EU-MERCI

EU coordinated **ME**thods and procedures based on **R**eal **C**ases for the effective implementation of policies and measures supporting energy efficiency in the **I**ndustry

HORIZON 2020 Project Nr. 693845

Technical analysis –Cement sector (NACE C23.5-23.7)

WP4: Picture of efficiency projects implemented by the Industry sector-by-sector and process-by-process

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1 Introduction

According to NACE classification, cement manufacturing and processing is included in NACE C23 (Manufacture of other non-metallic mineral products) and can be a part of the following subsectors:

- NACE C23.5 Manufacture of cement, lime and plaster
- NACE C23.6 Manufacture of articles of concrete, cement and plaster

This part also includes description of Lime manufacturing process which is included in classes of above mentioned NACE groups.

The total cement production in 2014 in EU28 countries was 166.8 million tonnes with the consumption above 150 million tonnes. The cement sector accounted for about 1.9% of EU-28 GDP in 2016.

In standard manufacturing plants each tonne of cement produced consumes from 60 to 130 ktoe in fuels and about 110 kWh of electricity, depending of the type of cement and the process used for production.

The main products of cement sector are:

- White cement
- Clinkers
- Other hydraulic cements
- Aluminous cement
- Slag cement
- Superphosphate cements

The main processes of cement manufacture are:

- storage and preparation of raw materials and fuels
- clinker production
- cement grinding and storage

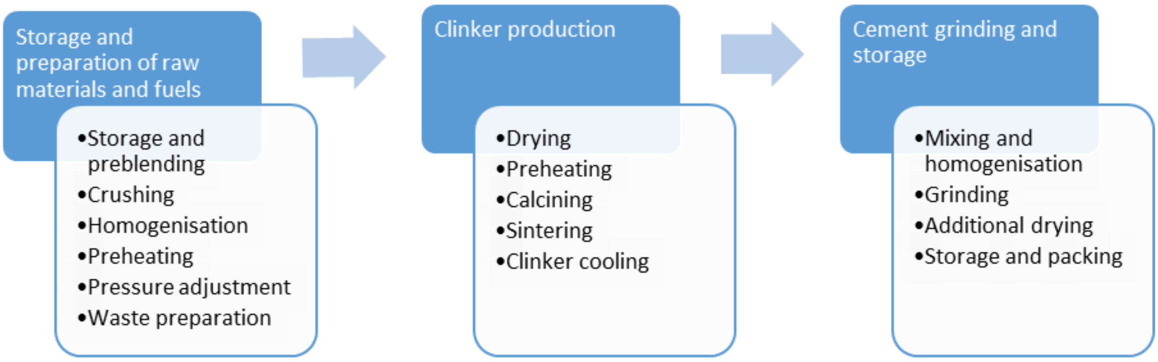

Figure 1: Cement production process.

