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Market Opportunity and Product-Market Fit in High-Temperature Heat Pumps (HTHPs)

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Abstract

The low-carbon heat and steam market is rapidly expanding, with high-temperature heat pumps (HTHPs) emerging as an up-and-coming solution. Despite growing scientific and technical interest, mainstream adoption and market penetration of HTHPs remain limited. A notable gap exists between the number of inquiries (customer leads) received by HTHP providers and the realized sales achieved. This discrepancy suggests that both HTHP providers and potential end-users face challenges in aligning product capabilities with market needs, underscoring the importance of optimizing product-market fit. The potential value of HTHPs varies significantly across different industrial use cases, depending on technology-specific attributes, industrial process requirements, and customer expectations. To address this challenge, the EU-funded Horizon Push2Heat project has developed a first draft of a matchmaking tool. This tool strategically aligns HTHP technologies with specific customer applications by mapping product features to user buying criteria. Identifying high-value use cases supports more effective product-market strategies and commercialization pathways. The matchmaking tool is grounded in a qualitative research study comprising in-depth interviews with three key stakeholder groups: (1) HTHP technology providers, (2) likely industrial end-users, and (3) scientific experts. These insights form the basis of a structured framework that enhances decision-making for both HTHP providers and end-users, facilitating more targeted market engagement and accelerating the deployment of HTHPs in high-potential applications.

Keywords: HTHP; Matchmaking; Product-Market-Fit; Key Success Factors; Sales Conversion

1. Introduction

The low-carbon heat and steam market is experiencing strong growth, and HTHPs are seen as a promising technology. While scientific buzz remains high, the mainstreaming and market penetration of HTHP still lag [1]. While HTHP providers are addressed and consulted on many requests from potential customers (leads), realized sales are significantly lower [2]. Figure 1 illustrates the challenge of lagging sales conversion within the sales funnel.

The challenge for HTHP providers, and likely customers, is to optimize the product-market fit [2, 3] by focusing on use cases where customer value peaks. This means focusing sales resources on highly promising (inbound) leads [7, 12]. To identify those leads and support efficient lead qualifications, a matchmaking tool, shown in Figure 2, was developed to match customer needs and buying criteria (Key Success Factors: KSF).

KSFs can be interpreted as clustered demand patterns based on technical and economic requirements to performance features of the concrete product (HTHP technology-related like efficiency/Total Cost of Ownership (TCO)/Levelized Cost of Heat (LCOH) [2, 4, 14, 16, 17, 21], retrofitability [12, 18]) and quality of service of a technology provider (service levels like support and warranty, contractual agreements like Power/Heat-Purchasing Agreements (PPA/HPA), contracting, Heat as a Service (HaaS) [2], and existing references [21]. The latter ones are summarized as company-related Competitive Advantage (CA).

2. Methods/Approach

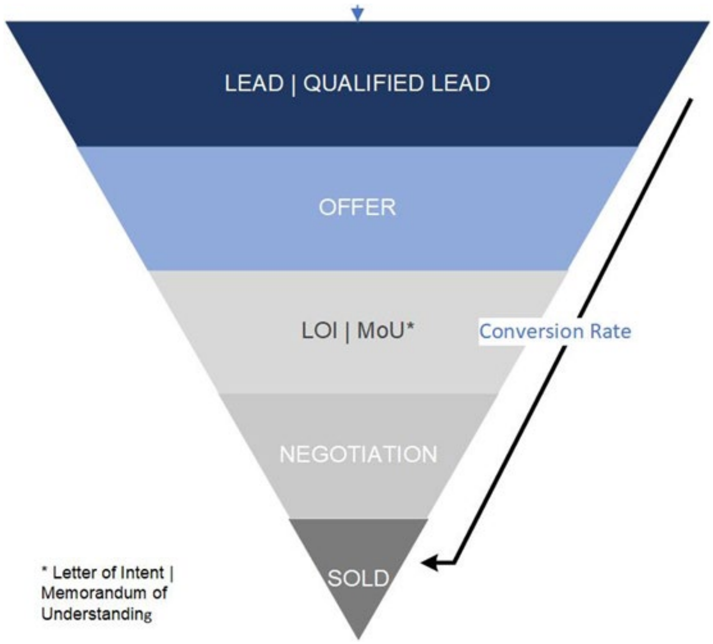

Figure 1. Sales funnel for typical HTHP providers.

