Deliverable 5.3 Business models and contractual agreements

Drafted by: Gabriele Fregonese (Sinloc)

Date: 06/07/2026

Grant agreement No: 101069672

Project start date: 1st September 2022

Duration: 54 months

Funded by the European Union

BASIC INFORMATION ON THE DELIVERABLE	
DISSEMINATION LEVEL	Public
DUE DATE OF DELIVERABLE	31/12/2025
ACTUAL SUBMISSION DATE	06/07/2026
WORK PACKAGE	WP5 - Maximizing technical and commercial impact
TASK	T5.3 – Business models and contractual agreements
TYPE	Report
NUMBER OF PAGES	59

Funded by the European Union

Report of Contributors				
	Name	**Organisation**	**Role/ Title**	**E-mail**
Report leader	Gabriele Fregonese	Sinloc	Senior Consultant	gabriele.fregonese@sinloc.com
Contributing Author(s)	Matteo Meneghetti	Sinloc	Consultant	matteo.meneghetti@sinloc.com
Reviewer(s)	Riccardo Marchetti	Eurac Research	Researcher	**riccardo.marchetti@eurac.edu**
Final review and quality approval				
	Simon Spoelstra	**TNO**	**Coordinator**	**simon.spoelstra@tno.nl**

Date	Version	Description
15/03/2026	0.1	**First draft**
25/03/2026	0.2	**First revision**
29/04/2026	1.0	**Final version**
03/07/2026	**1.1**	**Final revision**

DISCLAIMER OF WARRANTIES

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101069672 (SPIRIT).

This document has been prepared by SPIRIT project partners as an account of work carried out within the framework of the EC-GA contract no. 101069672.

Neither Project Coordinator, nor any signatory party of SPIRIT Project Consortium Agreement, nor any person acting on behalf of any of them:

(a) makes any warranty or representation whatsoever, expressed or implied,

(i). with respect to the use of any information, apparatus, method, process, or similar item disclosed in this document, including merchantability and fitness for a particular purpose, or

(ii). that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or

(iii). that this document is suitable to any particular user's circumstance, or

(b) assumes responsibility for any damages or other liability whatsoever (including any consequential damages, even if the Project Coordinator or any representative of a signatory party of the SPIRIT Project Consortium Agreement has been informed of the possibility of such damages) resulting from your selection or use of this document or any information, apparatus, method, process, or similar item disclosed in this document.

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

PROJECT PARTNERS

TNO: NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK

DTI: TEKNOLOGISK INSTITUT

DLR: DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV

EHPA: EUROPEAN HEAT PUMP ASSOCIATION

MYK: NV MAYEKAWA EUROPE SA

SINLOC: SINLOC-SISTEMA INIZIATIVE LOCALI SPA

EURAC: ACCADEMIA EUROPEA DI BOLZANO

EHP: EUROHEAT & POWER

DTU: DANMARKS TEKNISKE UNIVERSITET

TVP: TVP Solar

TIS: TIENSE SUIKERRAFFINADERIJ N.V.

TLK: TLK ENERGY GMBH

GEA: GEA Refrigeration Germany GmbH

SPIL: Spilling Technologies GmbH

SKPS: Smurfit Westrock Paper Services B.V.

SKC: SMURFIT WESTROCK CZECH SRO

SP: STELLA POLARIS AS

Funded by
the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

ABBREVIATIONS AND ACRONYMS

B2B: Business to Business

B2C: Business to Consumer

BAU: Business As Usual

COP: Coefficient Of Performance

E/G ratio : Electricity-to-gas price ratio

EaaS: Energy as a Service

EPC: Engineering, Procurement and Construction

ESCO Energy Service Companies

GHG: Greenhouse Gas

HaaS: Heat-as-a-Service

HTHP: High Temperature Heat Pump

KPI: Key Performance Indicators

MVR: Mechanical Vapor Recompression

O&M: Maintenance or Operation & Maintenance

OEM: Original Equipment Manufacturer

PbP: Payback Period

R&D: Research and Development

SME: Small and Medium Enterprises

SPIRIT: Implementation of sustainable heat upgrade technologies for industry

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

TABLE OF CONTENTS

Funded by the European Union

LIST OF TABLES

LIST OF FIGURES

Funded by the European Union

Funded by the European Union

1. INTRODUCTION

Industrial process heat represents one of the most challenging segments of the energy transition, due to the combination of high energy demand, stringent reliability requirements, and strong constraints on production continuity. Previous SPIRIT analyses have shown that a significant share of industrial heat demand lies below 200 °C and is therefore, from a purely technical perspective, addressable by High-Temperature Heat Pumps (HTHPs), particularly in continuous processes such as drying, evaporation, and low-pressure steam generation. Despite this technical potential, the actual penetration of industrial heat pumps remains marginal, indicating that the main barriers to deployment are not technological maturity alone, but economic and organizational feasibility (EHPA, 2024).

Deliverable D5.1 identified that industrial heat pump adoption is still at a nascent stage, constrained by high upfront investment costs, complex integration into existing production environments, and a general aversion to operational and financial risk in capital-intensive industries. These barriers are particularly pronounced in brownfield contexts, where retrofitting new heat supply technologies must be achieved without jeopardizing uptime, product quality, or safety. D5.3 builds directly on this problem statement by shifting the focus from technical feasibility to bankability and replicability, addressing the question of how HTHPs can be deployed under realistic commercial and contractual conditions.

Subsequent work in D5.2 further clarified that adoption decisions are primarily driven by bankability considerations rather than by energy efficiency metrics alone. From the perspective of industrial stakeholders, the decision to replace or complement conventional boilers with HTHPs depends on the combined effect of capital expenditure, payback time, exposure to operating costs, and the perceived ability to manage technical and operational risks. Within this framework, the transition from a business-as-usual model to service-based models such as Heat-as-a-Service (HaaS) is not merely a financial shift, but also a reallocation of risks and responsibilities along the value chain. D5.2 positioned HaaS as a promising but still niche option, whose viability cannot be assumed a priori and must instead be validated through concrete pilot evidence and contractual analysis.

Against this background, D5.3 aims to operationalize the adoption logic established in earlier deliverables. Its purpose is not to promote a specific business model, but to assess under which conditions different models - traditional asset-based and service-based - can deliver a robust and replicable investment case for industrial HTHPs. The analysis is grounded in the three SPIRIT pilot sites - Tiense Suiker, Smurfit Westrock, and Stella Polaris - which represent diverse industrial contexts, integration challenges, and levels of system maturity. These pilots provide a structured evidence base to test economic performance, risk allocation, and contractual feasibility under real-world constraints.

Two parameters emerge consistently from previous analysis as first-order drivers of economic viability and therefore frame the core analytical focus of this deliverable. The first is the electricity-to-gas price ratio (E/G ratio), which determines the avoided cost when substituting fossil-based heat with electrically driven heat pumps. The E/G ratio directly defines the economic corridor within which an HTHP-based solution can be competitive and, in the case of HaaS, whether a service tariff can be simultaneously attractive for the industrial off-taker and sustainable for the service provider. For this reason, D5.3 explicitly incorporates sensitivity analyses on energy price conditions to assess robustness across plausible market scenarios. The second critical parameter is CAPEX, including not only the cost of the HTHP unit itself but also the often substantial integration and balance-of-plant costs required in industrial environments. High and site-specific CAPEX remains a key barrier compared to conventional boilers and is particularly influential in brownfield retrofits, where additional piping, civil works, safety measures, and control system adaptations are required. In a service-based context, CAPEX directly affects tariff levels, contract duration, and risk premiums, making it a decisive factor in the bankability of HaaS arrangements.

Within this context, D5.3 pursues four main objectives. First, it defines and compares commercially plausible business model archetypes for HTHP deployment, focusing on traditional manufacturer-led models and service-based approaches. Second, it translates these business models into contractual logic, identifying the key contractual building blocks required to manage performance, operational continuity, and risk transfer. Third, it validates these models using techno-economic evidence from the SPIRIT pilots, quantifying economic performance and stress-testing the sensitivity to E/G ratio and CAPEX. Finally, it identifies improvement levers and replication conditions, clarifying which technical, organizational, or market developments are required to move from pilot-scale demonstrations to wider industrial uptake.

Methodologically, the deliverable combines a structured business model framework - based on value-chain analysis and Business Model Canvas logic with pilot-based techno-economic assessments. Where measured operational data are not yet fully available, calculations rely on best-available engineering estimates and clearly stated assumptions. Contractual aspects are addressed at a functional level, outlining mechanisms and principles rather than jurisdiction-specific legal drafting.

2. BUSINESS MODELS FOR HEAT PUMPS

2.1 Introduction to business models

A business model describes the rationale of how an organization creates, delivers, and captures value, in economic, social, cultural or other contexts. The definition of a business model is a preliminary step that must be taken before approaching an investment decision, to check whether all aspects of the concept are correctly assessed and if the project idea can be valuable.

The process of setting-up a business model is usually done by using some classical and theoretical methods (such as the Business Model Canvas) that can help thinking about the different aspects of the concept from scratch

Setting up a business model for High Temperature Heat Pumps means building strategies through which this technology can be brought to the market to offer a solution to the customers. Accordingly, there is no single business model; rather, several strategies may be adopted, each characterized by specific features, as well as distinct advantages and disadvantages.

The business model can then be assessed through the development of a business case based on real-world data, serving as a proof of concept.

Funded by the European Union

2.2 The business model canvas

The business model canvas is a simple tool widely used in business strategy to represent a business model. While several conceptualizations of business model exist, the most used model[1] is made of nine "building blocks":

- **value proposition**: is the core of the business model and represents the added value, the technology or the innovation that we want to deliver to the market. It sets the reason for selling a product/service, answering the question about what problem does it solve for customers;
- **customer segments**: the development of a business model requires accurate market analysis to check whether the product/service responds to the needs of existing and potential customers;
- **key partnerships**: the success of a business model also depends on structuring strong partnerships with suppliers, vendors or technology partners;
- **key activities**: actions needed to acquire new customers or to sell the new innovative product/service, focusing on the activities that could make the business model more successful;
- **key resources**: human, tangible or intangible assets that are needed to produce and sell the product/service;
- **channels**: how to distribute and communicate the existence of the product/service to the market and how customers could buy it;
- **customer relationships**: how to build and maintain a relationship with the customers over time, gathering loyalty and trust;
- **revenue streams**: how to make money from the product/service sold and how to calculate the right price for the customer;
- **cost structure**: what are the cost and expenses associated with the production and delivery of the product/service.

The business model canvas can be shown as a visual chart as follows:

[1] Osterwalder, Alexander; Pigneur, Yves; Clark, Tim (2010). Business Model Generation: A Handbook For Visionaries, Game Changers, and Challengers. Strategyzer series. Hoboken, NJ: John Wiley & Sons. ISBN 9780470876411. OCLC 648031756.

Figure 1. Business Model Canvas

The business model canvas can be virtually applied to any sector and business, since the "building blocks" represent all the aspects that should be assessed to define how to deliver the value proposition to the market.

In our specific scope of HTHPs, defining a business model means thinking about how these innovative solutions could be brought to the market. In particular, building on the results of the SWOT analysis presented in Paragraph 2.5, the business model canvas should help identify the key elements supporting the market uptake of the solutions.

2.3 Stakeholders in the value chain

Before entering the definition of the business models, it's worth analyzing how the value chain of High Temperature Heat Pumps is set up. In fact, the business model to bring this technological solution to the market depends on where a company positions itself in the market and which products/services it wants to offer.

The following figure shows a standard value chain for an industrial equipment, which starts from the R&D phase, passes through the manufacturing, sales and installation and eventually ends with the maintenance and operation.

Funded by the European Union

Figure 2 Business models and value chain of industrial heat pumps (Push2Heat, 2024)

Stakeholders who want to operate in the market must decide which parts of the value chain they want to cover. This is a business strategy decision, depending on several factors such as technical skills and knowledge, organizational structure, staffing and financial capacity.

In any market for industrial equipment, such as heat pumps, companies could offer only one activity within the value chain ("specialists") or a wide range of services in an integrated way ("integrator") or even operate as a general contractor, just focusing on the project management and organization of several subcontractors.

Here is a sample list of stakeholders who could be part of the value chain:

- **Researchers**: companies, universities, research institutes that develop and test innovative concepts;
- **Manufacturers**: design and construct heat pumps or components. Typically, they build the heat pumps according to the technical specifications required by the Customers (direct end-user or EPC contractor) and sell it to them. In some cases, they might offer also support to the installation and commissioning as well as technical maintenance (usually limited to OEM components directly manufactured and supplied);
- **Sellers**: buy the heat pump or its component from the manufacturers, according to the specific needs of the customer, and sell it to them. They could also offer installation, commissioning and maintenance;
- **Installers**: physically install and commission heat pumps, taking charge of the piping and connection of the new equipment to the Customer's facility. This activity requires specific expertise in heat pump technologies and knowledge of the production process in the site where the new equipment will be installed;
- **Maintainers**: ensure a correct maintenance of the system according to the schedule defined by the manufacturer of the heat pump and/or of the single components (e.g. oil and filter change, refrigerator recharge, replacement of spare parts, etc.);

Funded by the European Union

- **Operators**: run and operate the heat pumps, ensuring their functionality for the customer's production process. Operators monitor and control the systems aiming at the optimization of the process to achieve the best energy savings. The operator might be the Customer itself (final user) if properly trained and with know-how on the specific installed systems.