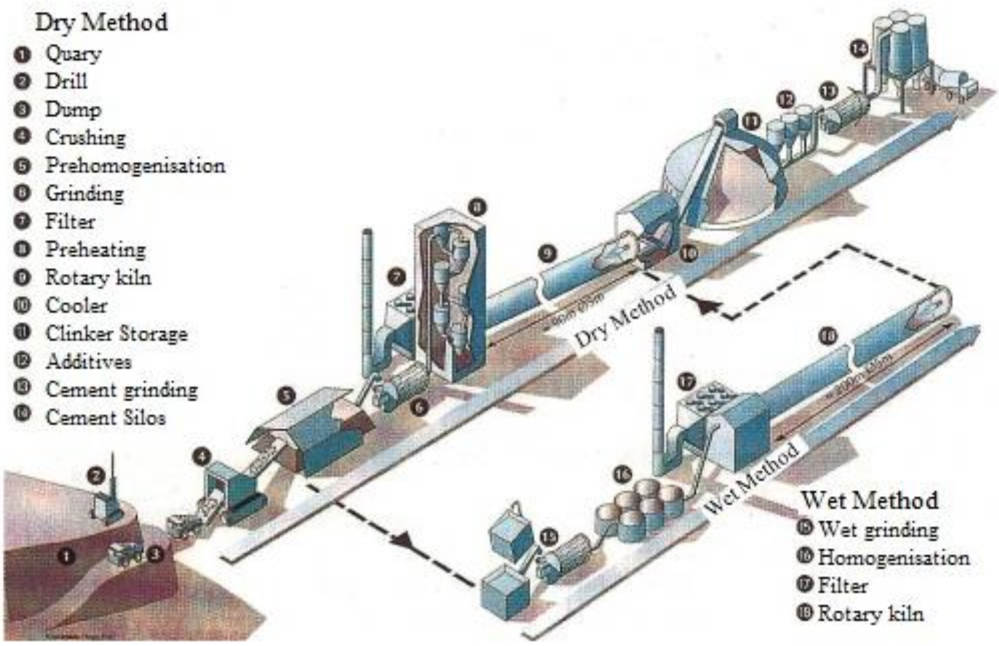

Figure 2: Scheme of cement manufacturing process.

2 Cement manufacturing

2.1 Storage and preparation of raw materials

Raw materials delivered to the plant usually differ from each other. In the storage process, separate piles of materials are created, that are set due to source and quality of the materials. The storage of raw materials mostly takes place in separate buildings but in case of small amounts of materials they can be stored in silos or bunkers.

The quality and quantity of material delivered to kilns is essential for its efficient work: thus the material has to be grinded before entering kilns. The portions of material transported to grinding mills are measured by the apron feeder followed by the belt weigh feeder. The process needs to be controlled in order to avoid contamination of the mixture, then additional elements can lower the quality of final product.

Different techniques are applied to the grinding process due to the further use of dry or wet kiln systems. The main technologies for grinding use tube mill, centre discharge, tube mill, airswept, vertical roller mill, horizontal roller mill. Technologies using tube mill, end discharge in closed circuit, autogenous mill, roller press, with or without crushers are less common. For greater efficiency of the kiln process the special classifiers and separators are used; for dry process the air separators are used.

In wet process when the raw material has high portion of moisture the material is fed to wash mill and then the slurry is transported to tube mill for further grinding. In some cases, further homogenisation may be needed. After the process the slurry is stored in silos or tanks.

2.2 Storage and preparation of fuels

Storage and preparation of fuels differs due to the state and kind of fuels used in the process. The most commonly used fossil fuels in Europe for the cement manufacturing process are petcoke and coal. The source of energy can be different due to the availability of the fuels in specific region. The storage of raw coal and petcoke is similar to the storage of materials, usually covered stores are used for conventional storage. Special care has to be considered to avoid the ignition of the stored fuels, for these reasons pulverised coal and petcoke is stored in protected silos. The oil is usually stored in vertical steel tanks, while natural gas is not stored near the plant. The distribution network is considered to play a similar role to a storage.

The preparation process of solid fuels is similar to the preparation of raw materials. Tube mill, airswept, vertical roller or ring-ball mill and impact mill are most commonly used for grinding the fuels. The fuels are then stored in silos ready to be fed to the kilns powering systems. The fineness of the grinded fuel is important to achieve high efficient combustion process. Fuel oil parameters need to be adjusted to the combustion and transporting systems inside the plant thus the temperature and pressure is raised affecting the viscosity. The parameters of gas obtained from the network are usually different than needed for the manufacturing process. The pressure needs to be decreased: it can be carried out by the through reduction valve, in this case the gas needs to be pre-heated. The reduction of pressure can be carried out using gas expansion turbines, with the advantage thet this process allows saving energy when the turbine is connected to a power generator.

2.3 Control and preparation of waste materials and fuels

The waste materials and fuels allow savings of natural resources but in most cases they need to fit European and national regulations. The use of waste also has strong impact on the final product thus the quality of waste has to be defined and controlled for every type of waste used in each process. The preparation system for wastes is similar to the preparation system of fuels and raw materials. The use however has to be controlled to maintain high efficiency of kiln process.

