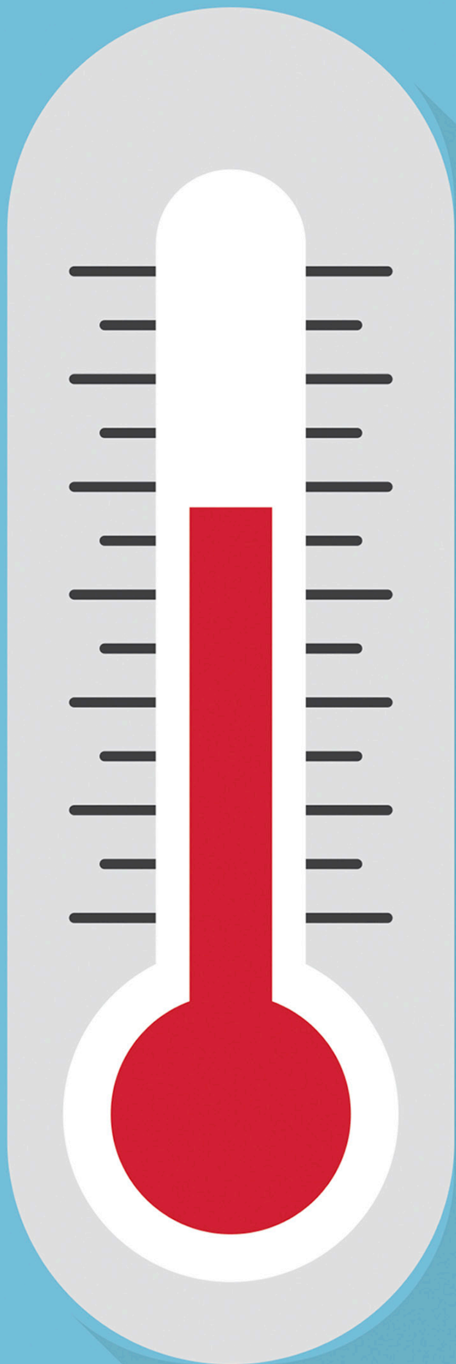
OPTING FOR ORC

Turboden explains how cement plants could achieve better energy efficiency while reducing production costs and CO_2 emissions through ORC technology for waste heat recovery.



Cement production is one of the most energy-intensive industries in the world, and the thermal and electric demand of the clinker process is the dominating cost factor. Furthermore, besides the CO_2 produced through fuel combustion, the cement process produces CO_2 through the chemical reaction inside the kiln, meaning the cement industry is responsible for 8% of global CO_2 emissions. The pressure on CO_2 reduction is increasingly strong, and the industry has been looking for various ways to both increase energy efficiency while reducing production costs and CO_2 emissions to be more sustainable.

Why WHR?

Within the several options a cement plant has, Waste Heat Recovery (WHR) from cement production process exhaust gas is a proven technology with a long track record of improving the energy efficiency of cement plants. In the cement production process, there are two main hot gas streams where heat can be recovered: The pre-heater tower (PH) and the clinker cooler (CC). WHR means allowing the waste heat at a medium/high temperature (higher than 250˚C) to leave the process, but converting this into useful electricity before it is discharged at a lower temperature level (below 120 – 200˚C) to the environment.

After the efficiency of a cement plant has been driven to the optimum, the remaining waste heat is converted into electricity which can be used inside the cement plant, reducing the cost related to the energy purchased by the grid. Electricity produced by WHR plants is carbon free, as it does not need fuel to be produced.

Besides the lower cost for electricity, there are often other benefits for cement plants. In fact, in many plants, the gas from both pre-heater and clinker cooler has to be cooled down before entering the filtration system. Nowadays the cooling of the gas is carried out using quenching towers in the PH side and air-to-air heat exchanger in the CC gas. Cooling the gas temperature in the heat exchangers instead of these systems allows further reduction of the electric consumption of air-to-air exchanger fans and does not require water to be sprayed in the quenching tower, saving significant resources that can be very valuable in dry countries.

