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Review of Business Models for Industrial Heat Pumps

Cordin Arpagaus[a], Sidharth Paranjape[a], Stefan Nertinger[b], Rigo Tietz[b] and Stefan S. Bertsch[a]

Eastern Switzerland University of Applied Sciences
[a] Institute for Energy Systems (IES), Werdenbergstrasse 4, CH-9471 Buchs,
cordin.arpagaus@ost.ch, Tel. +41 58 257 34 94
[b] Institute for Strategy and Marketing (ISM), Rosenbergstrasse 59, CH-9001 St. Gallen

Abstract:

The heat pump market is experiencing remarkable growth and rapidly expanding in various sectors. Industrial heat pumps are an emerging technology for electrifying and decarbonizing the heat supply, such as hot water, hot air, and steam. However, integrating industrial heat pumps into business models is not yet common. As a result, little research has been conducted linking business model frameworks to the rapidly evolving heat pump sector. Besides, there are challenges in the transition from fossil fuel heating to electrical-driven heat pumps, including unfavorable electricity-to-gas price ratios, regulatory issues, alternative heating technologies, low maturity of services, the requirement for tailor-made designs, more complex integration principles, simultaneous need for excess heat, and higher CAPEX (compared to fossil or electric boilers). This study reviews business models for industrial heat pumps based on scientific literature and interview results with manufacturers as part of the EU Horizon project PUSH2HEAT. The goal is to explore innovative business models that could emerge from industrial heat pumps based on the changing framework conditions. First, the status of business models is reviewed to identify gaps in the academic literature. Next, ideation inputs are considered from case studies on high-temperature heat pumps, analogies to other markets such as domestic heat pumps, large-scale heat pumps for district heating networks, waste heat recovery, combined heat and power generation, as well as lessons from other innovative business models in the energy sector (e.g., energy contracting, heat as a service). Then, various players in the value chain (e.g., planners, manufacturers, integrators, installers, service providers, etc.), their capabilities, and the added value will be analyzed. Finally, a short list of business models will serve as a basis for decision-making for existing players, such as utilities and new companies considering entering the heat market.

Keywords:

Heat pumps; industry; innovative business models; value-chain.

1. Introduction to industrial heat pumps

Industrial heat pumps (HP) will play an important role in decarbonizing process heat and improving the energy efficiency of industrial processes in the future while driving the shift from fossil fuels to renewable electricity as an energy source [1], [2]. There are more and more suppliers of industrial heat pumps, as summarized in the IEA Annex 58 project [3], [4]. Four types of heat pump technologies are most relevant for industrial applications:

- standard heat pumps with supply temperature < 80 °C,
- high-temperature heat pumps (HTHP) with supply temperature > 100 °C,
- steam-generating HP with mechanical vapor compression (MVR) and supply temperature < 200 °C,
- heat transformers with supply temperature < 300 °C [5].

These heat pump technologies cover heat capacities ranging from about 100 kW to 10 MW [4]. In most cases, the heat source is excess heat from the processes with a typical temperature level of 30 °C to 80 °C, while some are also used to provide cooling simultaneously.

Examples of existing and potential industries using industrial HPs include the food, paper, chemical, and refinery industries, where processes such as drying, pasteurization, sterilization, evaporation, and distillation can be made more energy-efficient [2].

An estimate of the European industrial HP market potential showed that the cumulative heating capacity of industrial HPs in EU28 is about 23 GW, consisting of 4'174 heat pump units that could cover 178 TWh/a of process heat demand up to 200 °C [6]. Standard HPs could meet 50% of the cumulative heating capacity of the total market with heating capacities up to 10 MW; for above 10 MW, tailormade HP solutions are required.

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In general, the ongoing energy transformation and the growth of renewable energies are changing the structure and value creation of the energy industry, enabling new business models that can be classified according to customer proximity [7]. In particular, there is a need for new business models for industrial heat pump market players (e.g., heat pump manufacturers, energy service companies ESCOs [8]) to strengthen market acceptance and faster market uptake.

This study aims to identify innovative business models to drive the market introduction of industrial heat pumps. Because there are limited sources of business models for industrial heat pumps so far, the current state of business models for large-scale heat pumps for district heating networks and domestic use is first analyzed to identify gaps in the scientific literature. Then, business models from empirical interviews from the perspective of manufacturers of high-temperature heat pumps are evaluated based on the value chain. Next, a short list of business models is summarized to serve as a basis for decision-making when entering the industrial heat pump market. Finally, the study should help motivate existing companies in the value chain and start-ups to develop new business models for commercializing industrial heat pumps.

2. Business model development

2.1. The "magic triangle"

At its core, a business model describes the rationale of how an organization creates, delivers, and captures value [9]. Value creation describes what benefits are created by the company, and value capture explains how the company can generate revenue from the offered benefits. To assist companies in designing business models, researchers and practitioners have developed tools and procedures to facilitate development. A simple way to describe business models is the "magic triangle," which consists of four essential dimensions – WHO, WHAT, HOW, and VALUE (see Figure 2).

