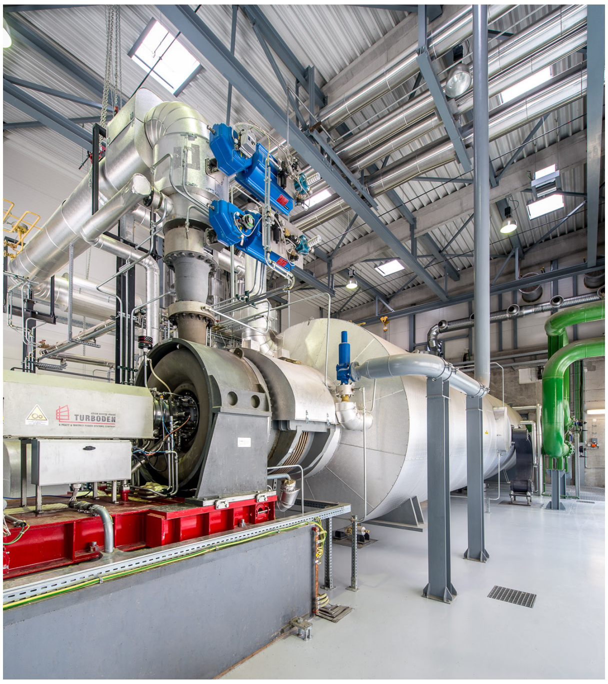
Unlocking eco-friendly energy solutions

Mirko Ferrari, Turboden, examines the role of ORC waste heat recovery technology as a tool to decarbonise the cement sector.

The global cement industry is facing one its hardest challenges when it comes to dealing with sustainability. On the one hand, it has to continue meeting global cement demand that is constantly rising year by year, and on the other hand, it has to reduce CO_2 emissions caused by the production process.

As of the beginning of 2024, around 145 countries worldwide have announced or are considering net-zero targets. For European countries, this challenge is to reach net zero by 2050.



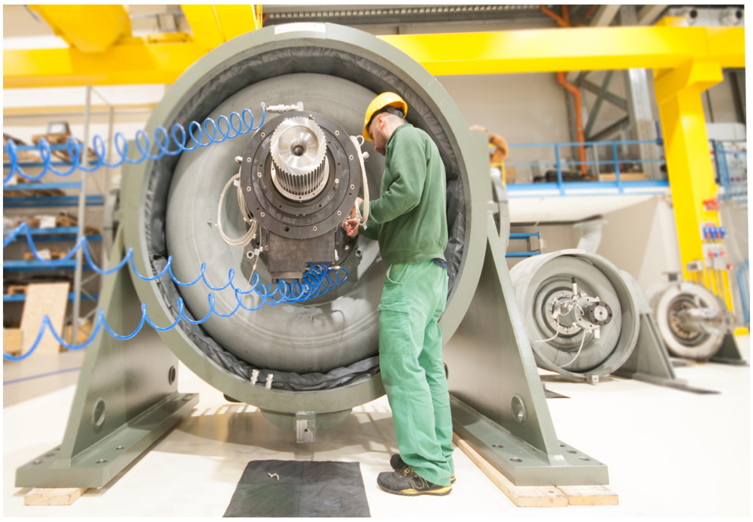
Turboden 5 MW ORC unit in a CRH cement factory in Slovakia.

However, according to the International Energy Agency (IEA), the direct CO_2 intensity of cement production (measured in tons of CO_2 per ton of cement produced) has been largely flat in the last five years, in contrast to the necessary annual decline of 4% by 2030, to get on track with the NZE by 2050 scenario.

Waste heat recovery

Taking this into account, enhancing the energy efficiency of the cement production plant is one of the quickest and most effective ways to reduce global fuel consumption and thus the related CO_2 emissions (Scope 2 – indirect emissions).

It logically ensues that employing waste heat recovery (WHR) methods stands as the most straightforward way to enhance the energy efficiency of the clinker production process, since it can generate up to 30% of the electricity consumed by the cement plant. This is achieved by harnessing the thermal energy present in the hot gaseous streams. Otherwise, not only would this energy be wasted, but it would also entail the use of valuable resources, like water or electricity, for the processing and cooling of these streams.



14 MW turbine assembling at Turboden workshop.

Over the last 15 years, the cement industry has witnessed the emergence of Organic Rankine Cycle (ORC) technology as a viable and secure alternative to the traditional Steam Rankine Cycle. The continuous improvement in technical solutions, the enhanced economic competitiveness, and the growing global focus on a greener and more sustainable environment made heat recovery through ORC more and more attractive. Governments around the world have also played a significant role in driving this shift towards sustainable practices.

