# Shrinking energy bills with ORC technology

**Sabrina Santarossa, Turboden, explains the benefits of ORC technology: a WHR solution that is becoming increasingly popular in cement plants around the world.**

Over the last 10 years, Organic Rankine Cycle (ORC) technology has become relatively prominent within the cement industry as it has being implemented successfully on a number of projects.

Furthermore, the interest in using Waste Heat Recovery (WHR) solutions to increase the energy efficiency and sustainability of the cement production process has grown due to the adoption of net zero policies, which are further pushing the development of ORC-based projects.

Recently, Turboden was awarded contracts for three new ORC systems to be installed in three different cement plants next year, thus bringing the number of Turboden ORC plants in the cement industry up to 13.

In the cement production process there are two main hot gas streams where heat can be recovered: the pre-heater tower (PH) and clinker cooler (CC). WHR means allowing the waste heat at a medium/high temperature (higher than 250 C) to leave the process but converting it into useful electricity before it is discharged at a lower temperature level (below 200 – 120 C) into the environment. In the cement process WHR, the heat contained in the PH and CC hot gas streams is typically transferred to the ORC unit through an intermediate fluid (e.g. thermal oil), as shown in Figure 1.

Unlike steam Rankine cycle technology, ORC units use organic fluids such as hydrocarbons, silicon fluids or refrigerants depending on ORC size and temperature level: the most-used organic fluid for cement heat recovery

is cyclo-pentane. The typical size is between 1 and 20 MWe, where the electricity produced is used internally in the plant, thus reducing energy bills.

The size of the recently acquired ORCs ranges from 6 – 10 MWe, in both cases, the technical solution enables the heat recovery from both clinker cooler hot air and pre-heater exhaust gas through the use of a thermal oil intermediate circuit. The cooling system is air-cooled, so no water is used in the WHR system. The ORC turbine is a high efficiency axial turbine based on the specific characteristics of the project. The turbine is the core of the plant, and it is designed internally by Turboden using advanced fluid dynamics software. Several patents have been developed for this component. Substitution of wear parts such as the turbine seal and bearings are minimised, in fact, the downtime is limited to 12 hrs for every 160 000 hrs of operation helping it to reach above 98% availability.

One of the new contracts has been signed with an Energy Service Company (ESCO) that has a Built Owned and Operated (BOOT) contract with a cement plant in the United Arab Emirates. This ORC will be the first that Turboden has been involved with in the area and the first contract with an ESCO in a cement plant. The necessity for cement producers to stay financially focused on their core production process encourages the development of different financial and investment solutions that allow them to benefit from the advantage of a lower electric energy bill obtained with a WHR system. In BOT or BOOT schemes, a third company owns and operates the WHR plant, and it is usually backed by investment funds aiming to invest in energy efficiency. Currently, many investors are looking to develop energy efficient projects to support net zero policies and increase sustainability.

## Reasons for selecting ORC technology

Firstly, ORC technology does not consume any water. In fact, the condensing heat is dissipated directly into the air utilising air-cooled condensers without negatively impacting performance. In the Middle East, and other global regions, water is a scarce and precious resource, so this is a significant advantage.

Secondly, the ORC system does not need supervisory personnel during normal operating conditions or the shut down procedure. This is extremely important for customers that will not be continuously present in the plant (such as an ESCO company), but also valuable to the cement producers that are focused on producing cement rather than power consumption. ORC systems are controlled using remote monitoring technology and require minimal yearly maintenance services. The properties of the organic fluid mean that the working fluid remains dry (no partial condensation) throughout the turbine, avoiding blade erosion. In addition, the organic fluids used are not corrosive and do not damage the materials used in the cycle.

Thirdly, the ORC is a completely automatic system, and it is designed to automatically adjust itself to the operating conditions: variations on exhaust gas temperatures and flows will not affect the functionality of the system, only the power output. Furthermore, partial load efficiency is much higher compared to steam turbines and the ORC functions at 10% of nominal load.

Other advantages are related to the efficient use of medium-to-low temperature thermal sources, such as the unexploited heat commonly available in cement production processes,

