

SECTION 2 THE CEMENT MANUFACTURING PROCESS

The following section discusses the cement manufacturing process in detail, with specific reference to the PPC Port Elizabeth (PE) factory, including process flow diagrams and photographs of the PE kiln system and operational equipment.

2.1 A DETAILED DESCRIPTION OF THE CEMENT MAKING PROCESS AT PORT ELIZABETH

PE manufactures Ordinary Portland Cement (OPC) and Surebuild Cement. PE's production is supplemented with clinker and / or cement from Slurry when necessary.

PE currently has 1 operating kiln, PEK 4. The kiln is a long dry kiln, which was commissioned in 1966. The kiln is 132m long and 3.75m in diameter, and is not equipped with a preheater.

The clinker from the PE kiln is cooled in a planetary clinker cooler. The kiln does not have a conditioning tower; however the exit gases from the kiln are cooled by direct water injection. All of the exhaust gas streams at PE (from the raw mill, finishing mill and kiln) pass through ESPs to minimise the dust emissions from the factory.

Cement clinker is made by crushing, blending and fine milling of limestone (calcium carbonate) and other materials containing silica, alumina and iron oxides, which are then heated to temperatures as high as 1,450°C in a kiln where the compounds react chemically to form clinker. The clinker is then cooled and ground with small quantities of gypsum and other additives to produce cement. The heating process is performed in a rotary kiln, which is inclined at 3 - 4° to the horizontal. The length and diameter of the kiln is dependent on the type of manufacturing process.