ORC technology in WHR

In this framework, Organic Rankine Cycle (ORC) technology represents a feasible option to recover the heat still available in the hot gases of the pre-heater and clinker cooler and turn them into clean power. ORC technology has been successfully applied to cement WHR plants for more than 10 years and has been a recognised technology since the 1970s, where the first geothermal plants based on ORC technology were starting up. During these decades, ORC has been used for medium/high temperature heat sources and has become a good alternative to the traditional steam Rankine cycle for plants with power output lower than 15 – 20 MWe. Unlike the steam Rankine cycle, ORC units use organic fluids such as hydrocarbons, silicon fluids or refrigerants depending on ORC size and temperature levels. The most used organic fluid for cement heat recovery is cyclo-pentane. In the waste heat recovery process at a cement plant, the heat contained in the PH and CC gas hot streams is typically transferred to the ORC unit through an intermediate fluid (e.g. thermal oil).

ORC technology offers several advantages compared to the traditional steam Rankine cycle.

An automatic and flexible system

The use of an organic working fluid enables efficient use of a medium-to-low temperature thermal source, such as the unexploited heat commonly available in cement production processes. ORC modules are designed to automatically adjust themselves to 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 can work down to 10% of nominal load.

No supervision personnel and low maintenance costs

ORC does not require supervision personnel in normal operating conditions, nor for shut down procedures. The systems are monitored and controlled remotely, and require minimal annual maintenance, thereby allowing cement plant technicians to focus on the cement production process. The organic fluid properties result in the working fluid remaining 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.

No water consumption

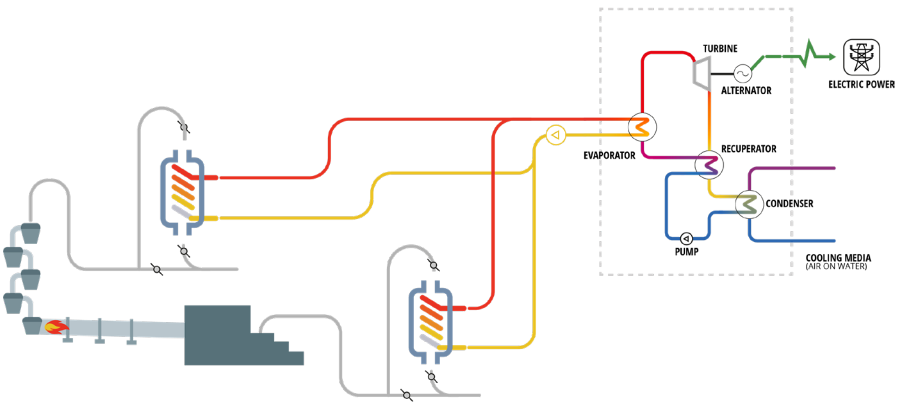
ORC units can be designed to function without water consumption; in fact the condensing heat is dissipated directly into the air utilising air-cooled condensers without negatively impacting performance. Possible configuration with no water consumption is a particularly interesting concept for countries where there is a shortage of water.

Smaller cement plants and at lower temperatures

Future cement processes will be more and more efficient, thus leaving lower temperature exhaust gas available for the heat recovery plants that can be easily exploited with ORC technology. The typical size of an ORC unit is from 1 MWe to 10 – 15 MWe thus making it suitable for applications in cement plants with a clinker production capacity of 2000 – 10 000 tpd.

High availability

On a statistical basis, a WHR plant with ORC has an availability higher than 99%.



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Lower pressure heat recovery exchangers

The pressure inside a thermal oil heat recovery exchanger is lower than 10 bar – unlike water, thermal oil can remain liquid at high temperature and low pressure, therefore there is no possibility of a steam hot spot like in a steam boiler.