The most common wastes used as raw materials are: fly ash, blast furnace slag, silica fume, iron slag, paper sludge, pyrite ash, spent foundry sand, soil containing oil, artificial gypsum. The quality of the waste use as raw material is especially important in white cement production due to the importance of colour standards.

Almost 40% of fuels used in cement production in Europe is covered by waste. This type of fuel can replace traditional fuels in cement kilns. Most of the waste fuels are sorted into usable before entering plant. The main types of waste fuels are solid and liquid recovered fuels and biomass. Other wastes can also be used in the process. Main types of non-hazardous solid wastes used in cement kilns are: wood, paper, cardboard, textiles, plastics, processed fractions, rubber/tyres, industrial sludge, municipal sewage sludge, animal meal, fats, coal/carbon waste, agricultural waste. The size of solid waste particles is important for the transportation and firing system. In some cases the waste need to be additionally prepared before entering the kiln combustion system. The liquid wastes are also specially prepared to suit calorific values required in the process.

The wastes are usually stored similarly to standard materials and fuels. Liquid wastes are usually hazardous thus the storage and feeding system has to be specially protected.

2.4 Clinker production

The main stages of the clinker production process are: drying, preheating, calcining and sintering. The manufactured clinker is then cooled and sorted. The main part of the clinker production system is the rotary kiln. Drying and calcining usually takes place in rotary kiln in specific segments or during other stages of firing.

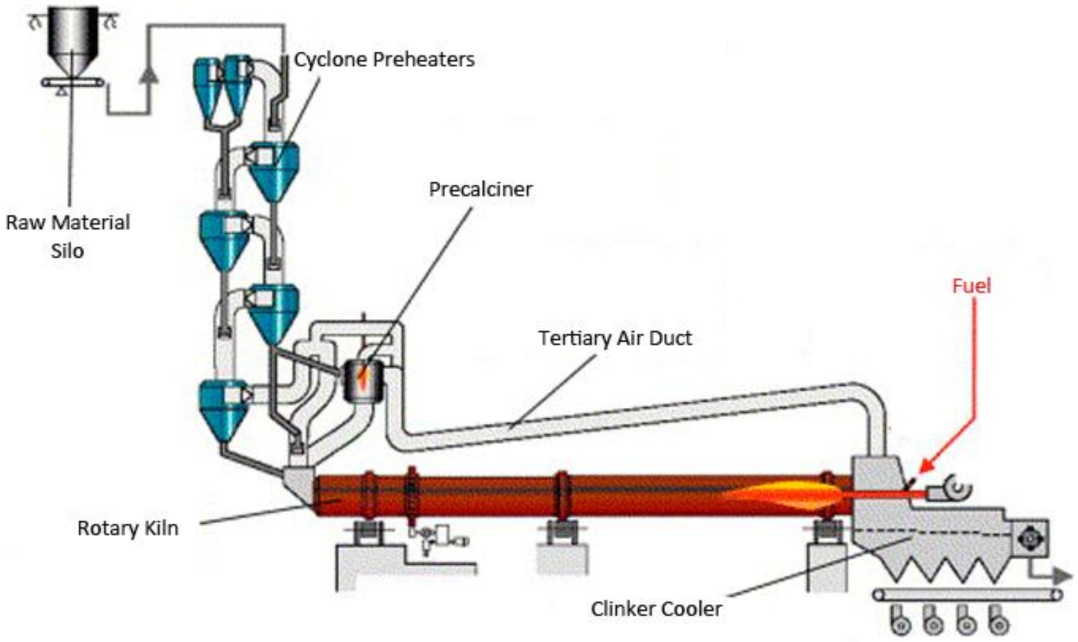

Figure 3: Clinker production scheme.

2.4.1 Preheating

There are two main types of technologies for preheating: grate preheaters and suspension preheaters. In grate preheaters the mix is transported horizontally on travelling grate through closed tunnel, that is divided into drying chamber and hot gas chamber. The preheater uses gases drown from kiln by fans. Semi-wet preheaters use multiple chambers system with special drying chambers used for drying.