Production of Cement by the Dry Process

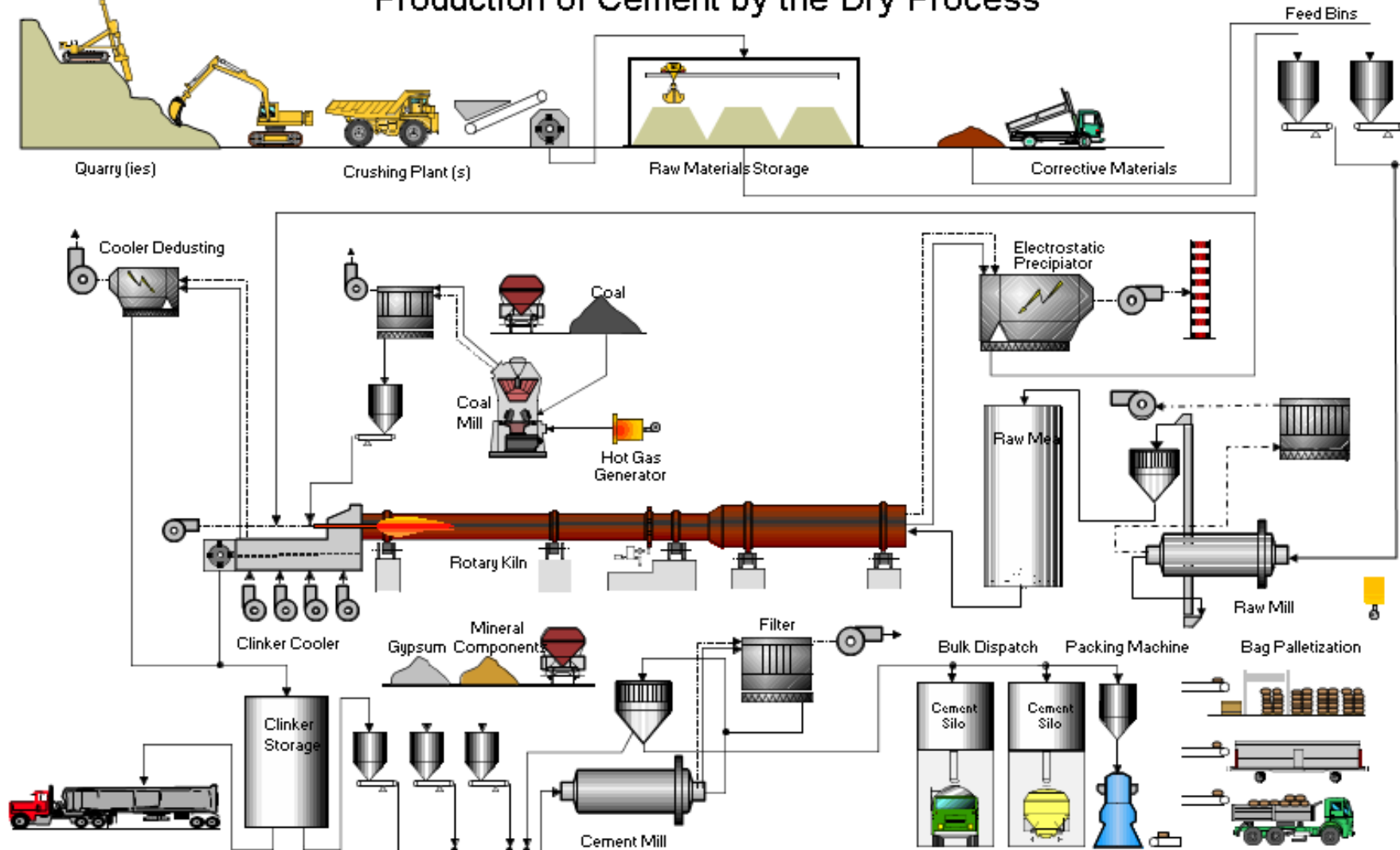


Figure 2-1: Process Flow diagram of the cement manufacturing process at Port Elizabeth. Please note that PE has long dry kiln with no preheater stage.

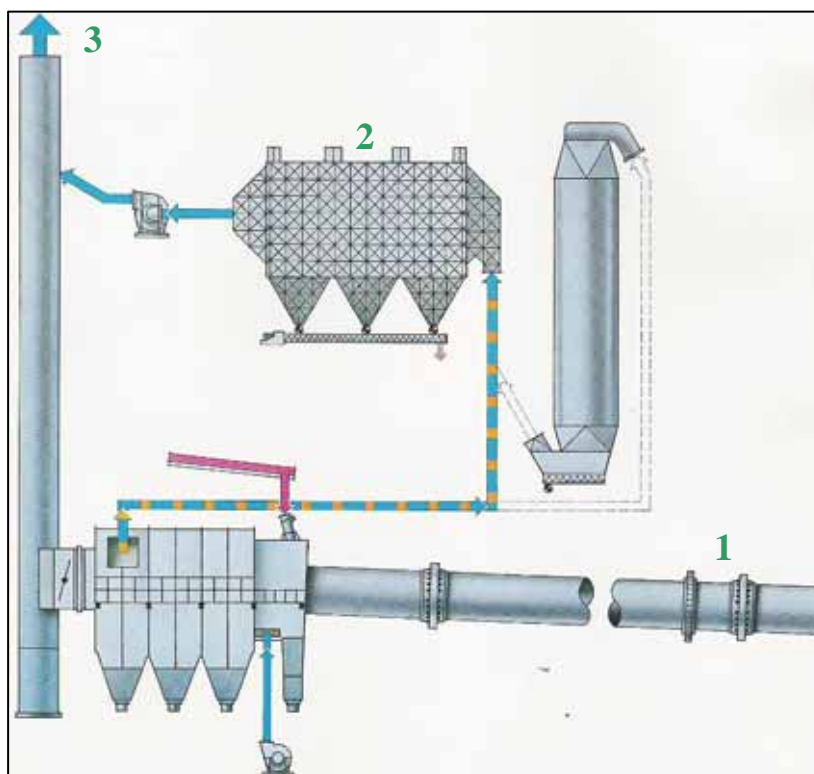


Figure 2-2: Image showing a long dry kiln, ESP and kiln stack. The gases travel back through the kiln (1), through the ESP (2), where the dust is removed, and exit through the stack (3).

2.1.1 Primary Raw Materials

Limestone used at PE is mined from Grassridge Quarry approximately 40 km north of the plant.

