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# Skills and competency recommendations

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# ABBREVIATIONS AND ACRONYMS

**ATEX**: ATmosphères EXplosibles, meaning explosive atmospheres

**BMS**: Building Management System

**CAPEX**:Capital Expenditure

**CEO**: Chief Executive Officer

**COP**: Coefficient of Performance

**CTO**: Chief Technology Officer

**DCS:** Distributed Control System

**E&I:** Electrical and Instrumentation

**EC**: European Commission

**F-gas**: Fluorinated greenhouse gas

**HEX:** Heat Exchanger

**HMI**: Human-Machine Interface

**HP4ALL**: Heat Pumps Skills For NZEB Construction

**IEA**: International Energy Agency

**IETS**: Industrial Energy-Related Technologies and Systems

**IHP**: Industrial heat pump

**ISO**: International Organization for Standardization

**JRC**: Joint Research Center

**LCC**: Life-Cycle Cost

**OPEX**: Operating Expenditure

**OST**: Eastern Switzerland University of Applied Sciences

**P&ID**: Piping and Instrumentation Diagram

**PFD**: Process Flow Diagram

**PLC:** Programmable Logic Controller

**PUSH2HEAT**: Pushing forward the market potential and business models of waste heat valorisation by full-scale demonstration of next-gen heat upgrade technologies in various industrial contexts

**R&D**: Research and Development

**R&I:** Research and Innovation

**SCADA**: Supervisory Control and Data Acquisition

**SPIRIT**: Implementation of sustainable heat upgrade technologies for industry

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# 1. INTRODUCTION

Industrial heat plays a central role in Europe's energy system, accounting for a significant share of final energy consumption and greenhouse gas emissions. Large volumes of this heat are still supplied by imported fossil fuels, exposing European industry to price volatility, supply disruptions and geopolitical risks. The energy crisis of 2022 starkly illustrated these vulnerabilities, while renewed tensions and market instability in 2026 have reinforced the need to reduce Europe's dependence on fossil fuel imports and accelerate the transition towards a resilient, electrified and low-carbon industrial energy system. Electrification of heating and cooling is therefore no longer a long-term ambition, but a strategic necessity for European industry.

Industrial heat pumps (IHPs) are a key technology to address this challenge today. These solutions can deliver high-temperature heat for industrial processes and are already deployed across energy-intensive sectors such as paper and pulp, food and beverages, chemicals, textiles and other manufacturing activities. By upgrading renewable or ambient energy sources and recovering waste heat from industrial processes, IHPs provide efficient, low-carbon heat while reducing both energy consumption and operational emissions. In addition to on-site process integration, IHPs can also connect industrial facilities with district heating networks, upgrading excess industrial heat and supplying it to surrounding buildings and communities, thereby strengthening local energy systems and enabling sector coupling.

While industrial heat pumps are commercially available and technically mature in some applications, their deployment potential depends strongly on the required temperature level, scale and specific industrial context. As highlighted in SPIRIT Deliverable 5.2 on *Policy, regulatory and non-technical barriers for industrial heat pumps*[1], their limited uptake is not due solely to technological constraints, but also to a range of non-technical barriers. These include high upfront costs, complex integration into existing industrial processes, infrastructure constraints, limited awareness and trust among decision-makers, misaligned policy and regulatory frameworks and persistent skills shortages across the value chain.

[1] SPIRIT Consortium (2026) Deliverable 5.2 – Policy, regulatory and non-technical barriers, https://spirit-heat.eu/wp-content/uploads/2026/01/D5.2-Policy-regulatory-and-non-technical-barriers.pdf

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Among these barriers, the shortage of skilled professionals is a critical cross-cutting issue. The successful deployment of industrial heat pumps requires a combination of professionals covering industrial processes, energy systems, system design, installation, commissioning and long-term operation. However, these skills are still limited in the market, which can slow down deployment even when favourable technical and economic conditions exist. This report analyses this issue through a literature review, survey analysis and lessons learned from the SPIRIT demonstration sites.

In line with its title, this work does not aim to establish a final or standardised competency framework. Rather, it provides an initial framework and recommendations and analytical inputs to support its future development. To do so, the report identifies the industrial heat pump value chain and maps the key professional figures, skills, knowledge and competencies required at each stage. This value-chain-based mapping helps clarify who is involved, where specific capabilities are needed and where potential skills gaps may emerge.

The report also presents lessons learned from two SPIRIT demonstration sites, focusing on the skills gaps encountered during implementation and how these were addressed. These insights provide practical evidence from real industrial applications and complement the broader analysis of professional profiles and competencies across the value chain.

In addition, the report includes a dedicated chapter on existing and planned training activities for industrial heat pumps. These initiatives are important for raising awareness and building foundational knowledge, although the customised nature of industrial heat pump projects also points to the need for more specialised training linked to specific technologies and industrial applications.

Based on these outcomes, the report concludes with recommendations to strengthen the availability of skilled professionals across the industrial heat pump value chain, support targeted capacity-building measures and accelerate the deployment of industrial heat pump solutions in Europe.

# 2. METHODOLOGY

This study combines value chain analysis, stakeholder engagement, case-based evidence, training review and targeted literature analysis to develop an initial competency framework for industrial heat pumps and related recommendations.

In line with the title of the deliverable, this work does not aim to establish a final or standardised competency framework. Rather, it provides an initial structured framework, together with analytical inputs and recommendations to support its future development.

The report opens with a targeted literature review and field research which are carried out to contextualise the analysis. While limited work specifically addresses competencies for industrial heat pumps, relevant insights from adjacent fields, industrial heat pump integration studies, policy reports and broader heat pump workforce discussions were considered (Chapter 3).

The analysis continues with a mapping of the industrial heat pump value chain[2] covering the main project phases from research and development, consulting, manufacturing and installation to maintenance and operation. Based on this structure, the key professional figures involved at each stage are identified and an initial set of required skills, knowledge and competencies is defined for each role, including both technical and cross-cutting aspects. This value-chain-based approach helps clarify who is involved, where specific capabilities are needed and where potential skills gaps may emerge (Chapter 4).

The deliverable also reviews existing and planned training activities for industrial heat pumps. This analysis helps assess how current initiatives contribute to raising awareness and building foundational knowledge, while also identifying the need for more specialised, application-oriented training linked to specific technologies, manufacturers and industrial applications (Chapter 5).

To complement the field and desk research, two real-world industrial heat pump demonstration projects within SPIRIT were analysed. These case studies provided practical insights into how competencies are applied in practice, with particular

[2] More details on the definition of the "industrial heat pump value chain" for the purposes of this report are provided in Chapter 4.

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attention to skills gaps encountered during implementation, operation and safety management, as well as the solutions adopted to address them. These findings were further supported by semi-structured interviews with technology providers and end-user companies involved in the selected demonstration sites. The interviews allowed for a deeper understanding of the professional profiles involved, the competencies considered critical, the skills missing or difficult to access, and the training needs identified from an operational perspective (Chapters 6).

The combination of these elements enabled the identification of key competency needs and gaps across the industrial heat pump value chain. These findings form the basis for the report's final recommendations (Chapter 7).

# 3. SETTING THE SCENE: LITERATURE REVIEW AND FIELD RESEARCH

## 3.1 State of knowledge on skills for industrial heat pumps

A review of available sources shows that the evidence base on skills and competencies specifically for industrial heat pumps is still fragmented. Dedicated competency frameworks for industrial heat pumps are not addressed directly in academic literature; instead, skill needs are typically discussed indirectly in reports and studies dealing with industrial heat decarbonisation, electrification of process heat or the broader heat pump workforce, with a strong focus on residential applications. At the same time, skills are increasingly framed not only as a project-level constraint but also as a strategic one in the energy transition. Accordingly, the state of knowledge needs to be reconstructed across several neighbouring bodies of work.

First, relevant insights appear in industrial heat pump application and integration studies, which highlight that successful projects require professionals who can combine an understanding of heat pump capabilities and constraints with deep knowledge of the host industrial process and its operating envelope. This "dual literacy" (heat pump system and industrial process) is repeatedly described as scarce. The IEA Heat Pump Programme & IETS report *Application of industrial heat pumps: Final report (Annex 35/13)*[3], for instance, explicitly points to a lack of actors (installers and decision makers) who possess this combined knowledge and can therefore integrate a heat pump in the most suitable way for the process context. Another key barrier identified in the same report is the limited awareness of industrial heat demand within companies. Although industrial heat pumps are technically mature for some applications, often knowledge of process heat consumption is often lacking, making it difficult to identify integration opportunities without costly and time-consuming measurements.

[3] International Energy Agency (2014), Application of industrial heat pumps: Final report - Annex 35/13 (https://heatpumpingtechnologies.org/publications/application-of-industrial-heat-pumps-part-1/)

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Second, evidence is provided by policy, market and energy-system reports focused on industrial electrification. In these sources, skills constraints are typically listed among the barriers to scaling heat pumps, alongside finance, energy prices, grid constraints and supply-chain issues.

Beyond "barriers" lists, the European Commission explicitly frames skills as a strategic constraint in its *Study on clean energy R&I opportunities to ensure European energy security by targeting challenges of distinct energy value chains for 2030 and beyond*[4]. The study identifies skills as the main criticality for the heat pump value chain and links the elevated risk to the decentralised nature of deployment, where each device must be installed and maintained on a specific site (including industrial sites).

This framing is summarised in Figure 1, which highlights skills as a key challenge alongside supply-chain and physical risks. While the document does not break skills down into occupational profiles or competency levels, it clearly flags workforce availability as a limiting factor for both domestic and industrial heat pumps.

| Value chain/ indicator | Geopolitical availability | Abundance | Circularity | Supply chain complexity | Supply chain location | Digital vulnerability | Physical vulnerability | Broader sustainability | Affordability | Skills |
|---|---|---|---|---|---|---|---|---|---|---|
| Industrial heat pumps | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| Domestic heat pumps | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 3 |

**Figure 1: Energy security indicator scores for the heat pump value chains assessed (Source: EC study on clean energy R&I opportunities for energy security, p.140)**

Third, where workforce issues are discussed more explicitly, the literature emphasises that industrial heat pumps pose a particular challenge because design and integration are often customised to end-user requirements, such as: temperature

4 European Commission (2024), Study on clean energy R&I opportunities to ensure European energy security by targeting challenges of distinct energy value chains for 2030 and beyond (https://cedelft.eu/publications/study-on-clean-energy-ri-opportunities-to-ensure-european-energy-security-by-targeting-challenges-of-distinct-energy-value-chains-for-2030-and-beyond/)

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levels, heat source/sink characteristics, space limitations, safety constraints and regulatory context. The last JRC report "*Heat pumps in the European Union*"[5] highlights that the shortage of skilled workers is already a bottleneck for both domestic and industrial heat pumps and stresses that customisation needs are particularly pronounced for industrial applications. It also notes that while basic installation training can be relatively quick, strong competition for workers across clean energy technologies can exacerbate shortages, with knock-on effects on installation time and costs.