Over the course of 2022 – 2023, Turboden, a Mitsubishi Heavy Industry Group company and a leading provider of ORC plants for medium/high temperature applications in energy-intensive industries, secured six new projects in the cement industry alone. This achievement underscores the increasing appeal for cement plants to use ORC technology.

Turboden 5 MW ORC unit in CRH cement factory in Slovakia.

While various strategies can be implemented to reduce carbon emissions from cement plants, such as transitioning to lower-carbon fuels, promoting material efficiency, and carbon capture technologies, WHR from the production process stands out as one of the most effective and efficient ways to immediately make cement plants more sustainable and financially rewarding. Combining WHR with other technologies will be crucial for cement plants in the future.

Benefits of using waste heat

By capturing and utilising waste heat to generate electricity (or both electricity and thermal power in the form of hot water up to 110˚C), cement plants can enjoy several benefits, including:

- Cost savings. Installing an ORC system can result in cost savings for cement plants by reducing the energy they have to buy from the national grid for production plant operation, thus lowering energy bills. Additionally, cement plants that install an ORC unit can ideally lock in electricity prices for the entire lifespan of the system, mitigating risks associated with energy market fluctuations. WHR Levelised Cost Of Energy (LCOE) is typically lower compared to other renewable energy sources like solar or wind which are not constant and depend on external conditions. By using an ORC unit, cement plants can also cool down the gas produced while generating electric power, eliminating the need for electricity-consuming air-to-air heat exchangers or water in conditioning towers. This last point is particularly relevant in countries where water scarcity is a real problem.
- Improving efficiency. Implementing an ORC solution enables cement plants to enhance their overall energy efficiency by harnessing the thermal power generated during the production process that would otherwise be dissipated into the environment.
- Enhancing competitiveness. With the increasing focus on sustainability and energy efficiency, cement plants that demonstrate their commitment to reducing their carbon footprint will be better positioned in the market.
- Environmental benefits. The cement industry is responsible for approximately 7% of global CO_2 emissions, according to the IEA. By reducing energy consumption and carbon emissions through ORC technology, cement plants can contribute to global efforts to mitigate climate change and minimise their impact on the environment.
- Reducing fossil fuel consumption in cement plants with power plants. The electricity produced by the ORC unit is used to power internal loads, thereby reducing the need for energy generated through less environmentally friendly means. This leads to lower energy bills and decreases global carbon emissions.

The process

Cement plants typically have two sources of recoverable thermal power that can be utilised through an ORC unit: exhaust gas from the preheater towers and hot air from the clinker cooler. Turboden has installed numerous ORC units in cement plants, recovering energy from either or both sources. The electrical power output of these units ranges from 1 – 11 MWe, depending on the exploitable thermal source conditions. However, Turboden can offer units with mechanical power ranging from 600 kWe up to 20 MWe from a single turbine; the company has successfully implemented more than 400 ORCs worldwide across different sectors.

The exhaust gas or hot air from the process enters a heat recovery exchanger, which transfers the thermal power in the gas stream to a thermal vector, typically thermal oil. The heat exchanger is designed to effectively handle the gas stream's specific conditions, managing pollutants and dust commonly present in the gas. The thermal vector then transfers the thermal power to the ORC working fluid, often cyclopentane for cement plant applications (being the working fluid that best fits with the thermal source characteristics in terms of temperature). The cyclopentane is evaporated and enters the turbine, the core product of Turboden, generating the required mechanical power, which is converted into electric power by a connected generator.

The expanded vapour then passes through an internal heat exchanger called a regenerator, where it releases heat to its liquid phase coming from the opposite side. After the regenerator, the vapour enters the condenser, where it further cools down and returns to a liquid phase. This condensation can occur through a cooling water circuit or by utilising ambient air directly. In the latter case, there is no water consumption for ORC plant operation, a significant advantage in water-scarce regions. The ORC working fluid is continuously pumped back through the regenerator to the evaporator, completing its cycle.

Advantages of ORC

Compared to other heat recovery solutions like the traditional Steam Rankine Cycle, ORC technology possesses several advantages. It exhibits flexibility during operation, as it can handle thermal power inputs ranging from 20 – 110% of the design inlet, while maintaining high efficiency close to the design level.