The "magic triangle" was developed at the University of St. Gallen (HSG) by Prof. Gassmann and team [10]–[12]. Briefly, the triangle aims to clarify the logic behind a business model by answering 4 questions (i.e., dimensions) about a business model:

1. WHO is your target customer? (Customer segment)
2. WHAT do you offer to the customer? (Value proposition)
3. HOW is the value proposition created? (Value chain)
4. How is VALUE achieved? (Revenue or profit mechanism)

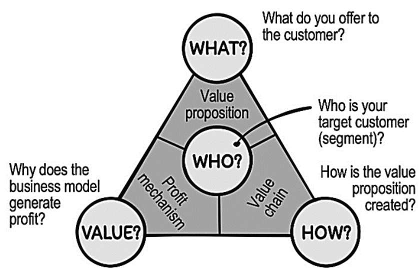

Figure. 1. Business model definition – the "magic triangle" (Adapted from [10]–[12])

The "magic triangle" is a qualitative representation to support companies in (re)designing their business model. The different dimensions can be further elaborated. By answering the 4 interrelated questions, a company's business model becomes more tangible.

- **WHO** - Each business model serves a specific group of customers. Defining the target customer is the first dimension in designing a new business model. Therefore, it should answer the question, "Who is the target customer?"
- **WHAT** - The second dimension describes what is offered to the target customer or the customer's value. This term is commonly referred to as the value proposition. It can be defined as a holistic view of a company's bundle of products and services that are of value to the customer.
- **HOW** - The third dimension describes how to build and disseminate the value proposition. To do this, a company masters multiple processes and activities, along with the resources and capabilities involved and the value chain behind creating that value.
- **VALUE** - The fourth dimension explains why the business model is financially sustainable and thus refers to the revenue model. Essentially, it combines aspects such as the cost structure and the profit mechanism applied and refers to the elementary question of any business, namely, how to make money from the business.

For a given technology, e.g., an industrial heat pump, the question is how to use it profitably. Depending on the business model, different actors can play the central role. It is, therefore, worth considering from whose perspective the business model is viewed. This study focuses on industrial heat pump manufacturers.

2.2. The “business model canvas” framework

This study also uses the “business model canvas” framework to describe innovative business models [9], [13], [14]. Business model canvas provides a common language for representing, evaluating, and changing key aspects of complex business models.

As shown in Table 1, the business model canvas contains nine elements arranged in a structured format. The nine interdependent building blocks are (1) customer segments, (2) value proposition, (3) customer relationships, (4) customer channel, (5) revenue streams, (6) key activities, (7) key resources, (8) key partners, and (9) cost structure. Applying the business canvas methodology involves answering a series of key questions in a particular sequence (see numbering (1) to (9) in Table 1). In this study, a business model canvas is developed from the perspective of industrial heat pump manufacturers.

Table 1. The Business Model Canvas framework, the mapping phases in development (numbering from 1 to 9), and the key questions (Adapted from [9], [13], [14])

(8) Key partners	**(7) Key resources**	**(2) Value proposition**	**(1) Customer segments**
Who can help you? • Who are our key partners? • Who are our key suppliers? • Which key resources are we acquiring from partners? • Which key activities do partners perform?	What do you need? • What key resources do these business activities require?	What do you do? • What value do we deliver to the customer? • Which customer’s problems are we helping to solve? • Which customer needs are we satisfying?	Whom do you help? • For whom are we creating value? • Who are our most important customers
(9) **Cost structure**	**(6) Key activities**	**(4) Customer channel**	**(3) Customer relationships**
What will it cost? • What are the most important costs inherent in our business model? • Which key resources are the most expensive? • Which key activities are the most expensive?	How do you do it? • What key activities do our value propositions, distribution channels, customer relationships, and revenue streams require?	How do you reach them? • Through which channels do our customer segments want to be reached?	How do you interact? • What type of relationship does each of our customer segments expect us to establish and maintain with them?
		(5) Revenue streams	
		What will it generate? • For what value are our customers willing to pay?	

3. Business models of heat pumps for district heating and domestic use

Before focusing on industrial heat pumps, this section briefly overviews published work on business models with heat pumps for district heating and domestic use. Table 2 summarizes the studies.

Various studies exist on the utilization of heat pumps for district heating networks in different European countries (e.g., Denmark [15], Austria [16], and Sweden [14]). A quick starting point for business model theory and contract theory concerning district heating can be found in the ReUseHeat report [17]. Their conclusions on urban waste heat recovery investments with a payoff of 15 years and more could apply to their respective regions. However, general conclusions should be made with caution.

Østergaard et al. (2019) [15] conducted a business analysis of heat pumps for small district heating systems combined with heat storage on Samsø island in Denmark. Simulations showed that heat pumps and heat storage are useful for fluctuating renewable energy in part-load operation but are not economically competitive with straw-fired boilers. However, this conclusion may not be entirely applicable outside of Denmark.

