Process heat up to 200 °C with innovative rotation heat pump – emission-free, economical and future-proof

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INTRODUCTION:

The pulp and paper industry faces increasing pressure to decarbonize its thermal energy systems. While electricity consumption has increasingly been optimized and in many regions partially decarbonized, process heat remains heavily dependent on fossil fuels. Steam generation for drying, evaporation, and board production continues to rely largely on natural gas, oil, or biomass combustion.

1. Executive Summary

High-temperature heat pumps have long been considered a promising solution for industrial electrification. However, conventional systems struggle when required to deliver temperatures above 140–160°C at meaningful efficiency levels. The temperature lift, declining coefficient of performance (COP) at higher output temperatures, and reliance on synthetic refrigerants constrain their application in core paper processes. Systems have been developed with these constrains in mind, with multiple stages to lower the temperature lift and new kind of refrigerants.

A new concept — the rotational heat pump — aims to overcome these barriers at once. By enabling temperature lifts exceeding 100 Kelvin in a single stage, maintaining competitive COP values at high output temperatures, and utilizing noble gases instead of synthetic refrigerants, this technology opens a pathway toward deeper electrification of process heat.

For pulp and paper industry the rotational heat pump may represent a step-change in what is technically and economically feasible.

2. The Process Heat Challenge in Paper Production

2.1 Where Fossil Fuels Are Still Used

Around 5% of global final energy consumption is attributable to industrial heat above 100 °C – and over 90% of this is still provided by fossil fuels. For paper and pulp facilities, this means high and volatile energy costs, a massive carbon footprint, and growing compliance risks from the EU Emissions Trading System (ETS) and upcoming PFAS restrictions on conventional refrigerants.

Paper production is inherently energy-intensive, particularly in its thermal processes. While mechanical energy demand can increasingly be met with renewable electricity, thermal energy remains dominated by combustion-based systems. However, tightening carbon regulations, volatile fuel pricing, and corporate sustainability targets are driving mills to evaluate electrification strategies more seriously than ever before.

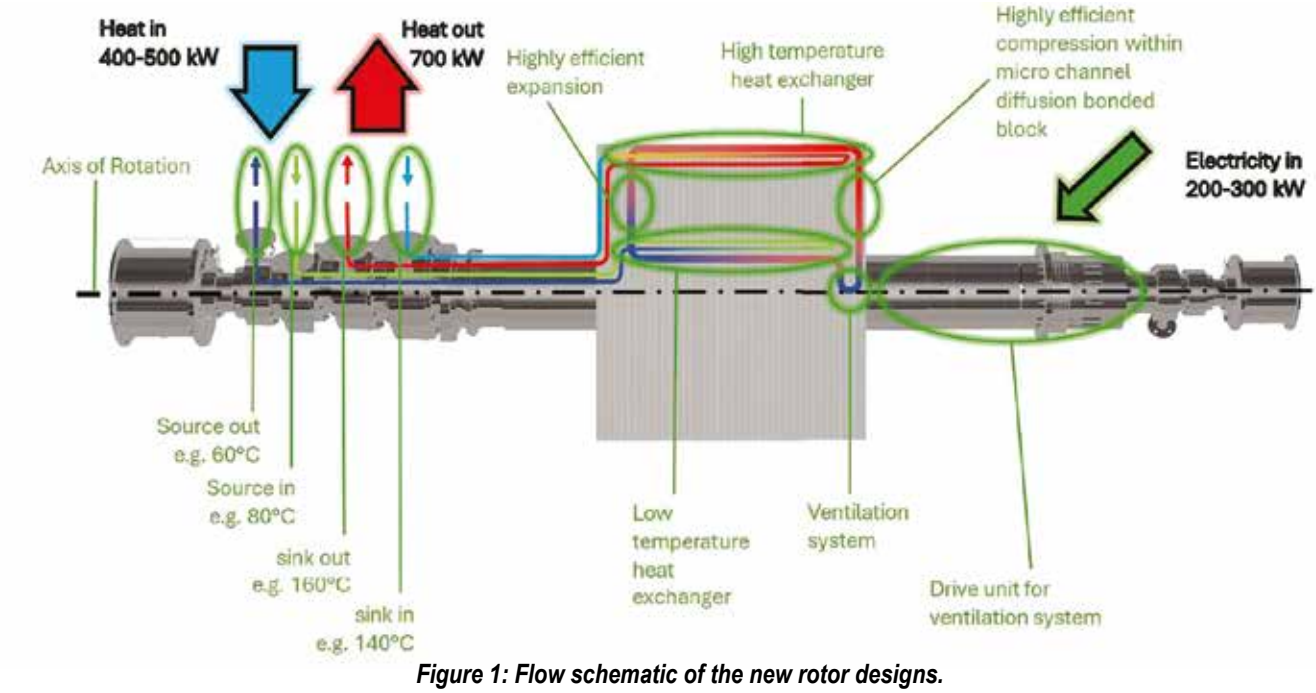

Figure 1: Flow schematic of the new rotor designs.

