from other industries. One example is fly ash from coal combustion.

◆ In concrete production, material recycling also occurs, thanks to the use of recycled aggregates.

◆ Not only is concrete a durable construction material, it is also 100% recyclable as either a recycled aggregate in concrete or in other applications (as road base, for example).







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