Terreros et al. (2020) [16] explored different potentials of heat pumps in rural district heating networks in Austria. Through simulations, it was found that the optimal bidding strategy for the heat pump is to buy 50% of the electricity on the day-ahead spot market and to offer 50% of the capacity for negative balancing energy for the automatic frequency restoration reserve, as this allows a significant reduction of the heat generation costs. The optimal operating strategy reduced heat generation costs by up to 17.7% for use cases with flue gas as a heat source for the heat pump and up to 27.5% for cases with sewage water. In addition, the results showed that variations in biomass price and call probabilities could significantly affect heat pump profitability.

In Sweden, Lygnerud et al. (2021) [14] applied the business model canvas concept to map the required change in the district heating networks to generate cost and emission savings by integrating small-scale heat pumps in buildings. The authors showed that by combining efficient small heat pumps in district heating networks with optimal control, maximum cost savings of 33% and CO_2 emission savings of 75% could be achieved. However, challenges exist due to the tendency of Swedish district heating companies to view heat pumps as competition.

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Vivian et al. (2018) [18] studied the economic performance of a low-temperature district heating system below 45 °C. They used booster heat pumps in customers' substations to provide the temperature required for space heating and domestic hot water. Two types of business models were considered a district heating utility responsible only for heat recovery and distribution and a utility that also invests in heat pumps and electricity. At the same time, the user pays for the delivered heat. The economic analysis showed that the system with booster heat pumps is already competitive with single gas boilers for multi-family buildings, provided a local low-temperature heat source with minor marginal costs can be used.

Heat pump flexibility can play a major role in enabling a transition towards a renewable heat and electricity sector. In this context, Fischer et al. (2017) [19] analyzed different business models that could arise from using the flexibility of domestic heat pumps in a smart grid context. Results showed that due to high-end customer prices, grid fees and complicated market requirements, less integrated business models were more attractive than the direct use of heat pump flexibility on the reserve or spot market or the provision of balancing energy. However, additional revenues could be generated by using heat pump flexibility, such as providing a secondary reserve or balancing energy.

Lyon et al. (2021) [20] considered the challenge of retrofitting existing residential buildings in Europe, where heat pumps struggle to compete against traditional heating systems. The alternative business model “heat as service” (HaaS) proposition was investigated, which involves a residential building occupier signing a contract for heating provision and heating equipment for a fixed monthly fee rather than purchasing the heat pump equipment. It was concluded that the HaaS business model could be a critical step for overcoming the end-user barriers for heat pumps, i.e., high upfront costs, risk of high running costs and lack of trust in the technology. The potential of HaaS has also been explored as a route to decarbonize the domestic heat supply in Scotland [21] to increase the uptake of low-carbon heat, improve the energy efficiency of people’s homes, and reduce fuel poverty.

Table 2. Studies on business models with heat pumps for district heating applications and domestic use

Paper	Description	Business model
Østergaard et al. (2019) [15]	• Heat pumps and heat storage combination for small district heating system in Denmark covering fluctuating renewables	• Simulations of optimal business economic design • No business model was discussed
Terreros et al. (2020) [16]	• Heat pumps in rural district heating networks in Austria • Flue gas and sewage water as heat sources	• Electricity market options • Costs savings by optimal bidding strategy (day-ahead & balancing market)
Lygnerud et al. (2021) [14]	• Combination of small-scale heat pumps in district heating networks in Sweden	• Efficiency gains impacting cost and CO_2 emissions (business model canvas method used for business model mapping)
Vivian et al. (2018) [18]	• Booster heat pumps with low-temperature district heating network (15 to 45 °C) • System is economically competitive to gas boilers • Utility investing in heat pumps and electricity	• District heating utility responsible only for heat recovery and distribution • Customer pays for heat delivered
Fischer et al. (2017) [19]	• Flexibility of residential heat pumps in a smart grid context	• Provision of the secondary reserve or balancing energy (business model canvas established for various business cases)
Lyon et al. (2021)[20]	• Retrofit existing residential buildings with heat pumps • Increasing trust in heat pump technology • Reduction of risk of high running costs	• Heat as a Service • Contract for the heating provision • No high upfront costs
Fleck et al. (2021) [21]	• Decarbonization of domestic heat in Scotland • Increase the uptake of low-carbon heat, improve the energy efficiency of homes, and reduce fuel poverty	• Heat as a Service
Britton et al. (2021) [22]	• Heat pumps for cooling or keeping temperatures in the UK domestic market	• Heat as a Service • Consumer pays for produced heat, annual service fee, initial installation

HaaS business models have also been reviewed in the UK domestic market by Britton et al. (2021) [22]. Recommendations for policy and research were made based on insights from facilitated group discussions with key stakeholders and experiences from HaaS trials in the UK. Based on the findings, policy and research recommendations were proposed to better understand the role of HaaS business models in decarbonization.