2.2 Why Conventional Heat Pumps Fall Short

Industrial heat pumps have proven highly effective in low- and medium-temperature applications — for example, upgrading waste heat from 30°C to 90°C. Yet the core thermal demands of paper production often exceed the practical limits of conventional vapor-compression systems, requiring higher temperatures.

Key limitations include:

Limited temperature lift.

- Most industrial heat pumps operate efficiently within a 30–60 K temperature lift. Larger lifts require cascading systems or multi-stage configurations, increasing complexity and cost.

COP degradation at high output temperatures.

- As discharge temperatures rise above 140°C, efficiency drops significantly. Electrical input increases disproportionately, reducing the economic attractiveness compared to gas boilers — especially where electricity prices are high.

Refrigerant limitations.

- Synthetic refrigerants are subject to F-gas regulations and phase-down schedules in many jurisdictions. Concerns regarding global warming potential (GWP), flammability, toxicity and long-term availability create uncertainty in planning and strategic risk for industrial use.

As a result, conventional heat pumps have until now primarily been deployed in peripheral or low-grade heat recovery applications with lower heat input, rather than directly replacing high-temperature steam generation in paper processes.

3. The Technology: A Completely New Operating Principle

Our partner company with over 15 years of intensive R&D has developed with the Rotation Heat Pump a technology that consistently implements the principle of the inverse Joule cycle (counter-clockwise) on an industrial scale. At the core of the system is a monolithic rotating block (“Integrated Rotor”) that combines compression, heat exchange, and expansion in a single mechanical element.

How it works:

- Rotation generates centrifugal forces that compress the working fluid – a noble gas mixture of Argon, Krypton, and Xenon – radially outward, heating it in the process.
- At the outer heat exchanger position, the gas transfers heat to the process fluid circuit (sink) and cools down.
- Flowing back against the centrifugal force, the gas expands, cools further, and absorbs heat from the heat source (e.g., wastewater, exhaust air) at the inner position.
- A fan ensures the continuous mass flow of the working gas.

The working fluid is non-toxic, non-flammable, has a GWP of zero, and is fully compliant with the EU F-Gas Regulation and upcoming PFAS restrictions. The Micro-Channel Diffusion-Bonded (MCDB) heat exchangers are integrated directly into the rotor, achieving very high heat transfer coefficients even under large thermal and mechanical loads. Conventional evaporators, condensers, and compressors are eliminated entirely.

4. Relevance for Paper & Pulp: Processes That Fit

The technical parameters of the RHP match the needs of the paper and pulp industry with remarkable precision. The following application areas offer the highest potential:

- Drying sections (70–150 °C): Direct integration into steam and hot air circuits with high temperature lift from waste heat sources in production.
- Evaporation in pulp production (85–130 °C): Use of vapor streams as heat source, efficiency gains through simultaneous cooling and heating operation.
- Bleaching and washing (40–90 °C): Combined use as cooling and heat source in one circuit – particularly economical due to excellent ROI characteristics.
- Waste heat recovery from cooling water, exhaust air, or wastewater (source temperature down to -30 °C): The RHP can efficiently lift even low source temperatures.

A particular economic feature: The RHP can deliver heat and cooling simultaneously in a single unit and in a single stage. This means the electricity required for cooling (already operationally necessary) is combined with the heating demand – the additional energy input for high-temperature heat is thus drastically reduced. For plants with simultaneous cooling and heating requirements – typical in pulp and paper processing – this results in exceptionally attractive payback periods.

Parameter	RHP	Conventional HP
Max. process temperature	200°C	~80–120°C
Max. temperature lift	100 K (single stage)	40–60 K
Refrigerant	Noble gas mixture (Ar/Kr/Xe)	HFC / F-gases
GWP	0	up to 3,900
Operating range	-30°C to 200°C	limited
Footprint [m²/MW]	9.6	variable, often higher
PFAS compliance	fully compliant	at risk from 2025+

Figure 2: Comparison RHP vs. conventional compression heat pumps.

Figure 3: RHP at test bench.

5. Integration Opportunities in Pulp & Paper Mills

5.1 Retrofitting Existing Steam Systems

One of the most attractive aspects of high-temperature heat pumps is their potential to integrate into existing steam networks.