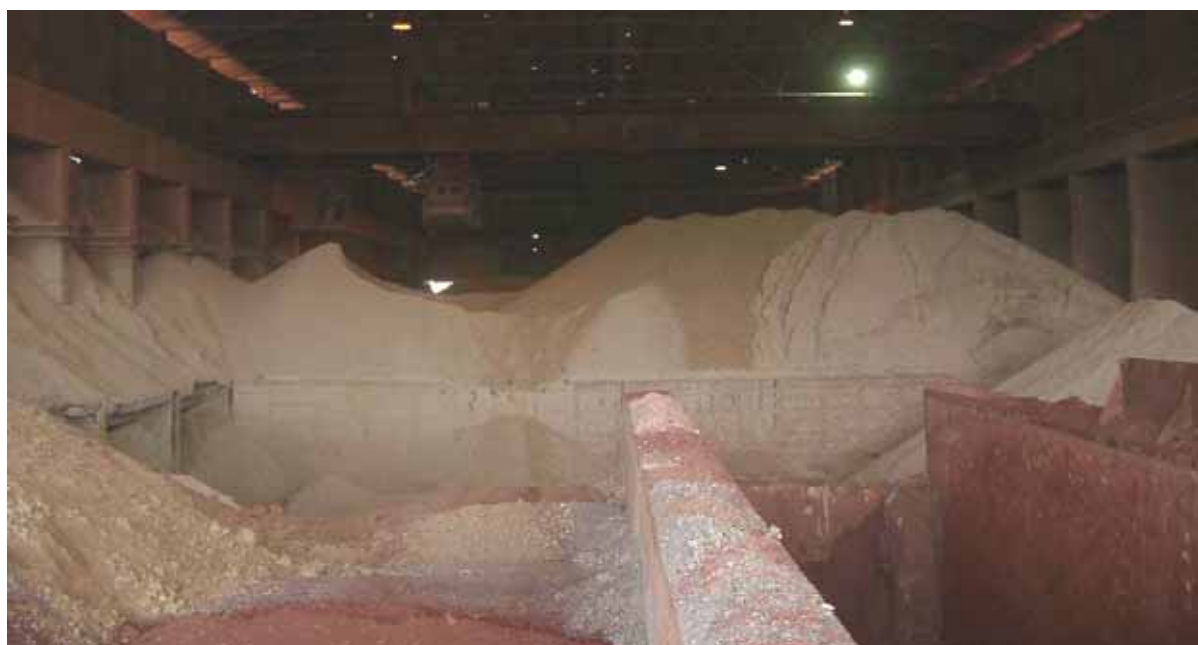


Figure 2-3: Photograph of the raw materials stockpiles at PE, the limestone can be seen in the background and clay and haematite in the foreground. Raw materials are stored undercover. At the quarry, the limestone is crushed to particles approximately 25mm in size and stored on stockpiles, where the material is homogenised prior to milling.

The limestone is passed through multiple-stage crushers at the Grassridge quarry, where it is reduced to less than 19mm in diameter. Sand, shale/clay and haematite are also used as raw materials. The raw materials are milled together in a raw mill, to a fine powder and sent to the blending silo for homogenisation. The homogenised powder, known as kiln feed, is stored in silos prior to use. Approximately 1.5 – 1.6 tons of kiln feed is required to produce one ton of clinker.

The primary fuel used in South African cement kilns is coal. It is transported to PE by rail, where it is ground to fine dust in a coal mill, and stored in a silo. The fine coal dust is accurately metered into the kiln firing system. The coal has a calorific value of 24-26MJ/kg, hence to produce 100 tons of clinker, 15-18 tons of coal are burned per 100 tons of clinker.

2.1.2 Secondary Raw Materials

Depending on availability and chemical composition, additional components may be added to the raw mix. These are referred to as “Secondary” raw materials. Examples are coal fly ash from power stations, steel slag, foundry sand, lime sludge, FCC catalysts from oil refineries, and many more.

Apart from raw materials, additional fuel sources may be added to the coal to fire the kiln. Examples include Spent Pot Lining (SPL) and tyres.

Only refractory SPL is currently used as a secondary material at PE. It is received from BHP Billiton, Richards Bay, and stored at the quarry. It is crushed and transported to the factory, where it is included with the coal for the firing of the kilns.

2.1.3 Clinker burning

The rotary kiln is a cylindrical steel vessel, which is inclined to the horizontal at 2.5% to 4.5%. The kiln slowly rotates at 0.5 – 4.5 revolutions per minute to allow the material to tumble through the kiln to ensure sufficient residence time in the kiln to achieve the required thermal conversion processes.



Figure 2-4: Photograph of the kiln at PE, showing the fans which cool the exterior of the kiln, and the control room housed in the background.

The finely ground coal is fed to the firing end of the kiln where it is burned to produce a gas temperature of approximately 2,000°C.

A preheater consists of several stages contained in a tall preheater tower, which uses the heat produced by the flame at the firing end of the kiln to preheat the raw materials as they move through the various stages of the tower. Kiln systems with preheaters are more fuel efficient than long kilns, using up to 50% less energy. Long dry kilns, such as at PE, have no preheater.