The matchmaking tool (so-called "BM-CoP: Business Model CoPilot") prototype (*BM-CoP v1*) is based on mixed-methods design research. Based on a literature review and desk research, a first conceptual, theory-driven approach to KSF and CA was developed. To improve results, interviews were conducted with experts from both HTHP technology providers and likely/existing customers, as well as scientists. Interviews relied on modularized questionnaires (tailored to the target group of science, customers, and tech providers) and were analyzed by qualitative content analysis (Figure 2).

The results of the qualitative content analysis included the development of the matchmaking prototype *(BM-CoP v2*; Figure 3), an Excel-based tool.

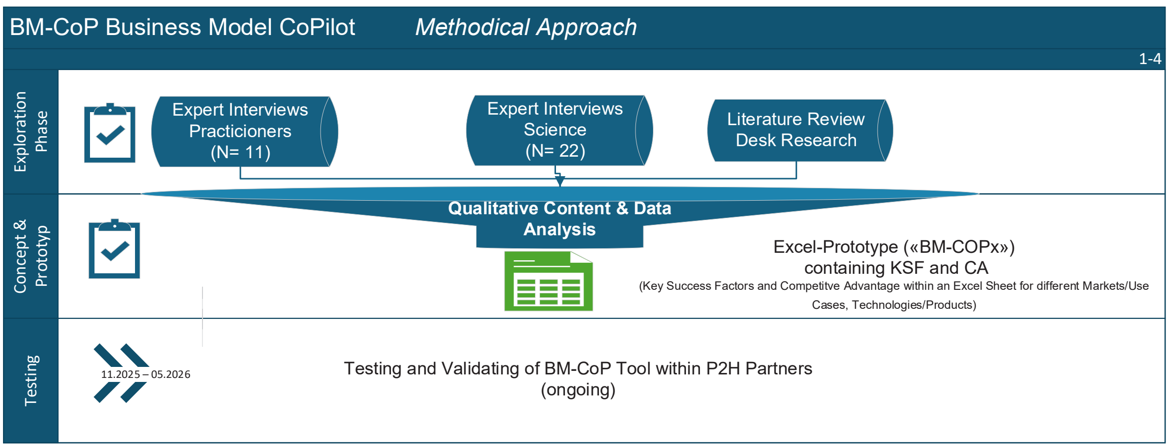

Figure 2. Methodical Approach.

3. Results and Discussion

Table 1 provides the BM-CoP framework for assessing KSF across various industries and use cases, including the paper and food & beverage industries. It outlines two dimensions of KSF acting as customer value drivers and customer pain relievers based on the interviews and the literature review [1-23]:

1. **Value drivers:** These are the market characteristics (e.g., market capacity, waste heat availability, emissions pain, temperature lift from heat source to heat sink, and flexibility of operation) that determine the size of the opportunity and the inherent value of an HTHP technology to the customer.
2. **Pain relievers:** These are the service and commercial offerings (e.g., reliability, service guarantee, high temperature capability, and HaaS) that an HTHP provider must offer to overcome customer pain points and secure market penetration.

Table 2 outlines the BM-CoP framework of CA for (self) evaluating HTHP technology providers and their customer sales proposition, focusing on both technical features and corporate capabilities – essentially, the "Jobs to be done" [26] an HTHP provider must fulfill to succeed in the sales funnel. These factors are essential and decisive in the phase in which a customer has invited competitors to offer (e.g., a tender) and the general GO for HTHP or a next-to-solution was taken [2].

4. Conclusions

For mainstreaming HTHP technology, the selection and matching of technology (product) and use case (customer, market) are crucial. Therefore, a deep understanding of customer needs and pains (KSF) as well as the product's strengths and weaknesses, based on the underlying technology and capabilities of the provider (CA), is necessary [2]. A multi-step research process, consisting of a literature and desk review, expert interviews with scientists, and expert interviews with practitioners, enabled the development of a framework for the most important and decisive KSFs and CAs. The final positioning is determined by a scoring procedure that reflects the different weights of each factor (KSF, CA) from the technology provider's perspective for each product-market relation (Figure 3).