Across these sources, a coherent set of recurring themes can be identified. One theme is the shortage of professionals able to act as system integrators i.e., individuals or organisations that can translate industrial process requirements into a workable heat pump solution, coordinate multiple disciplines (e.g. process, refrigeration, electrical and instrumentation, civil works, safety) and manage interfaces during implementation. Closely related is the need for strong commissioning competence: beyond mechanical completion, industrial heat pumps require careful tuning of control strategies, verification against performance expectations and a structured handover to operations teams. A further theme concerns safety and compliance, particularly when projects involve flammable refrigerants and industrial site requirements, which increases the need for risk assessment capability and for technicians trained in site procedures. Finally, many sources implicitly point to the growing importance of digital and control skills, while policy-oriented work indicates that increasing the deployment of industrial heat pumps at the pace required to meet climate and energy targets will intensify competition for skilled workers across the wider clean energy transition.

## 3.2 The perspective of the sector

Within the framework of the SPIRIT project, field research was conducted to capture the perspectives of industrial stakeholders on the main barriers to the widespread adoption of industrial heat pumps. Two surveys on this topic were shared with

[5] Volt, J., Toleikyte, A., Roca Reina, J. C., Mountraki, A., Letout, S., & others. (2025). *Clean energy technology observatory: Heat pumps in the European Union—2025 status report on technology development, trends, value chains and markets* (JRC144191). Publications Office of the European Union (https://setis.ec.europa.eu/heat-pumps-european-union-2025-status-report-technology-development-trends-value-chains-and-market_en)

industrial heat pump manufacturers and end-user companies in the chemical, paper & pulp and food & beverage sectors.

The main outcomes of this research are presented in SPIRIT Deliverable 5.2. Among the factors assessed, the availability of relevant skilled workers emerged as a recurring concern.

Responses from industrial heat pump manufacturers indicate that the lack of skilled workers is perceived as a moderate to significant barrier. As shown in Table 1, out of the ten respondents, two rated this issue as “extremely” important, two as “very” important and four as “moderately” important, while only a small number considered it a minor or non-existent obstacle. This distribution suggests that, although skills availability is not universally considered as the most critical barrier under current operating conditions, it is consistently recognised as a limiting factor within the sector.

| Level of obstacle | Number of responses |
|---|---|
| Extremely | 2 |
| Very | 2 |
| Moderately | 4 |
| Slightly | 1 |
| Not at all | 1 |

**Table 1: Perceived importance of lack of relevant skilled workers as a barrier to industrial heat pump adoption by industrial heat pump manufacturers**

The significance of this constraint is also likely to depend on the scale of manufacturers’ activities and their expected production growth. A manufacturer producing a limited number of customised units may be able to meet its current labour needs, whereas a substantial increase in annual production would require additional personnel with specialised design, engineering, manufacturing, installation and commissioning skills. The survey results should therefore be interpreted as a snapshot of current perceptions rather than as a complete assessment of the workforce requirements associated with future large-scale deployment.

As the survey did not distinguish respondents according to their current production volumes or expected growth, it was not possible to assess whether perceptions of the skills barrier vary with manufacturing scale. This represents a limitation of the findings and could be explored in future research.

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From the end-user perspective, the lack of skilled workers to manage new heat pump technologies was also identified as a relevant concern. When asked to assess perceived risks associated with the implementation of high-temperature heat pumps, respondents assigned an average score of 3.44 (on a scale from 0 to 5) to this factor (Figure 2)

This places it among the mid-to-high range of perceived challenges, alongside technological complexity (3.78) and return on investment (3.67), although slightly below concerns related to technology reliability (4.00) and cost of development and integration (4.22).

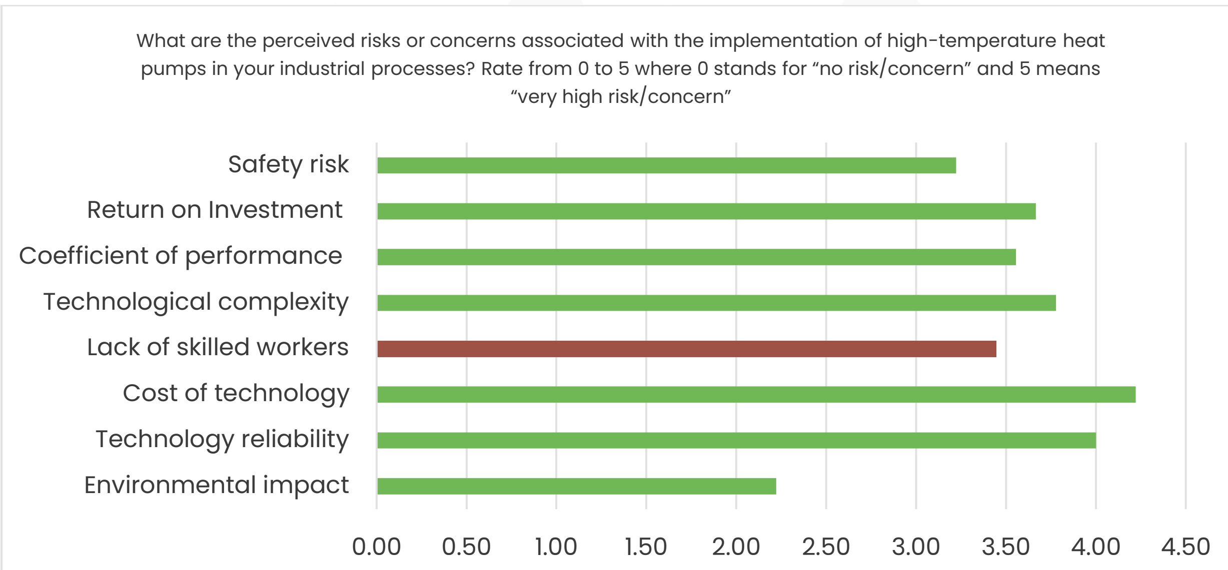


**Figure 2: Results from SPIRIT survey to end users on perceived risks and concerns associated with the implementation industrial heat pumps**

Overall, the survey findings indicate that the availability of adequately skilled personnel is not an isolated issue, but part of the wider set of challenges affecting industrial heat pump deployment. While economic and technical factors remain highly significant, workforce-related constraints also emerge as a relevant barrier that should be addressed to support broader adoption.

These results are consistent with early insights from the SPIRIT demonstration sites, which suggest that skills challenges are not only related to the overall number of available professionals, but also to the type of expertise required. In particular, industrial heat pump projects need professionals able to coordinate complex interfaces between technology providers, end users, contractors, safety requirements

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and industrial processes. This points to the importance of understanding not only which skills are missing, but also where they are needed across the value chain.

Addressing these challenges requires a clearer view of how the industrial heat pump value chain is structured, which professional figures are involved and which skills and competencies are required at each stage. Against this background, the following chapter provides a structured mapping of the industrial heat pump value chain and identifies the key roles and competency needs that can support the wider deployment of industrial heat pumps.

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# 4. A COMPETENCY FRAMEWORK FOR INDUSTRIAL HEAT PUMPS

This chapter presents a first value-chain-based mapping of the skills and competencies required for industrial heat pumps. In the context of this report, "value chain" is used to identify six key stages, from the design of industrial heat pumps to their maintenance (see Figure 4), rather than to describe a linear chain from raw materials to final product.

In line with the scope of the deliverable, it should not be understood as a final or standardised competency framework, but as an initial structured basis to support its future development.

The first section identifies the main stages of the industrial heat pump value chain, while the second maps the key professional figures involved at each stage, together with the main skills, knowledge and, where relevant, qualifications required. It aims to clarify who is involved, in which stage and where specific expertise is needed.

This work builds on a dedicated SPIRIT workshop on skills for industrial high-temperature heat pumps, organised by EHPA during the 5th Project Consortium meeting in Brussels on 16 October 2024. The final mapping resulting from the workshop reflects the perspectives of a wide range of stakeholders within the SPIRIT consortium, including end users, technology providers, research organisations, universities and industry associations. As a result, it provides a broad and well-rounded overview of the skills landscape for industrial heat pumps.

## 4.1 Mapping of the industrial heat pumps value chain

During the workshop, as a first step, the professionals involved in the industrial heat pump value chain were mapped by identifying the different stages of the value chain.

This work was based on the value chain presented in the paper *"Review of Business Models for Industrial Heat Pumps"*, developed within the framework of the PUSH2HEAT project (Figure 3).

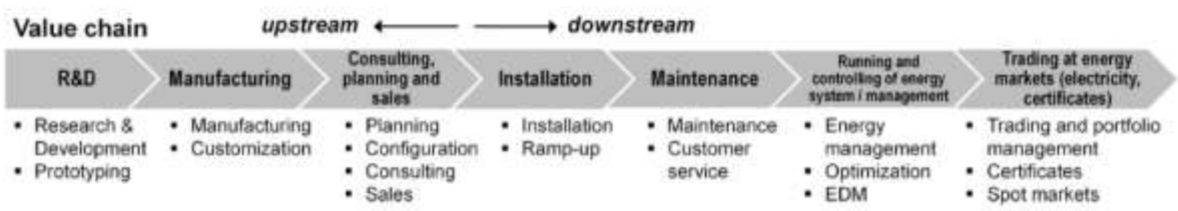


**Figure 3: value chain of industrial heat pumps (Source: PUSH2HEAT project)**

Based on this reference, the consortium agreed to focus on the first six stages of the value chain, excluding the more specific stage related to trading in energy markets (Figure 4).

Following the workshop discussion, the sequence was also adjusted to better reflect the typical development and delivery process for industrial heat pump projects.

In particular, consulting, planning and sales are positioned at the front end of the process, alongside or immediately after research and development, as these activities generally take place before project-specific manufacturing begins.

