

Heat Pump Awards 2026

Application submission

SPIRIT Demo 1: Full-scale Cascade Heat pump producing industrial steam at 145°C using waste heat at 18°C from a freezing plant

TNO | Large Heat Pump Award

1. Application overview

Award category	Large Heat Pump
Title of the project	SPIRIT Demo 1: Full-scale Cascade Heat pump producing industrial steam at 145°C using waste heat at 18°C from a freezing plant
Organisation Name	TNO
Exact address of the project	Stella Polaris AS, Kårvikvegen 306, 9307 Finnsnes, Norway
Funding	EU funds
Organisations involved in the project	End user: Stella Polaris AS, Heat pump manufacturer: Mayekawa Europe / MYCOM
Project ending date	28/02/2027
Project website	https://spirit-heat.eu/demo_sites/shrimp-processing/
Sector of application	Industrial

2. Applicant & EHPA contact details

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EHPA member involved	TNO
Role of EHPA member	Research organization

3. Project description and benefits

Project description (goal, problem addressed, and solution provided by the heat pump)

SPIRIT Demonstration 1 is a full-scale industrial high-temperature heat pump installation at the Stella Polaris shrimp processing facility in Finnsnes, Norway. The plant requires refrigeration for freezing and steam for cooking. Previously, waste heat from the ammonia refrigeration system was rejected to seawater, while steam was produced by a propane boiler.

The project connects these two energy demands through a Mayekawa cascade heat pump that upgrades waste heat from approximately 18-21°C to saturated steam at 145°C and around 4 bar(a). With a capacity of approximately 700 kWth, the system is designed to cover the full steam demand of the shrimp cooking process under normal operating conditions. To achieve a temperature lift exceeding 130 K, the system combines an ammonia bottom

cycle with a pentane top cycle. This innovative configuration enables direct high-temperature steam generation while using industrial waste heat as the primary energy source. The installation demonstrates industrial electrification, waste heat recovery, and high-temperature heat pump technology in a real production environment. The system has been commissioned successfully, produces steam on site, and is now operated by Stella Polaris with remote support from Mayekawa, demonstrating a successful transition from demonstration project to industrial adoption.

Expected or achieved benefits

The expected benefits are as follow:

- a) The heat pump is designed to provide approximately 700 kWth of process heat, covering the full steam demand of the shrimp cooking process under normal operating conditions.
- b) Stella Polaris recently installed an electric boiler to replace most of the propane-based steam production. However, due to the remote location of the facility and limitations of the local electricity grid, operating the electric boiler at full load can constrain other factory operations. By recovering waste heat instead of generating all steam with resistance heating, the heat pump significantly reduces electricity demand while allowing continued operation of all production processes at full capacity. The propane boiler remains available as backup during peak demand situations.
- c) Compared with continuous operation of the original propane boiler, the system is expected to reduce primary energy consumption by approximately 1,000 MWh/year and avoid approximately 600 tCO₂/year.
- d) Beyond the direct environmental benefits, the project increases confidence in high-temperature heat pump technology, advances the technology towards TRL 7, and provides a replicable example for food processing and other industries requiring steam above 135°C.

Obstacles/barriers encountered during development

As a first-of-a-kind industrial demonstration, the project faced challenges which generated valuable lessons for future industrial steam heat-pump deployments. Early involvement of all stakeholders during the Factory Acceptance Test proved essential for aligning instrumentation, controls, safety systems and process integration, reducing risks during commissioning. The project also highlighted the need for specialized system integrators with expertise spanning refrigeration, steam systems, controls and industrial process integration. In addition, dynamic modelling played an important role in identifying control and component-sizing issues before commissioning, reducing technical risks and supporting troubleshooting and optimization. Together, these lessons provide practical guidance for future high-temperature heat-pump projects and help accelerate industrial electrification across Europe.

Why should this project win an award?

145°C steam from 18°C waste heat. That single number tells the story. The project demonstrates a temperature lift of more than 130 K in a real industrial facility. That's the "coolest" thing about the project: "the freezing system helps cook the shrimp". By showing that high-temperature process steam can be generated from very low-temperature waste heat, the project pushes the boundaries of industrial heat-pump technology and demonstrates a pathway to decarbonize some of industry's most difficult heat demands.

4. Technical specifications

Capacity of unit(s)	The installed heat pump has a nominal heating capacity of approximately 700 kW _{th} and is designed to cover the full steam demand of the shrimp cooking process at Stella Polaris under normal operating conditions.
Energy sources used	The heat pump is electrically driven and primarily uses recovered waste heat from the Stella Polaris ammonia refrigeration system as its heat source. Waste heat at approximately 18-21°C, which would otherwise be rejected to the environment, is upgraded to produce process steam. Electricity is used to drive the compressors of the cascade heat pump system.
Coefficient of Performance (COP)	The expected COP (heating) of the cascade heat pump is 1.78 under design conditions.
Service provided	The heat pump provides industrial process heating through direct steam production. It upgrades waste heat recovered from the refrigeration plant (otherwise rejected to ambient) to produce saturated steam at approximately 145°C for the shrimp cooking process. The system therefore supports industrial electrification, waste heat recovery and decarbonization of food processing operations.
Refrigerant type	The heat pump uses a cascade configuration based entirely on natural refrigerants. The bottom cycle uses ammonia (R717) and the top cycle uses pentane (R601).

Heat pump details (compressor technology, heat exchanger, system configuration)

The installation consists of a cascade high-temperature heat pump system. The ammonia cycle is equipped with a Mayekawa reciprocating (piston) compressor, while the pentane cycle uses a Mayekawa screw compressor specifically designed for high-temperature operation. Flooded shell-and-plate heat exchangers are used for both evaporation and condensation duties to maximize heat transfer performance. The system is designed as a two-stage cascade configuration, enabling a temperature lift exceeding 130 K while using only natural refrigerants.

