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PROJECT 68 – TASK 1: STATE OF THE ART REVIEW OF HTHPS

Summary

This paper presents a comprehensive state-of-the-art review of industrial high-temperature heat pumps (HTHPs), synthesizing the latest findings from IEA HPT Project 68. An analysis of data from over 55 technology suppliers and 40 demonstration cases reveals three defining trends: a decisive shift to natural working fluids, which now constitute 75% of the reviewed technology portfolio; the maturation of credible platforms for higher temperatures and capacities; and a sharp increase in demonstration and commercial projects, particularly in the 130 °C to 200 °C range. The review confirms the technology's transition from niche R&D to mainstream commercial availability, with standardized solutions and established investment costs (300–1,200 €/kW) significantly de-risking decarbonization for industrial applications up to 160 °C. Consequently, the primary challenge for many industrial sectors is shifting from technology availability to optimal system integration. This analysis provides a data-driven foundation for stakeholders planning near-term HTHP implementation.

Keywords: High-temperature heat pump, State-of-the-art, database, technology review, industrial decarbonization, IEA

1. Introduction

The decarbonization of industrial process heating is a primary focus for manufacturers pursuing sustainable production, demanding strategic roadmaps based on reliable and independent technology assessments. For processes requiring heat at temperatures up to and beyond 200 °C, high-temperature heat pumps (HTHPs) represent a key enabling technology, offering an efficient route to replace fossil-fuel-based systems. While the potential of HTHPs is recognized, stakeholders have historically lacked a clear, consolidated, understanding of the technology. This paper addresses that gap by presenting an overview of the state-of-the-art of HTHPs.

The analysis is based on the latest findings from the International Energy Agency (IEA) Technology Collaboration Programme on Heat Pumping Technologies (HPT) Project 68 (Zühlsdorf et al. 2025). Building on its predecessor, Project 58 (Zühlsdorf et al. 2023), this work compiles and analyses data from over 55 international technology suppliers and more than 40 demonstration cases. The review focuses on market-ready technologies (TRL 4-9) to provide a realistic assessment of solutions available for near-term deployment.

By consolidating the latest technology data and project experiences, this paper and the Project 68 tries to bridges the gap between global decarbonization targets and the concrete, on-the-ground implementation of HTHPs in industry.

2. Results & Discussion

The data collected and analysed in IEA HPT Project 68 reveals several key trends in the maturation and deployment of industrial HTHPs. This section presents an overview of the current technology landscape, investment costs, and the evolution of working fluid selection.

Technology Landscape: Temperature and Capacity

The review of over 55 technology suppliers confirms a rapid expansion of HTHP capabilities, particularly in the 130 °C to 200 °C range. As illustrated in Fig. 1, which show the maximum supply temperature against heating capacity for available HTHP platforms, distinct patterns emerge:

- **Up to 130 °C:** This temperature range is now a mature market segment, a wide variety of standardized products are available.

- **130 °C to 160 °C:** This segment has seen the most significant growth. What was primarily a domain of pilot projects just a few years ago is now populated by a cluster of more or less standardized, solutions (TRL 6-8), typically in the 0.5 MW to 10 MW capacity range.
- **Above 200 °C:** Customized systems, capacities of 1 MW to 10 MW for temperatures up to 200 °C are now realistic and available from multiple suppliers. Systems (>10 MW), often based on centrifugal steam compressors, can reach temperatures of 250 °C 300 °C.

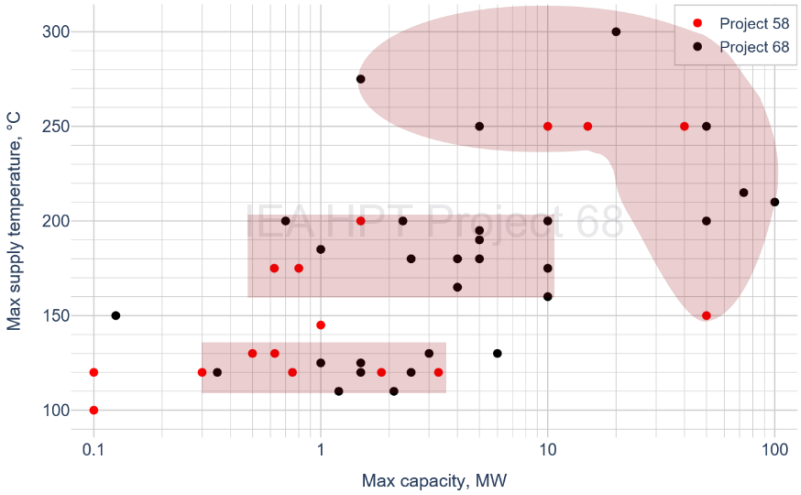

Fig 1: Maximal supply temperature of the described supplier technologies in Project 68 Task 1

This data clearly indicates that for many industrial applications requiring heat up to 160°C, the technology risk has been significantly reduced, shifting the focus from fundamental availability to optimal system integration.