Skovshoved & Sandqvist (2017) [23] discussed HaaS from a more academic perspective and aimed to identify value propositions for heat pumps in Sweden. The same study also described a business model in Denmark by Best Green, where end users pay an annual service fee and initial installation costs for the heat generated by the heat pump. However, the heat pump is purchased and owned by the service provider.

Further studies published on business models in the heat and energy sector with heat pumps include:

- solar heat pump water heaters [24],
- solar thermal air conditioners [25],
- district energy providers [13],
- perspective of the electrical grid operator [26],
- urban waste heat recovery [17],
- combining district heating and heat pumps in buildings [27],
- heat pump retrofits in metro Vancouver [28],
- small-scale heat energy production in Finland [29], and
- heat purchase agreements [30].

4. Business models specific to industrial heat pumps

To the best of the authors' knowledge, no free literature is available on business models specifically for industrial heat pumps. Therefore, interviews with manufacturers of industrial high-temperature heat pumps (i.e., SPH, Enertime, BSNOVA, and QPinch) with reciprocating and turbo compressors, absorption and thermochemical technology were conducted as part of the EU Horizon project PUSH2HEAT [31].

The following section summarizes the empirical findings from initial interviews with the heat pump manufacturers and ongoing studies. The interviews were conducted in a structured manner using a questionnaire. The aim was to gain a deeper understanding of the topic, identify innovative business models, and draw parallels between the general answers of the manufacturers. The "magic triangle" and the "business model canvas" framework were used to describe and visualize the business models.

4.1. Business models and value chain of industrial heat pumps

Figure 2 illustrates the main activities in the value chain of the industrial heat pump market ranging from research and development (R&D), manufacturing, consulting, design, distribution, installation, and commissioning to after-sales (maintenance, service), energy data management (EDM) and trading of heat (e.g., with heat storage and back-up systems) or CO_2 certificates on the energy markets. Innovative approaches to business models can be mapped along the value chain. As customer integration increases, so does the degree of collaboration with the customer and involvement in the value chain.

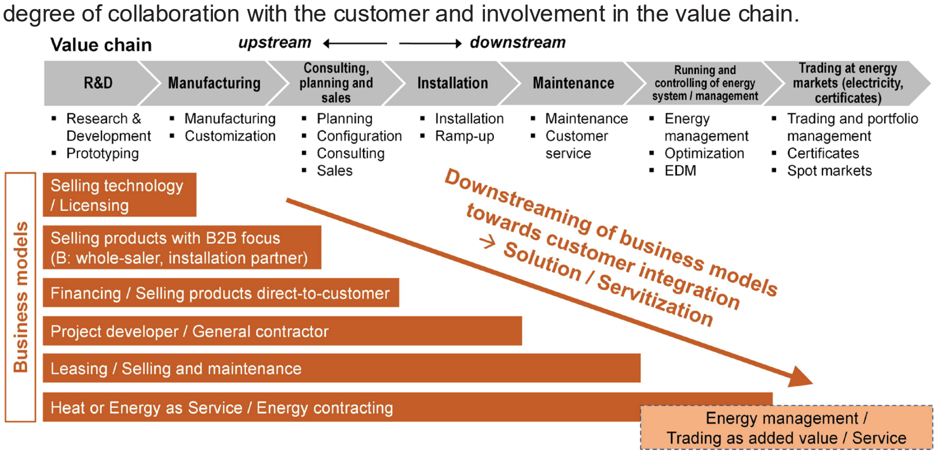

Figure. 2. Business models and value chain of industrial heat pumps (Source: PUSH2HEAT project)

Figure 3 shows three basic types of companies within the value chain, which differentiate by a targeted selection of core activities (indicated by arrows in different colors). A distinction is made between integrator, specialist, and solution provider. The integrator offers everything from a single source and masters the entire value chain in depth. The specialist supplies specific parts of the value chain and benefits from economies of scale, achieving quality advantages and flexibility. Finally, the solution provider (or orchestrator) can select the best from all specialists and thus offer the customer the most suitable solution.

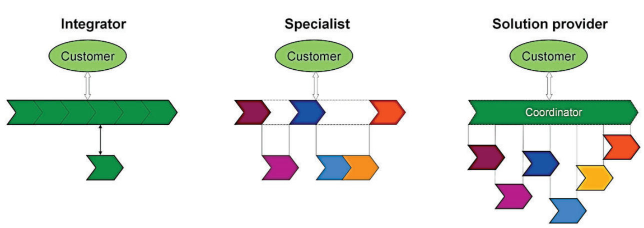

Figure. 3. Basic types of companies within the value chain (integrator, specialist, and solution provider)

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Table 3. List of likely business models from the perspective of a manufacturer of industrial heat pumps