Due to this adaptability, ORC turbines remain a viable option for cement plants considering the integration of Carbon Capture technologies like oxyfuel, or other exothermic processes, and post-combustion capture. These turbines can operate at high efficiency both before and after the modification of the kiln line.

In the case of other CCS technologies, such as the well-known post-combustion capture with amines, Turboden has conceptualised its large heat pump. This solution produces high-temperature steam to support the carbon capture process, steam that would otherwise be generated by burning traditional fossil fuels.

In addition to supplying the LHP for any amine-based CCS technology, Turboden, as part of the Mitsubishi Heavy Industry Group, which is a prominent player with its own proprietary amine, can support the customer with the complete CCS solution.

Turboden systems also operate automatically, eliminating the need for constant personnel presence at the plant, allowing cement plant operators to focus on their core business.

The WHR system is installed in bypass to the existing gas treatment line, ensuring uninterrupted clinker production even if the WHR unit experiences downtime. Furthermore, when compared to other green energy technologies like solar photovoltaic, WHR has higher economic efficiency due to higher utilisation rates (it can ideally operate throughout the cement plant's operating time, resulting in higher kWh production annually) and requires much less space.

Over recent years, the volatility of energy costs has demonstrated its ability to impact businesses, even in growing markets. WHR with ORC has evolved into a mature and proven technology that can secure a fixed electricity price for the plant's entire lifespan. This protects at least partially cement plants, as observed in previous years with existing Turboden ORC installations, from sudden and unpredictable peaks and fluctuations in energy prices.

Conclusion

With electricity and gas prices on the rise in many countries, the imposition of increasing carbon taxes on CO_2 emissions (already implemented in many countries), and the availability of incentives aimed at industrial decarbonisation, the historical cost barrier that hindered investments in energy efficiency intervention in cement plants is becoming increasingly fragile. The pursuit of a more sustainable world will ultimately break down this barrier, compelling more cement plants to invest in intelligent and effective solutions to enhance their efficiency. Drawing upon more than a decade of industry expertise and offering the flexibility to generate either electricity or high-temperature heat based on project requirements, Turboden is poised to embrace this challenge and spearhead the sector toward a more sustainable future. ■

Table 1. Turboden references in cement plants.

Customer	Country	Start-up	Kiln capacity (tpd)	Heat source	Heat carrier	ORC gross electric power (kW)
CIMENTS DU MAROC (Heidelberg Cement Group, former Italcementi)	Morocco	2010	5000	PH	Thermal oil	2000
HOLCIM ROMANIA (LafargeHolcim Group)	Romania	2012	4000	PH + CC	Thermal oil + superheated water	4000
CRH SLOVAKIA (former Holcim Group	Slovakia	2014	3600	PH + CC	Thermal oil	5000
CARPATCEMENT (Heidelberg Cement Group)	Romania	2015	3500	PH + CC	Thermal oil	3800
JURA-CEMENT-FABRIKEN (CRH Group)	Switzerland	2016	3000	PH	Superheated water	2300
CEMENTI ROSSI	Italy	2018	3500	PH + CC	None – direct exchange	2000
ÇİMKO (Sanko Group) - EPC: CTP Team & CTN	Turkey	2019	9500	CC	Thermal oil	7000
HOLCIM SUISSE ECLÉPENS (LafargeHolcim Group)	Switzerland	2020	2300	PH + CC	Thermal oil	1300
SÖNMEZ ÇIMENTO EPC: CTP Team & CTN	Turkey	2020	6000	PH + CC	Thermal oil	7300
SECIL EPC: CTP Team & CTN	Portugal	Under construction	3800	PH + CC	Thermal oil	7200
CIMPOR (SOUSELAS) EPC: CTP Team	Portugal	Under construction	4200	PH + CC	Thermal oil	8400
CIMPOR (ALHANDRA) EPC: CTP Team	Portugal	Under construction	3100	PH + CC	Thermal oil	6200
MEDCEM EPC: CTP Team & CTN	Turkey	Under construction	10 000	CC	Thermal oil	11 000
CIMSA ESKISEHIR EPC: CTP Team & CTN	Turkey	Under construction	4500	PH + CC	Thermal oil	5900

About the author

Mirko Ferrari is Sales Engineer for Industrial Heat Recovery at Turboden, focusing on projects in hard-to-abate industries. He supports potential customers to find optimised solutions for each project, tailored specifically to their case. He holds a Master's degree in Energy Engineering.