In this field, we could also envisage other types of operators which integrate two or more parts of the value chain (Cordin Arpagaus S. P., 2023). These players could be:

- **EPC Contractors (Engineering, Procurement and Construction)**: design the heat pump according to the requirements of the customer, buys the most suitable equipment from a manufacturer (or single components from several manufacturers), install and commission the heat pump. EPC contractors offer a turnkey solution to the customers, typically on a fixed-price, fixed-date basis. They may or may not undertake actual site work but they coordinate and manage all the process, including suppliers and service providers. The benefit for the Customer is to have a one-stop solution and a single contract to manage, reducing complexity and transferring the related risks to an external contractor (as these contracts include penalties and liabilities). EPC Contractors might also offer **Maintenance or Operation & Maintenance (O&M)** solutions to the customers;
- **Energy Service Companies (ESCo)**: provide service-based contracts to the customers, which typically include the design, supply, installation, operation and maintenance of technologies. Contractual payments may be linked to performance indicators such as energy efficiency (Energy Performance Contract) or the "amount of service" that the newly-installed equipment provides to the customer (Heat as a Service). Since payments are linked to specific KPIs, the ESCo has all incentive to achieve the contractual obligations and service level standards. This means that the ESCo must ensure that the installed equipment is fully working as expected and this is done through monitoring, control and regular maintenance.

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

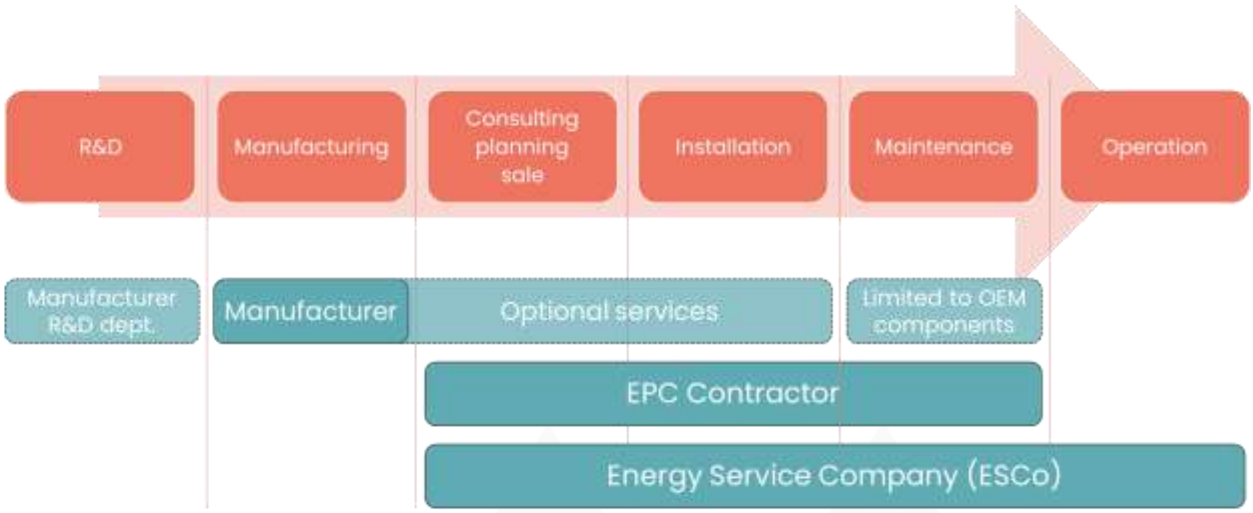

Figure 3. EPC contractor and ESCo positioning in value chain of industrial heat pumps

2.4 Business Models for High Temperature Heat Pumps

Since HTHPs are an innovative product that is still not widespread in the industrial sector, no specific business models have been developed and implemented yet. Consequently, insights were gathered through interviews with HTHPs manufacturers involved in the SPIRIT project to bridge this knowledge gap.

Currently, most HTHPs are **customized solutions**, specifically developed to fulfill the needs of a single customer and applicable to its own production process. Indeed, industrial heat pumps are not meant to heat spaces, for which standardized and modular solutions already exist, but to generate heat to be used in the industrial production process. This means that solutions need to be physically and technically integrated in a very specific context. Thus, unlike residential and commercial heat pumps which are standardized product becoming more and more widespread in the building sector, HTHPs still need to be specifically designed and manufactured upon request of the customer.

Moreover, the need for customized solutions and the lack of standardization implies that the market is not yet ready for these applications and that only few pilot cases have been tested so far.

Funded by the European Union

Thus, with the purpose of developing a theoretical business model, this section addresses the various components of the business model canvas **from the point of view of the HTHP manufacturers**. Since the scope of the SPIRIT project is to develop and test innovative solutions and bring them to the market, the business model needs to be centered on the suppliers of the technology. So, once the value proposition is set and defined targeting the added value that the SPIRIT solutions could generate for the users, the aim is to explore and fill in the building blocks according to what could support the achievement of the value proposition.

a) Building blocks of the business models

Thought the following sections, each building block of the business model canvas is filled addressing the HTHP producer's point of view.

Value proposition

The value proposition answers the question about the benefit that a product/service can generate for a customer and what problems it can solve. In the context of high temperature heat pumps for industrial use, defining it means establishing how these applications could support industrial users in the electrification of final energy consumption, reducing the use of fossil fuels, cutting greenhouse gas emissions and, eventually, reducing costs. From the point of view of the manufacturer, this is the objective to be pursued in developing the product and offering the service.

The value proposition around which the business model is built could be extremely summarized as follows:

> *"To generate high temperature process heat through heat pumps, in a cost-effective way, reducing primary energy consumption and cutting emissions"*

In detail, the value proposition could include several aspects that could be or be perceived as added value by the customers. Thes could include:

- Reducing the greenhouse gas emissions of the industrial process
- Increasing the share of renewable energies used in the production process
- Improving the corporate social responsibility and image
- Reducing the dependency on energy markets and their volatility
- Reducing operating costs in the long term (to be verified)
- Possibility to reuse excess heat

The development of a business model means identifying a solution to deliver these added value items to the customers.

Key partners

Key partners are essential to deliver the value proposition by providing critical resources and performing activities that the company cannot accomplish alone. The selection of partners influences operational efficiency, market reach, and innovation.

In the context of HTHP manufacturers, key partners include:

- Suppliers of key components: Ensuring the availability of high-quality parts like compressors and heat exchangers
- EPC contractors: Supporting complex project implementations
- Installers: Experts in integrating heat pumps onsite
- OEM integrators: Expanding market reach through established networks
- Demo customers: Showcasing technology in real-world conditions
- Public institutions: Advocating energy transition policies and incentives
- Investment funds and banks: Facilitating access to financial resources
- Technical consultants: Advising on integration with existing processes
- Research partners: Driving innovation and technology development

Key resources

Key resources are the critical assets required to deliver the value proposition, support operations, and build customer relationships. These can include physical, intellectual, human, or financial resources.

For HTHP manufacturers, key resources encompass:

- Know-how: Expertise in system design and integration
- Intellectual property: Proprietary technologies that secure competitive advantages
- Supply chain management: Reliable access to quality components
- Demonstration projects: Validating performance in operational environments.
- Sales networks: Industry connections for accessing customers
- Technical resources: For maintenance and service
- Skilled workforce: Specialized personnel ensuring effective execution of activities.

Key activities

Key activities describe the most important actions the company must perform to operate successfully and deliver its value proposition.

For HTHP manufacturers, these activities include:

- Development of cost-efficient heat pumps: Creating innovative and affordable solutions
- Demonstration projects: Building reference units to prove feasibility
- Standardization and modularization: Improving scalability and reducing production costs
- Sales and marketing: Engaging industrial users with targeted outreach
- Workforce development: Training and hiring to meet technical and operational needs

Key channels

Key channels determine how the value proposition is delivered to customers. For high-temperature heat pumps, installation and maintenance responsibilities influence the way manufacturers engage with clients. When manufacturers manage these processes directly, the channels emphasize direct engagement and control over the customer journey. In cases where responsibilities are shared with customers, indirect channels such as third-party partnerships play a significant role.

For HTHP manufacturers, the key channels are:

- Direct sales: Engaging industrial clients with tailored solutions
- Sales through distribution partners: Utilizing OEM integrators for wider market access
- Reference customers: Leveraging pilot projects to demonstrate reliability and performance

Customer relationship

Customer relationships outline the approach to maintaining and strengthening ties with clients. Different positioning along the value chain impacts how these relationships are structured. Direct management by manufacturers fosters strong, ongoing connections, while shared responsibilities encourage collaborative and consultative interactions with customers.

Funded by the European Union

In the HTHP business model, these relationships are shaped by:

- Direct sales of equipment: Providing personal support for industrial clients
- Turnkey project delivery: Offering one-stop-shop solutions, including installation and commissioning
- Sales through partners: Leveraging third-party expertise for broader reach
- Specialized tenders: Participating in targeted applications like waste heat recovery solutions

Cost structure

The cost structure can vary significantly depending on whether installation and maintenance are managed by the manufacturer or shared with the customer. When manufacturers assume full responsibility, costs related to logistics, installation, and post-sale maintenance increase. However, these costs may be offset by efficiency in service delivery and enhanced customer satisfaction. In contrast, when customers manage these activities, the manufacturer's upfront costs are reduced, but the model relies on effective coordination with third-party service providers.

For HTHP, the cost structure includes:

- Investment costs: Equipment, construction, and integration
- Operating costs: Energy consumption during operation
- Maintenance costs: Regular servicing and replacement parts
- Subsidy programs: Offsetting costs through public or private incentives

Revenue streams

Revenue streams adapt to the level of the service provided by the HTHP producer. If manufacturers directly manage these activities, additional income can be generated through service contracts, installation fees, and long-term maintenance agreements. In cases where customers manage these processes, the focus shifts to equipment sales and licensing fees, with potential revenue opportunities arising from providing technical support or specialized training to the customer's contractors.

For HTHP producers, the main revenue streams include:

- Direct sales: Selling hardware and equipment
- Installation and commissioning services: Revenue from on-site integration

Funded by the European Union

Maintenance contracts: Equipment-as-a-Service models for ongoing support
Subsidies and incentives: Financial support from public and private initiatives
Licensing fees: Monetizing intellectual property through third-party usage rights

b) Traditional Manufacturer's business model

Traditional HTHP manufacturers typically operate by offering a technology-based solution designed for precise industrial heating applications. Often, manufacturers do more than simply assemble a device; they customize HTHP units according to each client's specific temperature demands, pressure requirements, and site constraints. While they may rely on external suppliers for certain components (e.g., compressors), the technical design, packaging, specialized adjustments, and final assembly usually occur in-house. This allows them to ensure that each system aligns well with the client's operational needs, even if the operations involve chemical processing or food production. Additionally, tailoring the unit to achieve higher COP remains a core technical priority, as this parameter directly affects both energy savings and return on investment. These manufacturers thereby position themselves as specialized technology partners, delivering equipment plus engineering expertise. As a result, the business model relies heavily on customer-specific customization, tight quality control, and robust after-sales support.

Two main sales channels exist in this business model:

B2B business model

In the B2B channel, the manufacturer sells its HTHP to an intermediary actor, typically an EPC contractor or a specialized project developer. Within this arrangement, the manufacturer's role concentrates on ensuring the heat pump unit meets the technical specifications required by the EPC for integration into large-scale industrial projects. After manufacturing and testing, the unit is delivered to the EPC, who then oversees all subsequent steps, such as on-site installation, commissioning, and ongoing service activities.

From a commercial standpoint, the revenue stream in this scenario hinges on direct equipment sales and, at times, pre-arranged service agreements that cover spare parts or periodic inspections. Establishing reliable partnerships with EPCs is critical, as their reputations and relationships with end users heavily influence future procurement decisions. Furthermore, delivering a high COP is particularly valued, because any increase in energy efficiency significantly bolsters the EPC's financial proposition for potential industrial clients.

Overall, the B2B option suits customers (often large corporations) that already have an established structure for managing utility projects and are more apt to handle the financial and technical elements of industrial energy solutions. The manufacturer, in turn, benefits from focusing on core competencies: design, manufacture, and basic system testing, while relying on the EPC partner's expertise in field deployment.

B2C business model

A direct-sales or B2C pathway centers on selling HTHP systems straight to end users, typically medium-sized industrial plants or processing facilities without extensive internal project-management resources. In this mode, the manufacturer provides not only the equipment but often a broader service scope. Such services can range from engineering assistance and digital design reviews to in-person installation and dedicated maintenance packages. By offering a more integrated approach, the manufacturer addresses customer concerns about adoption of new technology, particularly relevant for HTHP systems whose performance under high-load or high-temperature operations may appear less familiar than standard refrigeration solutions.