In addition, the manufacturing stage, identified as a particularly complex and articulated phase, was further divided into five sub-stages: design, procurement, assembling, quality and logistics.

The resulting value chain structure serves as the backbone of the competency framework described in the following section.

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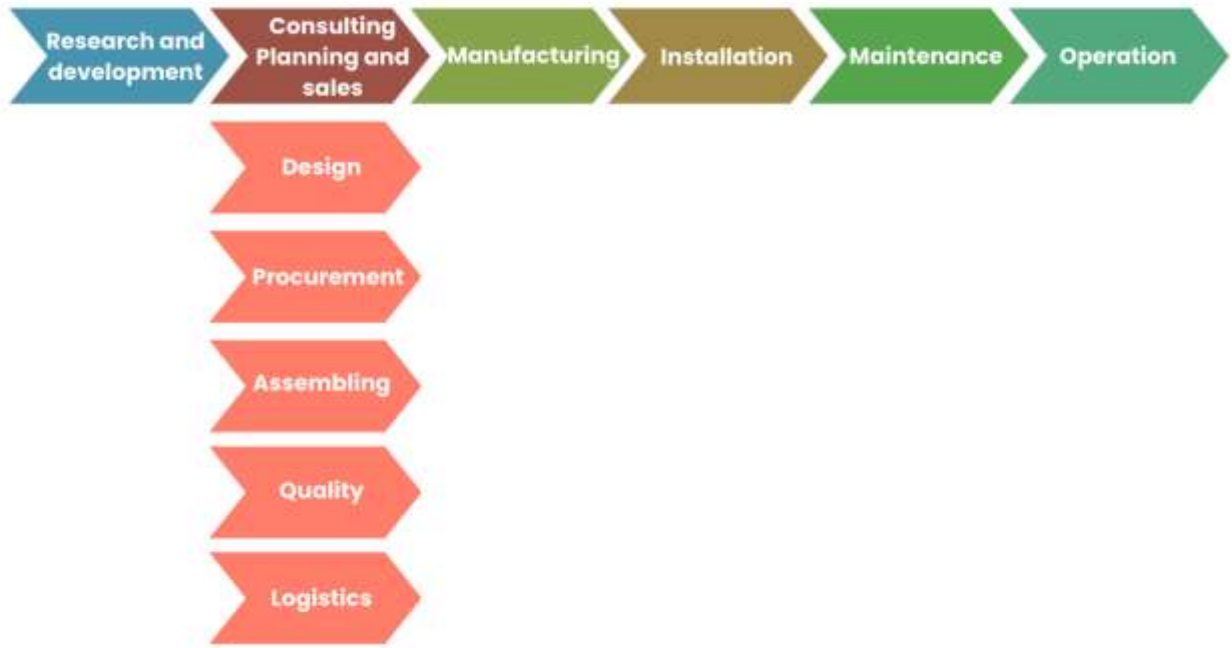


**Figure 4 Value chain of industrial heat pumps – SPIRIT project**

## 4.2 Professionals and skills – a competency framework for industrial heat pumps

In general terms, a competency framework is a structured description of the knowledge, skills and behaviours needed to perform a role effectively. It helps to clarify expectations, identify gaps and guide recruitment, training and certification pathways.

As a practical reference, this chapter draws inspiration from approaches developed for the residential heat pump sector, such as the framework produced in the HP4ALL project[6], which focused in particular on the role of the residential heat pump installer, while recognising that industrial applications require a broader set of roles and more cross-disciplinary coordination.

Industrial heat pumps rely on a wide range of professionals across all stages of the value chain. The following section provides a summary of the key professional roles

[6] Stefanica, D. (2023), D3.4 - HP skills and competency framework. HP4ALL Project / European Heat Pump Association, https://hp4all.eu/wp-content/uploads/2023/04/HP-Skills-and-Competency-Framework.pdf

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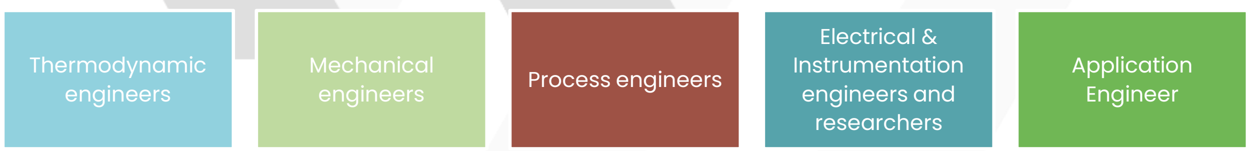
identified, together with their core skills and a brief description of their functions within each stage.

## 4.3 Research and Development


In the research and development phase, industrial heating needs are translated into practical heat pump concepts and system designs. It involves understanding how the system will be used, such as required temperatures, operating patterns and available heat sources and selecting the most suitable technical approach. Early designs are created, including how the heat pump will connect to the rest of the facility. The team also plans how the system will be monitored and controlled to ensure safe and reliable operation, while considering any safety and regulatory requirements.

To carry out these activities effectively, this stage typically involves a range of professional figures, including:




**Thermodynamic Engineer**

**Role**: Develop the heat pump cycle concept and assess the expected performance of prototype and pilot units. Define the operating envelope and use models to estimate COP, heating capacity and behaviour under different source and sink conditions. Translate performance targets into component requirements, such as compressor and heat exchanger needs. Define test conditions and acceptance criteria for performance verification. Work with process, mechanical, E&I and application engineers to ensure the concept is feasible, controllable, safe and suitable for real industrial use cases.

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**Key skills and knowledge:** Thermodynamics, simulation tools, programming languages, teamwork skills

## Mechanical Engineer

**Role**: Develop the mechanical design of prototype and pilot industrial heat pump systems. Define the layout, piping, component integration, pressure boundaries, materials and assembly approach, ensuring that the unit is buildable, testable and serviceable. They also support compliance with pressure equipment requirements and consider practical constraints such as manufacturability, maintenance access and oil/lubricant management. Work with thermodynamic, process, E&I and application engineering teams to align sizing targets, process connections, sensor placement, installation footprint and real-site constraints. Provide handover documentation such as drawings, bills of materials, material specifications and change records for later manufacturing and service activities.

**Key skills and knowledge:** 3D CAD software, PED, Oil and lubricants knowledge, component design, bill of materials, teamwork skills.

## Process Engineer

**Role**: Develop the process integration concept for prototype and pilot industrial heat pump systems. Define how the heat pump connects to the target process, including heat sources and sinks, water or steam interfaces, operating limits and behaviour during start-up, shutdown, or changing loads. Prepare key process design inputs, such as PFD/P&ID-level information and identify early safety or risk aspects, including hazardous-area issues where relevant. Work with thermodynamic, mechanical and E&I teams to align process connections, controls, alarms, interlocks and safety requirements.

**Key skills and knowledge:** ATEX certification, component design skills, steam production knowledge, teamwork skills.

## E&I Engineer/ Researcher

**Role**: Develop and validate the electrical, control and instrumentation design for prototypes and pilot industrial heat pump units. Define the power distribution approach, motor and drive integration, sensor layout, control logic, safety interlocks and data acquisition needed for testing and performance analysis. Ensure that the control system supports start-up sequences, capacity control, protective trips, diagnostics and safe operation. Work with process, thermodynamic, mechanical and application engineering teams to integrate controls, instrumentation and safety functions.

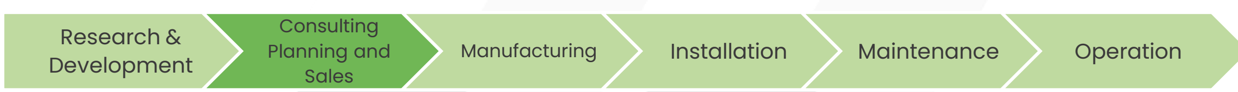
**Key skills and knowledge:** Heat pump control systems, safety procedures, instrumentation, electrical motors, high voltage equipment, teamwork skills.

**Application engineers**

**Role**: Act as the link between customer needs and the industrial heat pump product. Capture the required use case, including source and sink temperature ranges, operating patterns, availability targets and site constraints. Translate these needs into clear system requirements and ensure they are considered throughout the design and validation process. Support early feasibility studies, sizing logic, business-case inputs and pilot or demonstration projects. Work closely with thermodynamic, mechanical, process, electrical and controls teams to define testable requirements and validation scenarios. Also support sales and product management by translating validated technical performance into clear customer-facing specifications.

**Key skills and knowledge**: industrial process integration, requirements definition, energy performance assessment, stakeholder communication and basic knowledge of relevant safety and refrigerant standards, teamwork skills.

## 4.1 Consulting, planning and sales




During this stage, initial consulting and sales activities identify the customer's technical, operational and financial requirements, which provide the basis for developing the industrial heat pump solution. As R&D and technical planning progress, the proposed concept is further refined in consultation with the customer, taking into account technical feasibility, system integration, costs and project-specific constraints.

This phase includes confirming the customer's needs, developing the technical and commercial proposal, estimating costs, defining responsibilities and managing tender or contractual requirements. It also requires close coordination between technical, financial, commercial and legal specialists to ensure that the proposed solution is feasible, compliant and aligned with the customer's decision-making process.

Once the technical solution and commercial conditions have been agreed upon and the offer has been formally accepted by the customer, the project can proceed to detailed engineering and manufacturing. Consulting, planning and sales should therefore not be understood as a separate step following R&D or manufacturing, but as an iterative process that may precede R&D and subsequently develop alongside it.

The following paragraphs further investigate the main professional figures involved in this stage and describe their specific roles and responsibilities.

| | | | |
|---|---|---|---|
| Tender engineers | Accountants | Sales engineers | Legal & contract officers |

**Tender engineers**

**Role**: Convert customer requirements into a formal tender response: define technical scope, boundaries and assumptions; complete compliance matrices and interface lists; coordinate inputs (engineering, compliance, schedule, costing) into a deliverable proposal.

**Key skills and knowledge:** Technological background, production processes knowledge, cost regulation expertise.

**Accountants**

**Role**: Build and validate the bid's financial model: CAPEX/OPEX breakdown, cashflow/payment profile, margin and risk allowances; support option appraisal and (when requested) lifecycle cost framing using recognised appraisal/LCC guidance.

**Key skills and knowledge:** Economics background, analytical ability, financial and tax regulation expertise.

**Sales engineer**

**Role**: Lead consulting and solution shaping: capture process needs and site constraints, articulate value (efficiency/operability), coordinate technical clarifications with internal teams and align the offer with customer decision criteria and procurement route.