5. Renewable energy integration and grid response

Integration of renewable energy sources

The energy sources of the cascade heat pump are two fold: Heat source is the waste heat from the refrigeration plant and (2) the electricity to drive the compressor motors. The electricity mix in Norway is around 98% coming from renewable or low grade carbon sources, such as Hydroelectric.

Response to energy demand / smart grid integration

The current demonstration was not specifically designed as a smart-grid project; however, the steam network of Stella Polaris is designed with a hierarchical operating strategy: (1) the heat pump supplies steam whenever sufficient waste heat is available, (2) an electric boiler provides additional steam when required, and (3) the existing propane boiler remains available as backup capacity. This could be use in the future to provide flexibility for load management.

6. Innovation, monitoring and replicability

General (all awards)

Why the project is innovative *(all awards)*

This project demonstrates one of Europe's first full-scale industrial heat pumps producing 145°C steam from low-grade waste heat at approximately 18°C, corresponding to a temperature lift exceeding 130 K. Beyond the technology itself, the project demonstrates the successful integration of a steam-producing heat pump into a real food-processing facility, replacing fossil-fuel-based steam generation with waste heat recovery and electrification. The project also generated valuable lessons for future deployments.

Monitoring approach (performance, cost, and carbon targets) *(all awards)*

The system is continuously monitored using automated data logging of temperatures, pressures, flow rates, steam production, electricity consumption and operating hours. These measurements are used to assess technical performance, quantify energy and CO₂ savings, optimize control settings and evaluate long-term reliability. Monitoring data is compared with design and simulation results, providing a robust evidence base for both operational improvements and the wider replication of high-temperature heat pumps in industry. Moreover, the life cycle assessment was performed as part of the SPIRIT project.

For Large Heat Pump or Building Solutions Award

Why the project serves as a model for others *(Large Heat Pump or Building Solutions Award)*

This project demonstrates how low-temperature industrial waste heat can be upgraded to high-temperature process steam in a real production environment. It provides a proven blueprint for integrating high-temperature heat pumps with existing industrial refrigeration and steam systems, covering not only the technology itself but also system integration, controls, safety, commissioning and operation. The project shows that industrial processes currently relying on fossil-fuel boilers can be electrified without compromising production, making it a valuable reference for companies seeking to decarbonize process heat.

Potential for expansion to other locations/industries *(Large Heat Pump or Building Solutions Award)*

The concept is highly scalable and applicable wherever simultaneous cooling and heating demands exist, even with smaller temperature lift. While demonstrated at a shrimp-processing facility, the approach can be replicated in other industries such as food processing, dairy, beverage, meat, seafood, chemical, pharmaceutical and other processes requiring low pressure steam. The lessons learned on integration, commissioning and operation further reduce the barriers for future deployments across Europe.

Barriers to replication elsewhere *(Large Heat Pump or Building Solutions Award)*

The main barriers are the complexity of integrating heat pumps with existing industrial processes, the limited availability of specialized system integrators, and the upfront investment associated with first-of-a-kind projects. Additional challenges include site-specific safety requirements, control-system integration and the need for operational confidence in new technologies. These barriers can be overcome through increased deployment experience, standardized system concepts, early stakeholder involvement, specialized training programs and supportive policies that recognize the carbon reduction benefits of industrial electrification. Demonstration projects, such as SPIRIT, play an important role in reducing perceived risks and building confidence among industrial end-users.

Business opportunities for expansion, licensing, or commercial production *(Large Heat Pump or Building Solutions Award)*

The successful operation of a full-scale 145°C steam-producing heat pump creates opportunities for wider deployment of similar systems across European industry. The project not only showcases a commercially viable technology but demonstrate to other end-user that industrial heat pump are viable solution for steam production.

For Innovation Award

Technology/technique developed solely for this project *(Innovation Award only)*

No. The project builds upon existing Mayekawa heat pump technologies and combines them into a novel industrial application. The ammonia heat pump unit is a commercially available solution while the pentane unit was developed/lab tested prior to this project based on available compressor technology from Mayekawa. The pentane unit was demonstrated in this project and is now moving towards commercialization. The overall cascade configuration was specifically engineered for the Stella Polaris demonstration.

Differentiation from state-of-the-art solutions & market maturity *(Innovation Award only)*

The objective of the SPIRIT project is to bring the technology to TRL 7, demonstrating a technology in an operational industrial environment. The project therefore represents a significant step between pilot-scale testing and wider commercial deployment, providing valuable operational experience, performance validation and lessons learned for future industrial steam heat pump applications.

Regional benefits (energy savings, emissions, jobs, infrastructure) *(Innovation Award only)*

The project demonstrates how industrial electrification can be achieved while addressing practical grid-capacity limitations. At Stella Polaris, waste heat that was previously rejected to the ambient from the refrigeration system is upgraded to 145°C process steam, reducing the need for electricity-intensive steam generation. This helps relieve pressure on the local power infrastructure and allows industrial production to continue at full capacity without additional grid reinforcement.

Furthermore, the system reduces reliance on fossil-fuel backup generation and, compared with continuous operation of the previous propane boiler, is expected to reduce primary energy consumption by approximately 1,000 MWh/year and avoid approximately 600 tCO₂/year.

Commercial potential *(Innovation Award only)*

The commercial potential is significant because many industrial sectors require low-pressure steam within the temperature range targeted by this demonstration. Food processing,

beverage production, dairy, meat processing, pulp and paper, chemical manufacturing and other industries often have simultaneous heating and cooling demands that make them suitable candidates for industrial heat pumps.