From a financial point of view, B2C transactions involve the customer making an up-front capital investment or entering into a leasing or financing agreement brokered by the manufacturer. This larger risk exposure for the end user, compared to a B2B scenario, frequently prompts the manufacturer to emphasize clear ROI estimations, training sessions for on-site personnel, and remote-monitoring capabilities. Additionally, warranties and service-level agreements are crucial for demonstrating reliability and mitigating any perceived technological risk. By combining equipment

Funded by
the European Union

sales with robust after-sales offerings, manufacturers can build deeper client relationships and gain valuable operational feedback to refine future product lines.

c) Energy-as-a-Service and Heat-as-a-Service business models

An increasingly relevant model in the industrial heat pump sector is often described under the umbrella of "Energy-as-a-Service" (EaaS) or, more specifically for process heat generation, "Heat-as-a-Service" (HaaS). These approaches depart from the conventional capital-expenditure heavy schemes by allowing a third-party service provider, frequently an EPC contractor or an ESCo, to assume responsibility for financing, installing, operating, and maintaining a heat pump system. Although both EaaS and HaaS models share the same fundamental principles, "Heat-as-a-Service" is more closely aligned with the needs of HTHP applications in industrial contexts, as it directly addresses the core process requirement: generating heat at the specified temperature level (Cordin Arpagaus S. P., 2023).

Under a HaaS arrangement, the end user (e.g., an industrial plant) does not purchase and install a heat pump outright. Instead, the service provider invests in the HTHP equipment and ensures its ongoing performance, typically through a contract that spans a decade or more. This long-term agreement stipulates key parameters such as availability, capacity, and efficiency, which are backed by performance guarantees. The end user, in turn, pays the service provider a fee structured around heat consumption either in the form of a fixed cost per kilowatt-hour of heat delivered, a monthly or annual capacity fee, or some blend of both. These fees cover the capital cost of the heat pump, routine maintenance, and any necessary repairs, while also providing the service provider with a profit margin.

Such a model significantly lowers entry barriers for the industrial customer by removing the upfront capital expenditure required to procure an HTHP. Moreover, the technical and operational risks are effectively transferred to the service provider. For new or emerging technologies like high-temperature heat pumps, this risk transfer is particularly valuable. Traditional industrial users may be hesitant to adopt innovative systems due to uncertainties around their reliability, performance, or actual operational savings. By offloading these considerations to an experienced partner with robust financial resources, the customer can focus on its core activities without sacrificing the potential benefits of cleaner, more efficient process heat generation.

Manufacturers themselves recognize the growing interest in these service-based models but generally acknowledge that they do not have the structures in place to provide them directly. A manufacturer's traditional business model revolves around designing and producing HTHP equipment, not functioning as a financier or operator. To offer HaaS, manufacturers would need robust financial resources to handle upfront investment, manage long-term operational risks, and absorb potential performance shortfalls. Because such capabilities are usually outside the core competencies of technology suppliers, large EPC contractors or specialized ESCOs are typically better positioned to implement these schemes.

In practice, offering HaaS requires the service provider to have sufficient financial capacity and domain expertise to design, build, own, operate, and maintain an HTHP solution. EPC contractors or ESCos can leverage economies of scale purchasing multiple heat pumps at once for a variety of clients and potentially negotiate volume discounts with manufacturers of crucial components. Such arrangements foster more competitive pricing and can improve the overall payback period for the service provider. Additionally, EaaS or HaaS providers may take advantage of local incentives, CO_2 tax credits, or other environmental benefits to further improve the financial viability of a project. Predictable energy usage at industrial sites translates into stable, recurring revenue for the service provider over the life of the contract, which often extends for 10 years or more.

Despite these advantages, the HaaS model imposes important technical and economic requirements on the service provider. In particular, the Coefficient of Performance (COP) of the heat pump is critical to ensuring profitability. For low COP values, it becomes challenging to balance the cost of investment and ongoing operational expenses within the typically expected payback timeframe. On the other hand, higher COP ranges (above 5–6) greatly enhance the financial case, as the industrial user is likely to consume substantial amounts of heat over the contract duration. This underscores the vital role of technological advancement in HTHP design, where some solutions can offer COPs in the range of 4–10.

2.5 SWOT analysis of the business models

As industries face increasing pressure to decarbonize their operations, HTHPs are emerging as a promising technology to replace fossil fuel based process heat. These systems offer significant energy efficiency gains and emissions reductions, especially when integrated with renewable electricity. However, the path to adoption varies widely depending on the business model. This SWOT analysis compares the two primary approaches as defined in the previous paragraphs: the HaaS model, where the technology is delivered as a managed service with minimal upfront cost, and the Business-as-Usual (BAU) model, where the industrial client purchases, installs, and operates the system directly. Through a SWOT analysis of both models, we examine the strategic, financial, and operational implications of each, helping industrial stakeholders make informed decisions based on their risk appetite, capabilities, and decarbonization goals.

a) SWOT Analysis HaaS model

The Heat-as-a-Service business model represents an innovative approach to providing heating solutions, leveraging advanced technologies and renewable energy sources to deliver efficient and sustainable heating. This SWOT analysis aims to evaluate the strengths, weaknesses, opportunities, and threats associated with the HaaS model. By understanding these key factors, manufacturers and end-users can make informed decisions about adopting HaaS, ensuring that they capitalize on its benefits while mitigating potential risks.

While the following matrix shows a complete overview, we can briefly summarize the key results of the analysis:

- **Strengths**: HaaS is a model that establishes a long-term relationship between the service provider and the end user, which is essential to ensure an optimal allocation of performance-related risks among the parties involved. From the service provider's point of view, this is very important to increase its marketing potential to provide solutions to companies which are not able to sustain the upfront financial cost. From the end-user perspective, this model has the advantage of requiring limited or no upfront investment, helping annual budgeting for energy and making it easier to shift to HTHPs and comply with regulatory requirements on decarbonization.
- **Weaknesses**: HaaS usually have complex contractual structures and require strong technical and financial capability for the service providers (Kastalli, 2013). In the specific case of HTHPs, the innovative technology, the lack of standardization, the uncertainty about risks and result as well as the customization costs may prevent service providers from offering these solutions to the market.
- **Opportunities**: HaaS models could be an opportunity to speed-up the decarbonization process of firms, responding to regulatory requirements as well as the need to show sustainability practices (Jess Britton, 2021). HaaS could

also be an opportunity for service providers to monetize waste heat servicing clients.

Threats: main threats are the high dependency of the convenience of the model on the electricity/gas prices on the energy market as well as, from the end-user perspective, the high exit barriers from these contracts.

Stregths	Weaknesses
Long-term partnerships: clients often prefer multi-year service agreements, enabling predictable income and scalability. **CapEx to OpEx shift**: avoid upfront costs improving cash flow and budgeting. **Energy efficiency optimization**: Providers have a direct incentive to optimize systems for efficiency, reducing waste heat and cutting energy bills **Performance-based delivery**: Guarantees on heat availability and temperature ranges reduce downtime risks for critical processes	**Technical complexity:** Industrial heat requirements are often bespoke, involving high pressures, process-specific temperatures, and strict regulations **High customization cost:** Tailoring systems for different facilities increases engineering, installation, and integration costs **Integration risks:** Retrofitting or interfacing with legacy systems can cause downtime or inefficiencies if not done precisely **Limited supplier ecosystem:** Currently, few providers have the technical and financial capacity to deliver industrial-scale HaaS contracts, especially for HTHPs which are still not standardized
Opportunities	**Threats**
Process heat decarbonization: Strong demand for low-carbon steam across several industries **Waste heat recovery systems:** Potential to monetize unused heat streams and convert them into HaaS offerings **Carbon pricing & ESG pressure:** Industrial clients face increasing pressure to reduce emissions and disclose sustainability practices, and HaaS could be a fast way to undertake decarbonization process with low to no upfront investment cost	**Volatile energy markets:** Industrial heat demand is high thus fluctuation of energy prices leads to high financial risks **High exit barriers :** Once systems are installed, removing or replacing them is expensive, making the client more dependent on the service provider, which can deter cautious clients from initial commitment **Competing solutions:** Onsite CHP, hydrogen boilers, and electrification of process heat might be preferred for strategic or control reasons **Technological obsolescence:** Rapid innovation in industrial heating tech may outdate installed systems before ROI is fully achieved

Table 1. SWOT matrix for the Heat-as-a-Service Business Model

b) SWOT Analysis BAU model

The business as usual model represents the traditional approach to conducting business where, in the case of HTHP, it means selling the technological solution to the end-user or to an EPC contractor.

The analysis highlights the importance of balancing the benefits of a BAU approach with the need for adaptability and innovation in an ever evolving business landscape, as shown in the SWOT matrix and summarized as follows:

Funded by the European Union

Strengths: The traditional BAU model has the advantage, from the manufacturer's point of view, to have an immediate cash flow from the sale of the equipment. From the end-user perspective, instead, it has the advantage of controlling the ownership of the asset and, in some cases, to directly be eligible for subsidies for the initial upfront cost as well as benefitting from the short and long-term cost savings (which, in the case of HaaS, are usually shared with the service provider).

Weaknesses: BAU model requires high upfront investment cost, which may not be sustainable for SMEs, as well as high internal skills and expertise to install, maintain and operate a HTHP, increasing project and performance risk.

Opportunities: direct purchase of HTHPs allows better customization and process integration, as well as higher flexibility for future integration or adaptation to the industrial process.

Threats: the end-user is fully responsible for the technological, operational and financial risk, thus this model requires strong ability to manage and hedge these risks.

Stregths	Weaknesses
Ownership control: users retain full ownership and control of the asset, giving them flexibility in operations and maintenance **Eligibility for subsidies**: Government grant programs support CapEx-based installations, making it more convenient to invest directly **Long-term cost savings**: Once installed, HTHPs can provide significant energy cost reductions compared to fossil fuel systems **Integration potential**: Easier to align with internal energy and process strategies, particularly in energy-intensive facilities with in-house engineering teams	**High upfront investment**: Large CapEx required may deter many industrial firms, especially SMEs or those with tight budgets **Limited internal expertise**: Many industrial teams lack experience in designing, sizing, and maintaining HTHPs, increasing project risk **Split incentives**: In leased facilities, tenants may bear energy costs while landlords own infrastructure, creating disincentives for investment **Performance risk**: Without performance guarantees, systems may be oversized, underperforming, or poorly integrated with process heat demands
Opportunities	**Threats**
Cost reduction trends: As HTHPs scale manufacturing and installation costs are likely to fall, making BAU financially more accessible and viable **Customization**: Direct ownership allows full tailoring of the system to the process needs of the site without being limited by third-party service constraints **Funding access**: Many industries can access decarbonization grants, green loans, or tax incentives for direct purchase models. **Process integration**: Can be better integrated with internal waste heat, CHP, or thermal storage systems **First-mover advantage**: In carbon-intensive sectors, early adopters can enhance ESG reporting and competitive differentiation	**Technology obsolescence**: Rapid innovation may make purchased systems outdated before ROI is fully achieved. **Operational risk**: client bears full responsibility for downtime, maintenance, and performance — potentially impacting production. **Financial risk**: Large upfront costs tied to uncertain long-term energy savings can make the investment unattractive without strong guarantees. **Competitor models (like HaaS)**: Emerging service-based alternatives may outcompete BAU by offering flexibility, lower upfront cost, and performance risk

Table 2. SWOT matrix for the traditional Business Model

c) Comparison between the two alternatives

The main difference between the two models can be identified in the allocation of risks among the parties. While in the BAU model the end-user bears the financial, operating and performance risks, in the HaaS model these risks are transferred to the service providers. Of course, this risk transfer has a cost for the end-users, which is typically applied to the price of the energy (heat) sold to the customer. In other words, **HaaS contracts typically cost more in absolute financial terms** (the sum of the annual payments to the service provider are higher than the avoided upfront cost). This is not only because of the financial cost of investment by the service provider, but also because bearing the operating and performance risks requires additional remuneration.

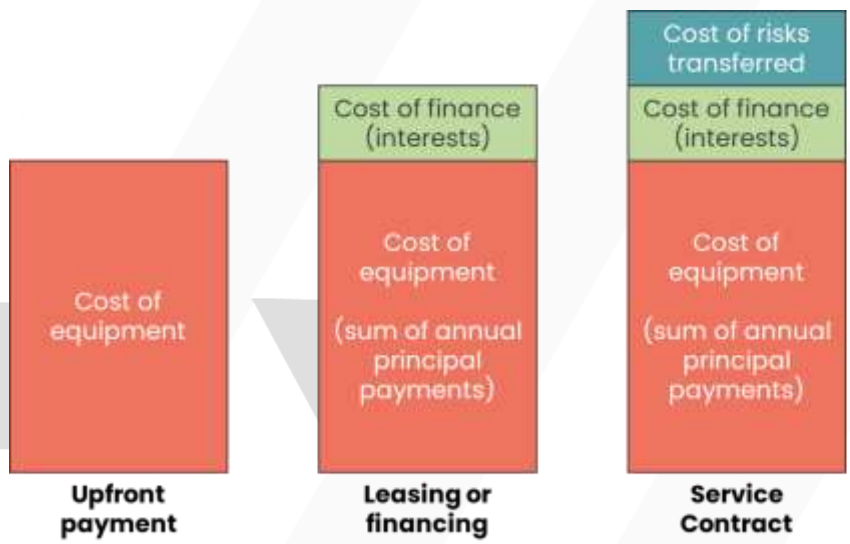

Figure 4. The additional cost of finance and risk transferring

The higher cost of HaaS does not mean it's less convenient than other business models. In general, the "convenience" of one business model is measured according to the value it can generate for the customer. Since value is a subjective concept that depends on the utility one derives from the service, convenience depends on several subjective factors. In the case of HaaS, the "value for money" depends, in particular, on the benefit that the user derives from using the machine without owning it, transferring all technical and financial risks, and avoiding upfront costs.