**Key skills and knowledge:** Process engineering background, marketing and communication skills.

**Legal and Contract officers**

**Role**: Draft/review tender and contract terms: manage departures/qualifications, allocate liability and performance guarantees, ensure procurement/contracting compliance (especially in public tenders) and embed relevant regulatory responsibilities (e.g., PED/ATEX/F-gas obligations where applicable).

**Key skills and knowledge:** Law degree, contracting expertise, liability regulation, negotiation skills.

## 4.2 Manufacturing


In the manufacturing phase, the validated outputs from R&D are turned into a complete, buildable industrial heat pump unit. This includes taking the design specifications, drawings and requirements and preparing them for efficient and consistent production.


The phase covers both adapting the design for manufacturing and carrying out the actual production activities, such as sourcing components, coordinating suppliers and assembling the system. It also ensures that key parts are tracked and meet quality standards. The process can be seen as a series of steps: design finalisation, procurement, assembly, quality checks and logistics, which together transform engineering plans into a fully assembled unit that is tested, documented and ready for delivery to the site.

The following section analyses each manufacturing substage in more detail and identifies the main professional figures involved.

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## 4.2.1 Design

In the design stage, the validated concept from R&D is turned into a production-ready industrial heat pump design. This includes finalising the layout of key components such as compressors, heat exchangers, piping, valves, electrical cabinets, sensors and control systems. Engineers also make sure the unit can be manufactured, assembled, tested, transported and later integrated into the customer's industrial site.

| Electrical & instrumentation engineers | Mechanical engineers | Thermodynamic engineer and researcher | Drafter | Process Engineer |
|---|---|---|---|---|

**Electrical & Instrumentation Engineers**
**Role**: Develop the electrical and control design. Specify the PLC/DCS logic, sensor layout, switchgear and safety interlocks. Ensure the control strategy meets the requirements (start-up sequences, protective trips) and complies with directives (e.g. low-voltage safety). Produce wiring diagrams for the assembly team. Work with mechanical and thermodynamics teams to integrate controls and safety functions.
**Key skills and knowledge:** Heat pump control systems, safety procedures, instrumentation, electrical motors, high voltage equipment, hardware expertise

**Mechanical Engineers**
**Role**: Create the mechanical design of the unit. Size and select compressors, pumps and heat exchangers; design the frame and piping routings; and choose materials resistant to operating conditions. Perform strength and vibration analysis. Generate mechanical drawings and specify connection flanges/manholes. Ensure the design will be manufacturable and meets Pressure Equipment Directive and pressure-vessel standards.
**Key skills and knowledge:** Pumps, compressors, piping, heat exchangers

**Thermodynamic engineers and researchers**
**Role**: Perform cycle design and simulation. Calculate capacities, COP and performance under expected operating conditions. Select refrigerant and two-phase system configurations. Provide the basis for pressure and temperature requirements, which feed into the mechanical design and control strategy. Assist in determining whether modifications (e.g. economizers, boosters) are needed to meet load or temperature targets.

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**Key skills and knowledge**: thermodynamics

**Drafters**

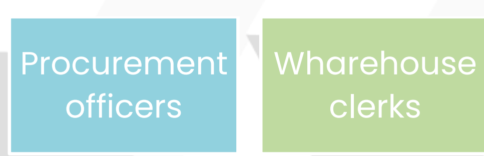
**Role**: Convert the engineers' concepts into detailed 3D models and production drawings. Produce assembly drawings and parts lists that the shop floor will use. Revise drawings based on engineering reviews, ensuring accuracy of dimensions and part identifiers. Maintain the design documentation repository.
**Key skills and knowledge**: 3D modelling, AutoCAD

**Process Engineers**

**Role**: Interface with the customer process requirements. Define how the heat pump will connect to the plant (interface temperatures, flow arrangements, control points). Provide process data (e.g. source/sink characteristics) to the design team. Ensure the design aligns with client process flow (integration phase input).
**Key skills and knowledge**: thermodynamics

### 4.2.2 Procurement

In the procurement stage, the components and materials needed to build the heat pump are sourced from suppliers. This includes major equipment such as compressors, heat exchangers, pumps, refrigerant circuits, control panels, instrumentation, insulation and structural frames. Particular attention is given to component quality, delivery times, certification and traceability, especially for safety-critical parts. Below, the main professional figures involved in this stage are identified and their specific roles are described.




**Procurement officers**

**Role**: Manage purchasing of all components and services needed for manufacturing. Issue Requests for quotations to suppliers, evaluate quotes for technical compliance and price and issue purchase orders. Ensure vendors provide required documentation (material certificates, test reports). Monitor order status, follow up on delays and coordinate deliveries. Liaise with design team to clarify technical details of ordered parts.
**Key skills and knowledge:** Procurements software

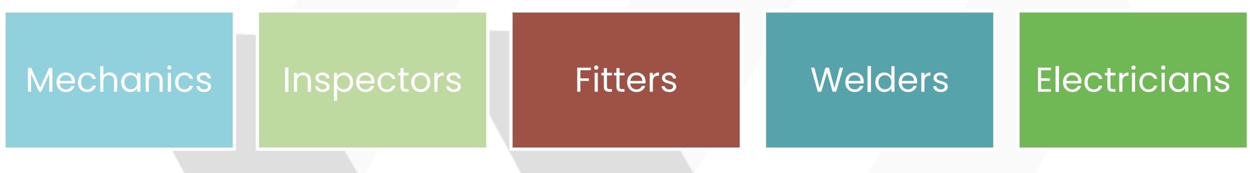
**Warehouse clerks**

**Role**: Receive and inspect incoming parts and materials. Verify that deliveries match POs (correct models, quantities, certificates). Store parts properly (some may be hazardous or heavy). Update inventory systems. Prepare kits for the assembly stage by staging parts and issuing pick lists.

**Key skills and knowledge:** Inventory management, goods receiving and inspection and safe handling and traceability of industrial components.

### 4.2.3 Assembly

During assembly, the industrial heat pump unit is physically built. Mechanical, electrical and control components are installed and connected according to the design. This can include assembling the refrigerant circuit, mounting heat exchangers and compressors, installing pipework, wiring sensors and control panels and integrating safety systems. The aim is to produce a complete unit that is ready for inspection and testing. The following section identifies the main professional figures involved in the assembly stage and describes their specific roles in ensuring that the heat pump unit is correctly built, connected and prepared for testing.




**Mechanics**

**Role**: Perform physical assembly of the heat pump. Fit and torque mechanical components per the drawings (compressors, pumps, piping). Align shafts, install motors and couplings and assemble heat exchanger bundles. Use certified procedures for pressure-containing joints. Follow the assembly manual step by step and raise any dimensional or fit issues.

**Key skills and knowledge:** Vessel certification, understanding manufacturing drawings and assembly manuals.

**Inspectors**

**Role**: Oversee the assembly process. Check each sub-assembly against design specs and quality standards. Conduct in-process inspections (e.g. dimensional checks, pressure tests) and document results. Authorize proceeding to next step or flag nonconformities for correction. Ensure traceability of parts (marking welded vessels, recording calibration status).

**Key skills and knowledge:** Senior technicians, knowledge of production plans, regulation compliance.

**Fitters**

**Role**: Install and connect structural and mechanical parts. Assemble piping, mounts and non-welded joints (using bolts/gaskets). Adjust alignments under guidance. Assist mechanics and welders by holding parts, applying sealants and performing preliminary fittings as needed.

**Key skills and knowledge:** Mechanical assembly skills, ability to read manufacturing drawings and safe handling and fitting of industrial components

**Welders**

**Role**: Complete all welding and brazing operations per approved welding procedures. Weld heat exchanger tubes, pressure vessel seams and critical piping. Ensure weld quality meets standards. Label and log each weld for traceability.

**Key skills and knowledge:** Welding certification, 3D awareness

**Electricians**

**Role**: Execute all electrical installation. Mount control panels, run conduit and cables. Wire motor connections, power supplies and control circuits following the design wiring diagrams. Perform continuity and insulation tests after wiring. Ground the electrical system as required.

**Key skills and knowledge:** Electrical background, technical degree, wiring plan reading skills

### 4.2.4 Quality

The quality stage checks that the industrial heat pump has been built correctly and performs as required. This includes inspections of the assembly, pressure and leak tests, electrical checks, control system verification and functional testing. Where possible, the unit may also undergo performance testing to confirm that it meets the expected heating capacity, temperature levels, efficiency and safety requirements. Below, the main professional figures involved in this stage are identified and described.

**Inspectors**

**Role**: Conduct final quality checks before shipping. Perform functional tests (pressure/leak tests, control runs, insulation tests) and verify all safety devices operate correctly. Review the complete assembly against the approved design and check all certifications are in place. Issue final inspection report and authorize release.
**Key skills and knowledge:** Safety procedures, regulation expertise, production plan, technical discipline, knowledge on quality standards set by regulation and company

**Quality Engineers**

**Role**: Develop and enforce quality control processes. Review inspection results and test reports and handle any corrective actions. Ensure that manufacturing records meet regulatory and customer requirements. Coordinate audits (internal or customer) of the manufacturing process. Drive continuous improvement in production quality.
**Key skills and knowledge:** Safety procedures, regulation expertise

## 4.2.5 Logistics

In the logistics stage, the completed heat pump is prepared for delivery to the customer's industrial site. This includes protecting sensitive components, preparing transport documentation, organising packaging or skidding and planning the shipment of what may be a large and heavy unit. The goal is to ensure the heat pump arrives safely, with the necessary documentation and is ready for installation and commissioning. The next sections outline the key professional figures active in this stage and explains their main responsibilities.


**Logistic Officers**

**Role**: Plan and manage the shipment of the completed heat pump. Arrange transport (trucks/cranes) suitable for the size and weight of the unit. Ensure export/import regulations are met if needed (e.g. customs documentation for refrigerant-containing equipment). Coordinate with the warehouse and assembly teams to schedule packing and dispatch.
**Key skills and knowledge:** Communication skills, problem-solving

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**Warehouse clerks**

**Role**: Pack and prepare the finished equipment for delivery. Inventory final components and accessories, issue packing lists and secure the unit for transport (padding, bracing). Update stock records to remove shipped items. Handle any last-minute shipping paperwork.

