Turning waste heat into cement industry value

As the cement industry accelerates towards decarbonisation, rising energy volatility and growing electricity demand are creating new challenges for competitiveness and investment. In this context, waste heat recovery through organic Rankine cycle technology has emerged as a proven solution, enabling cement producers to generate clean on-site power, improve energy efficiency and reduce their exposure to volatility in the energy markets.

■ *by **Exergy International Srl**, Italy*

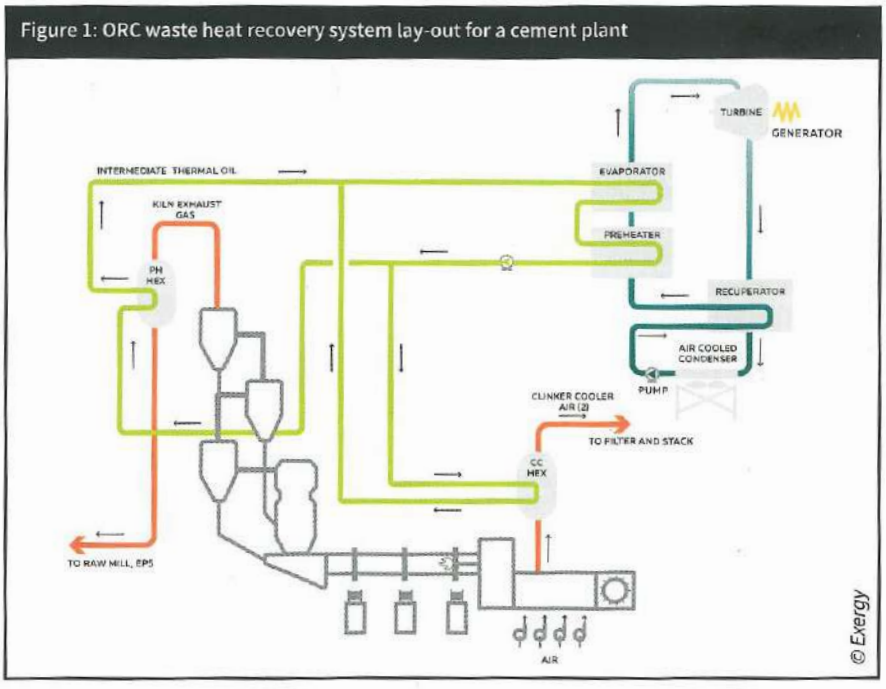
The energy market is undergoing a profound structural transformation, while at the same time being exposed to increasingly frequent and rapid shifts in operating conditions. Energy-intensive industries such as the cement sector face a challenging environment due to several factors, including price volatility driven by an uncertain geopolitical landscape, challenges in electricity accessibility due to inadequate infrastructure to support an integrated renewable energy mix, and ongoing concerns over energy security while industry remains heavily dependent on imported fossil fuels.

For the cement sector, these dynamics directly impact competitiveness and investment decisions. Producers are required to pursue decarbonisation in line with net-zero road maps, while continuing to safeguard economic sustainability.

Therefore, selecting the most appropriate decarbonisation technologies is far from simple. Investment decisions must take into account multiple variables and constraints. For example, the geographical positioning of cement plants in relation to CO_2 transport infrastructure is becoming increasingly critical, influencing priorities both at group level and for individual sites, and in some cases reshaping decarbonisation pathways.

However, what remains clear is that the transition will be highly electricity intensive. The shift towards electrified processes, carbon capture technologies and new production pathways is expected to at least double electricity demand. As highlighted by Cement Europe, access to large volumes of affordable, stable and low-carbon electricity will therefore be a critical enabler for both decarbonisation and long-term competitiveness.

Figure 1: ORC waste heat recovery system lay-out for a cement plant



A market-ready response to decarbonisation and competitiveness

In the current context of high price volatility and weakened energy security, waste heat recovery (WHR) stands out as a compelling solution to address both challenges. By converting process heat losses into electricity, WHR enables continuous, on-site generation of clean power, while at the same time improving overall energy efficiency, reducing the plant's exposure to electricity supply by up to 30 per cent.

WHR technology is already well established in the cement sector, with several gigawatts of installed capacity worldwide. Continuous advances are making these systems increasingly competitive, flexible and bankable by improving cycle efficiency and extending applicability across different plant sizes, as well as reducing the plant's footprint, delivery time and costs.