In the specific case of HTHPs, due to the innovativeness of the product and lack of track record on its actual functioning, it's unlikely that end-users will be willing to bear the technical risks. Instead, the end-user will be willing to pay an additional cost to have a turnkey solution and a full service provided at its premises, without risks. Of course, at the same time, the cost of the contract needs to be balanced by the benefit the solution could generate over time.

Thus, **the business case for a real-world application of the HaaS business model for HTHP can be made only if the solution is able to generate enough economic benefits to cover its overall cost** (purchase, installation and service, including the remuneration of the service provider). Possibly, the solution should also leave an additional benefit for the end user, making the HTHP solution more convenient than keeping on generating heat and steam through fossil fuel.

The following table summarizes the key differences between the BAU and HaaS business models for several aspects analyzed.

Table 3 Comparison between Haas and traditional BAU models

Aspect	HaaS Model (Service-Based)	Traditional BAU Model (CapEx-Based, Ownership)
Ownership	Provider owns and operates the HTHP system	Industrial client owns and manages the system
Upfront Cost	Low/no upfront cost for client; shifts CapEx to OpEx	High upfront capital investment required
Risk Profile	Provider assumes performance, maintenance, and efficiency risk	Client bears all operational and financial risks
Flexibility	Standardized offerings, potentially less tailored	Fully customizable to site-specific processes
Expertise Required	Low in-house technical expertise needed	Requires internal knowledge or external consultants
Maintenance	Included in service contract	Responsibility of the client (or extra specific contract)
Performance Incentive	Provider is incentivized to optimize performance and reduce downtime	Client manages performance without external accountability
Financing Model	Ongoing service payments (OpEx)	Capital depreciation and potential tax incentives

Funded by the European Union

Energy Efficiency	Typically optimized over lifecycle by provider	Depends on client's internal optimization and monitoring
Technology Obsolescence	Risk shared or mitigated via upgrades or SLAs	Client bears obsolescence risk; replacement is additional CapEx
Decarbonization ROI	Enables faster adoption of low-carbon solutions	May be slower unless externally subsidized
Speed to Deploy	Faster for clients, due to low financial barrier	Slower due to internal procurement and financing cycles
Most suitable for	SMEs, facilities with limited CapEx, early movers on decarbonization	Large firms with CapEx capacity, bespoke process needs, or in-house energy teams

2.6 Contractual agreements

The potential uptake of HTHPs in the market could be encouraged by innovative business models, such as HaaS, which could lower the upfront investment cost and the exposure to risk for the customer. Implementing a HaaS model in practical terms means drafting a contract which includes all the necessary clauses to transfer the risks from the customer to the service provider. On the other hand, the contract needs to be balanced as both parties involved need to gain utility in entering the contract.

A solid contractual structure should, in fact, assign obligations to each party defining liabilities and payment mechanisms which make the risk transferring effective. While the interest of the customer is in purchasing heat avoiding technical risks related to ownership, the interest of the service provider is to have a guarantee on the amount of heat that the customer will purchase from the HTHP.

a) Main structure of HaaS contracts

One of the most widely spread examples of HaaS contract is the one applied by district heating network operators. In district heating networks, the operator owns and manages the heat production plant, the distribution network and the heat exchanger installed at the client's premises. The operator sells heat in the form of hot water delivered to the heat exchanger at a fixed temperature (generally between 75°C and 90°C) throughout the year. The heat is then absorbed by each client connected to the network for heating spaces and domestic sanitary water. In exchange, the clients pay the bills for the supply of heat according to the amount of energy absorbed, measured by a meter installed on the heat exchanger (Kristina Lygnerud a, 2020).

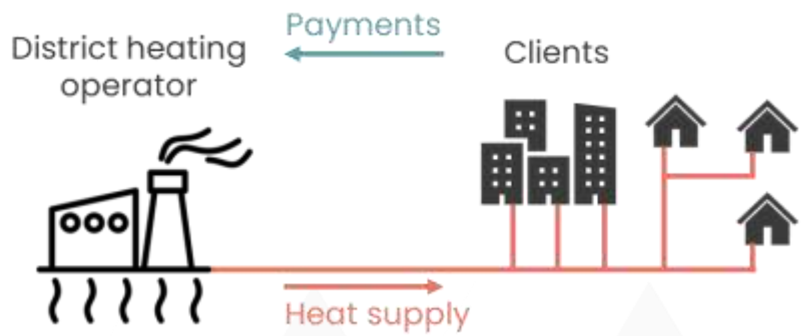

Figure 5. Scheme for a standard district heating network

In technical terms, in HaaS contracts:

- the main obligation of the service provider is to supply a certain amount of heat (measured in MW and MWh) at a temperature (°C) higher than an agreed threshold as measured by a meter;
- the main obligation of the Client is to purchase the heat and pay the due tariff.

The main specificity of HaaS contracts applied to the industrial sector, compared to district heating, is that the service provider only has one single customer. This implies several aspects to be considered in the contractual regulation:

- the heat should be supplied at the specific temperature required by the client;
- the HTHP needs to be engineered to deliver the required amount of energy at the required temperature for the agreed number of days;
- the HTHP needs to be installed at the client's premises and integrated with the industrial production process;
- the service provider is not subject to market risk (in terms of number of clients connected to the network) but to a specific demand risk (the amount of heat actually absorbed by the customer).

Funded by the European Union

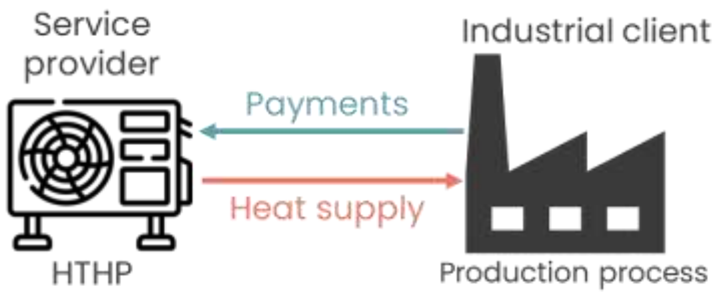

Figure 6. Scheme for a HaaS application for HTHP

b) Tariffs and payment mechanism

In HaaS contracts, tariffs are usually based on the "avoided cost" principle. According to this principle, tariffs are set by the service provider to make it convenient for the client to switch from the current heat production system to HaaS. On the other hand, the tariff should be high enough for the service provider to recover the initial investment cost for the installation of the new system and to cover the operating and maintenance costs.

In practical terms, if an industrial customer is currently producing heat through a gas boiler, then its cost to produce heat is calculated as the sum of the cost for the supply of natural gas and the other O&M related costs. In addition, according to national regulation, it could also be subject to payment of CO_2 emissions tax.

Shifting to HaaS, where heat is produced through a HTHP and delivered by a service provider, means that client will pay a comprehensive price for heat which reflects the cost for the supply of electricity, the depreciation of the upfront investment cost and the O&M of the system over time. In general, this shifting is convenient if the set price is lower than the current cost for heat for the Client and, at the same time, higher than the overall heat production cost for the Service Provider.

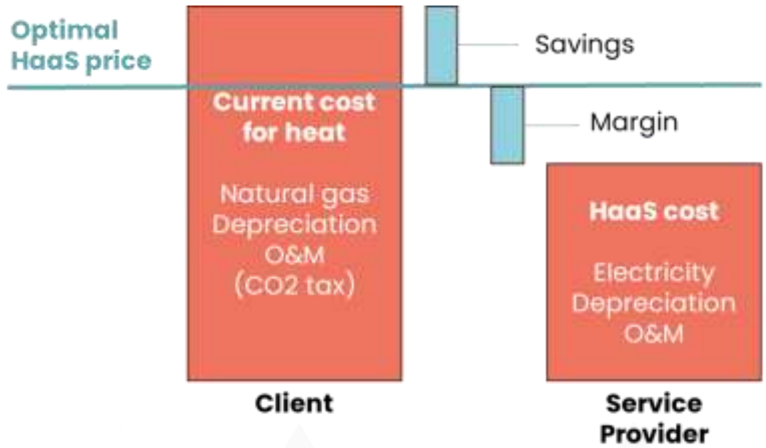

Figure 7. Scheme for the definition of HaaS price (without considering risks)

In nominal financial terms, as illustrated in Paragraph 2.5c) and Table 3, HaaS contracts usually have a higher cost than the traditional way of generating heat through gas boilers. This is because the upfront investment cost for the HTHP is much higher than the one for an equivalent gas powered boiler and because the transferring of risks to the Service Provider needs to be remunerated through the heat price.

c) Fixed and variable prices

Like all private contracts, HaaS contracts could feature a wide range of ways of setting the price for the service (WBCSD, 2022). In particular, the components of the price could be:

- **Subscription/Upfront fee**: an initial fee to be paid upfront to the service provider for the installation of the heat production system onsite;
- **Fixed annual fee**: a fee, defined in terms of €/yr or €/MW, to be paid annually for the service, regardless of the amount of heat exchanged;
- **Variable fee**: a fee to be paid to the Service Provider according to the amount of heat purchased by the Client (€/MWh). This fee could be indexed to the fluctuation of electricity prices in case electricity supply is included in the service;
- **Additional service fee**: the price due for additional services included (e.g. operation, additional maintenance, etc.).

The pricing structure should reflect the customers' needs. For example, large industries with high energy consumption are willing to pay higher fixed fees in exchange for a lower price per MWh, while smaller consumers could prefer higher variable prices but lower fixed instalments. In some cases, the service provider could require the customer

Funded by the European Union

to purchase a minimum amount of energy per period (i.e. MWh/yer), needed to cover up its costs and break even (*take or pay* clause).

d) Payment clauses

Payments from the customer to the service provider can be structured in various ways: the contract could foresee a fixed monthly payment, to be reviewed annually according to the actual performance, or a variable monthly payment according to the exact amount of energy supplied.

Another typical clause of HaaS contract is the sharing of savings. The service provider may guarantee a cost saving compared to the customers' current solution and agrees to share the savings. The company may structure the variable component in the savings-sharing price model to incentivize the ESCO to achieve greater savings or may include minimum savings targets.

e) Risk transferring clauses

One implied key feature of *servitization* is the transfer of risks to the service provider. In HaaS contracts, by purchasing heat instead of a complex machinery, the customer only pays for the *result* while avoiding all technical risks of the mean of production. These risks, taken by the service provider, include:

- **Engineering/Design risk**: risk that errors in the engineering/design of the machinery lead to errors/delays in its construction, faults or accidents in its operation;
- **Construction risk**: risk of errors in the construction/assembly of the machinery that could lead to delays in its delivery, faults or accidents in its operation;
- **Installation/integration risk**: risk of errors/accidents during the onsite installation of the machinery and its integration with the customers' industrial process that could lead to faults or accidents;
- **Operating risk**: risk of faults in the operation of the machinery causing downtime or issues to the customers' production process and the application of penalties for the service provider;
- **Performance risk**: risk that the machinery cannot deliver the agreed performance (heat, temperature, etc.) causing the application of penalties;
- **Maintenance risk**: risk of longer downtime due to maintenance, causing higher energy costs for the customer and penalties for the service provider.

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

To be able and willing to bear these risks, **the Service Provider must rely on his abilities in managing, preventing, hedging and reacting to them**. **Knowledge of the technology, skills and experience of the personnel are needed in all stages** of the supply process: engineers/designers must accurately calculate and predict the technical performance of the machinery, as to guarantee the result to the customer; operators must know how to run the machinery and optimize its efficiency over the usage cycles; maintainers must know the key components of the machine that need to be inspected, cleaned, lubricated and/or replaced.

> **This is a key issue for the future uptake of HTHPs**. Since this technology is relatively new, there is too little track record on its potential performance and reliability over time. Service providers have not become familiar with HTHPs yet and are not able to predict their performance with enough reliability. This uncertainty makes Service providers less willing to take the technical risks needed to offer result-based contracts such as HaaS.

Another risk that could be transferred to the Service Provider is the energy price risk. HaaS contracts could, in fact, feature a fixed price of heat over a period (typically one or two years). In some cases, if the energy supplied to the heat generator comes from sources not linked to energy market prices (e.g. from waste-to-energy or renewable energy plants), the price could be fixed for a longer period.