**Key skills and knowledge:** on-the-job training, practical skills

# 4.3 Installation

Research and Development → Consulting Planning and Sales → Manufacturing → **Installation** → Maintenance → Operation

In the installation phase, the industrial heat pump is delivered to the customer's site and integrated into the existing industrial facility. At this stage, the focus shifts from manufacturing the unit to preparing the site, positioning the equipment, connecting it to mechanical, electrical and control systems and ensuring that all works are carried out safely and in line with applicable requirements. This phase includes activities such as civil works, lifting and placement of the unit, pipework and electrical installation, control system setup, safety checks and preparation for commissioning. Effective coordination between contractors, engineers, inspectors and site teams is essential to ensure that the heat pump is correctly installed, ready for testing and suitable for handover to the customer.

The following paragraphs further investigate the main professional figures involved in the installation phase and describe their specific roles and responsibilities.

| | | | | | |
|---|---|---|---|---|---|
| Commissioning engineers | Technicians and riggers | Legal officers | Civil engineers | Safety engineers | Contractors |
| Crane operators | Construction workers | Third-party quality inspectors | Project managers | Electrical workers | Programmers |

**Commissioning engineers**

**Role**: Plan and execute pre-commissioning and commissioning: verify installation completeness, coordinate start-up, perform functional and performance tests (incl.

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controls and safety devices), document results, manage punch lists and support operator training/handover.
**Key skills and knowledge:** Technological knowledge of Heat Pumps, process integration experience

## Technicians and riggers

**Role**: Select, inspect and use rigging gear (slings, shackles, spreader beams) and connect/disconnect loads; guide lifts, manage load balance/centre-of-gravity issues, control the fall zone and coordinate with crane operators/signal persons for safe, precise placement
**Key skills and knowledge:** On-the-job training, 3D awareness

## Legal officers

**Role**: Manage the compliance "paper trail" and permissions enabling installation: permits, notifications, contracts, liability/insurance clauses and evidence files; ensure obligations linked to directives/standards affecting the installation (e.g., pressure equipment, explosive atmospheres, refrigerants) are contractually and procedurally controlled.
**Key skills and knowledge:** Law degree, expertise in national and local regulations

## Civil engineers

**Role**: Translate design intent into buildable site works: foundations/plinths and supports, penetrations and equipment access, drainage and plant-room readiness; verify that plant spaces/machinery rooms and enabling works meet applicable structural and installation-site constraints (incl. ventilation/safety provisions where relevant).
**Key skills and knowledge:** General legal requirements knowledge (junior level)

## Safety engineers

**Role**: Own and enforce the site safety management system: risk assessments and method statements, permit-to-work controls (lifting, hot work, confined space), contractor coordination and verification that ATEX/PED-related constraints are respected during installation and testing activities.
**Key skills and knowledge:** ATEX, vessel and safety certification

## Contractors

**Role**: Carry out the on-site works needed to install the industrial heat pump and connect it to the customer's facility. This may include mechanical, piping, electrical and control-system installation, as well as supports, pipework, cable routes, wiring and

utility connections. They work according to drawings, method statements, safety procedures and project specifications, while coordinating with engineers, installers and commissioning teams to prepare the system for start-up and handover.
**Key skills and knowledge:** Industrial installation experience, ability to read technical drawings, mechanical/electrical awareness, site safety knowledge, coordination skills, quality documentation and relevant certifications where required, such as electrical or refrigerant-handling competence.

### Crane operators

**Role**: Safely set up and operate cranes/lifting equipment for offloading and placing heat-pump modules/skids; follow lift plans and signalling; maintain exclusion zones and safe clearances; coordinate with riggers and signal persons to position loads accurately without damage.
**Key skills and knowledge:** safety certification, 3D awareness, precision handling.

### Construction workers

Execute on-site build and assembly tasks: positioning/bolting equipment, installing supports and pipework, insulation and basic mechanical fit-up, housekeeping and protection of equipment; work to method statements and coordinate with safety leadership and commissioning readiness checks.
**Key skills and knowledge:** Safety certification, on-the-job training, practical skills.

### Third-party quality inspectors

**Role**: Independently verify installation quality and compliance: witness/verify required tests (e.g., pressure/leak/functional safety checks), check traceability and documentation, issue inspection reports/nonconformities and (where applicable) support notified-body or accredited inspection evidence needs.
**Key skills and knowledge:** Regulatory knowledge, technological skills are a plus.

### Project managers

**Role**: Integrate all installation activities across disciplines: plan and control schedule/cost/resources, coordinate contractors and interfaces (civil–mechanical–electrical–controls), maintain governance and reporting, manage risk/change and drive readiness for commissioning and handover.
**Key skills and knowledge:** Project management competence, scheduling & cost control, contractor management, risk & change management, basic OSH awareness

### Electrical workers

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**Role**: Install and verify electrical infrastructure and connections: power supplies, protection devices, earthing/bonding, motor and auxiliary circuits, instrument wiring; perform safe isolation and electrical testing/verification; resolve installation defects prior to commissioning.
**Key skills and knowledge:** Licensed/competent electrician (national scheme), electrical safety & isolation competence, cable termination/testing skills, knowledge of applicable wiring rules

**Programmers**
**Role**: Configure, develop and validate control software and integrations: implement sequences, alarms, interlocks and safety logic; integrate signals with SCADA/BMS/DCS where required; support functional testing during commissioning; document configuration, versions and setpoints for handover.
**Key skills and knowledge:** PLC/controls engineering competence, programming, industrial comms integration, testing & documentation discipline

## 4.4 Maintenance

Research and Development → Consulting Planning and Sales → Manufacturing → Installation → **Maintenance** → Operation

In the maintenance phase, the industrial heat pump is kept safe, reliable and efficient throughout its operating life. This stage includes routine inspections, performance monitoring, troubleshooting, repairs, replacement of worn or faulty components and verification of safety devices. Maintenance also involves managing spare parts, updating service records, coordinating planned interventions with the customer and ensuring that the system can be safely shut down, worked on and returned to service. Because industrial heat pumps include mechanical, electrical, refrigerant, control and safety systems, this phase requires close coordination between technical, operational, commercial, procurement and logistics roles.

The following paragraphs further examine the main professional figures involved in the maintenance phase and describe their specific responsibilities.

| Service engineers | Technicians | Sales officers | Procurement officers | Logistics officers and inspectors | Operators |
|---|---|---|---|---|---|

**Service engineers**

**Role**: Perform technical maintenance to keep the industrial heat pump safe and efficient. This includes inspecting the refrigerant circuit, checking for leaks, supporting repairs or recharge activities, calibrating instruments, checking lubricants and testing safety devices. They coordinate with procurement, logistics and operators to manage spare parts, replacements, handover and return-to-service activities.

**Key skills and knowledge:** Knowledge of operation manuals for troubleshooting, F-gas handling certification, training on electrical safety and hazardous-area procedures.

**Technicians (Mechanics, Welders, Fitters, Electricians)**

**Role**: Carry out the physical maintenance work on the industrial heat pump. This includes mechanical repairs, replacement of components, checks on pressure equipment, safety relief devices, structural integrity and electrical maintenance under safe isolation procedures. They work under the direction of service engineers and coordinate with operators to ensure the system is safely isolated before maintenance begins.

**Key skills and knowledge:** Vessel certification, manufacturing drawing comprehension, 3D awareness, wiring plan reading, safety training, welding qualifications

**Sales officers**

**Role**: Manage the commercial side of industrial heat pump maintenance. They prepare service contracts, renewal proposals and upgrade options based on equipment condition and usage. They also coordinate planned maintenance visits with clients, service engineers and logistics teams to ensure the work is scheduled and supported with the required spare parts.

**Key skills and knowledge:** Maintenance and sales expertise, familiarity with service agreements, customer communication, Competence in daily system checks, alarm recognition and safe shutdown procedures.

**Procurement officers**

Source and order spare parts and external services needed for industrial heat pump maintenance. They ensure replacement components, such as compressors, valves and sensors, meet the required technical specifications and certifications. They also track lead times for critical spares, manage warranty claims and returns and coordinate with service engineers and logistics teams to ensure timely delivery and traceability.

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**Key skills and knowledge:** technological knowledge of systems, understanding of spare parts compatibility, lead-time management and compliance labels

**Logistics officers and inspectors**

**Role**: Manage spare parts inventory and related compliance documentation for industrial heat pump maintenance. They receive and inspect incoming parts and consumables, check certificates, verify correct labelling and prepare part kits for maintenance jobs. They also manage returns of failed parts for analysis or warranty and update inventory and maintenance records.

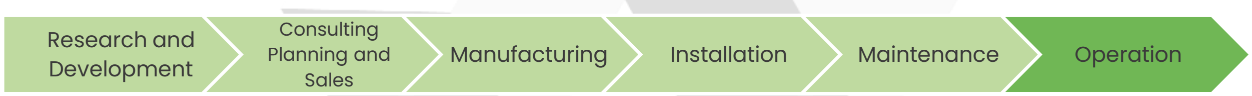
**Key skills and knowledge:** Analytical skills for proper labeling, expertise in hazardous material handling and inventory control, familiarity with documentation requirements.

**Operators**

**Role**: Carry out first-level monitoring of the industrial heat pump during daily operation. They record operating parameters, alarms and anomalies such as unusual temperatures, pressures, or system behaviour. They also prepare the unit for maintenance through safe shutdown and isolation, then support checks before the system returns to service.

**Key skills and knowledge:** Heat pump control systems, thermodynamics, safety procedures, instrumentation, electrical motors, high voltage equipment, hardware expertise

## 4.5 Operation




In the operation phase, the industrial heat pump is actively used within the customer's industrial process to provide heating, cooling, or heat recovery according to production needs. The focus of this stage is to run the system safely, efficiently and within its defined operating limits. This includes starting and stopping the unit, adjusting loads and operating modes, monitoring temperatures, pressures, flows, power consumption and alarms and responding correctly to abnormal conditions or equipment trips. Operation also involves continuous performance optimisation, coordination between the end user and the heat pump manufacturer and proper recording of events, settings, maintenance actions and safety-related checks.

Because the heat pump interacts with both the industrial process and the control system, this stage requires close collaboration between operators, process engineers and E&I engineers.

