Hedging the energy bet

The commitment by a growing group of cement companies towards a sustainable production base and the current energy crisis that is engulfing Europe in particular puts in focus the benefits of waste heat recovery (WHR) systems. WHR systems can provide a reliable supply of electricity at a stable cost to cement plants worldwide.

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Waste heat recovery (WHR) systems enable cement plants to hedge their electricity costs to some extent in the currently volatile energy market. The levelised cost of electricity (LCOE) obtained with a WHR plant over 20 years (EUR25-50/MWh) is comparable and even lower than renewable energy sources such as on-shore wind, solar, and geothermal (higher at EUR40-55/MWh). Therefore, WHR is a reliable and low-cost source of electric energy and it can be combined with other renewable energy sources to further decrease dependence on the use of fossil fuel in electricity generation.

Waste heat recovery systems provide a reliable supply of electricity at a stable cost

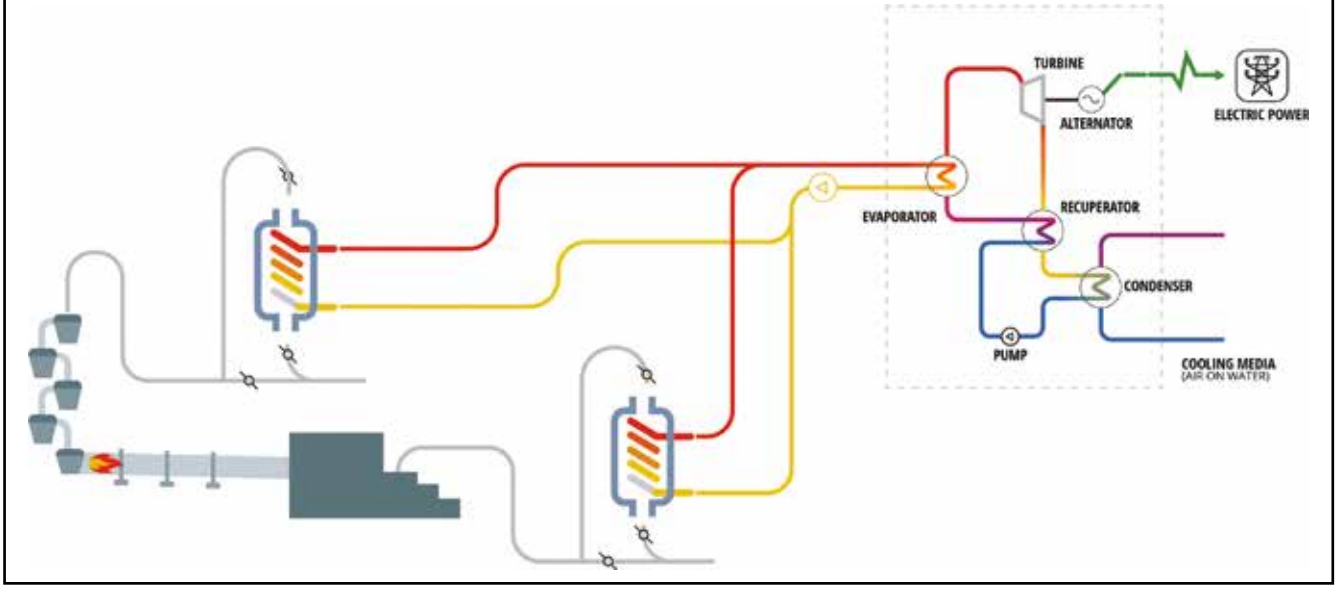
Organic Rankine cycle WHR technology

Organic Rankine cycle (ORC) technology has become quite well known in the cement industry as an effective WHR method and several WHR projects have been successfully implemented in the sector. To generate electricity, the waste heat from a preheater or clinker cooler leaves the process at a medium- to high temperature (>250˚C) and is converted into useful electricity before being discharged at a lower temperature level (<120-200˚C) to the environment.

