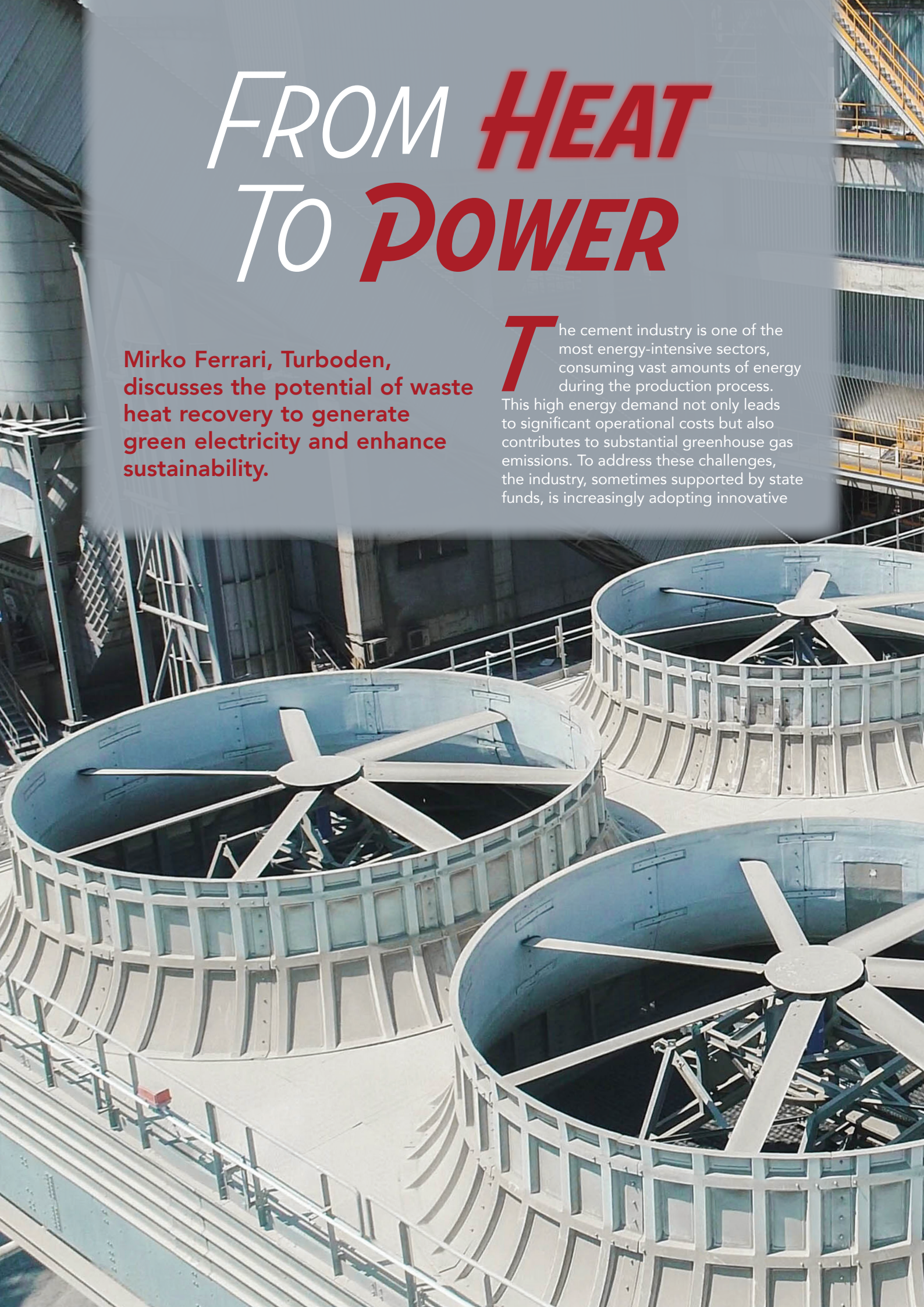
From Heat To Power

Mirko Ferrari, Turboden, discusses the potential of waste heat recovery to generate green electricity and enhance sustainability.

The cement industry is one of the most energy-intensive sectors, consuming vast amounts of energy during the production process. This high energy demand not only leads to significant operational costs but also contributes to substantial greenhouse gas emissions. To address these challenges, the industry, sometimes supported by state funds, is increasingly adopting innovative



solutions, such as carbon capture, switching to lower-carbon fuels, and promoting material efficiency to reduce the clinker-to-cement ratio and consequently the clinker demand. Among these alternatives, heat recovery from the production process stands out as one of the most effective and efficient ways to immediately embark on a journey towards a more sustainable and profitable cement plant.