The following paragraphs further examine the main professional figures involved in the operation phase and describe their specific responsibilities.

| Operators | Process engineers (end user) | Process engineers (manufacturer) | E&I engineer |
|---|---|---|---|

**Operators**

**Role**: Carry out day-to-day operation of the industrial heat pump within the defined operating window. They start and stop the system according to schedule, change modes and loads according to procedures and respond to alarms or trips using HMI tools and operating data. They monitor key indicators, manage first responses to equipment trips, make the plant safe when required, identify alarm causes and escalate issues to engineers. They also ensure that operating events, leak checks, maintenance actions, settings and alarms are properly recorded in the logbook.
**Key skills and knowledge:** control system knowledge, operational process expertise, measurement systems, data storage, basic data analysis, operational procedure training and required equipment certifications such as ATEX zone entry or F-gas awareness where applicable.

**Process engineers**

**Role**: Optimise the operation of the heat pump within the wider industrial process. On the end-user side, they ensure the system fits real plant conditions; on the manufacturer side, they support correct use and performance optimisation. They define operating procedures, set safe operating limits, analyse performance data, adjust setpoints, and work with E&I engineers and operators to address abnormal behaviour or efficiency losses.
**Key skills and knowledge:** data analysis methods, applied thermodynamics, heat-exchanger knowledge, process integration expertise and experience with plant operating envelopes.

**Electrical & instrumentation (E&I) Engineers**

**Role**: Ensure the integrity of the control and instrumentation systems during operation. They maintain and adjust the PLC/DCS and HMI so that measurements, alarms and plant status information remain reliable. They calibrate sensors, verify signals for flow, pressure, temperature and power and update alarm or trip settings to support safe operation, including refrigerant leak shutoff and interlocks. They also diagnose faults by checking instrument plausibility and control logic and support operators during trips by investigating sensor or control-related causes.

**Key skills and knowledge**: Control system knowledge, operational process expertise, measurement systems, data storage, functional safety awareness, change management and control system integration.

# 5. TRAINING PROGRAMMES ON INDUSTRIAL HEAT PUMPS

A number of training programmes and courses related to Industrial Heat Pumps have emerged in recent years, reflecting the growing interest in these technologies and their role in industrial decarbonisation. These initiatives typically target engineers, energy professionals and researchers with an existing technical background and aim to introduce the fundamentals, potential applications and design considerations of industrial heat pump systems.

Examples of planned initiatives specifically addressing industrial or high-temperature heat pump applications include the following (Table 2).

| Course initiative | Provider | Main focus | Duration | Target audience | Practical component |
|---|---|---|---|---|---|
| **SPIRIT Summer School on Industrial High-Temperature Heat Pumps** Link | Danish Technical University in collaboration with the European Heat Pump Association | High-temperature heat pumps for decarbonising industrial process heat; strong R&D and integration focus | 10 days | PhD students, industry professionals and consultants with thermal energy / thermo-fluid background | Lectures, expert talks, project work, site visits and real-world/pilot HTHP applications |
| **Masterclass Warmtepompen Industrie** Link | TVVL, commissioned by Stichting Post HBO Koudetechniek | Industrial heat pumps under specific industrial conditions; operation range, integration, pinch technology and practical cases | 2 days, | Professionals seeking specialised knowledge of industrial heat pumps; admission may depend on intake interview | Theory, practical cases and group exercises |
| **Continuing Education Course "Industrial Heat Pumps"** Link | OST – Institute for Energy Systems | Industrial and high-temperature heat pumps for process heat, especially 90–150°C; market, economics, technology, | 1-4 days | Energy managers, planners, consultants, energy suppliers, contractors, plant engineers, manufacturers, distributors and | Lab training and industrial excursion |

| | | | | | |
|---|---|---|---|---|---|
| | | integration and case studies | | energy-sector suppliers | |
| **Large-scale Heat Pumps for Industry and District Heating** Link | DTI – Danish Technological Institute | Large heat pumps for heat production in industrial plants and district heating systems | 1 day | Likely aimed at professionals involved in large-scale heat pump projects in the industry and district heating areas | Lectures, smaller exercises, group exercise; it may include a lab tour of DTI's large-scale heat pump facilities |

**Table 2: Training courses on industrial heat pumps**

These initiatives play an important role in raising awareness of industrial heat pump technologies and their potential. Short-term courses and summer schools are particularly useful for building foundational knowledge and encouraging exchange between academia, technology providers and industrial stakeholders.

However, industrial heat pumps are highly customised and context-specific systems. Their design, integration and operation depend on the manufacturer, the host industrial process and the specific application. For this reason, general training formats can only provide a starting point and are not sufficient to develop the practical competencies needed for real-world deployment. This was also reflected in the case studies and stakeholder consultations conducted as part of this study. While general knowledge of thermodynamics and heat pump principles is often available, system-level expertise remains limited.

Addressing this gap requires more structured and practice-based learning. Future training should support the development of hybrid professional profiles combining process engineering, thermal systems and system integration expertise. Hands-on learning linked to real industrial projects and demonstration sites will be especially important. Overall, existing initiatives are an important first step but further specialised and application-oriented training is needed to build the professional capabilities required for wider industrial heat pump deployment.

The following chapter builds on this discussion by looking at the practical experience of two SPIRIT demonstration sites. It examines the skills gaps encountered during

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project implementation, the solutions adopted to address them and the lessons learned from integrating industrial heat pumps into real operating environments.

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# 6. INSIGHTS FROM SPIRIT DEMONSTRATION SITES: SKILLS NEEDS AND GAPS IN PRACTICE

As emerges from Chapter 4, the professionals and skills required to develop, integrate and operate an industrial heat pump are shared among several actors across the value chain. This is particularly important because industrial heat pumps are complex, large-scale systems made up of multiple components, often supplied by different manufacturers and integrated into existing industrial processes.

The SPIRIT demonstration sites provide a valuable opportunity to observe these dynamics in real industrial environments. The project aims to demonstrate high-temperature industrial heat pump technologies integrated into operational production processes in the food and paper sectors, with sink temperatures between 135 °C and 160 °C. Each demonstration involves three main types of partners: a technology provider, a knowledge provider and an industrial end user. Together, these partners contribute to proving that industrial heat pumps can be integrated into existing processes without disrupting production, while also generating technical knowledge and practical guidance on heat pump integration.

The first demonstration site is located at Stella Polaris, a prawn processing facility in Norway. The company cooks, peels, freezes and packs cold-water prawns for international customers. In their factory in Tromsø, steam is used for cooking, cleaning and other processes and it is mainly produced by a propane boiler. As part of its ambition to reach zero-emission production by 2030, Stella Polaris is working to reduce steam consumption and move away from fossil fuels. Within SPIRIT, a cascade high-temperature industrial heat pump supplied by Mayekawa will be integrated into the site while the coordination of the demonstration site is supported by TNO. The system will recover waste heat from the existing refrigeration plant, which would otherwise be rejected to seawater and upgrade it to produce steam for prawn cooking.

The second demonstration site is located at Tiense Suikerraffinaderij in Belgium, a sugar production facility that processes sugar beets into sugar for industrial and consumer markets. Sugar production includes several heat-intensive steps, such as diffusion, evaporation and crystallisation, making it a relevant application for industrial heat pump integration. Within SPIRIT, Tiense Suiker will integrate a high-temperature

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heat pump supplied by GEA into the core of the production process, with the aim of supporting future electrification and decarbonisation of the site. The Danish Technological Institute acts as knowledge provider, supporting the technical coordination of the demonstration.

The following paragraphs present the main lessons learned from these demonstration sites in relation to skills and competencies. The insights are based on interviews with Stella Polaris and Mayekawa for Demo-site 1 and Tiense Suikerraffinaderij and GEA for Demo-site 2.

More specifically, the interviews were guided by the following questions:

- What are the main professional figures that have been involved in the demonstration site from the start?
- Was it clear from the beginning which professional profiles needed to be involved?
- Have there been any issues related to skills gaps among the professionals involved? Were any specific competencies missing at the start of the project? If yes, which ones and how were these issues addressed?
- Based on your experience at this demonstration site, is there a need to increase the number of certain professional profiles? If so, which ones?
- Were all safety standards to be applied in the demonstration site clear from the beginning? Is there enough in-house knowledge on safety to run the heat pump? How will these aspects be handled?
- Is there any specific lesson learned from the demonstration site implementation that is relevant to skills and competencies?
- Did staff in the end-user company receive, or will they receive, additional training on the operation of the heat pump during the project? If yes, in which areas, by whom and how?
- More generally, are there enough professionals in Europe to meet the needs of the industrial heat pump value chain? If not, which types of professionals are most lacking and what is needed to address this gap?

Based on the answers provided during the interviews, the insights have been structured into four main areas:

1. **The professional figures involved in the demonstration sites**, highlighting the roles and responsibilities across different project phases.

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2. **The skills gaps identified and the solutions adopted to address them**, including the use of external expertise and internal adjustments.
3. **The training and safety aspects**, focusing on how competencies were developed during the project and how safety requirements were managed.
4. **The key lessons learned**, summarising the main takeaways regarding skills and competencies for the implementation of industrial heat pump systems.

## 6.1 Professionals involved

### Demonstration site 1 – Stella Polaris & Mayekawa

The implementation of the demonstration site at Stella Polaris involved a range of professional profiles from both the technology provider (Mayekawa) and the end user.

From Mayekawa's side, the core team consisted of a project engineer, designer, controls engineer and project manager. Depending on the project phase, additional profiles were involved, including production personnel, mechanics, welders, fitters, electricians and inspectors. During start-up, the project engineering team provided support. For operation and maintenance, the end user is trained to perform daily operation, while maintenance is generally handled by external contractors. Mayekawa may provide support for specific critical tasks, such as compressor maintenance, usually through a contractor rather than directly to the end user.

On the end-user side, Stella Polaris does not have a large in-house engineering team and relies on subcontractors. Multiple contractors were involved across different technical areas, including ammonia, steam, electrical systems and refrigerant charging. There was no single coordinating party covering the full scope.

In terms of in-house competencies, the CEO (with a refrigeration/thermodynamics background) and the CTO/technical manager (civil engineering/physics) were identified as critical. Stella Polaris also relied from an early stage on external specialists, including support for regulations and safety, as well as contractors for installation and piping. Technical discussions with Mayekawa were also part of the process.

Regarding the identification of required professional profiles, a difference was observed between the technology provider and the end user. For Mayekawa, the required profiles were clear from the beginning, based on experience from a similar project. For Stella Polaris, this was more gradual. While there was an initial understanding of the main needs and reliance on trusted external partners, the company joined the project at a later stage and some responsibilities still had to be clarified. Several months of meetings were therefore needed to define roles, responsibilities and coordination arrangements.