In the cement production process there are two main hot gas streams where sensible heat can be recovered: the waste gas flow from the preheater (PH) and the waste gas flow from the clinker cooler (CC).

The heat in the hot gas streams is typically transferred to the ORC by an intermediate fluid such as thermal oil

Figure 1: organic Rankine cycle waste heat recovery system in a cement plant



ORC WHR systems can be seamlessly integrated into cement plants

(see Figure 1). Unlike steam Rankine cycle (SRC) technology, ORC units use organic fluids such as hydrocarbons, silicon fluids or refrigerants to perform the thermodynamic cycle. The choice of fluid depends on the size of the ORC system and the temperature level of the exhaust gas. In cement applications, which are typically in the range of 1-20MWe, the most used organic fluid is cyclopentane.

ORC systems can be seamlessly integrated into the operations of a cement plant. The heat recovery exchangers are installed in the bypass to the main gas ductline to prevent any impacts from the WHR plant on the main cement production process.

The successful operation of cement production is always given priority, eg, the requirement for raw mill hot gas.

In addition, specific studies are carried out to optimise the electric power generated by the WHR system and the utilisation of the waste gas, minimising costs at the same time. In terms of operating costs, a reliable and easy to operate and maintain solution with a long lifetime (>20-25 years) is recommended.

In brownfield projects ORC technology suppliers such as Italy-based Turboden (part of the Mitsubishi Heavy Industry group) can provide the optimum equipment configuration to minimise the system's footprint.

Where the limitation of noise is important, a low-noise configuration can be supplied. Sometimes noise can also be a limitation and a low noise configuration can be provided.

ORC vs steam Rankine cycle systems

ORC technology has several advantages compared to SRC technology, particular in medium-to smaller-sized (2-15MWe) systems.

Firstly, the ORC system does not consume any water as the condensing heat is dissipated directly into the air by air-cooled condensers without negatively impacting performance such as in steam Rankine cycle. This is of particular benefit in countries where the water supply is scarce and a precious resource.

Secondly, ORC does not need supervisory personnel during normal operating conditions or a shutdown procedure. This enables cement producers to focus on their main task: producing cement. Furthermore, ORCs are remotely monitored and controlled and only require minimal annual maintenance activities.

The organic fluid properties result in the working fluid remaining dry (no partial condensation) throughout the turbine, avoiding blade erosion. Moreover, these organic fluids are not corrosive and do not damage the materials used in the cycle.

The ORC is a completely automatic system that adjusts itself to the operating

Table 1: selection of waste heat recovery projects to date

Plant	Start-up	Country	Kiln capacity (tpd)	Heat source	Heat carrier	ORC gross power (kWe)	Type of cooling
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
CRH Slovakia	2014	Slovakia	3600	PH+CC	Thermal oil	5000	Wet cooling tower
Carpatcement	2015	Romania	3500	PH+CC	Thermal oil	3800	Air-cooled
Jura Cement Fabriken	2016	Switzerland	3000	PH	Superheated water	2300	Wet cooling tower
Cementi Rossi	2018	Italy	3500	PH+CC	None-direct exchange	1500	Air-cooled
Çimko	2019	Turkey	7500	CC	Thermal oil	6500	Air-cooled
Holcim Suisse	2020	Switzerland	2300	PH+CC	Superheated water	1300	Air-cooled
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
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

The ORC turbo-generator is at the core of Turboden's WHR system

conditions: variations on exhaust gas temperatures and flows will not affect the functionality of the system, just the power output. Furthermore, partial load efficiency is much higher compared to steam turbine technology and the ORC can work down to 10 per cent of nominal load.

Other advantages relate to the efficient use of medium-to-low temperature thermal sources, such as the unexploited heat commonly available in cement production processes and high availability. Based on statistics of the operating fleet, a WHR plant employing ORC technology has more than 98 per cent availability.

Project experiences

Today, Turboden has designed and supplied more than 400 Turboden ORC plants worldwide. Of this total, 35 are used in WHR plants for energy-intensive industries such as cement, glass and steel and in small combined cycle with gas turbines or internal combustion engines.