Suspension preheaters use cyclones in the preheating process. The cyclones may allow calcination during preheating process. The heating gasses are usually drowned from the rotary kilns and transported upwards against the raw meal. The raw material mixture is transported vertically downwards from one cyclone to another. The standard number of cyclones is between four and six.

Other types of preheating like shaft preheaters are in decline due to low efficiencies.

2.4.2 Kiln firing

During clinker production, the mixture for cement manufacture is fed to rotary kilns. In dry method the mixture is usually transported through preheaters before entering the rotary kiln, whereas in wet method after the homogenisation process the mixture is transported directly to the long rotary kiln thus the whole process of drying, preheating, calcining and sintering takes place in the kiln. The fuel and air are distributed to burners which control the firing process. The correct proportions of fuel and air and right distribution of both is essential for efficient heating process. The long rotary kilns for wet method are separated into different zones according to their role. Typically the secondary burning takes place in specific chamber.

2.4.3 Clinker cooling

The main tasks for clinker coolers are to reduce the temperature of clinker and to recycle the heat from hot clinker. The main types of clinker coolers are rotary coolers and grate coolers. The main type of rotary coolers is tube cooler, that uses similar principles to rotary kiln but for cooling with cold air. The other special type of rotary cooler is planetary cooler, it uses several tubes attached at the exit of the kiln. It allows to achieve high exit temperatures of the air but may need additional water injection for cooling. Precalcination cannot be done in the planetary cooler due to its construction.

The grate coolers use air passed upwards through the grate to cool the clinker. The types of grates used in grate coolers differ from each other by the way of transportation. The main types are: travelling grate coolers and reciprocating grate coolers. In traveling grate coolers the principle of transport is similar to a preheater grate. The air is blown by fans underneath the grate. This method allows poor recovery of the heat and presents high mechanical difficulties thus it is not implemented in modern installations. In reciprocating grate coolers the clinker is pushed by rows of plates. The grate does not move. The movement of the plates is generated by hydraulic or mechanical drives. The air is blown upwards through the grate similarly to the traveling grate coolers. Modern grate cooler designs allow better air distribution in order to avoid typical clinker cooling problems.

There are also vertical coolers used as the aftercoolers. They are called gravity coolers and are usually dust free. The air in gravity coolers is blown through tubes and does not contact the clinker.

2.5 Cement grinding and storage

The clinker and additives are stored in silos and in closed sheds. The amount of clinker and additives for cement grinding fed to a mill is usually measured by belt weigh feeder.

Cement grinding and clinker production can be done in separate plants. The basic technologies for grinding cement are: mills and presses. The level of fineness achieved after grinding differs due to the type of cement produced. The main types of technologies used in grinding process are: tube mills, vertical roller mills, roller presses and for finish grinding systems other tube mills and horizontal roller mills.

Ball mills which are a main type of tube mills are the least energy efficient of all types and require the highest energy consumption. Additional drying operation is available during the process of grinding to a limited extent. The vertical roller mills use two to four grinding rollers riding on horizontal table or bowl. This process also enables drying during the grinding process. The rollers allow materials of relatively high moisture content. The horizontal roller mill uses horizontal shell which is rotated. The roller inside the shell is set horizontally and can be pressed hydraulically onto a shell. The material leaving the mill is transported to a separator which returns the oversized particles to the mill.

After grinding process the cement is transported by mechanical or pneumatic conveying systems to silos in which it is stored before packaging and dispatch. Main silos types are: single-cell silos with a discharge hopper, single-cell silos with a central cone, multi-cell silos, dome silos with a central cone.