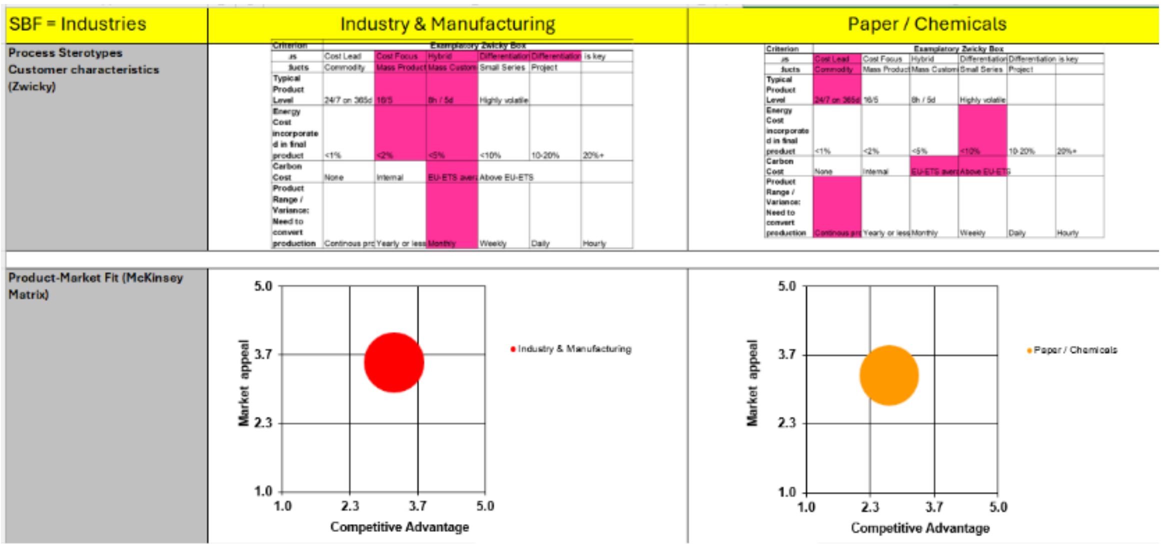

Figure 3. Screenshot of the Excel-based "Business Model CoPilot Tool" (BM-CoP v2) for product-market fit matchmaking.

It should be noted that the matchmaking tool serves in the pre-sales phase of the customer journey, where likely customers are aware of and considering different solutions to address their steam cooling and/or carbon problem [17, 21]. As each customer's and their process settings are different, it goes without saying that more sophisticated, tailor-made techniques and tools (including on-site visits) are required to convert leads into real sales and contracts [11, 21]. By sampling and clustering customer profiles into patterns (KSF), granularity is lost, but gains are automation and potential for AI-based tools (sales automation [25]). By increasing the efficiency of the pre-sales process and identifying the most promising leads, it offers the potential to focus limited personal resources on efficacy, triggering conversions and realizing turnovers.