The prepared raw mix, now referred to as kiln feed, is fed to the kiln system, directly into the long dry kiln. Long dry kilns are not equipped with preheaters and as a result, the initial heating of the kiln feed occurs in the kiln itself. To ensure sufficient heating for the thermal processes, the kiln is designed to be much longer. Long dry kilns represent an older less energy efficient cement manufacturing technology, and are being phased out as more cement manufacturing plants change to the newer shorter kilns with multi-stage preheaters.

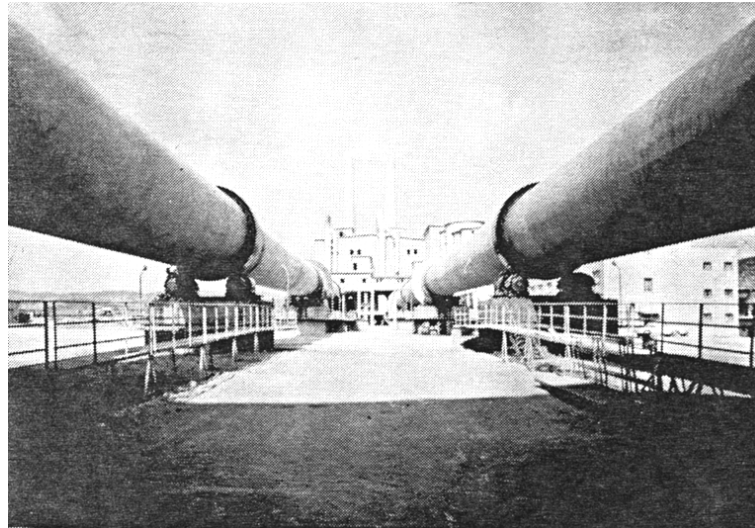


Figure 2-5: Photograph showing two long dry kilns.

As the raw meal is transported through the kiln system, it is heated through 4 thermal zones:

- a) First the Calcining zone, where limestone is chemically converted to lime as the temperature of the material is raised to approximately 900°C. This causes the liberation of carbon dioxide from the limestone and is known as calcination. This stage occurs in the back end of a long dry kiln, such as PE K4. The gas exit temperature at this stage is 420°C.
- b) The second thermal zone is the Upper-Transition zone, where the temperature of the material increases to approximately 1,200°C.
- c) The third is the Sintering or Burning zone where the temperature of the material increases to approximately 1,450°C, and clinker nodules, with a diameter of 3 – 20mm, are formed.
- d) The final zone is the Cooling or Lower-Transition zone: in the last few metres of the kiln, the clinker is cooled to approximately 1,250°C.

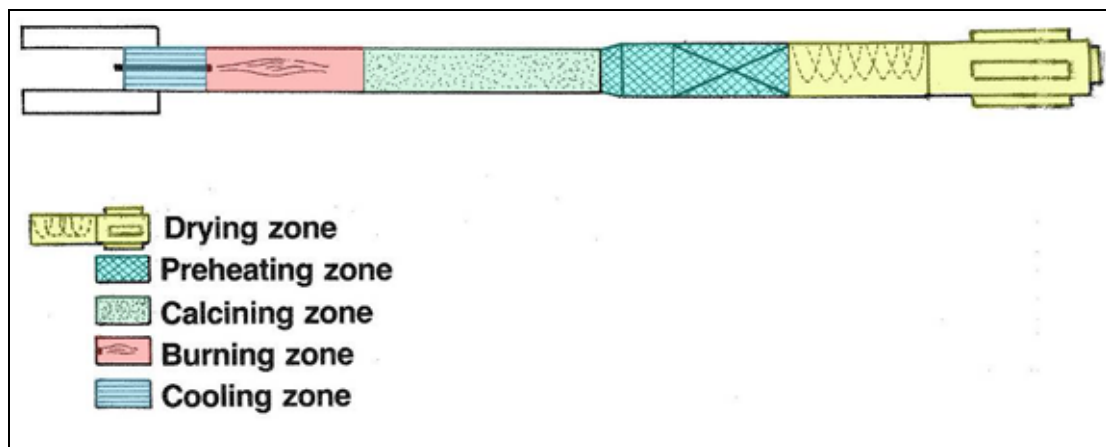


Figure 2-6: Thermal zones within the kiln.

Exhaust gas from the kiln system is used to dry raw materials, solid fuels or mineral additions in the mills. At PE, exhaust gases are dedusted in an ESP and exit through the stack.