In this evolution, organic Rankine cycle (ORC) technology has emerged as the preferred solution, progressively overtaking traditional steam Rankine cycle systems in new installations.

ORC benefits

In cement applications, ORC systems are particularly well suited to recover heat from kiln preheater and clinker cooler exhaust gases. In a wide range of

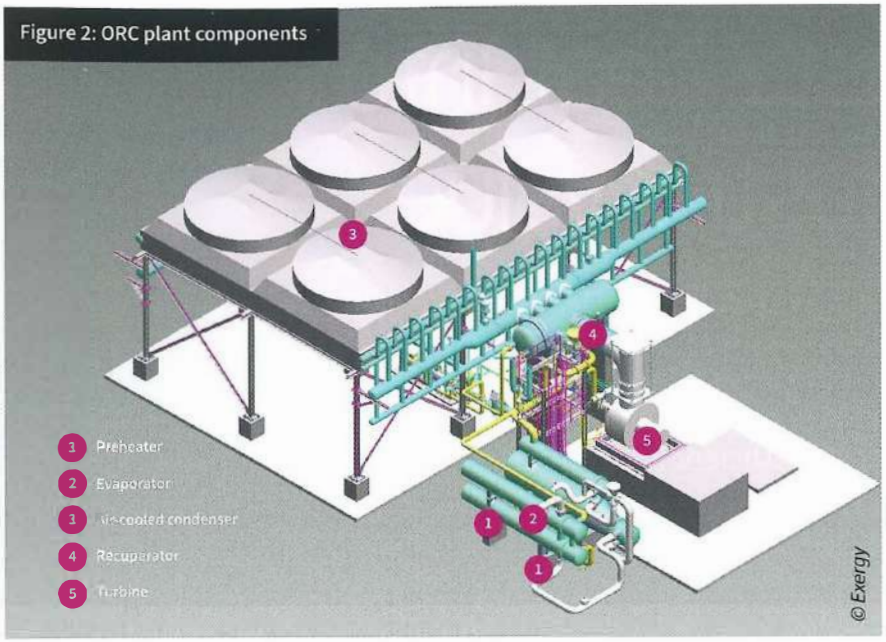


Figure 2: ORC plant components

temperatures from 150°C upwards for low- and medium-power requirements, ORC systems achieve higher efficiency compared with steam-based cycles, both at design conditions and, importantly, under part-load operation, adapting more effectively to process variability. This higher efficiency directly translates into improved project economics.

Another key advantage is sustainability. ORC systems, unlike a steam Rankine cycle, operate with organic working fluids in a closed loop and can be combined with air-cooled condensation systems, eliminating water consumption.

In terms of operation, ORC systems are characterised by high levels of automation and low maintenance requirements. They do not require dedicated operating personnel, and routine activities are limited to periodic visual inspections and scheduled maintenance during the plant lifetime, contributing to reduced operating expenditure.

ORC technology integration in cement plants

In a typical cement plant configuration, ORC systems recover heat through an intermediate loop, which transfers thermal energy from dusty exhaust gases to a clean heat transfer fluid (such as thermal oil or water), and subsequently to the ORC working fluid (see Figure 1).

The main components of an ORC system include heat exchangers, a turbine, condenser and recuperator (see Figure 2). The turbine is the core element, converting thermal energy into mechanical power, which is then transformed into electricity by the generator. The condenser can be either water- or air cooled, with the latter providing clear advantages in water-scarce environments.

An ORC system can be easily deployed in greenfield applications as well as in existing cement plants for process optimisation. Its design can be tailored to site-specific constraints, including the available footprint. Compared with other decarbonisation technologies, time to market is relatively short, with commissioning typically achievable in around 12 months. Importantly, the ORC unit operates independently and does not interfere with the core cement production process.

A strategic lever for competitiveness

Installing an ORC-based WHR system provides several strategic advantages for cement producers by ensuring access to a stable, predictable and clean source of electricity. Key benefits include:

- improved process energy efficiency
- reduced Scope 2 CO_2 emissions
- enhanced sustainability performance
- increased profitability through reduced grid electricity dependence
- lower exposure to electricity price volatility
- enhanced competitiveness in global markets.