In addition, the demonstration highlighted the need to strengthen specific competencies, particularly in relation to safety and ATEX requirements associated with the pentane heat pump.

Overall, the Stella Polaris experience shows that when an end user operates with a lean internal engineering structure, early involvement of a general contractor or coordinating technical partner can be valuable. Such a role can help guide the process, clarify responsibilities and ensure coordination across the different specialised actors involved.

#### Demonstration site 2 – Tiense Suikerrafinaderij & GEA

The implementation of the demonstration site at Tiense Suikerrafinaderij involved a wide range of professional profiles across engineering, execution, commissioning and operation, both from the end user and the technology provider (GEA).

From the end-user side, Tiense Suikerrafinaderij reported the involvement of multiple disciplines. These included process engineers and project engineers, as well as civil engineering support for building-related works, which was partly outside their core expertise and therefore partially outsourced. Electrical engineers were involved to connect the heat pump to the electricity infrastructure, while piping engineers were responsible for piping design and installation. Programming and automation specialists were engaged to develop the interface between factory systems and the heat pump. In addition, notified bodies and compliance specialists were involved to carry out legal checks on site.

Execution activities required skilled workers across disciplines, including civil works, piping, welding and electrical installation. Additional roles included scaffolding teams for access structures and insulation teams for insulating pipes and installations. Production and operations personnel were involved mainly in the operational phase, including running the equipment and handling steam for the process.

From the technology provider's side, GEA described a similarly broad set of roles extending beyond core project engineering. These included application and technical engineers, particularly in heat exchangers and thermal transfer, as well as automation and control specialists, who were involved from the early stages. System modelling and full system calculations were carried out to validate the concept. The project also involved screw-compressor developers, as well as expertise in ATEX and explosion-protection requirements, supported by electrical engineering for compliant cabling.

In addition to internal roles, GEA worked closely with external suppliers and research institutes to address specific technical challenges. These included oil suppliers, bearing manufacturers and research institutes for testing components such as O-rings under specific conditions. External partners were also involved in the development of the steam generation system, including evaluation of different technical approaches.

Regarding the identification of required professional profiles, both the end user and the technology provider indicated that this was not fully clear from the beginning. From the end-user perspective, initial project plans differed from the final implementation. For example, the installation was initially planned within an existing building, but later required a new standalone structure, which increased the need for civil engineering works. In addition, more effort than expected was required for process engineering, particularly in defining and integrating the heat source and sink, including thermal calculations and heat exchanger selection. This led to a more extensive involvement in process integration than initially anticipated.

From GEA's perspective, a significant share of the required roles and scope, estimated at more than 50%, was not defined at the start of the project. Key aspects that emerged during the project included the extent of ATEX and explosion-protection requirements, oil-related considerations under high-temperature and high-pressure conditions and the scope of execution activities such as cabling, piping, insulation, leak testing and vacuum work. Some of these activities were taken on by GEA due to the absence of a dedicated contractor or system integrator.

## 6.2 Skills gaps identified and solutions

### Demonstration site 1 – Stella Polaris & Mayekawa

Insights from both Mayekawa and Stella Polaris indicate that, while individual competencies were generally available, challenges emerged in their integration and application at the system level.

From Mayekawa's perspective, individual professionals involved in the project possessed the required theoretical competencies. However, there was no single role responsible for coordinating all efforts, challenging decisions and guiding the process from a practical, system-level perspective. As a result, although competencies were covered on paper, integration across disciplines proved difficult in practice.

Specific competencies were often missing and had to be sourced externally. These included the role of a general contractor with knowledge of the steam circuit, as well as expertise in risk assessment and ATEX-related requirements, who had to be hired by Stella Polaris. The reliance on multiple individual contractors led to a fragmented approach. In the absence of sufficient in-house experience, this also made it difficult to assess and validate the quality of outsourced work. In addition, the remote location and R&D nature of the project limited the availability of contractors willing to take responsibility for the entire scope.

From the end-user perspective, Stella Polaris did not identify major internal skills gaps beyond the need for additional expertise, which was addressed by engaging external companies. At the same time, the company strengthened its internal capabilities in specific areas. In particular, Stella Polaris advanced its factory digitalisation through SCADA systems and brought in an electrical and instrumentation engineer to support monitoring, alarms and control logic, which were considered critical for the project.

Looking ahead, Stella Polaris expects to continue relying on external specialists for heat pump service and maintenance, including tasks such as charging oil and pentane and other specific service activities. Rather than significantly expanding in-house technical profiles, the company aims to maintain core internal competencies to understand system fundamentals and oversee external suppliers.

Regarding safety, ATEX-related requirements were identified as a key challenge and were not fully understood at the beginning of the project. Over time, Stella Polaris considers that it has developed sufficient in-house capability to operate the system safely, supported by written procedures, training and continued access to external expertise where needed.

### Demonstration site 2 – Tiense Suikerrafinaderij & GEA

Both Tiense Suikerrafinaderij and GEA identified several skills gaps and challenges during the implementation of the demonstration project, particularly related to system integration, regulatory interpretation and specific technical domains.

From the end-user perspective, the implementation phase was described as challenging, partly because the application involved aspects that were new for the technology provider. While GEA was considered strong in compressors, refrigeration and piping, it was perceived as having less experience in process-side integration, particularly in relation to safely and reliably producing and handling steam. As a result, questions raised during the project sometimes revealed gaps in experience with these specific applications.

A key missing capability identified by Tiense Suikerrafinaderij was the absence of a system integrator or contractor. In their view, such a role is typically required to manage the installation of the heat pump within a factory environment and to integrate it into the steam and process context. As this role was not present, the end user had to take on a significant share of the integration work, with contribution from GEA.

Another challenge concerned the interpretation of legal and regulatory requirements, including aspects related to the machinery safety and compliance. This was described as particularly complex due to the novelty of the application and the use of pentane as a working fluid. While relevant European legislation exists, it is not always clearly defined for this specific type of system, requiring interpretation and adaptation to the project context. To address this, Tiense Suikerrafinaderij sought expertise from partners experienced in boilers and similar types of equipment and involved notified bodies familiar with the applicable legislation. These external experts supported the translation of regulatory requirements into concrete design and installation choices, with the aim of ensuring a high level of safety.

From GEA's perspective, several technical skills gaps were also identified. These included limited knowledge related to oil behaviour in high-temperature and high-pressure hydrocarbon heat pump systems. In some cases, even suppliers were not able to provide complete answers, which led to additional testing activities, including the use of a research institute. Specific concerns included the interaction between pentane and oil, particularly the potential impact on oil viscosity.

GEA also identified challenges related to ATEX and explosion-protection execution. To address these, an ATEX consultant was involved and differences in local implementation requirements were observed, which led to adjustments in areas such as cabling.

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In addition, a practical skills gap was noted on the service side. While some technicians held certifications for working with hydrocarbons, they did not always have experience with large-scale industrial hydrocarbon systems, which became relevant during on-site work and commissioning.

Overall, the experience highlights the importance of system integration capabilities, access to specialised technical knowledge and the ability to interpret and apply regulatory frameworks in the context of new and complex industrial heat pump applications.

## 6.3 Training and safety aspects

### Demonstration site 1 – Stella Polaris & Mayekawa

From the technology provider's perspective, safety standards, including ISO standards, EU directives and ATEX requirements, were clear on paper. Where uncertainties existed, these were addressed through external expertise, with formal assessments and reports produced. However, the implementation and practical application of safety measures were assigned to individual contractors. In this context, neither Mayekawa nor Stella Polaris always had sufficient in-house experience to fully assess or validate the work carried out.

Following an incident during the project, several improvements were introduced. These included clearer documentation and written instructions, more structured safety procedures and a clearer allocation of responsibilities. The end user is expected to implement safety, emergency and evacuation protocols.

Regarding training, Mayekawa prepared a customised operation and maintenance manual and will provide final training on the operation, maintenance and safety of the heat pump. The training covers daily operation checks, basic troubleshooting, monitoring of key parameters and maintenance schedules. Both short-term (daily checks) and long-term monitoring recommendations are included. Heavy maintenance tasks, such as compressor overhaul and refrigerant handling, are expected to be carried out by external contractors.

Remote monitoring will be set up, with operation and monitoring during the project involving collaboration between Stella Polaris on-site and Mayekawa remotely. After project completion, the end user is expected to appoint a contractor for ongoing support, with Mayekawa providing support and spare parts through this contractor.

From the end-user perspective, ATEX requirements represented the main safety challenge and were not fully understood at the beginning of the project. Over time, Stella Polaris considers that it has developed sufficient in-house capability to operate the system safely, supported by written procedures, training and continued use of external expertise where required.

In terms of training, personnel working in ATEX areas are required to complete a hazardous-area safety course provided by an external training provider. In addition, staff received guided walk-throughs and system-related orientation. Stella Polaris indicated openness to further guidance on more specific training needs for technicians.

At the time of the interview, the heat pump was not yet fully operational, with commissioning activities ongoing and Mayekawa expected to return to support this phase.

#### Demonstration site 2 – Tiense Suikerrafinaderij & GEA

From the end-user perspective, Tiense Suikerrafinaderij identified both safety and operational aspects as key areas requiring attention during the project.

Regarding food-production constraints, a detailed analysis of contamination-related risks was carried out. It was noted that detecting potential contamination within the steam line is technically challenging. A risk assessment was therefore performed to identify the main risks. In this context, pentane leaks were not considered the highest risk, as pentane is gaseous and the process includes degasification, meaning it would leave the system. Instead, oil was identified as the main contamination-related risk. It was also emphasised that, in food production, physical distance does not eliminate risk: even if the heat pump is located far from the production line, any connection to the process creates a potential contamination pathway, which must be treated as a risk.

In terms of operation, Tiense Suikerrafinaderij does not expect to increase staff numbers. The intention is to operate the heat pump internally, while relying on support from GEA or other external service providers when needed, rather than developing full in-house specialization in heat pump technology.

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Regarding safety standards, these were not fully clear at the beginning of the project. While the company considers that it has sufficient overall safety knowledge, additional focus is planned on training staff in ATEX and explosion-risk aspects. This applies not only to project team members but also to technicians who may work in the facility over time. Examples of unsafe practices, such as welding or cutting activities that generate sparks, were highlighted, along with the importance of working under appropriate safety procedures. It was also noted that safety considerations became progressively more prominent throughout the project, leading to the implementation of certain measures, some of which may be reassessed in the future.