In fixed price contracts, the main advantage for the customer is the higher and more accurate predictability of its energy cost over time, easing the company's capital budget. On the other hand, the service provider must manage or hedge the energy price risk to ensure stable profitability of the operation.

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

3. SPIRIT PILOTS BUSINESS CASES

The objective of a business case is to demonstrate if, and under which conditions, the adoption of industrial HTHPs is economically viable for end-users. Indeed, while it's clear that replacing gas boilers with heat pumps brings sure benefits in terms of decarbonization, from an economic and financial point of view the actual convenience of this switch is still crucial for the market uptake of this technology. The high investment cost, due to the lack of standardization of the machinery as well as the costs for its integration into an existing production site, makes it harder for the end user to gain a satisfactory payback time on the investment.

Within the SPIRIT project, three pilot cases at full scale are being developed and tested in real world environments, providing useful data for a preliminary economic-financial and cost-benefit analysis for HTHPs. By analyzing in detail the results of the pilot implementations, it's possible to provide accurate and real numbers to define the business cases.

The analysis of the business cases starts with an assessment of the financial sustainability of the investment. This analysis considers the upfront cost for the manufacturing, installation and integration of the HTHP in the industrial site, the operating costs over time and the energy/economic savings associated with this new machinery, as a replacement to the existing gas boilers. Then, operational benefits and environmental impact are also included in the assessment to determine whether the inclusion of these variables in the calculation may offset the high investment cost and reduce payback time (thus increasing the economic convenience of the investment).

Since several variables need to be considered for the economic viability of an investment in HTHPs, such as gas-electricity price ratio, hours of utilization, etc., a scenario and sensitivity analysis will be performed to show which conditions affect the success of the business cases.

As a conclusion, a risk analysis is conducted, commonly for all three pilots, to complete the overview of the business cases providing some insights on additional factors that need to be considered in the in decision making process for such an investment.

Funded by the European Union

3.1 Stella Polaris pilot case

The Stella Polaris pilot illustrates both the opportunities and challenges of integrating HTHPs into **food processing**. Mayekawa, the heat pump manufacturer, supplied the main equipment (including compressors and oil pumps) together with technical support and operator training. Installation and on-site maintenance were managed directly by Stella Polaris or external specialists. A key feature of this case is the use of a **two-stage HTHP** capable of raising temperatures from 20 °C to 160 °C. While technologically advanced, this configuration increases investment costs and affects the economic feasibility of replacing the existing gas steam boiler.

> The assessment of the HTHP's impact is based on simulations developed with the support of TNO and Mayekawa, as this deliverable was prepared before the system had been commissioned and operated for a sufficient period to provide validated data. Consequently, the one-year testing period could not be completed. Nevertheless, the analysis relies on the best available estimates of operating costs.

The financial viability of the installation strongly depends on the annual operating hours. The unit is designed for 3,842 hours per year, and achieving high utilization is essential to ensure cost effectiveness. Lower use, either in duration or capacity, would significantly reduce the economic benefits, highlighting the importance of accurate process integration and demand forecasting.

Finally, in the Norwegian context, the relatively low electricity-to-gas price ratio (one of the few cases in Europe where it remains below one) plays a crucial role in determining the attractiveness of industrial electrification solutions.

a) Investment cost

The overall investment cost for the Stella Polaris pilot is estimated at approximately €2.20 million. This amount reflects the combined financial effort of Mayekawa, as HTHP technology provider, and Stella Polaris, as industrial end user. The allocation highlights a relevant adaptation and integration cost, with around 53% associated with the HTHP equipment, engineering and technology provision, and around 47% related to site adaptation, process integration and end-user implementation activities.

The cost profile confirms the specific nature of the pilot. The HTHP was not procured as a standard market product but developed as a tailored two-stage system designed to meet a demanding temperature lift, stringent safety requirements and the operational constraints of a food processing environment. On the end-user side, the investment is mainly focused on the modifications required to host and integrate the system safely and effectively within the existing production site, including dedicated infrastructure and ancillary works necessary for compliance with food industry requirements.

The costs considered in this analysis exclude any expenditure linked to the technical issue that occurred in February 2025, as this event falls outside the scope of the pilot investment assessment.

b) Operating costs

Stella Polaris estimates the expected maintenance cost over time according to the **ordinary maintenance** timetable (incl. oil and filter change, refrigerant, spare parts, etc.). As said, since the testing of the heat pump will only last less than 1 year, no maintenance will be done within the project timeframe, so the estimation of 42,735 €/year is just a theoretical projection.

The installed HTHP will operate for 3,842 hours annually, corresponding to 226 production days at 17 hours per day. Consequently, the heat pump will function at roughly 60-70% of its full capacity. Optimizing operating hours and capacity factors could be essential to support the justification of capital investments.

The impact on energy costs and savings of the introduction of HTHP is quantified in the following chapter through a differential approach, which makes it possible to determine the net energy savings due to technology.

c) Expected energy savings and results

At present, the Stella Polaris facility relies on a propane fired steam boiler to supply thermal energy to the production process. The prawn cooking line is the dominant energy consumer within the plant, accounting for approximately 90% of total propane consumption and 95% of total electricity demand. This corresponds to an annual propane consumption of approximately 2,829 MWh.

The installation of HTHP in parallel with the existing propane boiler allows a substantial reduction in annual propane consumption by replacing it with electricity. This substitution is particularly advantageous in the Norwegian context, where electricity is almost exclusively generated from renewable sources and is available at relatively low prices. Under current market conditions, the electricity-to-gas price ratio is favorable, with a value of 0.74 (excluding CO_2 taxation). Unlike direct electric boilers, HTHP introduces a COP that improves energy efficiency by producing more heat per unit of electricity consumed. In this case, the two stage HTHP is estimated to achieve a COP of 1.59. While this value is modest compared to typical market references, it reflects the high temperature lift required (from 20 °C to 160 °C). However, this brings an additional positive effect, reducing the already high energy demand due to energy transition towards electrification, thus reducing the overall pressure of the system on the electricity grid.

The system is expected to deliver primary energy savings of approximately 1,096 MWh per year. The economic assessment is based on the following reference energy prices: an electricity price of 40 €/MWh and a propane price of 81.71 €/MWh (this one including both the fuel cost for 53.73 €/MWh and the CO_2 tax component for 27.98 €/MWh). On this basis, the operation of the HTHP is expected to generate annual cost savings of approximately 128,000 € under current market conditions.

Considering the investment costs and the expected annual savings, the Stella Polaris pilot is characterized by an overall simple payback period (PbP) of 17.2 years.

In addition to the economic impact, the replacement of the propane-fired boiler with the HTHP generates a **substantial environmental benefit**. For the Stella Polaris pilot, the annual reduction in greenhouse gas emissions is estimated at 558 tons CO_2-eq. This value was calculated using reference emission factors for propane combustion from the UK Government's Greenhouse Gas Reporting Conversion Factors 2025[2] and electricity carbon intensity data from the Energy Institute Statistical Review of World Energy[3]. The Norwegian context, dominated by hydropower, ensures an exceptionally

[2] https://www.climatiq.io/data
[3] https://ourworldindata.org/grapher/carbon-intensity-electricity

almost-zero carbon intensity of the electricity mix, further amplifying the environmental advantage of the HTHP solution.

d) Scenario and sensitivity analysis

As described in the previous section, Norway predominantly generates electricity from renewable sources, which is sold at relatively low prices. The resulting Electricity-to-Gas price ratio stands at a favorable 0.74 (excluding CO_2 tax). However, in the scenario analyzed, this ratio is still insufficient to ensure a payback period attractive enough to incentivize investment in HTHP systems, with the current estimate at approximately 17 years.

If an acceptable payback period is set between 10 and 15 years, and assuming CAPEX remains unchanged, the analysis indicates that the Electricity-to-Gas price ratio would need to fall within the range of 0.46 to 0.66, values significantly lower than the present ratio and quite unlike to happen in Norway (considering the already near to 100% renewable electricity production mix). The result of the Electricity/Gas price ratio analysis is shown in Figure 8.

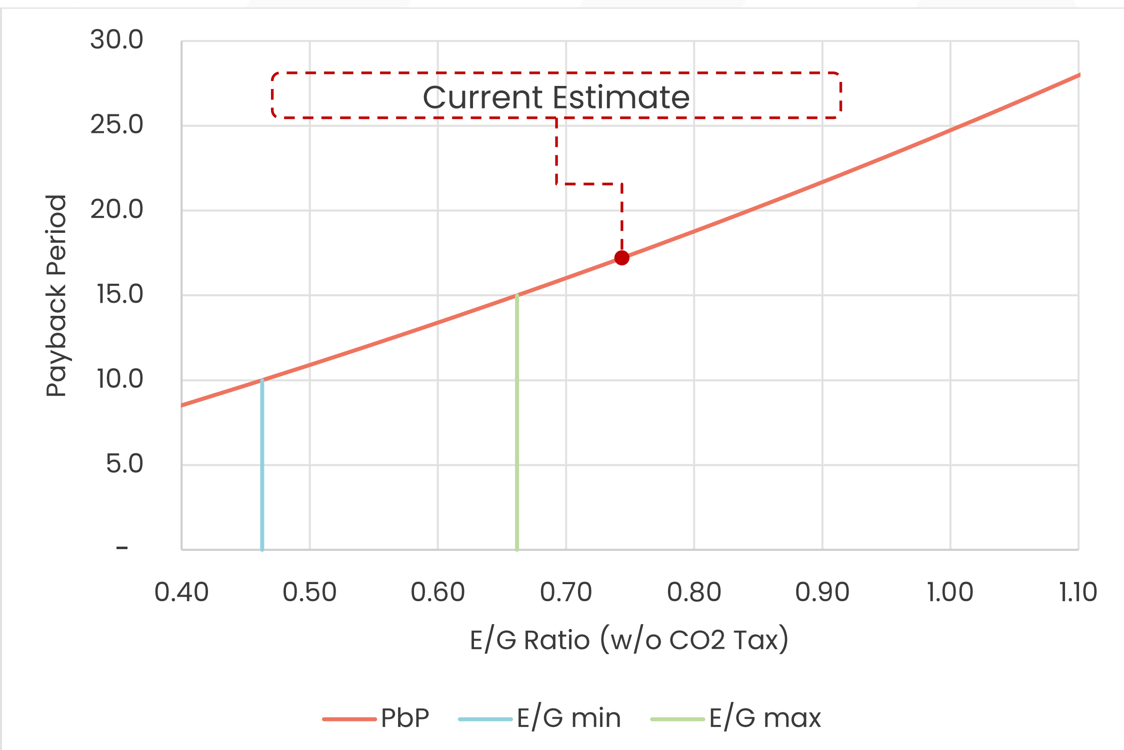

Figure 8. Stella Polaris E/G price ratio sensitivity analysis

An additional factor that shows a significant impact on the effectiveness of the investment is the CAPEX value, which is heavily influenced by the costs of adapting existing infrastructure and facilities. If the acceptance criterion is maintained as a payback period between 15 and 10 years, and operational costs are held constant, then CAPEX would need to be reduced by 10% and 42% respectively to meet these targets. The impact of CAPEX variation in PbP is represented in Figure 9.

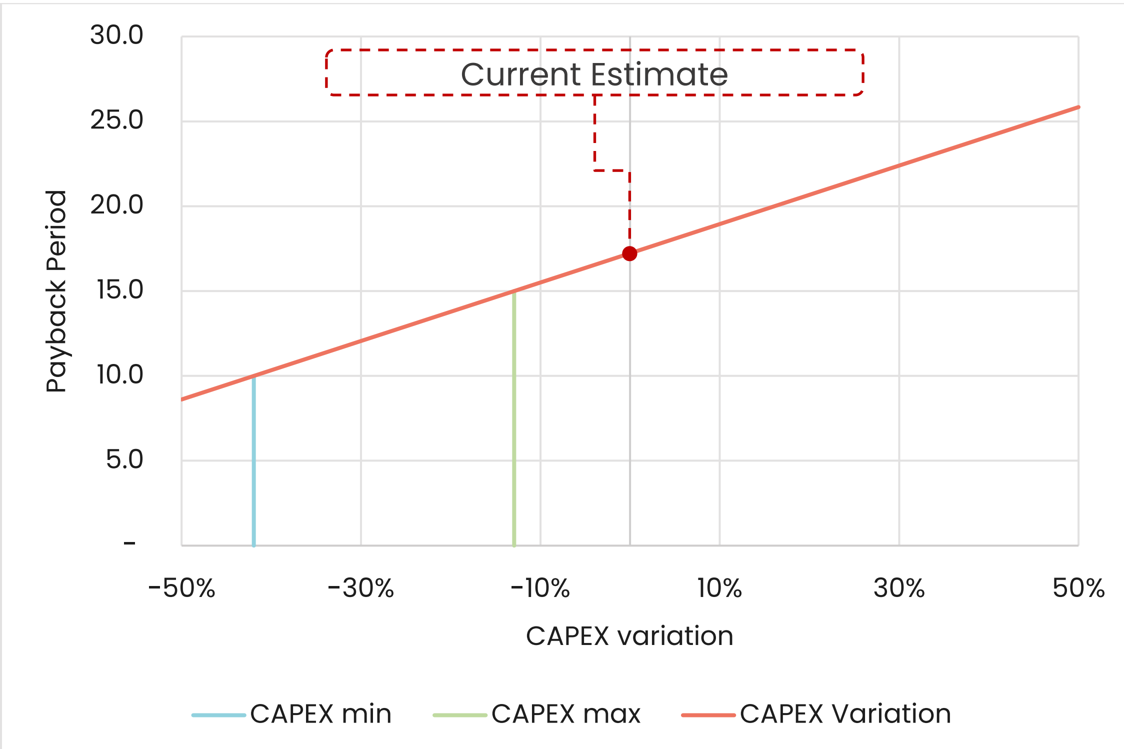

Figure 9. Stella Polaris CAPEX reduction sensitivity analysis

3.2 Tiense Suiker pilot case

The Tiense–GEA pilot focuses on integrating HTHP within a sugar production cycle that runs in **two main timeframes:**

- From September to the end of January, the production process runs continuously (24/7), focusing on extracting sugar from sugar beets and producing raw sugar and molasses;

after the beet campaign, the process continues until April, crystallizing residual sugar from molasses.