Business model	Value proposition (WHAT)	Revenues (VALUE)	Key activities (HOW)
Licensing of heat pump technology	• Subcontractor using HP technology for own production • Users: Local partner	• Licensing fees from subcontractor (recurring), e.g., depending on units	• Licensing agreement • Trustworthy subcontractor
Selling heat pump technology (IP)	• Buyer receives state-of-the-art technology without any R&D risks	• One-time sales	• Technology readiness • IP purchase contract
Selling heat pump products with a B2B focus (B: wholesaler, project developer, installation/sales partners)	• Local partner (distributor) as a one-stop shop for user customer	• Income and profits from sales	• Trustworthy sales partner/dealer network
Selling heat pump products Direct2Customer	• Customization One-Stop shop: installed pump (Financing as added service)	• Earnings from sales and installation • Customer loyalty/customer data • Provisions from a financing partner	• Sales • Installation resources
Project developer / General contractor	• “One-stop-shop” solution from idea to operating system	• Fixed income for the successful project (in-time, in-budget)	• Coordination of entities/partners • Sales resources • Resources for installation and planning
Leasing / Selling and maintenance	• Low capital spending • All services included • Service level agreed	• Fixed earnings over the project duration • Provisions from financing/leasing partner or earnings in case of self-financing	• Service level and leasing agreements • Resources for installation, planning, maintenance
Energy contracting	• Guaranteed efficiency performance (energy, costs, CO_2, white certificates, etc.) • Monetization of efficiency increase (achieve financial benefit)	• Fixed, recurring earnings • Further revenues arising from efficiency surpluses	• Risk management and assessment of projects and contracts
Heat as a Service (HaaS)	• Heat for a fixed price over the contract duration	• Fixed, recurring earnings	• Financial resources
Energy as a Service (EaaS) (Running the whole energy infrastructure of a customer)	• Energy for a fixed price over the contract duration	• Fixed, recurring earnings	• Construction and provider of a heat pump in own response
Trading and profiting on arbitrage: • Energy markets (e.g., spot markets EPEX/EEX), • Selling Carbon certificates (CO_2-ETS, CO_2-voluntary like VCS, Gold • Electricity (renewables) - Efficiency (White like ESC, EEC)	• Earnings from certificates	• Service fees, provisions from sales of certificates • Energy management fees	• Trading capabilities • Energy management capabilities
Energy consulting and management	• Energy management competence	• Consulting fees • Energy management service fees	• Energy management and consulting capabilities

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Table 3 summarizes the list of likely business models from the perspective of an industrial heat pump manufacturer and describes the business models based on value propositions, revenue streams and key activities (according to the “magic triangle”). The list of business models is intended to serve as a common basis for further discussion and is, therefore, neither very detailed nor conclusive or complete. The target customers are industrial companies (i.e., end users of the pulp, paper, food, and oil industry) that need to decarbonize their heat supply in the wake of climate targets. A brief description of each likely business model for industrial heat pump manufacturers follows.

4.2. Licensing of heat pump technology

When licensing a heat pump technology or parts of the technology, a subcontractor uses the technology to produce heat pumps. The heat pump manufacturer receives recurring license fees from the subcontractor, e.g., depending on the number of sold units. The business model requires a license agreement and a trustworthy subcontractor. For example, licensing can be interesting for a European heat pump manufacturer to reach certain markets (e.g., USA, China).

4.3. Selling heat pump technology (IP)

When selling a heat pump technology's intellectual property (IP), the buyer receives the most advanced technology without R&D risks. For the technology provider, it is a one-time sale based on an IP purchase agreement and the provision of the technology according to a defined technology readiness level (TRL).

4.4. Selling heat pump products with Business2Business (B2B) focus

When selling heat pump products over B2B (B: wholesaler, project developer, installation partners), the local partner is a one-stop shop for customers. Revenues are generated from the sale of heat pump products. Important is a trustworthy distribution partner and distributor network.

4.5. Selling heat pump products Direct2Customer

The heat pump products are sold directly to end customers by salesforce, and technicians or subcontractors carry out the installation. This is today's traditional and most common business model for industrial heat pump manufacturers. It leaves the customer with most of the risks (i.e., financial and technical). For a "new" technology like HTHP, this generates extra risk for the customer. In comparison, this risk is quite low for refrigeration systems due to long market experience. In most cases, key aspects are maintenance and service by third-party companies. Certain heat pump manufacturers are developing modular heat pumps to offer customized solutions. Here, the aim is to offer a package (i.e., package supplier). Some compressor manufacturers sell their products directly to heat pump manufacturers as subcontractors.

4.6. Project developer / General contractor

A project developer/general contractor acts as a one-stop shop and offers the heat pump solution from concept to commissioning. This provides a fixed income for the successful project (in-time, in-budget). The business model requires coordination of units/partners, sales resources, and resources for installation and planning.

4.7. Leasing / Selling and maintenance

Leasing (including maintenance) promises low investment costs, and all services are included depending on the agreed service level. Service level and leasing agreements and installation, planning, and maintenance resources are required. This generates fixed income over the project duration. Heat pump manufacturers might find this business model interesting but require a financial partner with know-how.