3 Lime manufacturing

Main limestone products are:

- Quicklime,
- Dolomitic lime,
- Calcium hydrate,
- Dolomitic hydrated lime

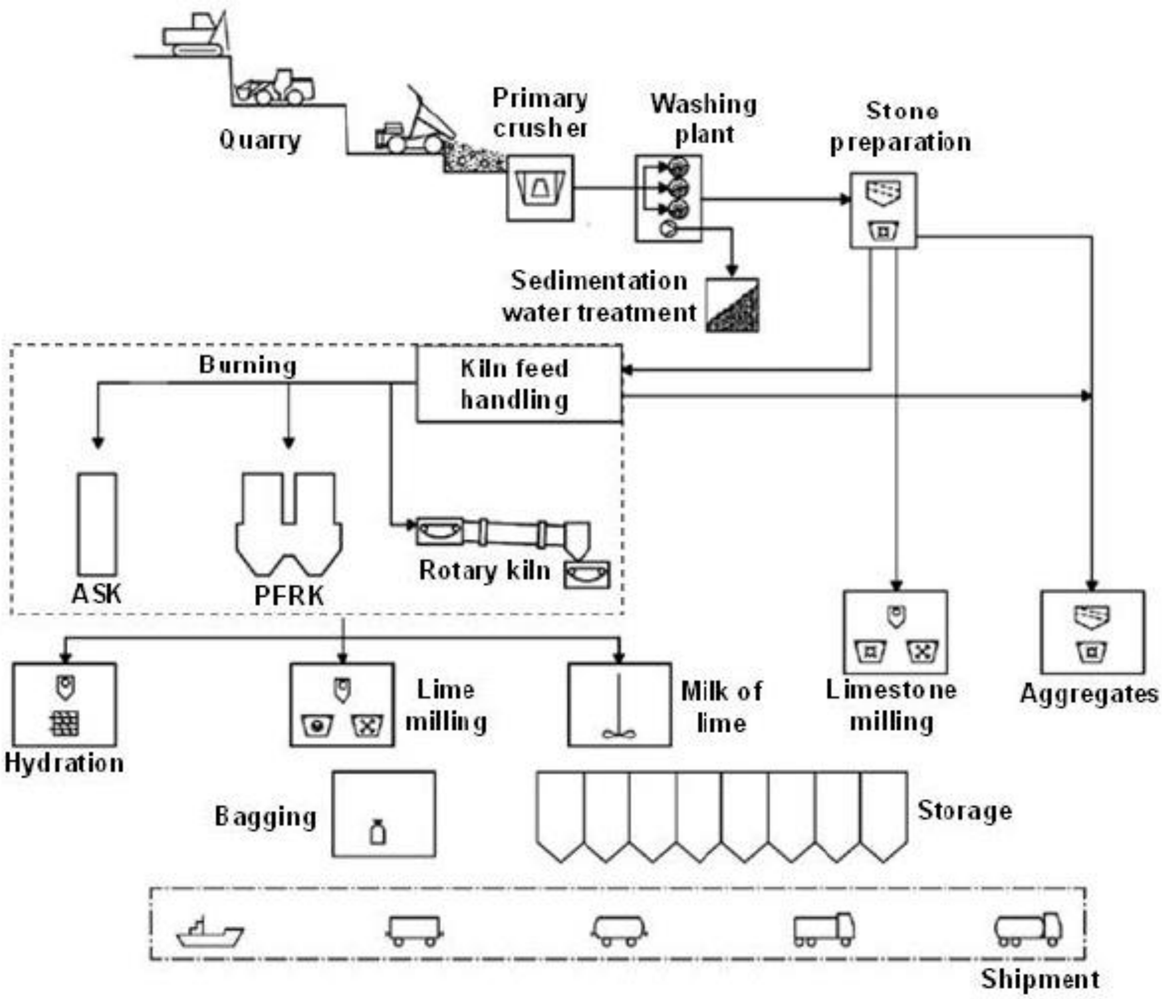

Figure 4: Overview of lime manufacturing process.

The main operation in the process is burning of calcium and/or magnesium carbonates. The burning process takes place in kilns, which for lime manufacturing can be one of six general types:

- Long rotary kiln (LRK),

- Rotary kiln with preheater (PRK),
- Parallel flow generative kiln (PFRK),
- Annular shaft kiln (ASK),
- Mixed feed shaft kiln (MFSK),
- Other kilns (OK).