Figure 3: fully field-erected ORC system

Figure 4: modular, fully customised ORC unit

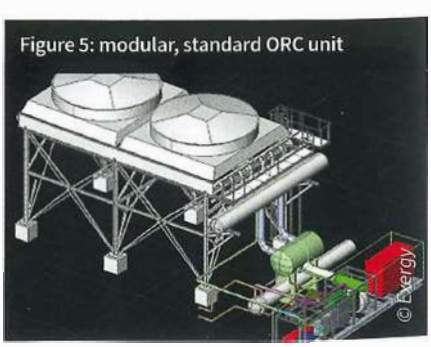


Figure 5: modular, standard ORC unit

Fully customised ORC at Pederobba, Italy

In 2020 Exergy International Srl supplied a 3.5MWe fully customised ORC unit to Cementirossi SpA for installation at its Pederobba cement plant in Italy. The cement plant has a clinker capacity of 2500tpd.

The ORC unit was installed outdoors and its heat source temperature (diathermic oil) is approximately 100-280°C. The plant employs an air-cooled condensing system and has a gross efficiency of 22.8 per cent.

These benefits can be achieved either through a direct investment or by using energy service companies, transferring the WHR-ORC from a direct investment to a power purchase agreement.

From custom design to modular systems

The diversity of operating conditions across cement plants requires a range of solutions capable of addressing different technical and economic drivers. These vary from fully tailor-made systems designed to maximise heat recovery across both the preheater tower and clinker cooler, to configurations focussed solely on clinker cooler recovery, as well as solutions enabling cooling tower shutdown. In addition, there is a growing demand for plug-and-play systems that can reduce installation costs in high-cost countries or in regions where skilled on-site labour is limited.

In response to these evolving requirements, ORC technology has developed into a flexible platform capable of covering a wide range of application scenarios, from fully customised installations to more standardised and modular approaches.

Exergy International, a global provider of clean energy technologies for the energy transition, specialises in the design, supply and construction of ORC power plants, with nearly 600MWe in portfolio across multiple applications, including 12 WHR plants in industrial sectors.

Exergy International's offering for the cement industry reflects this need for flexibility, covering ORC solutions from 1 to 15MWe, alongside the "ORC-lite" series of standard modular units.

This portfolio addresses different project conditions through distinct product categories:

- fully field-erected and customised plants from 5 to 15MWe (see Figure 3)
- modular and fully customised systems from 2 to 5MWe (see Figure 4)
- modular – standard ORC- lite from 1 to 2 MWe (see Figure 5).

The ORC-lite series has been developed to address market demand for more compact and rapidly deployable solutions.

These standardised systems are pre-engineered, pre-assembled and factory-tested, and are delivered as compact skid-mounted or containerised units. This approach enables:

- easy integration into existing industrial sites
- faster and simpler transportation and installation
- reduced civil works and foundation costs
- lower production and assembly costs.

The containerised and modular nature of the new ORC-lite units also allows for relocation between sites, transforming the plant into a flexible energy asset. This feature opens the door to alternative financial models such as leasing or rental schemes, helping to mitigate upfront capital investment.

Exergy International's systems are based on its proprietary Radial Outflow Turbine (ROT) technology. In addition to delivering high efficiency (up to six per cent higher than axial turbines) and high availability (~99 per cent), proven in operational plants, the ROT offers a significant maintenance advantage. A patented mechanical group design enables turbine maintenance without draining the organic fluid from the cycle, reducing downtime from approximately one week to less than one day. This translates into higher plant availability and increased revenues from electricity generation.

Faster ORC implementation for long-term success

As the cement industry navigates an increasingly complex energy landscape, the ability to combine decarbonisation with economic resilience is becoming a defining factor for long-term success. WHR, and in particular ORC technology, already offers a mature and reliable pathway to achieve both objectives.

The shift towards standardised, modular and containerised solutions represents an accelerator for implementation. By lowering entry barriers, shortening project timelines and introducing greater flexibility, these systems have the potential to unlock a much broader adoption of WHR across the sector.

In this context, Exergy International's ORC can play a key role in accelerating the transition, enabling cement producers to turn waste heat into a strategic resource – one that supports decarbonisation targets while reinforcing industrial competitiveness in a rapidly evolving energy scenario. ■