4.8. Energy contracting

Energy contracting is a comprehensive energy service normally provided by an energy service company (ESCO) [22]. The flexible operation of utility processes holds great potential and creates opportunities for third-party involvement. Examples include outsourcing activities by industry towards ESCOs, especially for technologies used in utility processes. Energy contracting guarantees performance in terms of efficiency (e.g., energy, cost, CO_2, white certificates, etc.). Efficiency improvements allow for fixed, recurring revenues. Additional revenues result from efficiency surpluses. Risk management and evaluation of projects and contracts are required.

4.9. Trading and arbitrage profits

As a complementary revenue stream, an industrial company may install a heat pump for its processes and use unused capacity for trading/arbitrage. Participation in trading on the energy markets (e.g., spot markets on the European Power Exchange (EPEX), European Energy Exchange (EEX)) and sales of carbon certificates in the emissions trading scheme (CO2-ETS, CO_2-voluntary such as Verified Carbon Standard (VCS, Gold) enable revenue from certificates using heat flexibility [32]. Revenue arises from service fees,

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provisions from certificate sales, and energy management fees. Key activities include trading capabilities and energy management capabilities.

4.10. Heat as a Service (HaaS)

An increasingly popular business model for industrial heat pumps is heat as a service (HaaS) [20]–[23], [33]. Instead of a company investing directly in a new heat pump, HaaS allows a third party (e.g., service provider, ESCO) to bear the capital costs and guarantee the availability and performance of the heat pump system during the contract period. The ESCO designs, builds, owns, operates, maintains, and finances the heat pump system [33]. In addition, the ESCO can achieve better economies of scale and potentially receive volume discounts by buying several heat pumps. Delta-EE Ltd. estimated that the number of customers currently using a HaaS-type business model is in the low 1,000s across Europe in the domestic sector [20].

Among others, the Danish Energy Agency introduced a subsidy program to encourage direct heat pump uptake in oil-heated homes in areas where district heating is not available [20]. Under this business model, the company that buys HaaS essentially pays an upfront cost for the installation of the heat pump, a fixed price per kWh of heat delivered and a fixed annual fee to the service provider to pay for the cost of the heat pump, installation, and any maintenance costs. Depending on their business model, energy service providers are free to adjust each of these three factors. The minimum contract period is typically 10 years [20]. In another example, Fleck et al. (2021) [21] described the potential of HaaS as a way to decarbonize residential heat supply in Scotland.

4.11. Energy as a Service (EaaS)

Beyond HaaS, there are also further developments possible, such as Comfort as a Service, Cooling as a Service [34], Temperature as a Service, or more general Energy as a Service (EaaS) [35]. The EaaS market is flourishing and is expected to be worth over 140 billion by 2027 [36].

Figure 4 shows an example of an EaaS concept from ANEO Industry AS (Norway) [37] for high-temperature heat pumps to generate steam between 100 °C and 150 °C (1 to 5 bar(a)). With its sustainable EaaS platform, ANEO reduces fossil emissions and energy consumption in the process industry and increases energy efficiency. ANEO's services include engineering, installation, operation, and maintenance of industrial heat pumps from the initial case study to the system's life cycle.

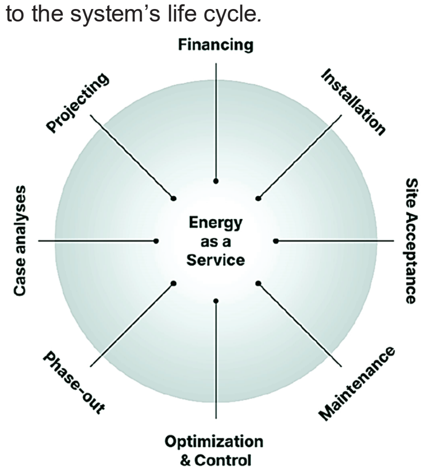

Figure. 4. Example of an Energy as a Service (EaaS) concept from ANEO Industry AS (Norway) [37] for high-temperature steam-producing heat pumps. Currently, ANEO's EaaS is more a HaaS, but the intention is to supply electricity within the same framework.

Like HaaS, the basic idea of EaaS is to take financial and technical risks (i.e., investment, operation, and maintenance) of the heat pump system out of the scope and liability of the end customer, meaning that the investment risk, financial risk, and operational risk are placed in the scope and liability of a service provider. The EaaS provider purchases the heat pump system under a contractual agreement with a technology partner and certain performance guarantees, such as operability, availability, capacity, etc., with penalties for non-performance.

Energy is guaranteed at a fixed price during the contract period (e.g., service agreement). This results in fixed, recurring revenue while profit for the EaaS provider is generated over the life cycle of the heat pump system (typically 10 years) and covers management, administration, risk mitigation, etc., in addition to profit margin. Depending on the project's location, investors in EaaS agreements can benefit from predictable cash flow, CO2 tax credits, and renewable energy certificate revenue. The EaaS business model allows the customer to focus its capital and resources on its core business.