Waste heat recovery in the cement production process

In a 'classic' configuration, a heat recovery plant can produce up to 30% of the electrical energy used by the production plant, enabling the facility to generate a significant portion of its electricity needs on-site.

This self-production helps protect the plant from sudden spikes in electricity prices from the grid.

Compared to other technologies for green electricity production, such as wind and solar, heat recovery plants have the advantage of lowering the footprint required per MW installed and offering greater consistency, not being dependent on meteorological conditions.

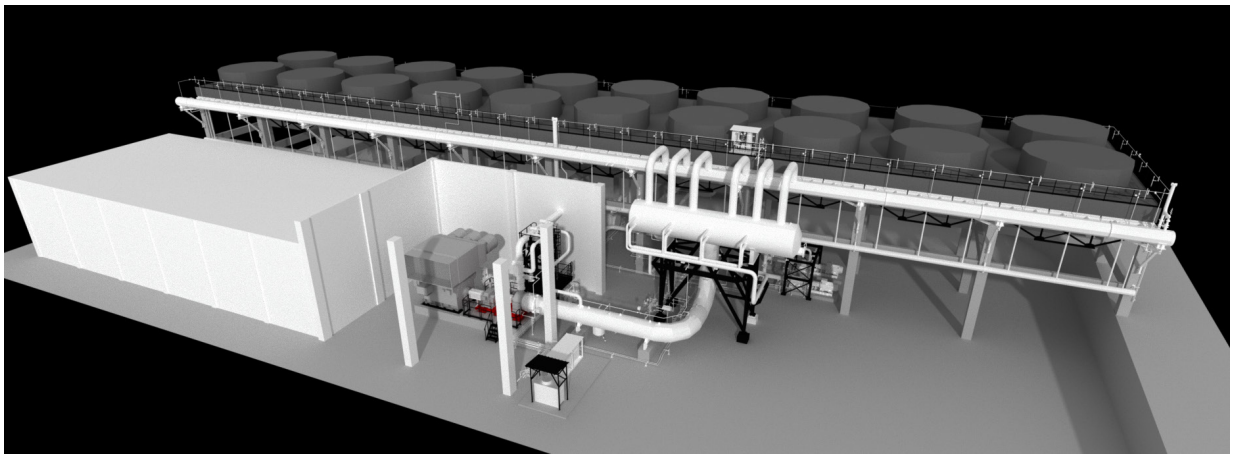
Additionally, this technology not only allows the plant to recover heat and produce electrical energy from it, but it also saves the consumption of electricity or water, typically used to cool down and treat the hot streams before being emitted to the atmosphere.

The integration of heat recovery with other technologies will be essential for the cement plants of the future.

This concept is becoming increasingly evident in the sector. Thanks to advancements in its organic Rankine cycle (ORC) technology, which nowadays can compete with the traditional steam Rankine cycle (SRC), Turboden, part of Mitsubishi Heavy Industries, has secured six new projects in the cement industry over the past two years, totalling 33 MW of gross

Turboden's ORC power plant for Sönmez Çimento in Turkey. In operation since 2020, the unit generates 7.3 MW by exploiting the pre-heater exhaust gases and the hot air from the clinker cooler.

Turboden's 1.3 MW ORC module at Holcim Eclépens facility, in Switzerland. The ORC is fed by superheated water, which is also used to supply the district heating network of the town near the plant.



Turboden's largest ORC heat recovery power plant under construction for Riyadh Cement Company. The 13 MWe project will support the Kingdom of Saudi Arabia in its transition towards cleaner and more sustainable energy sources.

installed capacity. It has also commissioned four ORC units in this time, adding about 30 MW of gross capacity to its operational fleet.

Turboden has more than 20 ORC plants and approximately 115 MW of installed capacity in the cement sector alone. This contribution is part of more than 400 plants installed worldwide across various applications, including geothermal, biomass, waste-to-energy, and more.

Key reference projects

In particular, Turboden has been selected as the supplier for the first ORC project in a cement plant in Saudi Arabia. This 13 MW unit will be the largest ORC installation in a cement plant worldwide to date.

In this project, a single ORC unit will be installed to exploit the thermal power recovered from two kilns. Utilising one ORC unit for both lines, rather than two dedicated units, reduces the specific investment and overall footprint of the heat recovery plant. Thanks to the high flexibility of Turboden ORC units, the unit will be able to continuously operate even if one kiln is down for maintenance. This minimises the downtime of the heat recovery plant, thereby reducing the payback time of the investment, increasing energy production, and indirectly reducing CO_2 emissions.