Rather than fully replacing boilers immediately, a rotational heat pump can be:

- Installed in parallel with existing gas or biomass boilers.
- Used as base-load heat generation.
- Combined with boilers for peak demand coverage.

This hybrid approach reduces risk and allows gradual electrification without compromising process stability.

5.2 Dryer Section Applications

Dryer sections are typically the largest consumers of steam in paper production. High-temperature heat pumps capable of delivering steam-equivalent heat open the possibility to:

- Reduce gas burner dependency.
- Electrify a significant portion of drying load.
- Lower direct CO^2 emissions without redesigning the entire drying system.

While full electrification of dryer sections may require electrical infrastructure upgrades, the ability to supply high-grade heat from upgraded waste energy represents a compelling decarbonization pathway.

6. Your Implementation Partner: BM Green Cooling GmbH – Over 30 Years of Experience in the Paper Industry

Deploying a high-temperature heat pump like the RHP is not a plug-and-play project – it requires deep process understanding, industry-specific expertise, and a partner who knows the particular demands of paper and pulp production from first-hand experience. BM Green Cooling GmbH, headquartered in Schwarzenbruck (Bavaria), is exactly that partner: specializing in energy-efficient cooling solutions for paper mills across Europe for over 30 years, delivering complete turnkey projects from initial concept through commissioning and 24/7 ongoing service.

Over decades of project work, BM Green Cooling has demonstrated what many in the paper industry considered impossible: over 80% freecooling throughout the year, groundwater and river process water cooling without compressors, full heat recovery, and reliable climate control even in aggressive process air environments. This deep cooling expertise is the ideal foundation for integrating the RHP holistically into existing process infrastructure. BM Green Cooling supports your project end-to-end:

- Feasibility studies & economic analysis: Assessment of your heat sources, thermal loads, and savings potential – including pinch analyses, weather studies, groundwater studies, and best-practice consulting

Figure 4: Size of an example unit.

- Professional plant engineering & system design: Turnkey planning of heat pump integration including interfaces to steam, water, and process control systems (Siemens controls, 690 V power supply)
- Energy-efficient cooling solutions for paper production: Freecooling, adsorption cooling, heat recovery, and natural refrigerants – including solutions for aggressive process air and special operating conditions
- Seamless commissioning & service: From joint concept development through live operations – with 24/7 support and sustainable maintenance by experienced specialists
- Refrigerant & regulatory consulting: Guidance on F-gas transition, PFAS compliance, funding applications, and CO^2 savings documentation

7. Economics: Why the Switch Makes Financial Sense

The financial framework for high-temperature heat pumps has improved fundamentally thanks to rising CO^2 prices, volatile gas prices, and attractive funding programs (EU Innovation Fund, national decarbonization programs). Concrete ROI drivers include:

- COP > 3.0 at a 100 K temperature lift means: for every kilowatt-hour of electricity invested, at least 3 kWh of heat is generated – a fundamental efficiency leap compared to natural gas.
- Simultaneous cooling and heating operation: the energy input already required for cooling processes becomes a heat source – the additional investment pays back proportionally faster.
- Elimination of F-gas costs, inspection obligations, and disposal expenses through the PFAS-free, GWP-0 working fluid.
- High availability and long-term stability thanks to the monolithic rotor with no conventional seals, condensers, or evaporators.

The RHP technology is comprehensively protected by five granted and two pending patent families and is the result of over 15 years of intensive R&D. First industrial installations are currently in the implementation phase. The market for high-temperature-capable, future-proof heat pumps will become a strategic competitive factor for Paper & Pulp plants in the coming years.

8. Carbon Reduction Potential

Replacing gas-fired steam generation with high-temperature heat pumps can eliminate a substantial share of carbon emissions in paper production. For mills operating in regions with low-carbon electricity grids, the indirect emissions associated with electrical input may be dramatically lower than direct combustion emissions.

This contributes directly to corporate ESG objectives and customer-driven decarbonization requirements. As sustainability increasingly influences procurement decisions in packaging and paper markets, the ability to demonstrate process heat electrification may become a competitive differentiator.

9. Closing Perspective

High-temperature process heat has long been considered one of the most difficult segments to electrify in heavy industry. The rotational heat pump concept challenges that assumption.

By combining high temperature lift, improved efficiency at elevated output temperatures, and refrigerant-free operation using noble gases, Rotation Heat Pump presents a technically compelling approach to replacing fossil fuel-based steam systems.

For the pulp and paper industry — an industry defined by large-scale thermal processes — such innovation may play a pivotal role in achieving meaningful decarbonization while maintaining the operational reliability that mills depend upon.

BM Green Cooling GmbH will assist you in every step along the way of implementing this new and innovative heat pump technology to your mill. With our experience and the new technology we will move towards greener future together.