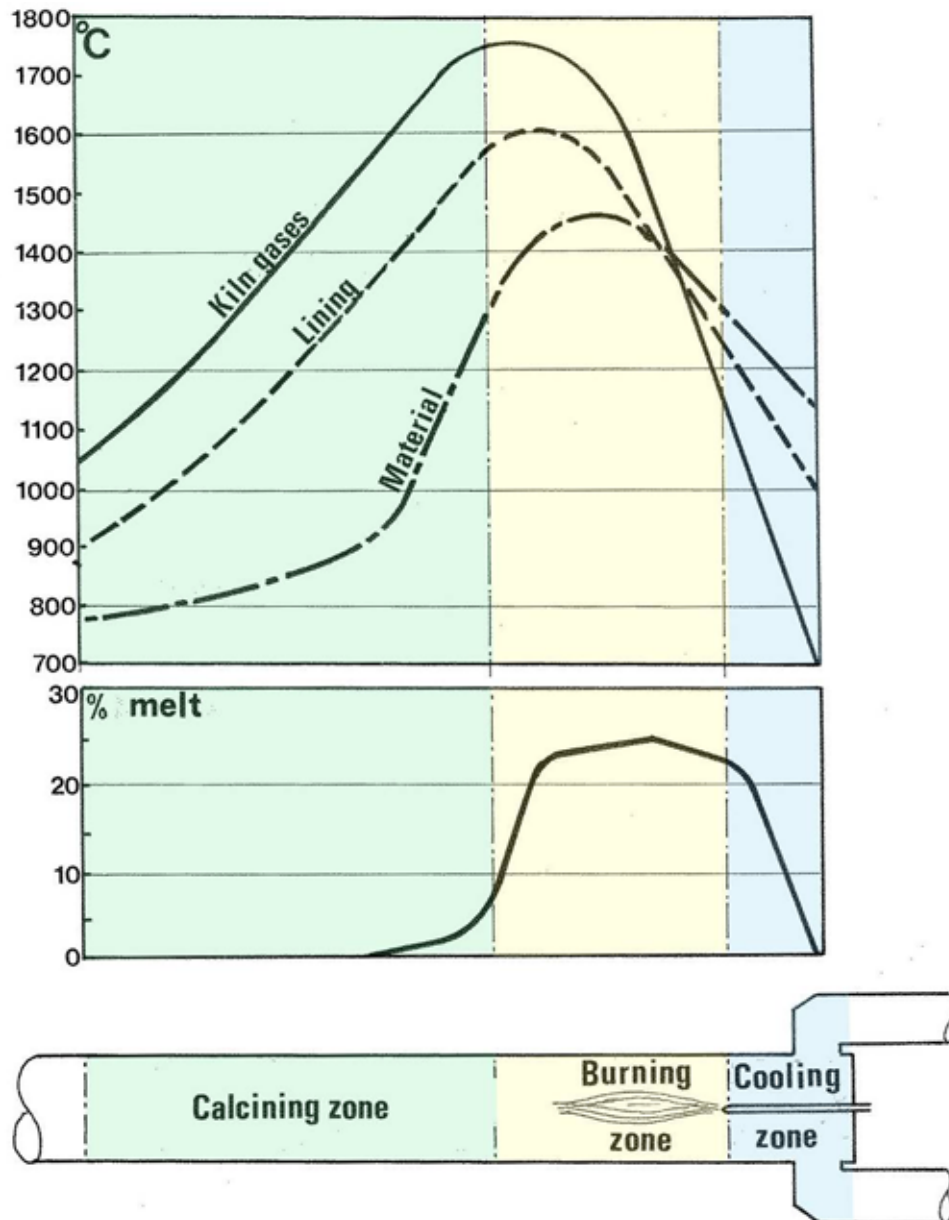


Figure 2-7: Kiln reaction profile for long dry kiln without calciner⁵.

2.1.4 Clinker

Once the clinker has formed, and has arrived at the firing end of the kiln, it drops into a planetary cooler, where the clinker is cooled to approximately 100°C above ambient. It is then transported to the clinker storage silos.

⁵ Technical data, KHD, Cologne, Germany



Figure 2-8: Photograph of cooled Clinker.

The properties of clinker (and thus, of the cement produced from it) are mainly determined by its mineral composition and its structure (silicates, aluminates and ferrites of the element calcium). Some elements in the raw materials such as the alkalis, sulphur and chlorides are volatilized at high temperature in the kiln system resulting in a permanent internal cycle of vaporization and condensation (“circulating elements”). A large part of these elements will remain in the kiln system and will finally leave the kiln incorporated in the clinker. A small component will be carried with the kiln exhaust gases and will mainly be precipitated with the particulates in the dedusting system.