During the beet and molasses campaigns, operations run at full capacity, leaving the remainder of the year for cleaning, maintenance, and plant downtime.

The assessment of the HTHP impact for the Tiense-GEA pilot is primarily based on data provided by Tiense. At the time of the analysis, the HTHP system had been only recently commissioned and was therefore not yet supported by a sufficiently long operational period to fully validate performance under steady-state conditions. Investment costs can be considered consolidated, while the operational assessment combines measured data for the current reference scenario with short- and long-term operational estimates provided by Tiense for the HTHP operating scenario. As a result, the analysis reflects a hybrid approach, integrating real operational data with forward-looking estimates based on the best available information.

a) Investment cost

Compared to the initial estimates developed during the planning and design phase, the cost projections for the Tiense pilot increased significantly, mainly due to the complexity of integrating the HTHP into an existing industrial production environment. The overall financial commitment is estimated at approximately €6.1 million, split between the specialized HTHP technology supplied by GEA and the implementation costs borne by Tiense.

In percentage terms, around 57% of the total investment is associated with the HTHP equipment and related technology provision, while approximately 43% refers to end-user costs, including site adaptation, process integration, capital works, R&D-related activities and engineering support during the testing phase. The increase compared to the initial assumptions reflects unforeseen integration requirements, external installation constraints, compliance-related adaptations and extended installation and commissioning timelines.

b) Operating costs

No formal maintenance schedule or further operating-cost breakdown has been finalized for this pilot.

For the economic viability analyses carried out below, a reference value of € 50,000 per year for ordinary maintenance costs is considered.

c) Expected energy savings and results

Currently, Tiense's baseline energy expenditure is approximately € 701,500 per year, including both gas and electricity. Notably, about 28% of that expenditure is attributed to CO_2 fees, highlighting the growing impact of carbon costs.

Preliminary calculations show an annual operating cost reduction driven by eliminating gas consumption and corresponding CO_2 fees. However, electricity usage is expected to increase due to HTHP operation, resulting in annual energy cost of 303,600€. This new value represents a net saving of roughly € 397,870 per year under initial estimates. Over the long term, rising electricity prices might temper these gains, but steeper CO_2 fees could simultaneously boost the economic appeal of electrified heating. Consequently, considering the stabilized new annual cost of €447,810 in the long run, Tiense forecasts an average annual net saving of €364,097[4].

Considering an average annual net saving of €364,097, a payback period of about 17.3 years is calculated to recover the investments faced. More accurate calculations will follow as real-world operating data is collected and verified.

The annual reduction in GHG emissions is estimated at 2,139 tons of CO_2-eq, reflecting the avoided emissions from gas combustion and the comparatively lower carbon intensity of the Belgian electricity mix. Emission factors were derived from the UK Government's Greenhouse Gas Reporting Conversion Factors 2025[5] and electricity carbon intensity data from the Energy Institute Statistical Review of World Energy[6]. This

[4] Value obtained considering the average operational savings along a 20 year period.

[5] https://www.climatiq.io/data

[6] https://ourworldindata.org/grapher/carbon-intensity-electricity

demonstrates the considerable climate benefit achievable through electrification of process heat in the sugar industry.

d) Scenario and sensitivity analysis

As illustrated in the previous section, the baseline E/G price ratio for the Tiense Suiker site is 2.61 (excluding CO_2 compensation). Under current conditions, this ratio does not lead to a sufficiently attractive payback period for an HTHP investment, with the present estimate standing at approximately 17 years.

Assuming an acceptable payback period between 10 and 15 years, and assuming operational conditions remain unchanged, the analysis shows that the E/G ratio would need to decrease significantly. Specifically, the ratio should fall to approximately 1.75 to achieve a 10-year payback period, or 2.40 to meet a 15-year threshold. These values remain below the current reference ratio, indicating that electricity would need to become comparatively cheaper (or gas comparatively more expensive) before the investment reaches financial viability within the expected timeframe.

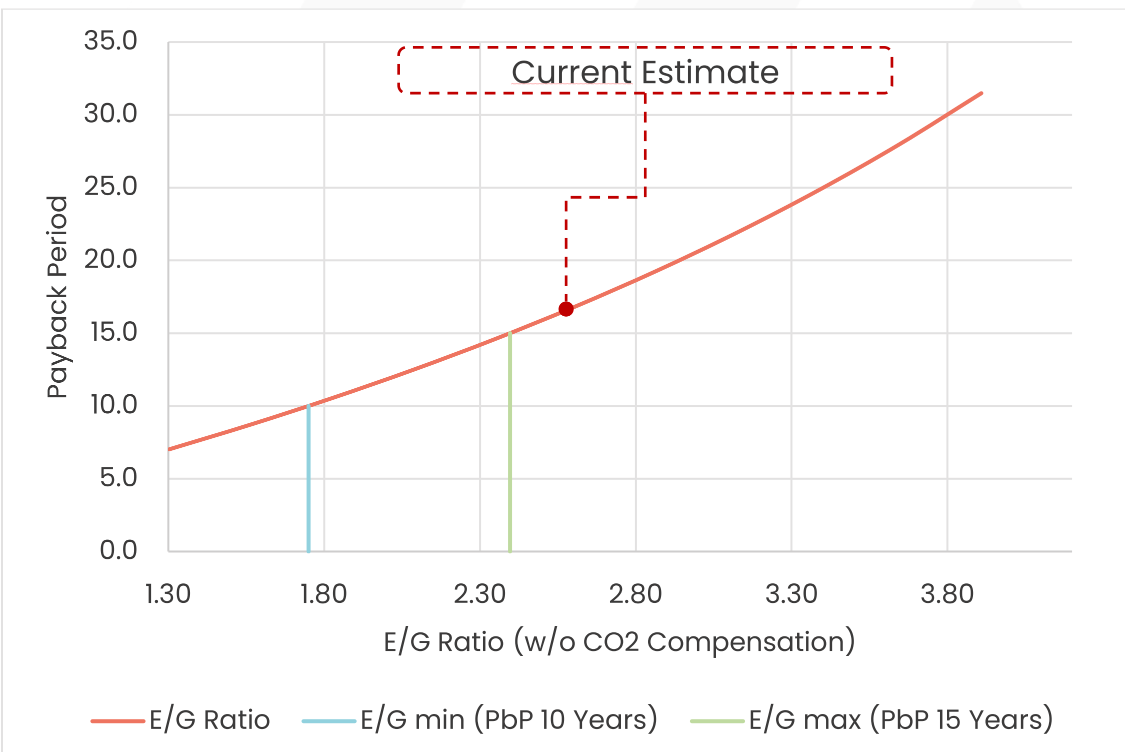

Figure 10. Tiense Suiker E/G price ratio sensitivity analysis

In addition, CAPEX substantially influences the investment's performance, particularly due to the significant infrastructure adaptations required at the Tiense Suiker facility.

Maintaining the payback period criterion between 10 and 15 years, and keeping operating costs constant, the model indicates that CAPEX would need to decrease by approximately 41% and 11%, respectively.

Figure 11. Tiense Suiker presents the sensitivity analysis on CAPEX reduction and its impact on the payback period.

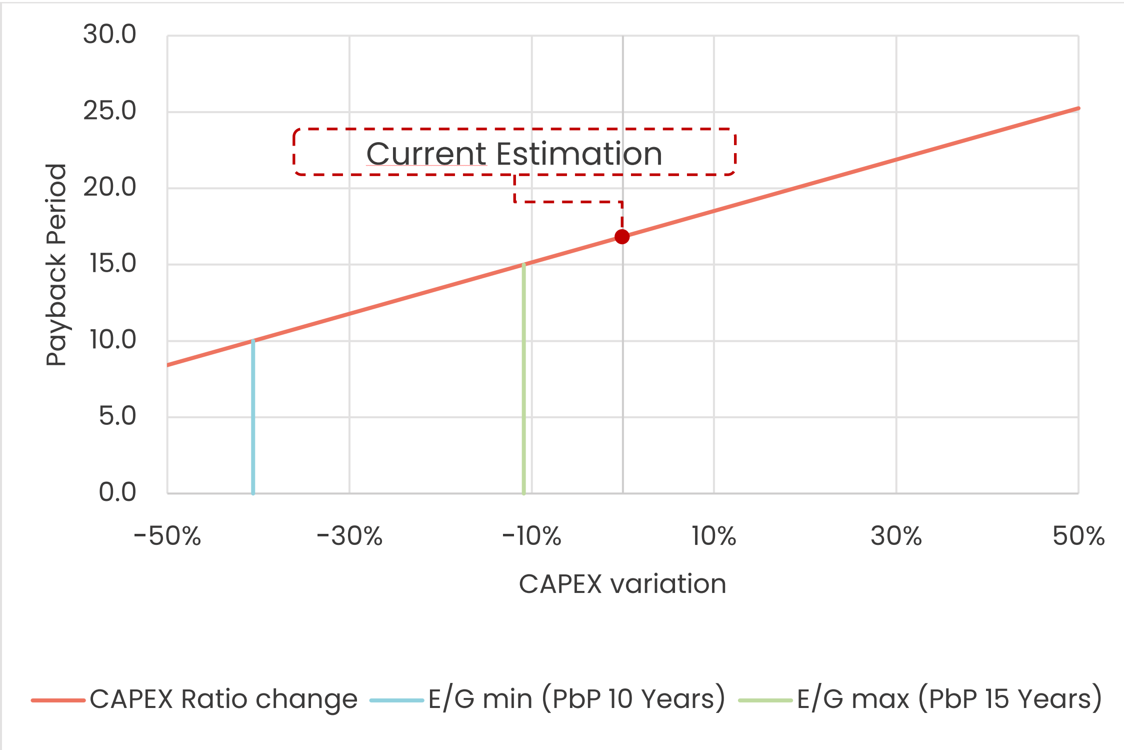

Figure 11. Tiense Suiker CAPEX reduction sensitivity analysis

3.3 Smurfit Westrock business case

The Smurfit Westrock pilot is implemented in a pulp and paper production facility and focuses on the demonstration of a Mechanical Vapor Recompression (MVR) based HTHP provided by Spilling and integrated into the existing steam cycle. The pilot is based on the use of hot condensate as heat source, which is already part of the plant's energy cycle and is currently used for boiler feedwater preheating. For this reason, the installation primarily serves as a technical demonstration of the Spilling solution in an industrial environment, rather than aiming at increasing energy recovery at the site, which has already achieved a significant level. This configuration highlights specific constraints of pulp and paper processes, where the main unused waste heat sources are typically available at temperatures below the direct operating range of MVR technology, thus requiring, in future applications, the integration of an additional HTHP stage to unlock higher decarbonization potential.

The assessment of the HTHP impact for the Smurfit Westrock-Spilling pilot is based on data provided by both Smurfit Westrock and Spilling. At the time of the analysis, the HTHP system had not yet entered operation, and therefore no validated operational data were available. Consequently, the evaluation relies on analytical assessments and engineering-based estimates of the potential energy, economic and environmental impacts of the installation, reflecting the expected performance of the system under the defined operating conditions. The results should therefore be interpreted as indicative of the system's potential rather than as measured operational outcomes.

a) Investment costs

The overall investment directly attributable to the pilot installation amounts to approximately €0.95 million, with around 35% related to site adaptation and process integration activities and around 65% associated with MVR system supply, modularization and deployment activities.

Smurfit Westrock's cost contribution relates to the works required to host and integrate the MVR unit within the existing production environment. These activities include the equipment necessary for on-site installation, civil works needed to accommodate the system within the plant layout, and engineering activities required to ensure proper integration with the existing industrial process. These costs are therefore highly site-specific and reflect the technical and infrastructural conditions of the pilot configuration.

Spilling's investment is mainly linked to the manufacturing and deployment of the MVR system, including delivery, commissioning, automation and the modularization of the containerized configuration adopted for the pilot. Personnel costs connected to these activities are embedded within the relevant cost categories and are not reported separately.