Investment Costs

The specific investment cost (CAPEX) of the HTHP unit is a critical factor for project developers. The collected data, presented as a function of maximum supply temperature in Fig. 2, shows a range of 300 to 1,200 €/kW.

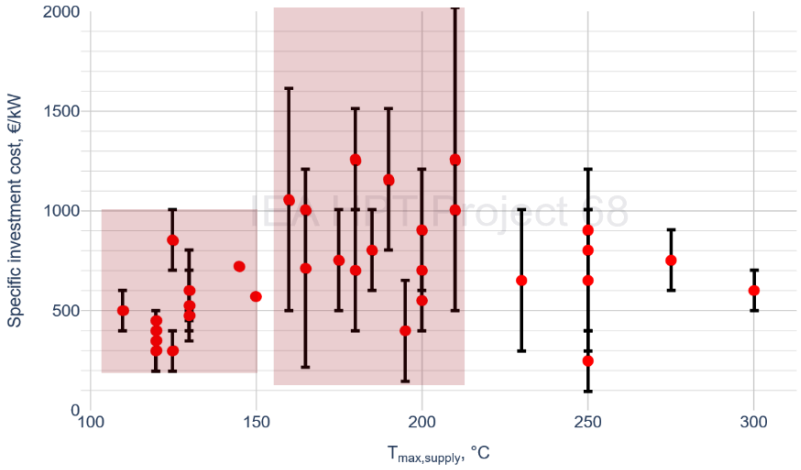

Fig 2: Specific investment cost of the described supplier technologies

The data reveals a clear correlation between cost, temperature, and market maturity:

- **100 °C to 150 °C:** Costs are clustered in a tighter and lower band, reflecting the availability of standardized, serially produced modules often adapted from the mature industrial refrigeration sector. This segment represents the most competitive and predictable cost-point in the current market.

- **160 °C to 200 °C:** Costs are both higher and more scattered. This reflects the use of more specialized components, higher-grade materials, and a lower production volume for these more advanced systems, which are frequently engineered on a case-by-case basis

Working Fluids

A trend observed in Project 68 is the shift towards natural working fluids. As illustrated in Fig. 3, natural refrigerants - such as water, hydrocarbons, CO_2, and water/ammonia - now constitute 75% of the reviewed technology portfolio. This represents a substantial increase compared to the preceding Annex 58.

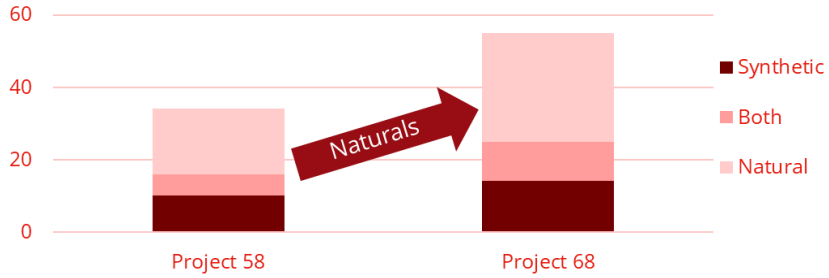

Fig 3: Development in working fluids of HTHPs in project 68 Task 1

This development is driven by regulations phasing down synthetic F-gases, a desire to mitigate long-term supply-chain risks, and the growing maturity of system designs that handle flammable or high-pressure fluids.

3. Conclusions

The international market for industrial high-temperature heat pumps is rapidly maturing, moving from niche R&D to mainstream commercial availability. Technology is now a proven and preferred solution for heat delivery up to 130 °C, with a strong and growing portfolio of systems from numerous suppliers. The decisive shift towards natural working fluids, which now represent 75% of reviewed technologies, allows industries to decarbonize while mitigating regulatory and supply-chain risks. While deployment above 160°C is still led by demonstration projects, the sharp increase in real-world installations de-risking the technology for new sectors. As these systems become standard, the focus will shift from proving fundamental viability to optimizing system integration, supported by cost reductions and evolving service models.

4. References

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