2.1.5 Milling and Final Product (Cement)

Portland cement is produced by grinding clinker, with a small proportion of gypsum (or calcium sulphate di-hydrate) and an extender, such as limestone, slag or fly ash. Gypsum is used to control the setting times of the final cement products. The materials are milled together in a finishing mill. The final cement product is stored in silos by product type.

PE manufactures OPC and Surebuild; each cement type is defined by the proportion of materials added during the above milling process.

2.1.6 Cement dispatch

Cement is dispatched either in bulk or in 50kg bags and distributed from the manufacturing plant via rail or road. The 50kg bags are palletised, with 40 bags per pallet and loaded via forklifts onto road trucks.

2.1.7 Summary of inputs and outputs

The cement manufacturing process has several inputs and outputs. Raw materials and fuel products (inputs) are converted to clinker (product), emissions and Cement Kiln Dust (CKD) (outputs) in the cement kiln.

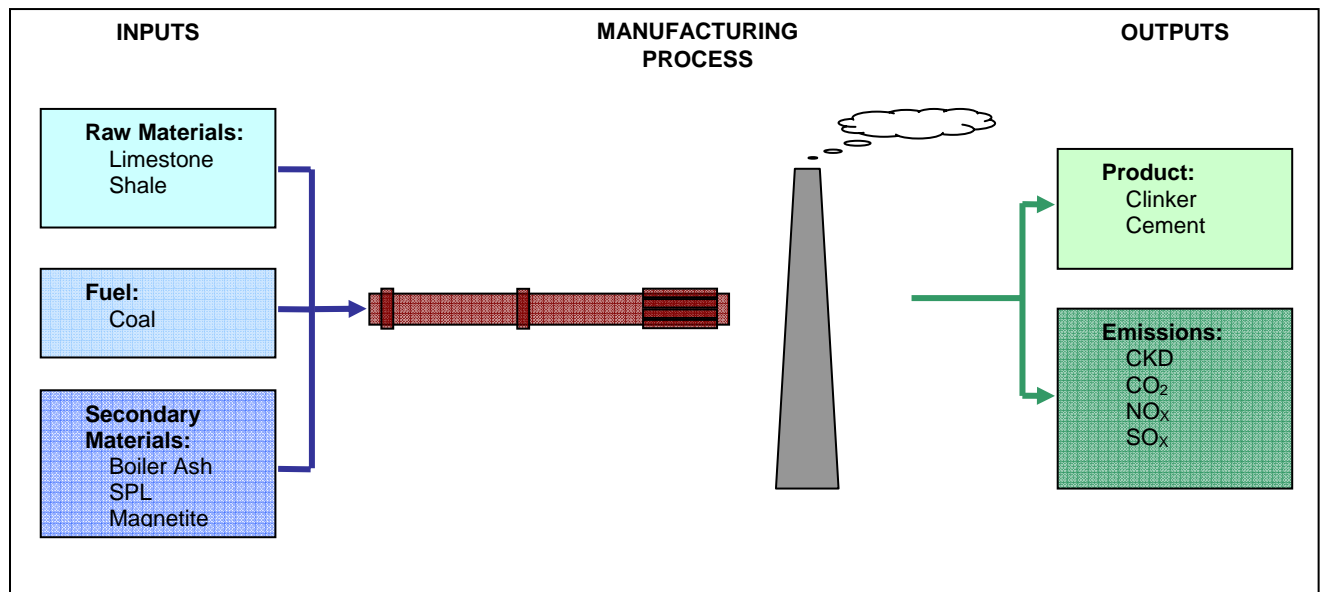


Figure 2-9: Flow diagram showing inputs and outputs in the cement manufacturing process

It should be noted that there is no continuous process waste generated from the cement manufacturing process.

The main constituents of fuel ash are silica and alumina compounds which combine with the raw materials to become part of the clinker. As the cement manufacturing process is a thermal process, there are resultant pollutants emitted through the stack. Under normal operating conditions, emissions that can be expected from the stack include:

- a) Cement Kiln Dust (CKD)
- b) Sulphur Dioxides (particularly SO₂)
- c) Nitrogen Oxides
- d) Carbon Dioxide and Carbon Monoxide
- e) Trace Metals