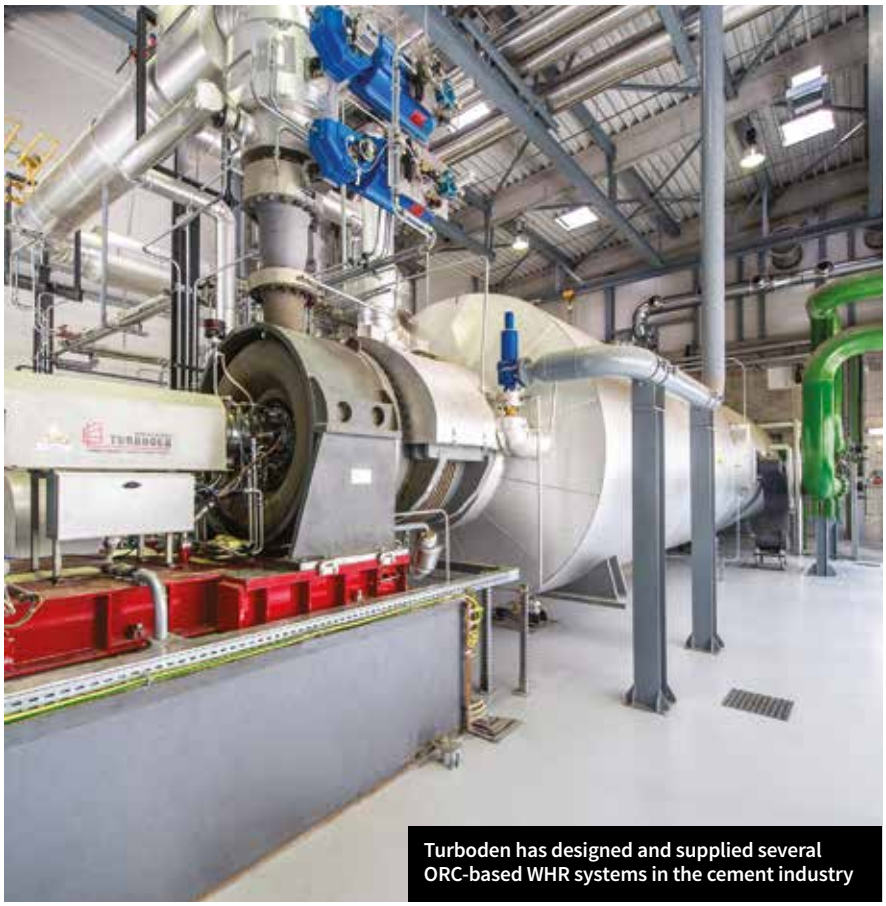
Furthermore, in the last year, Turboden has been awarded three new ORCs contracts to be installed in three different cement plants next year, bringing the number of Turboden ORC plants in the sector to 13. The size of the most recent ORCs to be ordered are in the range of 6-10MWe. In both cases, the technical solution allows heat recovery from both clinker cooler hot air and preheater 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 type developed by Turboden based on the specific characteristics of the project. The turbine is the core of the plant and is completely designed by Turboden thanks to the company's long experience and advanced fluid dynamic software. Several patents have been developed on this component. The substitution of wear parts, such as the turbine seal and bearings, is minimised and downtime is limited to a half day for every 160,000h of operation, contributing to reach >98 per cent availability.

Conclusion

Carbon reduction targets and a requirement for greater sustainability in cement production are now part of the strategic plan for most cement companies. Waste heat recovery systems can be a key part in achieving net zero cement operations through the generation of 'clean' electricity.

In addition, the LCOE of a WHR plant is competitive when compared to other renewable energy sources.

Moreover, the electricity generated by these systems also helps to protect cement producers against the volatility of energy prices, an issue that has come under the spotlight particularly in recent times due to current geopolitical situation. ■



Turboden has designed and supplied several ORC-based WHR systems in the cement industry