To meet its need for less expensive energy or simply to supply power in off-grid remote locations, the cement industry is developing solutions to generate power from plant waste heat flows. These waste heat recovery (WHR) systems find increasing uptake among cement producers worldwide.

Thermal power contained in the cement waste heat streams such as kiln combustion gas and clinker cooler air can be converted into electric power using organic Rankine cycle (ORC) turbogenerators.

As ORC systems are automatic, they are easy to operate and require minimum maintenance. In addition, the option to run them without water offers a competitive solution when compared to traditional steam-based heat recovery systems.

**ORC in cement WHR**

The remaining waste heat from the preheater exhaust gas (300-400°C) and clinker cooler air (250-350°C) can be recovered and used to generate power, reducing the need to purchase electric power from the national grid.

The heat contained in the exhaust gases is typically transferred indirectly via a thermal oil/saturated steam or pressurised water circuit to the ORC plant.

Often two separate heat exchangers are installed, with different technical features due to the different characteristics of the exhaust gas (sticky gas from the preheater and abrasive dust from the clinker cooler). The electricity generated using the recovered waste heat does not require extra fuel consumption nor generates additional emissions. The use of the self-generated power within the cement works enhances the energy efficiency of the plant and contributes to a higher operating profit.

An ORC system can produce sufficient power to cover 10-20 per cent of the total plant requirement. For example, a Turboden ORC system that produces 0.5-1MW/d/t of clinker capacity using the heat from both kiln and cooler exhausts would meet this power demand.

**System benefits**

ORC technology offers several advantages compared to traditional steam-based Rankine cycle WHR.

**Automatic 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. The ORC module 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, just the power output.

No supervision personnel
ORC systems do not need staff to supervise operations under normal conditions nor in shutdown procedure. Control is carried out via remote monitoring and annual maintenance is minimal. As a result, plant technicians are able to focus on the cement production process.

Flexibility
The ORC’s flexibility allows the use of different heat carriers like thermal oil, pressurised water and saturated steam. Different organic fluids can be used according to the temperature level and power size.

Smaller cement plants and lower temperatures
As the efficiency of cement production processes is expected to increase further into the future, exhaust gases will have lower temperatures, making an even stronger case in favour of ORC technology.

The typical size of ORC systems ranges from 1-15MWe and they are therefore suitable for cement plants with clinker production capacities of 2000-10,000tpd.

ORC in practice
ORC technology is now widely used in the cement sector. Brescia-based Turboden has installed more than 260 ORC plants since the 1990s and units currently in operation have an uptime of over 98 per cent. Success stories have included Holcim’s Alesd plant, Romania, and the company’s Rohoznik facility in Slovakia. Italcementi’s Ait Baha works in Morocco and the production unit at Fieni, operated in Romania by HeidelbergCement-owned Carpat Cement.

Holcim Romania’s Alesd plant – reducing CO₂ emissions
In 2012 a 4MWe ORC unit was started up in Holcim’s Alesd plant, Romania. The system is fed by the heat recovered from the preheater exhaust gas and from the clinker cooler air.

An intermediate thermal oil loop transfers heat from the preheater gas to the ORC cycle and a second loop of pressurised water transfers heat from the clinker cooler air (250°C) to the ORC plant. Condensing heat is dissipated through an intermediate water cooling loop and wet cooling towers.

Since 3Q12 the ORC has enabled the Alesd plant to reduce its indirect CO₂ emissions by up to 11,600t, or 15 per cent of total indirect CO₂ emissions from previously purchased electrical power from the grid.

Italcementi’s Ait Baha unit, Morocco – the first hybrid WHR and solar power plant
A 2MWe Turboden ORC unit has been operating since 4Q10 at Italcementi’s Ait Baha plant in Morocco. The WHR system is fed by waste heat from the kiln. In 2014 solar parabolic collectors were added to the power generation unit to exploit solar energy and support the ORC-generated power with thermal energy.

As the plant needed to lower its water consumption a WHR exchanger was installed rather than the classic water conditioning tower. An intermediate thermal oil loop transfers heat from the preheater exhaust gas to the ORC cycle. Condensing heat is dissipated through an intermediate water cooling loop and a dry air-cooling system which requires no water. The power generated is about 9GWh/year, while the savings in terms of CO₂ emissions are around 6700tpa.

In 2014 the WHR system was combined with a concentrated solar power (CSP) unit. CSP is a renewable energy source adapted for use in areas in which solar radiation is high and space is available. An innovative system of linear parabolic collectors concentrates the solar radiation, heats air fluid and supplies additional thermal power to the ORC unit, increasing total energy production.

As the first example of a hybrid ORC-solar application, the Ait Baha plant is one...
of the most advanced and highly-efficient cement works.

**Holcim Slovakia – Rohoznik plant**
In Rohoznik, Slovakia, a 5MWe ORC unit has been working since the start of 2014.
In this case two thermal oil heat exchangers were installed and the thermal oil was unified to feed a single ORC unit. An open cooling water circuit is used to condense the organic fluid.

**Carpat Cement Fieni plant, Romania**
The 3Q15 will see the commissioning of a new 4MWe ORC unit at Carpat Cement’s Fieni works, Romania.
Heat contained in preheater and clinker cooler exhaust gas is transferred to the ORC via a thermal oil circuit. The condensation of the organic fluid is carried out in the air condenser, therefore no water is used in the WHR plant.

**Advances in the making**
New solutions that minimise the investment cost to the cement industry while increasing electrical efficiency are under study.
In particular the direct heat exchange between exhaust gas and organic fluid is considered. Direct heat exchange solution is already a viable and proven solution for ‘clean’ heat sources. Two direct-exchange Turboden ORCs have already been connected to reciprocating engines and one ORC installation recovers heat from a hot rolling mill in Singapore. Other direct exchange ORCs are under construction or in the development phase. Also in direct exchange solution the ORC has demonstrated flexibility when there is a high thermal load variation.
Work on the direct heat exchanger option takes into consideration the specific nature of the cement production process and the characteristics of its hot gas streams including the high dust content, type of dust (sticky or abrasive) and possible peak operation.
This approach offers several advantages, including:
• a more compact layout
• lower operating and maintenance costs
• higher electric output
• lower investment cost.

When compared with a traditional thermal oil-based solution, direct heat recovery exchange systems have an estimated 10-15 per cent higher net output.

However, currently the need for the heat exchanger to be close to the ORC skid presents issues in terms of layout.

**Conclusion**
Thanks to its ability to recover heat at low temperatures even for relatively small sized plants, combined with good electrical efficiencies and high flexibility, ORC technology has the potential to be the ideal technological solution to implement effective and profitable WHR systems in cement plants. Furthermore, a broader vision that takes into account the environmental benefits and long-term strategy constitutes an appropriate response to the need to diversify the supply of electrical energy as well as lower the unnecessary use of energy and global CO₂ emissions.

**References**