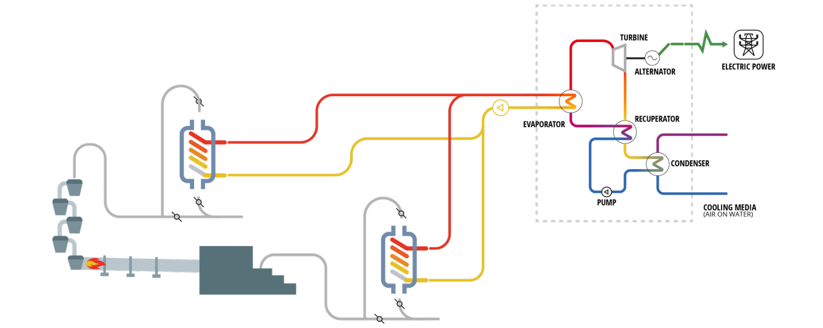


**Figure 1. Waste Heat Recovery scheme in cement production process.**

**Table 1. List of Turboden ORC projects.**

| Plant | Start up | Country | Kiln capacity (tpd) | Heat source | Heat carrier | ORC gross power (kWe) | Type of cooling | Notes |
|---|---|---|---|---|---|---|---|---|
| Ciments du Maroc | 2010 | Morocco | 5000 | PH | Thermal oil | 2000 | Air-cooled | |
| Holcim Romania | 2012 | Romania | 4000 | PH+CC | Thermal oil + superheated water | 4000 | Wet cooling tower | Optimisation done according to CC low temperature. |
| CRH Slovakia | 2014 | Slovakia | 3600 | PH+CC | Thermal oil | 5000 | Wet cooling tower | |
| Carpatcement | 2015 | Romania | 3500 | PH+CC | Thermal oil | 3800 | Air-cooled | Air cooled condenser no water consumption. |
| Jura Cement Fabriken | 2016 | Switzerland | 3000 | PH | Superheated water | 2300 | Wet cooling tower | CC hot air used for heating district network. |
| Cementi Rossi | 2018 | Italy | 3500 | PH+CC | None – direct exchange | 1500 | Air-cooled | PH gas and CC air is mixed and recovered with a single heat exchanger. |
| ÇİMKO | 2019 | Turkey | 7500 | CC | Thermal oil | 6500 | Air-cooled | PH gas used entirely for raw mill. |
| Holcim Suisse Eclépens | 2020 | Switzerland | 2300 | PH+CC | Superheated water | 1300 | Air-cooled | In winter recovered heat is partially used in a heating district network. |
| Sönmez Cimento | 2020 | Turkey | 6000 | PH+CC | Thermal oil | 7500 | Air-cooled | |
| SECIL | Under construction | Portugal | 3900 | PH+CC+Solar | Thermal oil | 7200 | Air-cooled | Deep study on integration with concentrated solar panel. |
| TD 100 HRS ACC | Under construction | UAE | | PH+CC | Thermal oil | 10 000 | Air-cooled | |
| TD 80 HRS ACC | Under construction | Portugal | | PH+CC | Thermal oil | 8000 | Air-cooled | |
| TD 60 HRS ACC | Under construction | Portugal | | PH+CC | Thermal oil | 6000 | Air-cooled | |

as well as higher availability, where a WHR plant with an ORC has an availability greater than 98%.

In addition to the above-mentioned characteristics, the operation of a WHR Plant will not adversely affect normal cement production and a WHR system based on ORC technology is designed according to the following parameters:

- No effect on the cement line (the heat recovery exchangers are installed in bypass to the main gas duct line to prevent any influence of the heat recovery plant on the main production process) and priority must remain on the cement production process (e.g. raw mill hot gas requirements).
- Maximum utilisation of the waste gas: specific studies are carried out to optimise the WHR power consumption and cost.
- Optimum arrangement of equipment to minimise land use.
- Possible low-noise configuration.
- Reliable, simple operation and maintenance, long operation lifetime (longer than 20 – 25 years).

In addition to all the advantages listed above, it is instructive to calculate the Levelised Cost Of Electricity (LCOE) obtained with a WHR plant over 20 years and compare it to the LCOE of other renewable energies. Depending on the size of the ORC, layout constraints, country of installation, and operating hours per year, the LCOE is between 21 and 43 €/MWh. Renewable energies such as on-shore wind, solar, geothermal, etc. can reach a minimum LCOE of 40 – 50 €/MWh, and in most cases the average is closer to 70 – 80 €/MWh. In this scenario, WHR is a reliable and low-cost source of electric energy and it can be combined with other renewable energies to further decrease the dependence on fossil fuels for electricity production. For a cement plant to have its own $CO_2$ free, low-cost electricity production means it is less dependent on external factors that influence electricity cost. In many countries electricity prices have heavily increased in the last year and cement plants with WHR have been less affected by this huge large increase in costs.

## Global experience

Today, there are currently more than 400 Turboden ORC plants worldwide, 35 out of 400 are used in WHR plants in energy intensive industries such as cement, glass, and steel, in small combined cycles.

Among the ORCs active in cement plants today, the smallest produces 1.4 MWe for Holcim Eclepens, Switzerland, while the largest will be installed in the UAE and will produce up to 10 MWe. A list of projects can be found in Table 1, where it is possible to look at the different solutions implemented according to the specific characteristics of the respective cement plant's needs.

## Conclusion

Recent projects awarded to Turboden have underlined the growing need for WHR in the cement industry as it strives to act in a more sustainable way.

The benefits of WHR are also connected to the importance of being less dependent on volatile energy prices, where the ability to produce energy using a waste heat source guarantees a stable price of electricity (which can amount to 30% of a cement plant's needs). In addition, the LCOE of a WHR plant is competitive when compared to those of other renewable energy sources. ■

## About the author

Sabrina Santarossa is Sales Manager for Industrial Heat Recovery in Turboden with a focus on projects in the cement, glass and steel production process.

Sabrina supports potential customers to find the optimised solution for each project. She holds a master degree in Chemical Engineering.