To ensure safe operations, a work permit system is already in place. Personnel are not allowed to work in the area without permits and planned activities must be discussed in advance. Where necessary, job-specific risk assessments can be carried out. Training on ATEX-related aspects will complement these procedures.

Training activities are planned to cover production, operation and maintenance. These will be delivered by GEA and/or internal staff. At the time of the interview, GEA was still operating the system under supervision, with a formal training phase, documentation and handover planned for a later stage. After handover, Tiense Suikerrafinaderij expects to operate the system independently, with support from GEA available via remote assistance or on-site service when needed. The expected support model follows a structured approach, from user-level checks to helpdesk support, on-site technicians and escalation to back-office expertise if required.

It is estimated that at least 10–15 people will be trained, including engineers, supervisors, operators and technicians, reflecting the need to cover multiple shifts. Training materials are expected to include a handbook, presentations, site tours and potentially detailed work instructions with step-by-step guidance for operating the system.

From the technology provider's perspective, GEA also highlighted training and safety as critical aspects. They identified a need for additional professional profiles, particularly application engineers capable of developing and integrating large systems, service technicians with experience in industrial hydrocarbon heat pumps and profiles combining thermodynamics/refrigeration knowledge with automation and control expertise. They also emphasised the importance of modelling and data interpretation skills, both for system design and for analysing system behaviour after commissioning.

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Regarding safety, GEA confirmed that requirements were not fully defined at the beginning of the project, particularly due to the shift to a hydrocarbon refrigerant (pentane), which significantly changed the safety approach. As a result, a substantial effort was required to define a comprehensive safety concept in collaboration with the end user. This included defining ATEX zoning and execution, developing maintenance procedures and establishing site-wide safety measures covering both the heat pump unit and the surrounding infrastructure, such as housing and ventilation. External consultants were involved to support this process.

GEA also noted that the food-production context introduced additional constraints. Material choices, such as the use of stainless steel instead of carbon steel, were influenced by food safety requirements. The selection of oil was also affected, as food-grade oil was not feasible, requiring additional qualification efforts. Detecting and preventing contamination became a key concern, including the identification of suitable monitoring solutions. Material compatibility issues were also highlighted, such as the interaction between ammonia (present in trace amounts in the live steam generated during sugar production), water and copper, which could lead to corrosion and potential leakage.

Finally, GEA confirmed that training will be provided on site, combining theoretical and practical elements. This will include system start-up and shutdown procedures, as well as daily and weekly maintenance routines. Responsibilities are differentiated between plant staff, who are expected to perform regular operational checks and service engineers, who will handle more complex maintenance activities.

## 6.4 Key lessons learned - main conclusions

### Demonstration site 1 – Stella Polaris & Mayekawa

The experience from the demonstration site highlights several lessons related to skills and competencies, from both Mayekawa and the end user Stella Polaris.

From Mayekawa's perspective, the end user was considered capable and experienced within its own industrial field. However, the project introduced additional complexity due to its R&D nature and the implementation of new concepts, including high-temperature operation and ATEX/explosion-proof design. In these areas, internal competencies were limited and required outsourcing to external specialists.

The involvement of multiple specialised contractors, without a single coordinating party, increased both complexity and risk. This was particularly challenging in the absence of strong in-house capacity to validate and assess the work carried out by external parties. In addition, the remote location of the site created logistical challenges and limited the availability of contractors.

Based on this experience, Mayekawa highlighted several key points, including the importance of continuing internal training, providing clear and structured documentation and ensuring a minimum level of quality in interface documentation.

From the end-user perspective, Stella Polaris identified the need for stronger internal follow-up and inspection of external contractors. The company noted that there had been a high level of trust in external parties and that more rigorous verification and documentation, such as declarations of conformity, are necessary, particularly for high-risk and ATEX-related work.

Overall, the experience underlines the importance of clearly defined responsibilities, adequate internal capacity to oversee external work and robust documentation practices when implementing complex industrial heat pump systems.

### Demonstration site 2 – Tiense Suikerrafinaderij & GEA

The experience from the demonstration site highlights several lessons related to skills and competencies, from both the end user and the technology provider.

From the end-user perspective, the central lesson learned is the importance of having a system integrator involved in the project. It was emphasized that while GEA provides the heat pump as a machine and the company acts as the end user, there is a need for a dedicated party responsible for installing and integrating the system into the factory and process context.

From the technology provider's perspective, a key lesson concerns the importance of a strong pre-planning phase before committing to the project budget. It was highlighted that experienced technicians should be involved early in the process to address practical questions and develop a realistic understanding of the project scope. This approach could help identify major implications at an early stage, rather than discovering them during project execution.

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Another important lesson relates to the need for clearly defined responsibilities for execution and installation. In this project, the absence of a dedicated contractor or clearly defined execution scope created an "open gap," which resulted in GEA taking on a significant share of on-site planning and execution tasks, including electrical installation planning, piping, insulation, vacuum work and leak testing.

The experience also highlighted how execution-related aspects and local requirements can significantly affect project scope and costs if not identified early. Examples include additional requirements for trace heating when the unit was not installed in a heated building, as well as changes in cabling due to local regulations.

# 7. CLOSING REMARKS AND RECOMMENDATIONS

The analysis presented in this report confirms that skills are a central enabling factor for the wider deployment of industrial heat pumps. While industrial heat pump technologies are commercially available and technically mature for certain applications, their readiness and deployment potential vary depending on the required temperature level, system scale and specific industrial context. Further technological development and demonstration may therefore still be needed for more demanding applications.

At the same time, successful implementation depends on the availability of professionals able to assess feasibility, design and integrate solutions and install, commission, operate and maintain these complex systems in real industrial environments.

While industrial heat pump technologies are already commercially available and technically mature for certain applications, their readiness and deployment potential vary depending on the required temperature level, system scale and specific industrial context. Further technological development and demonstration may therefore still be needed for more demanding applications. At the same time, successful implementation depends on the availability of professionals able to assess feasibility, design and integrate solutions, and install, commission, operate and maintain complex systems in real industrial environments.

The value-chain mapping developed in this report shows that industrial heat pumps require a broad set of technical and non-technical profiles. These range from thermodynamic, mechanical, process, electrical and instrumentation engineers to technicians, contractors, safety experts, project managers, operators, procurement officers, logistics staff and commercial or legal profiles. The deployment of industrial heat pumps therefore depends not only on individual technical expertise, but also on coordination between different actors and disciplines.

The findings from the SPIRIT demonstration sites further confirm that skills gaps are particularly visible at the interfaces between technology providers, end users, contractors and regulatory or safety requirements. In both demonstration sites, the need for strong system integration capabilities emerged as a key lesson. Industrial heat pump projects require professionals who can understand the heat pump technology, the host industrial process, safety and regulatory constraints and the practical realities of installation and operation. Where this coordinating role is missing, responsibilities may become fragmented, delays may occur and additional effort is needed to clarify technical scope, safety requirements and execution responsibilities.

A first recommendation is therefore to recognise system integration as a critical competency area for industrial heat pumps. Future competency frameworks should explicitly include profiles able to bridge process engineering, thermal systems, refrigeration, electrical and control systems, safety and project coordination. These profiles may be internal to technology providers or end users, or provided by specialised contractors, but their role should be clearly identified from the beginning of a project.

A second recommendation is to strengthen targeted training and upskilling across the industrial heat pump value chain. General awareness courses and summer schools are valuable for building foundational knowledge, but they are not sufficient on their own to prepare professionals for real-world deployment. More specialised, practice-based training is needed, particularly on system integration, process heat analysis, commissioning, control strategies, safety requirements and operation in industrial environments.

A third recommendation is to develop recognised training and certification pathways for key professional groups involved in industrial heat pump deployment. This should include engineers, technicians, contractors, installers, operators and safety-related profiles. In line with the recommendations of SPIRIT Deliverable 5.2, EU-wide recognised certifications and training programmes could help increase trust, improve quality and reduce uncertainty for industrial end users considering the adoption of heat pump technologies.

A fourth recommendation is to support the upskilling of existing professionals from adjacent sectors, especially refrigeration, HVAC, industrial maintenance, electrical engineering and process engineering. Many of the required skills already exist in the market, but they need to be adapted to the specific requirements of industrial heat pumps. This is particularly important for contractors and service providers, whose availability can be limited, especially in remote industrial areas.

A fifth recommendation is to strengthen safety and regulatory competencies. The demonstration sites showed that requirements related to ATEX, pressure equipment, refrigerants, hazardous areas, food safety and site-specific procedures can be complex and may not be fully clear at the beginning of a project. Training should therefore include not only technical operation, but also regulatory awareness, risk assessment, documentation, work permits, emergency procedures and safe maintenance practices.

A sixth recommendation is to improve project planning and role definition from the earliest stages. Industrial heat pump projects should clearly identify which professional profiles are needed, which responsibilities belong to the technology provider, the end user, contractors and external specialists and where coordination is required. Clear documentation, interface management and early involvement of experienced technicians, safety experts and system integrators can help avoid delays and reduce implementation risks.

A seventh recommendation is to expand education and training offer at both vocational and university levels. Training providers, universities and professional education organisations should increasingly include industrial heat pump integration, process heat decarbonisation, industrial electrification and high-temperature heat pump operation in their curricula. At the same time, on-the-job training, updated technical manuals, demonstration-site learning and manufacturer-specific training should be further developed to complement formal education.

Finally, capacity-building efforts should be coordinated across industry, research organisations, education providers, policy makers and industry associations. Technology providers can contribute application-specific expertise, industrial end users can provide access to real operational environments and public authorities can support the scale-up of recognised training schemes. Initiatives such as the SPIRIT Summer School and other industrial heat pump training programmes should be replicated and complemented with more practical, application-oriented learning formats.

In conclusion, strengthening the skills base for industrial heat pumps is essential to accelerate their deployment in Europe. A future competency framework should build on the value-chain approach developed in this report and define the key roles, skills, knowledge areas and training pathways needed at each stage. By addressing skills shortages, improving coordination and supporting targeted upskilling, Europe can reduce one of the key non-technical barriers to industrial heat pump adoption and support the transition towards a more resilient, electrified and low-carbon industrial energy system.

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