The operation of a WHR plant should not affect normal cement production and a WHR system based on ORC technology is tailored design considering following parameters:

- No effect on the cement line – the heat recovery exchangers are installed in bypass to the main gas duct line to prevent the heat recovery plant affecting the main production process.
- Maximum and optimum utilisation of waste gas: Specific studies are done to optimise the WHR electric power and cost.
- No water consumption: WHR plants have the option of running without water, thus saving a resource that is becoming scarce in many countries.
- Optimum equipment arrangement to minimise land occupation.
- Low noise configuration.
- Reliable, high availability, simple operation and maintenance, and long operation lifetime (longer than 20 – 25 years).

Since 2010, Turboden has installed 10 ORCs in cement plants across seven countries. Turboden is an Italian company and part of MHI group, with 40 years of experience in ORC technology. Today, there are currently 400 Turboden ORC plants, with 35 out of 400 being used in WHR plants in energy intensive industries such as cement, glass and steel and in a small combined cycle.

Of the working ORCs, the smallest produces 1.4 MWe for Holcim Eclepens, Switzerland, while the largest produces more than 7 MWe in Sonmez, Turkey. Another 7 MWe ORC is under construction for Secil in Portugal, and it will be started up during the first quarter of 2022. The complete list of references is reported in Table 1, which shows the different solutions studied according to the characteristics of each cement plant and their specific needs.

Financing and investing scheme

WHR potential is still huge and remains widely unexploited. Sometimes there are barriers slowing down the implementation of WHR plants, even in regions with medium-high prices of electricity, related to restrictions in CAPEX expenditures, requirements for off-balance sheet investments and other financing or investing limitations. The necessity of the cement

Table 1. Turboden's WHR solutions for each cement plant and their specific needs.

Plant	Start up	Country	Kiln Capacity (tpd)	Heat source	Heat carrier	ORC gross power (kWe)	Type of cooling	Notes
CIMENTS DU MAROC (HeidelbergCement Group, former Italcementi)	2010	Morocco	5000	PH	Thermal oil	2000	Air-cooled	
HOLCIM ROMANIA (LafargeHolcim Group)	2012	Romania	4000	PH+CC	Thermal oil + superheated water	4000	Wet cooling tower	Optimisation done according to CC low temperature
CRH SLOVAKIA (former Holcim Group)	2014	Slovakia	3600	PH+CC	Thermal oil	5000	Wet cooling tower	
CARPATCEMENT (HeidelbergCement Group)	2015	Romania	3500	PH+CC	Thermal oil	3800	Air-cooled	Air cooled condenser – no water consumption
JURA-CEMENT-FABRIKEN (CRH Group)	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 (Sanko Group)	2019	Turkey	7500	CC	Thermal oil	6500	Air-cooled	PH gas used entirely for raw mill
HOLCIM SUISSE ECLÉPENS (LafargeHolcim Group)	2020	Switzerland	2300	PH+CC	Superheated water	1300	Air-cooled	In winter recovered heat is partially used in a heating district network
SÖNMEZ ÇIMENTO	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

producer to stay financially focused on its core production process encourages different financial and investing solutions and thus the advantage of a lower electric energy bill obtained with a WHR system.

In some countries, finance is available at a rate higher than 10%. In such countries, the possibility of getting international financing at a lower rate helps the customer' business plan. International institutions like the International Financing Corporation (IFC) and the European Bank for Reconstruction and Development (EBRD) are interested in financing industrial projects where WHR plants are implemented. Another possibility for customers to benefit from deferred payments is to involve SACE (Italian ECA). There are also cases where the customer prefers not to finance the project by themselves, and requires an external investor. Besides leasing or renting alternatives, BOT, BOOT, ESCO scheme or customised contracts are available.

Conclusion

ORC systems demonstrate several advantages compared to other technologies. ORC can adapt very well to variable heat sources, maximising the electricity produced throughout the year and benefiting the cement plant. To overcome some of the barriers still present in the market, a deeper look into financing schemes could help to improve the uptake of ORC systems for WHR plants in the cement production process.

The target of decreasing CO_2 emissions and increasing sustainability is by now clear and is part of the strategic plan of almost all cement companies; net zero can hopefully be achieved, in pawrt, thanks to WHR. ■

About the author

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