5. Business model building blocks of a heat pump manufacturer

Finally, Table 4 attempts to compile various business model building blocks from an industrial heat pump manufacturer's perspective based on the interview responses. This overview represents a snapshot and needs to be refined in further studies to identify the relevant building blocks for each business case.

Table 4. Business model building blocks from the perspective of an industrial heat pump manufacturer

(8) Key partners	**(7) Key resources**	**(2) Value proposition**	**(1) Customer segments**
• Heat pump producer • Suppliers of key components (e.g., compressor, heat exchanger, valves, control system, etc.) • Distribution partners like OEM integrators to expand the network • Demo customers for on-site visits • Regional, national, and European public institutions for the promotion • Private and public investment funds and banks for financing projects • Technical consultants and process integration experts • Universities and research partners	• Know-how about heat pump design and compressor integration • Intellectual property • Supply chain management for key components • Proof-of-concept and demonstration projects • Sales with a large industry network • Dedicated sales force • Technical resources for after-sales service and maintenance	• Sustainable process heat supply • Reductions in energy consumption, energy costs, and CO_2 emissions (i.e., carbon-free on-site heat source) as a contribution to carbon neutral/net zero strategies • Saving fossil fuels • Integration into existing industrial processes • Training the customer regarding heat pump technology (how it works and what benefits it can bring)	• Various energy-intensive industries (e.g., food & beverage, paper, chemical, oil) • Sugar mills, distilleries, petrochemical plants, paper mills, gypsum, ceramics, etc. • Steam and drying processes • Energy service suppliers (ESCOs) and providers of district heating networks; infrastructure providers for large industry parks • B2B resellers, wholesalers, project developers, and utilities
(9) Cost structure	**(6) Key activities**	**(4) Customer channel**	**(3) Customer relationships**
• Investment costs for equipment and technical works (i.e., construction, mechanics, electrification, electricity grid, etc.) • Operating costs (i.e., electricity consumption during lifetime) • Maintenance costs (i.e., annual inspections, spare parts) • Subsidy programs	• Development of high-quality heat pump technology (TRL9) • Demo units • Standardization and modularization • Sales and marketing activities • Hiring and training new competent employees	• Direct sales • Sales through distribution partners • Reference customers (i.e., pilot projects)	• Direct sales of equipment to end users or integrators • Direct sales of turnkey projects (100% one-stop-shop) • Sale of heat pump products through partners • Special leveraged tenders (e.g., waste heat recovery, virtual power plants)
		(5) Revenue streams	
		• Direct sales of heat pump equipment (hardware) • Installation and commissioning • Maintenance and service contracts (EaaS) • Subsidies and incentives • Licensing/IP fees	

5.1. Customer segments

As heat pump technology is a cross-sectional technology, the end users of industrial heat pumps can be found in various process industries. Most requests come from the food and beverage industry, followed by the paper and chemical industries. End users own energy-intensive industrial plants such as sugar mills, distilleries, petrochemical plants, paper mills, gypsum, ceramics, etc. The focus is on processing heat supply through steam and drying processes. Process integration is often performed confidentially within an industrial company. Developing specific industry solutions to take advantage of the multiplication potential is possible. Customers can also be B2B resellers, wholesalers, project developers, utilities, and energy service companies (ESCOs) focused on plant operations (facility management).

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5.2. Value proposition

The main added value to customers by industrial heat pumps is the conversion of several industrial sectors to a sustainable process heat supply and significant reductions in energy consumption and CO_2 emissions (i.e., carbon-free on-site heat source). This enables:

- Reduction of energy consumption and energy costs (i.e., operating costs)
- Increasing the share of renewable energies
- Reduction of greenhouse gas emissions (CO_2, carbon emissions, carbon neutrality)
- Saving of fossil fuels (e.g., independence from gas imports)
- Reducing dependency on energy markets and their volatility (level of energy autarky)
- Increasing the use of energy from excess heat sources
- Profits from trading on the spot market

Training the customer about how a heat pump works and what benefits it can bring is also a value proposition. The heat pump manufacturers assist potential customers in the selection, purchase and integration process and provide customers with a lower-cost alternative (life cycle costs) compared to competing or existing heating technologies such as gas boilers or biomass. At the same time, technical innovation will stimulate the creation of numerous jobs and significantly contribute to the economy's growth.

5.3. Customer relationships

Building trust, good sales and customer support, and a good network in the industry are crucial for establishing successful customer relationships. In service concepts, a distinction is made between long-term and short-term customer relationships. In the eyes of the customers, individual and customized solutions are important.

5.4. Customer channels

The customer relationship can take place through various channels:

- Direct sales of heat pumps to end users
- Direct sales of heat pumps to integrators
- Direct sales of turnkey projects (100% one-stop-store) to end users
- Sales of heat pump products through partners
- Special tenders with leverage effect (e.g., waste heat recovery)

As a confidence-building measure, demo sites of industrial heat pumps for on-site visits are important.