The lime manufactured in burning process can be distinguished based on the reactivity. There are four main types of lime: soft, medium, hard and dead burned. The characteristic of lime depends on the temperature and time of burning process, crystalline structure of limestone, impurities of the limestone and kiln type or fuel type used during the burning operation.

Some types of lime need additional hydration. In hydration process the slaked lime is produced. Term slacked lime refers to hydrated lime milk of lime and lime putty. The hydrators usually consist of slacking plants, hammer mills and dynamic and static separators. The final product of hydration process of hydrated lime is a dry powder. Lime putty and milk of lime are products diluted in water.

Some types of lime need additional grinding after the burning process which is executed by mills. Most of the mills use air classification systems.

The last phase of the process is storage and packing. For different kind of lime there are different methods of storage e.g. quicklime is usually stored in dry conditions due to dangerous effect of hydration of quicklime.

4 Energy intensity of key processes

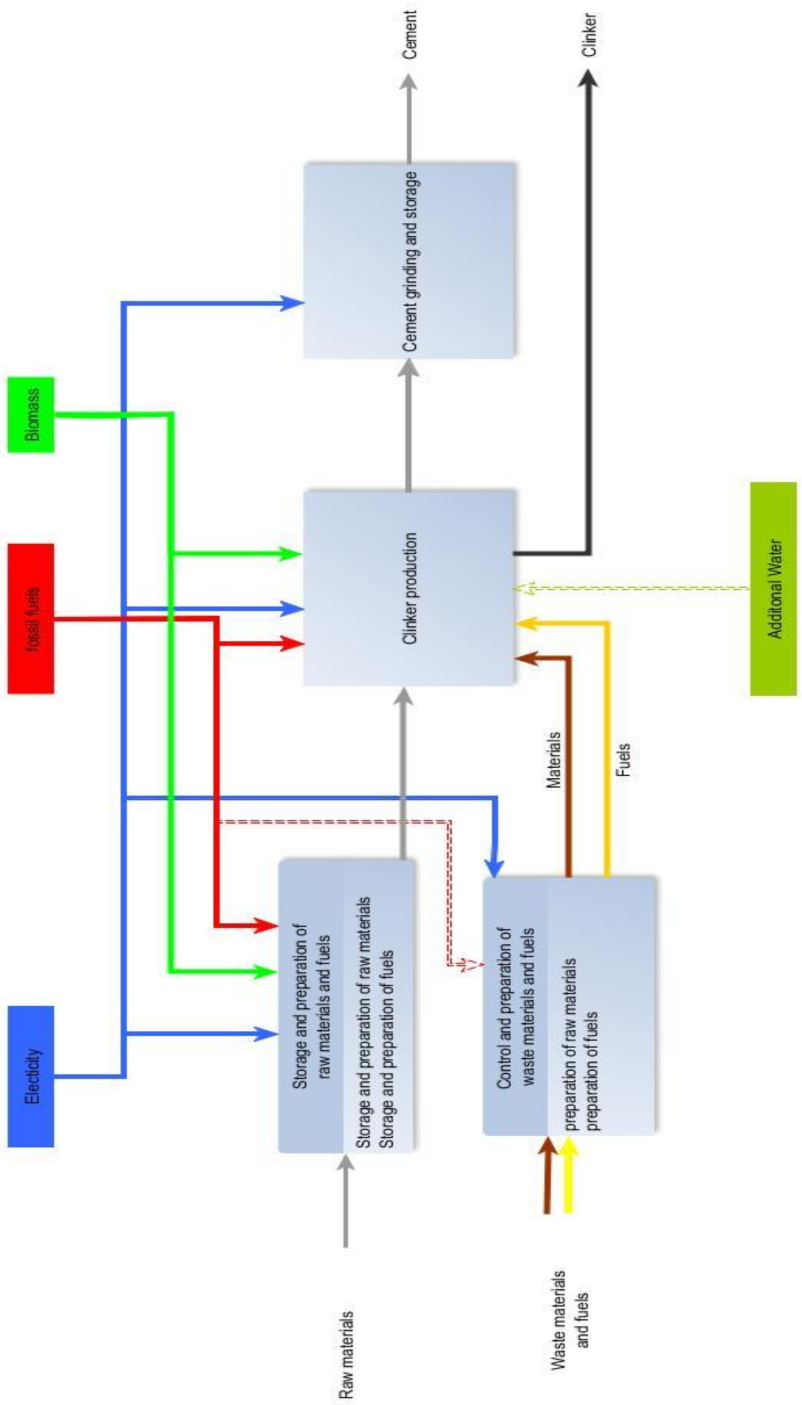

Figure 5: Fuels consumption in Cement industry.

Thermal energy is mostly used during the process. It is used for drying and heating of products and materials. Main fuels used by plants are: fossil fuels and wastes including biomass. The consumption of fuels differs widely in different countries depending of the availability of fuels. The energy consumption is higher when the fuels need additional drying.

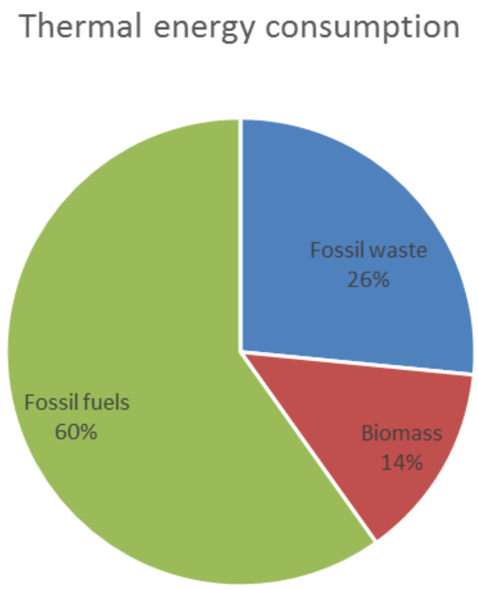

Figure 6: Use of sources for thermal energy consumption.

Most of the energy is consumed in the firing process during clinker production. The level of consumption is different for different types of process (wet, dry etc.) and different type of kilns.

Table 1: Average energy consumption by kiln type.

Kiln type	Thermal energy consumption [GJ/t clinker]
DRY WITH PREHEATER AND PRECALCINER	3.6