This project is a further proof that, nowadays, ORC technology can also be applied to larger-scale industrial applications that, until a few years ago, were exclusively reserved for SRC technology.

ORC technology: how it works

In cement production, the two primary sources of recoverable heat are the exhaust gases from the pre-heater tower and the air from the clinker cooler. These hot streams, typically at temperatures above 250 – 300˚C, can be effectively harnessed using ORC technology.

The heat recovery exchangers are typically installed in parallel to the existing flue gas treatment line to avoid any interference with the core production process.

The thermal energy from the gas is transferred to the ORC working fluid, causing it to evaporate and flow towards the high-efficiency Turboden axial turbine, which it drives. The expanded vapour then exits the turbine and enters the condenser, where it is cooled and condensed back into a liquid. The ORC working fluid is then pumped back to the evaporator, completing the closed-loop cycle.

Unlike traditional SRCs, ORC systems utilise organic fluids which are better suited for medium-to-high temperature heat sources. This allows for the efficient conversion of waste heat into clean electricity, with the potential to eliminate water consumption in the heat recovery process.

Turboden's ORC systems are designed to run automatically, self-adjusting to varying operating conditions, ensuring optimal performance even with fluctuations in exhaust gas temperatures and flows. This flexibility is crucial for cement plants, where process conditions can change

Table 1. Turboden experience in cement plants.

Plant	Country	Kiln Capacity (tpd)	ORC gross electric power (kW)
Ciments du Maroc (Heidelberg Cement)	Morocco	5000	2000
Holcim Romania (Holcim Group)	Romania	4000	4000
CRH Slovakia	Slovakia	3600	5000
CarpatCement (HeidelbergCement)	Romania	3500	3800
Jura-Cement-Fabriken (CRH Group)	Switzerland	3000	2300
Cementi Rossi	Italy	3500	1500
Çimko (Sanko Group)	Turkey	9500	7000
Holcim Suisse Eclépens (Holcim Group)	Switzerland	2300	1300
Sönmez Çimento	Turkey	6000	8100
Secil Outão	Portugal	3800	7000
Cimpor Souselas	Portugal	4200	8000
Medcem	Turkey	10 000	11 000
Çimsa Eskişehir	Turkey	4500	5900
Lafarge Emirates (Holcim Group) (Investor: ENGIE)	UAE	7500	10 000
Cimpor Alhandra	Portugal	3100	6000
Riyadh Cement Company	KSA	10 000	12 600
Holcim Obourg – Go4Zero	Belgium	6000	7500
Colacem Sesto Campano	Italy	3000	2300
OYAK Ankara	Turkey	3500	3500
OYAK Adana	Turkey	3500	3500
OYAK Mardin	Turkey	3500	3500

frequently. Additionally, ORC units require minimal maintenance and can be monitored remotely, allowing cement plant technicians to focus on core production activities.

Thanks to its flexibility, ORC technology can be integrated into more complex projects, such as those involving carbon capture. For instance, in the case of oxyfuel technology, the ORC plant can be designed to operate efficiently whether the kiln is running on air or in pure oxyfuel mode.

Leveraging its experience in the sector, Turboden has been selected as the ORC supplier for the Go4Zero project at Holcim's cement plant in Obourg, Belgium.

Turboden's ORC turbine portfolio ranges from approximately 600 kW up to 40 MW of mechanical power output, depending on the conditions of the exploitable thermal source, with gross plant efficiency reaching up to 27% and beyond.

Additionally, with experience in utilising more than 10 different working fluids, Turboden can tailor optimal solutions for different temperature levels of the heat sources.

Economic analysis: the levelised cost of electricity

In addition to the advantages already mentioned, it is instructive to calculate the levelised cost of electricity (LCOE) for a heat recovery plant over its lifetime (above 20 years) and compare it to the LCOE of other renewables.

Depending on the size of the ORC plant, layout constraints, country of installation, and operating hours per year, the LCOE might range between 25 and 55 €/MWh.

Renewables such as onshore wind, solar and geothermal can achieve a minimum LCOE of 40 – 60 €/MWh, with the average typically closer to 50 – 80 €/MWh.

Considering this outcome, it is clear that heat recovery using ORC technology is a well-proven, reliable, and cost-effective method for generating electricity. It efficiently harnesses a significant portion of energy that would otherwise be wasted, making it also an environmentally friendly solution.

The future of sustainable cement plants

In a cement production sector increasingly oriented towards sustainability, the introduction of carbon taxes, incentives for industrial decarbonisation, and rising energy prices are progressively lowering the barriers to investment in heat recovery solutions. Waste heat recovery through ORC technology now represents a mature, reliable, and economically advantageous solution. ■