5.5. Revenue streams

The current revenue streams come mainly from direct heat pump equipment (hardware) sales to customers or integrators and a little from installation and commissioning. This means turnkey projects will be sold directly to end customers (100% one-stop-shop). In the future, revenue will also be generated from the sale of maintenance and service contracts. Energy as a Service is a very interesting business model (e.g., lease-like contracts with fixed lease rates and residual purchase value at the end of the contract). Important sources of revenue are also local, national, and European subsidies and incentives.

5.6. Key activities

Because industrial high-temperature heat pumps are a relatively new technology, the development (R&D) of a stable, high-quality product is a top priority. Some heat pump manufacturers need more operational experience (i.e., operating hours) to increase the technology readiness level from TRL7 to TRL9. A goal is also to build standardization and modularization into the product line. In sales, high growth and demand for heat pump products are expected in the coming years. At the moment, sales activities are reactive rather than active. Nevertheless, numerous discussions are being held with customers in various countries, particularly Europe, to sell the technology throughout Europe. Depending on the order situation, project planning is a key activity for which additional employees must be hired. Project execution also expects a strong increase in personnel for the delivery, installation, and commissioning of the heat pump products. The biggest challenge will probably be finding enough competent employees and training them quickly and properly.

5.7. Key resources

The most important resources are internal know-how about heat pump design and the integration of compressors into a heat pump circuit, which may be based on intellectual property. Supply chain management for key components is important for delivery capability (i.e., enabling short delivery times). Proof-of-concept and demonstration projects are important to customers. Internally, marketing and sales with a large industry network are advantageous. A balance is needed between new human resources for marketing (e.g., dedicated sales force) and technical resources for after-sales service and maintenance.

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5.8. Key partners

Important partners for a heat pump manufacturer are subcontractors and equipment suppliers for the core components such as compressors, heat exchangers, valves, control systems, etc. For commercialization, some heat pump manufacturers act as original equipment manufacturers (OEM). They actively work with distribution partners in selected countries to expand their sales network by integrating heat pump products into their portfolio. It is also crucial to have companies as demo customers that operate the first units to gain operational experience (i.e., running hours). For example, demo units are returned to the heat pump manufacturer after 6 to 12 months to check for wear.

Furthermore, there is the possibility of inviting end customers for an on-site visit to see the demonstration units in operation to build trust in the market (i.e., seeing is believing). Finally, important partners are also:

- Regional, national, and European public institutions for promotion,
- Private and public investment funds and banks for financing projects,
- Technical consultants and experts for knowledge transfer, and
- Universities and research partners for further development of the heat pump technology (e.g., cooperations with other technology providers).

5.9. Cost structure

The costs arising from the sale of industrial heat pumps and services are mainly investment costs for equipment and technical work (i.e., construction, mechanics, electrification, electricity grid, etc.), but also operating costs (i.e., electricity consumption during lifetime) and maintenance costs (i.e., annual inspections, spare parts). In some cases, subsidy programs are used to pre-finance project development.

6. Conclusions

Industrial heat pumps are on the rise for the electrification of process heat in industry and are an important cross-cutting technology for the transition to renewable energies. Accordingly, the market will experience increased competition in the coming years, pushing industrial heat pump manufacturers to develop new business models. This review has shown that business models for industrial heat pumps are overall insufficiently described and that a scientific research gap exists. Initial findings could be summarized based on empirical responses from interviews with manufacturers and literature research analyses.

The most widespread business model appears to be the Direct2Customer, which primarily involves project development and directly selling heat pumps to end customers. Revenues from installation and commissioning and future services from maintenance and servicing supplement this. However, each heat pump technology (e.g., vapor compression, MVR, absorption, thermochemical heat pump) requires its own business model evaluation using the proposed model building blocks. The highly customer-integrated business models such as Energy-as-a-Service (EaaS) and especially Heat-as-a-Service (HaaS) are opening new market opportunities for industrial heat pumps. However, none of the heat pump manufacturers interviewed has yet implemented HaaS in connection with industrial heat pumps. So far, only individual energy service companies (ESCO) now offer EaaS business models for industrial heat pumps.

As an outlook, an attempt could be made to quantify the effectiveness and impact of the different business models, e.g., on marginal prices, consumer behavior or societal acceptance. Further interviews with industry partners in the industrial heat pump value chain need to be conducted for a more detailed investigation of customer needs and business models. A PESTEL analysis with political, economic, social, technological, environmental, and legal influencing factors will be realized within the PUSH2HEAT project.

Further research could examine the structure of business relationships between the organizations involved in manufacturing, distributing, and using industrial heat pumps. Such an ecosystem-level analysis can identify ways to better align the respective business models to accelerate the adoption of heat pumps by industrial customers and ensure high-quality installations.

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