In parallel, Spilling also incurred additional R&D expenditures connected to broader company-level technology development. These activities supported the performance requirements of the Smurfit Westrock case and included innovation work on improved components, predictive maintenance solutions and containerised system design. However, these R&D costs are not included in the CAPEX of the pilot business case, as they are not directly attributable to the specific MVR installation but rather to the wider development of Spilling's replicable technology portfolio.

b) Operating costs

At the current stage of the Smurfit-Westrock pilot, the assessment of operational expenditure is necessarily limited, as the system has not yet been in operation for a sufficient period to generate representative field data. As a result, only a preliminary estimate of operational costs can be provided, based on standard assumptions and supplier indications rather than measured performance. In line with Spilling's assumptions, annual programmed maintenance is considered equal to 4.5% of the MVR manufacturing cost, corresponding to an estimated annual value of 19,350 €.

Special maintenance and other operational costs cannot be determined yet because of limited operating time and insufficient field data. These factors will need long-term monitoring after stable operation begins.

c) Expected energy savings and results

In the Smurfit-Westrock pilot, the introduction of the MVR leads to a reduction in fuel consumption of the existing boiler, due to a partial load reduction, while at the same time causing an increase in electricity consumption associated with the operation of the MVR unit. As a result, the overall energy balance reflects a substitution of propane with electricity rather than a net recovery of unused heat. In this context, the economic performance of the solution is strongly influenced by the relative prices of electricity and fuel, as well as by the contribution of avoided CO_2 emission costs.

Based on the data provided by Smurfit-Westrock and Spilling, the estimated annual reduction in natural gas consumption amounts to 2,350 MWh/yr, corresponding to an energy cost saving of approximately 110,440 €. This benefit is partially offset by the additional electricity consumption required by the MVR, estimated at 680 MWh/yr, leading to an increase in electricity costs of approximately 96,990 €. The resulting net energy related saving is therefore limited. A significant contribution to the overall economic balance is provided by the avoidance of CO_2 emission costs, associated with the reduced combustion of fossil fuel. The annual emission reduction is estimated at 418 tonnes of CO_2, corresponding to a monetary benefit of approximately 32,730 €, based on the assumed CO_2 price. Taking into account all these elements, the direct annual cost savings associated with the Smurfit-Westrock pilot are estimated at approximately 46,182 €.

Funded by the European Union

Considering expected long-term trends in energy prices, the projected increase in CO_2 emission taxation and the inclusion of maintenance costs, the average annual saving over the system lifetime is estimated at approximately 49,835 €. On this basis, the resulting simple payback period is approximately 19 years. While relatively long, this value is consistent with the demonstration-oriented nature of the pilot and with the specific boundary conditions of the installation, where the MVR does not exploit a fully unused waste heat source.

From an environmental perspective, the pilot still delivers a relevant benefit. The annual reduction in greenhouse gas emissions is estimated at approximately 220,322 kg CO_2-eq per year, reflecting the partial displacement of fossil fuel consumption and the electrification of part of the steam generation process.

d) Scenario and sensitivity analysis

The reference scenario for the Smurfit-Westrock pilot results in a PbP of approximately 19 years. The objective of the scenario and sensitivity analysis is therefore to assess under which conditions the payback period could be reduced to a range between 10 and 15 years, generally considered more attractive for industrial investments. The analysis focuses on two key parameters: the E/G ratio and the CAPEX.

In the reference case, the E/G ratio, calculated without considering CO_2 compensation, is equal to 3.02. Results show that the business case is highly sensitive to variations in this ratio. An increase in the electricity-to-gas price ratio leads to a rapid deterioration of economic performance, pushing the payback period well beyond acceptable thresholds. This highlights a strong exposure of the pilot to electricity price volatility, which is a critical risk factor for this specific configuration. Conversely, a reduction in the E/G ratio would improve the economics. As illustrated in Figure 12, a decrease of approximately 9% would reduce the PbP to 15 years, while a decrease of around 24% would be required to achieve a 10-year PbP.

Funded by the European Union

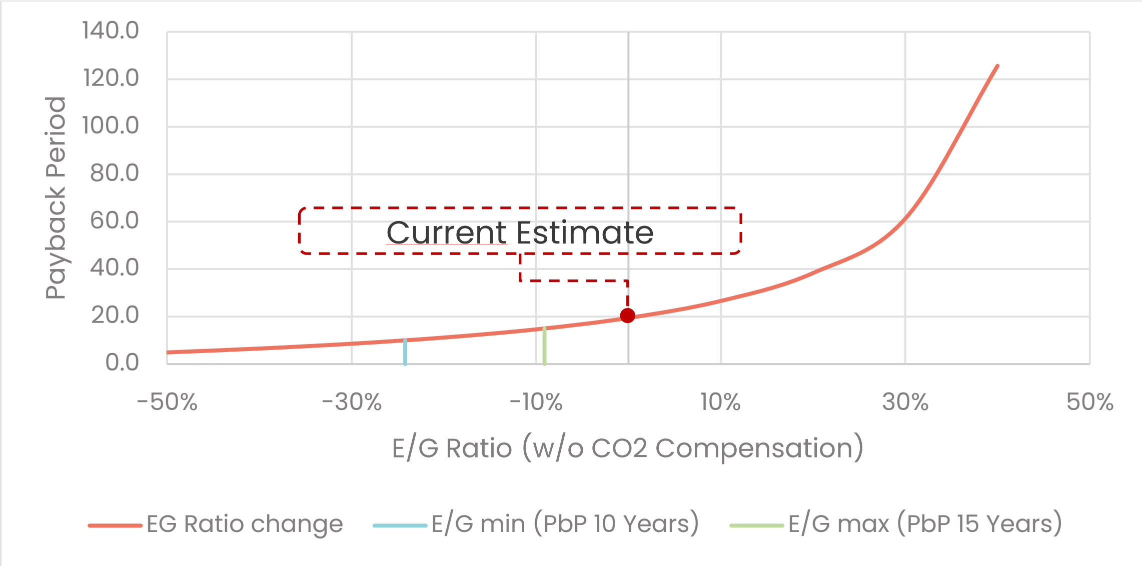

Figure 12. Smurfit-Westrock E/G price ratio sensitivity analysis

A complementary sensitivity analysis was carried out on CAPEX. Results indicate that, keeping all other parameters constant, a CAPEX reduction of approximately 23% would be required to reach a 15-year PbP, while a 49% reduction would be required to approach a 10 year PbP.

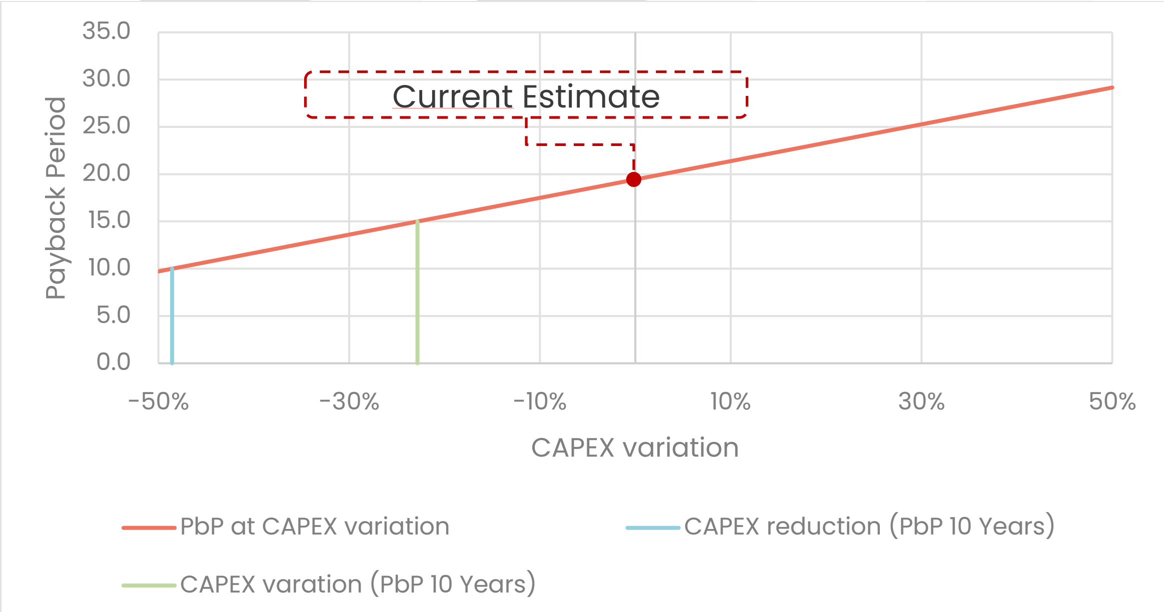

Figure 13. Smurfit Westrock CAPEX reduction sensitivity analysis

These results underline the importance of further cost reductions through standardization, modularization and deployment of ready-developed solutions in order to improve the commercial attractiveness of the MVR based system in future applications.

4. BUSINESS MODELS FOR THE SPIRIT SOLUTIONS

One of the initial hypotheses explored within the SPIRIT project was the potential deployment of HTHP solutions through a Heat-as-a-Service business model. From a conceptual perspective, HaaS is particularly attractive for industrial end users, as it allows companies to benefit from advanced, capital-intensive technologies while removing the burden of upfront investment from their balance sheets. By transferring ownership, operational responsibility and performance risk to a specialized service provider, HaaS can lower entry barriers and accelerate the adoption of innovative energy technologies, especially in sectors where capital allocation is constrained or investment horizons are short. As introduced in Section 2.6b), HaaS contracts are typically structured according to the avoided cost principle, whereby the heat tariff offered to the client must remain below the current cost of heat production, while still allowing the service provider to recover investment costs, cover O&M expenditures and, in a market context, remunerate risk and profit.

4.1 Evaluation of the HaaS model in the SPIRIT pilots

The HaaS model was tested in the three pilots of the SPIRIT project, considering it as a tool for removing the burden of upfront investment for industry. All pilot projects demonstrate intricate integrations, distinct operating requirements, and significant process constraints that make implementing this business model challenging.

As illustrated in Figure 14 for Stella Polaris, Figure 15 for Tiense and Figure 16 for Smurfit Westrock, the current cost of heat generation based on gas or propane boilers (including fuel costs and applicable CO_2 taxation) is, in all cases, lower than the estimated HaaS cost derived from the depreciation of the upfront HTHP investment and the associated O&M costs over a 20 year period. It is important to note that the HaaS cost values presented in these figures do not yet include explicit remuneration for risk transfer (particularly relevant in retrofitting existing plants) or provider profit, which would further increase the heat tariff and therefore worsen the economic comparison.

To better understand the potential evolution of the HaaS model, the figures also explore the impact of percentage CAPEX reduction scenarios on the resulting HaaS cost. The results highlight significant differences across the pilots, driven primarily by the relative price of electricity compared to gas. In the Stella Polaris case, a CAPEX reduction of approximately 30% already allows for the creation of a potential economic advantage for the HaaS scheme. This outcome is largely enabled by the exceptionally low cost of electricity in Norway, reflected in an E/G ratio without CO_2 compensation of 0.74, which strongly favors electrification.

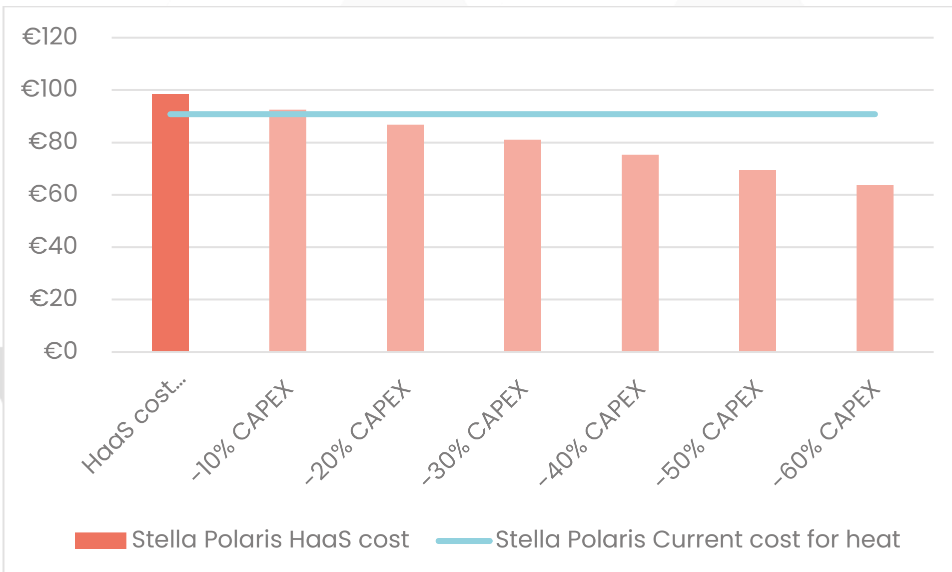

Figure 14. Stella Polaris current cost for heat and HaaS cost comparison for different levels of CAPEX reduction (expressed in €/MWh).