DRY WITH PREHEATER WITHOUT PRECALCINER	3.7
DRY WITHOUT PREHEATER (LONG DRY KILN)	3.8
SEMI-WET/SEMI DRY	4.0
WET / SHAFT KILN	5.2

Electrical energy consumption from external sources reaches about 10% of whole energy requirement and is used mainly by grinding mills and exhaust fans. Grinding mills require about 60% of electrical energy used in the plant and the exhaust fans use approximately 20% of electrical energy. The other processes and systems that require electrical energy are: control systems, transport systems, auxiliary systems etc..

5 Efficient technologies according to BREF/BAT

Even though a full list of the efficient technologies according to BREF/BAT is reported and fully described in the EU-MERCI portal, a summarized list is here reported:

1. Dry process with multistage preheating and precalcination
2. Improved and optimised kiln systems and a smooth and stable kiln process, operating close to the process parameter set points by applying:
    - process control optimisation, including computer based automatic control systems
    - modern, gravimetric solid fuel feed systems
    - preheating and precalcination to the extent possible,
3. Recovering excess heat from kilns, especially from their cooling zone
4. Applying the appropriate number of cyclone stages related to the characteristics and properties of raw material and fuels used
5. Using fuels with characteristics which have a positive influence on the thermal energy consumption
6. When replacing conventional fuels by waste fuels, using optimised and suitable cement kiln systems for burning wastes
7. Minimising bypass flows
8. Employ cogeneration plants for the production of steam and electricity or combined heat and power plants
9. Reduce of the clinker content of cement and cement products
10. Minimise electrical energy consumption by:
    - Using power management systems
    - Using grinding equipment and other electricity based equipment with high energy efficiency
    - Using improved monitoring systems
    - Reducing air leaks into the system
    - Process control optimisation