In contrast, for both Tiense and Smurfit Westrock, the higher electricity prices substantially limit the effectiveness of CAPEX reductions. As already highlighted in the SWOT analysis presented in Section 2.5, volatile energy markets represent a key risk for the deployment of service-based business models, particularly in energy-intensive industrial applications. With E/G ratios without CO_2 compensation of 2.61 for Tiense and 3.02 for Smurfit Westrock, reductions in investment cost translate into much smaller decreases in the HaaS heat price. In these cases, the analyses show that only CAPEX reductions exceeding 50% would bring the HaaS cost close to or below the current cost of heat, a threshold that is not realistic under present market conditions.

Funded by the European Union

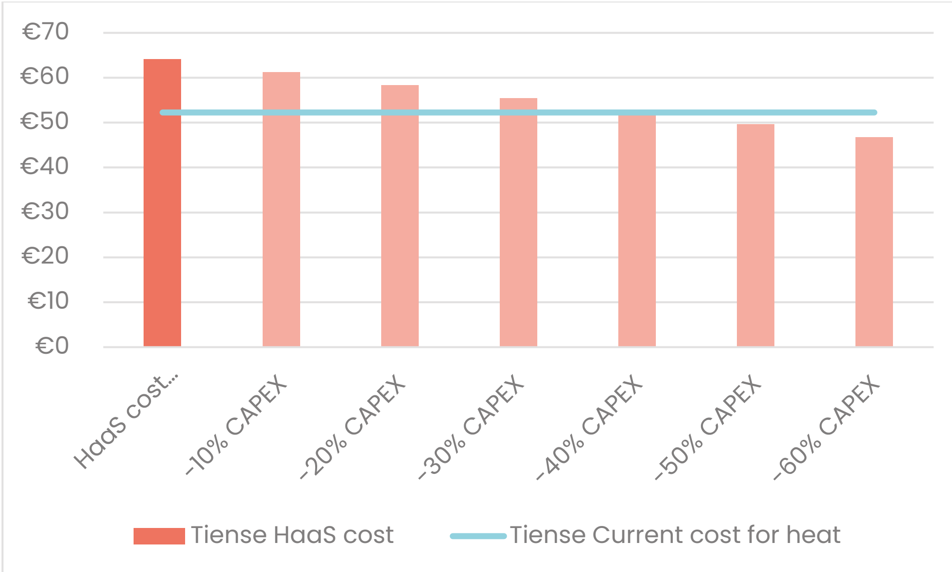

Figure 15. Tiense current cost for heat and HaaS cost comparison for different levels of CAPEX reduction (expressed in €/MWh).

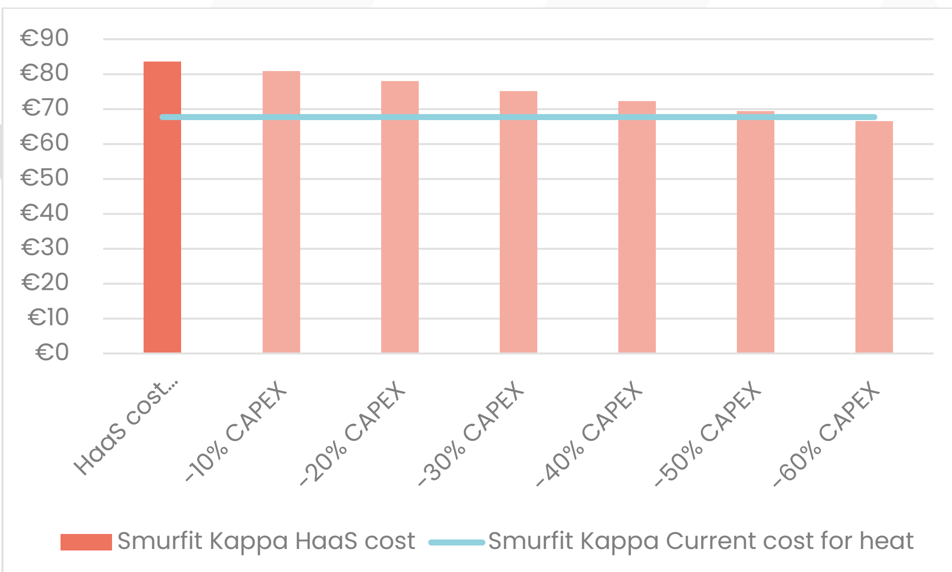

Figure 16. Smurfit Westrock current cost for heat and HaaS cost comparison for different levels of CAPEX reduction (expressed in €/MWh).

Overall, the results of the analysis indicate that, under current technical and market conditions, the HaaS model cannot yet be implemented as a viable business model for the SPIRIT HTHP solutions. The combination of high upfront investment costs for HTHP systems and electricity prices that are often comparable to, or higher than, fossil fuel alternatives prevent service providers from offering heat tariffs that are simultaneously attractive to industrial clients and economically sustainable for the provider. As a result, while HaaS remains conceptually appealing as a mechanism to remove investment barriers for end users, it does not currently constitute a feasible standalone business model for large scale deployment of the SPIRIT solutions. Further reductions in technology costs, improved electricity-to-fuel price ratios and supportive policy frameworks would be required before HaaS could play a central role in the commercialization of HTHP based industrial heat solutions.

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

5. CONCLUSIONS AND IMPROVEMENT OPPORTUNITIES

This deliverable assessed business models and contractual arrangements for SPIRIT High Temperature Heat Pump (HTHP) solutions by combining market evidence, contractual logic and the techno-economic results of three peculiar industrial pilots. Across the cases, the analysis confirms that the economic viability of HTHPs deployment is primarily driven by two interacting factors: the relative price of electricity versus gas fuels and the amount of upfront investment required to engineer, construct and integrate HTHP systems into existing industrial environments.

From an economic perspective, the assessment already considers the main policy-driven cost factors affecting the business cases, including existing carbon pricing mechanisms such as ETS or equivalent CO_2-related cost components where relevant. However, no specific HTHP-dedicated support schemes were identified in the pilot countries as directly applicable to the analyzed use cases. This implies that the financial results presented in this deliverable mainly reflect market-based conditions and general decarbonization-related cost signals, rather than technology-specific incentives. Further information on national subsidies and broader energy transition measures is provided in D5.2, where country-level policy instruments are analyzed in greater detail.

The conclusions must also be interpreted in relation to the specific operating profiles of the pilots. The analysed cases do not represent fully continuous industrial operation. In particular, two pilots are linked to production cycles with significant seasonality or limited annual operating hours, which materially constrains the economic benefit generated by the HTHP. This is a relevant boundary condition, as higher utilisation rates would improve the distribution of fixed investment costs over the heat produced and would increase the cumulative value of energy savings. Therefore, the economic results cannot be directly generalized to industrial cases with significantly higher annual operating hours, where the financial performance of HTHP solutions could be materially stronger.

The Stella Polaris pilot illustrates most clearly that the electricity-to-gas price ratio is a decisive lens for interpreting feasibility, even under extreme ambient conditions. Despite a challenging operating context with a demanding temperature lift, the economic balance remains largely dictated by the competitiveness of electricity compared to propane and by the CO_2 taxation context. Conversely, in the other pilots, where electricity prices are significantly higher than other fuel prices, the substitution of fuel with electricity limits the achievable operational savings and increases exposure to electricity price volatility.

The pilots also show that current investment costs remain a major barrier to diffusion. Sensitivity analyses indicate that, to bring payback periods into a more investable range of 10–15 years, **CAPEX reductions on the order of approximately 10% to 40% are typically required**, depending on the site context and energy price assumptions. **This range is consistent with the cost reduction trajectory identified in D4.1, where a CAPEX reduction of around 25% is expected to be enabled by standardization of HTHP technology**. Such a reduction would be broadly aligned with the investment cost decrease required to improve bankability in several SPIRIT business cases. Conversely, if this standardization pathway is not achieved, or if site-specific integration costs remain structurally high, dedicated financial support will be needed to close the gap between technical feasibility and acceptable investment returns.

This result reinforces the centrality of industrialization and cost-down pathways for HTHPs, particularly for brownfield retrofits where integration effort and site adaptation can represent a significant share of total costs. The evidence from SPIRIT confirms that HTHP economics cannot be assessed only on the basis of the equipment cost. **Civil works, process integration, safety requirements, auxiliary systems, commissioning, automation and regulatory compliance can substantially affect the overall investment**, especially in food and process industries with strict operational constraints.

The conventional deployment model, where the industrial end user purchases, owns and operates the system has been also compared with the HaaS model, where a specialized provider owns and operates the asset and sells heat as a service. The comparison highlights that the conventional model provides the client with full control over operational strategy and energy price exposure and allows the investment decision to be assessed through standard corporate metrics (e.g., payback, cost of heat, compliance-driven decarbonization value). In turn, HaaS is potentially attractive because it can remove the upfront CAPEX burden from the client, transfer performance and availability risk to the provider, and package O&M, monitoring and guarantees within a single tariff.

However, the analysis also shows that this shift changes the economic balance: **under HaaS, the tariff must embed not only electricity and O&M costs but also capital**

Funded by the European Union

recovery and the remuneration of risk and profit, making the outcome structurally more demanding than an owner operated case. Therefore, the comparison suggests that HaaS can only outperform conventional deployment when either: (1) the provider can finance and operate the asset at materially lower cost and risk than the client, and/or (2) the client's avoided cost of heat is sufficiently high and stable to create a viable price corridor for both parties.

Currently, the idea of using HaaS as a business model for SPIRIT solutions cannot be validated. **The HaaS approach relies on the avoided cost principle, which requires the HaaS heat tariff to be less than the client's existing heating expenses** while still allowing the provider to recoup capital expenditures, cover operating and maintenance costs, manage risks, and earn a profit. However, calculations based on real pilots show that, under current conditions, achieving this mutually beneficial price range is tough. High initial costs paired with only modest savings in brownfield projects make it hard for service providers and industrial clients to agree on a tariff that's both attractive for clients and financially viable for providers, especially when factoring in risk premiums and profit margins.

Although current pilot conditions do not yet prove that HaaS-based deployment is immediately viable, the findings point to technical and systemic opportunities that could enhance cost effectiveness and eventually make service-based business models more feasible. **Pairing HTHPs with solar thermal plants could be a valuable design choice to raise the temperature of the heat source** where high-quality waste heat is unavailable, improving thermodynamic efficiency and reducing the electricity required for heat generation. As outlined in Section 13 of D4.2, high-vacuum flat plate collectors show particular promise for higher-temperature preheating, although their suitability depends on case-specific factors such as seasonal industrial demand, local solar irradiation, ambient temperatures and available installation space.

Integration with district heating networks can also improve the investment case by stabilizing demand, increasing operating hours and reducing the negative effects of partial-load operation. This may improve cash flow predictability and enable long-term contractual arrangements. District heating operators may also act as investors or asset owners, reducing the capital burden for industrial sites and supporting business models where HTHP assets are integrated into wider heat supply systems rather than assessed only within a single industrial process.

Integration with district heating networks can also improve the investment case by stabilising demand, increasing operating hours and reducing the negative effects of partial-load operation. This may improve cash flow predictability and enable long-term contractual arrangements. District heating operators may also act as investors or asset owners, reducing the capital burden for industrial sites and supporting business models where HTHP assets are integrated into wider heat supply systems rather than assessed only within a single industrial process.

Overall, the analyses indicate that HTHP technology can reach economic sustainability when two enabling conditions are progressively combined: **standardized solutions capable of reducing CAPEX and targeted support mechanisms able to compensate for the residual cost gap** during early market deployment. The required support does not necessarily need to be large in all cases. Even moderate subsidies or investment support schemes, if combined with CAPEX reductions, adequate operating hours and favorable electricity-to-fuel price conditions, can shift HTHP projects from technically promising demonstrations to financially viable industrial decarbonization investments.

6. REFERENCE LIST

Cordin Arpagaus, S. P. (2023). Review of Business Models for Industrial Heat Pumps. *ECOS - INTERNATIONAL CONFERENCE ON EFFICIENCY, COST, OPTIMIZATION, SIMULATION AND ENVIRONMENTAL IMPACT OF ENERGY SYSTEMS.*

Cordin Arpagaus, S. P. (2023). Review of Business Models for Industrial Heat Pumps. *Proceedings.com*.

EHPA, E. H. (2024). *Financial barriers to the widespread adoption of heat pumps.*

Jess Britton, A. M. (2021). Exploring the potential of heat as a service in decarbonization: Evidence needs and research gaps. *Energy Sources*.

Kastalli, I. V. (2013). Servitization: Disentangling the Impact of Service Business Model Innovation on Manufacturing Firm Performance. *Journal of Operations Management*.

Kristina Lygnerud a, J. O. (2020). Business models combining heat pumps and district heating in buildings generate cost and emission savings. *Elsevier*.

Push2Heat. (2024). Retrieved from push2heat.eu: https://push2heat.eu/

WBCSD, W. B. (2022). *Heat as a service: How to decarbonize commercial and industrial heat use with third-party capital investments.*

Funded by the European Union