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	Criterion	Definition	Key Performance Indicator (KPI)	Description	Value Driver | Value Capturing
KSF: Value drivers	**Market Capacity | Volume [1,2,3]**	Capacity of market (segment) in Europe (>90°C)	*Market volume estimated (EUR, CHF, LBP)*	How large is the market in a particular segment?	Scalability (the more companies), growth (Euros)
	Market Potential [1,2,3]	Number of customers	*EUR/ CHF estimated*	Market size / Market volume	Growth, Sales
	Replication and Scalability [12,16]	Comparable processes and buying patterns within an industry enable scalable solutions across multiple plants and similar companies.	*Assessment of more-of-the-same HUT solutions potential within industry; potential of Economies of Scale*	How much is the market in a particular segment?	The bigger the market, the better the scalability, profitability, but also competition
	Flexibility – Load Management [23]	Customers need a high degree in flexibility due to different workloads of production varying over workdays / weeks	*Efficiency at different workloads in terms of capacity/performance, temperature / part-load-ability*	The more flexibility is needed, the more customer value is rising with a technology containing a high efficiency at different workloads	Assess the demand for flexibility of customers (continuous production (24/7 the same) to very volatile production with peaks, interruptions etc.)
	Temperature Lift - Value driver [6,16,22]	Typical temperature lifts	*Educated guess based on main process of market resp. customers*	Temperature lift source and sink	Efficiency relies on temperature lift, the particular relationship on the used technology
	Emissions pain [17,21]	The bigger the pain (EU-ETS, carbon cost, customer awareness, sustainability), the more likely the electrification of heat and steam	*Eductated guess Euro/t-CO2e; EU-ETS;*	Carbon Cost is a key driver for HTHP, carbon cost depends on the country and industry	Rising carbon cost lead to more pressure to electrify the steam
	Availability of waste heat [4,21]	The amount of available source heat/waste heat and their price	*Waste heat factor, volume of waste heat*	Estimate of the share of primary energy consumption that results in recoverable waste heat	The business case increases with the amount of waste heat, in particular if otherwise cooling is necessary
	Need for 100% heat/steam source vs. Combined system [21]	Requirement/Importance to fulfill 100% of the heat demand by the HUT solution	*Deficit (%) of solution*	Is it necessary to fulfill 100% of the energy demand by HUT	No Need for Co-Heating infrastructure and back-ups (CAPEX, OPEX, CO_2, Complexity)
KSF: Pain relievers	**Reliability, Service Guarantee [9]**	Key requirement to guarantee service >8000hrs/year	*Service hours promised, time of reaction in case of incidents*	Depending on the company, its size, and location, sophisticated service levels are needed	Service level agreements and service layers/reaction time
	Need to offer Contracting / PPA, HPA, Heat-aaS ("Top Line Customer") [18]	Top-line companies (sales-driven) prefer contracting or PPA/HPA/Heat-aaS* Bottom-line companies (profit-driven) prefer minimizing OPEX and often own Energy Engineering skills themselves	*Projected cost per steam etc. / Euro/MWh Electricity*	Ability to offer HaaS or the like	Bigger reach out to likely customers
	High temperature need [3,4]	Proportion of likely customers/processes within the industry needing temperatures above 120° (more than saturated steam)	*Volume of high temperature heat*	Need for one or more steps	Feasibility of the project
	One-Stop Shop as a requirement	Heating capacity of a typical plant or reference process	*Utilization of HTHP solution*	To what extent can the demand X of heat/steam of customer be fulfilled by HTHP solution (One Stop Shop)	The "more" one-stop shop, the less redundant (fossil) co-firing or back-ups necessary
	Cooling is Pain	Cooling of HUT is a pain reliever for customer (replacing cooling towers, driving efficiency of process)	*Priority of cooling*	Add-on as a selling point, in particular for AHT	Willingness-to-pay for cooling

Table 1. Key Success Factors based on interviews and literature review.

	Criterion	Definition	Key Performance Indicator (KPI)	Description	Value Driver | Value Capturing
CA: Tecnical USP and features	**High efficiency at volatile sinks and sources (temp and capacity) [9, 10, 20]**	Assessment, how technology deals with volatile sources, and sinks (both volume and temperature) efficiently	*Educated guess*	Is the technology able to deal with volatility and maintain a high degree of efficiency (COP)	The more flexibility, the better
	CAPEX / Total Cost of Ownership TCO /LCOH [2, 4, 14, 16, 17, 21]	Cost/MW installation Projected total cost of Total Cost of Ownership (incl. maintenance, downtimes, spare parts, recycling, ramping-up, etc.)	*EUR / MWh*	Cost/MW installation Projected TCO	TCO most decisive criterion
	Replication: Business Case [2,4,16,17,21, 24]	Experience and proof-of-concept of same or likewise industries help predict projects' profitability and feasibility (more-of-the-same)	*Simulation models; References, book orders*	predicted profitability of the project, business case	Simulation and experiences help identify the most promising business cases (industries with similar processes e.g. breweries)
	Operating Mode [16, 22]	Temperature Range	*Temperature ranges (1-step, 2-step etc.)*	Need for further steps, and installations	The fewer installations needed, the better the business case
	Flexibility to use various refrigerants [4, 5, 19]	Natural/synthetic according to requirements at the customer's site and in compliance with safety and health policies	*Self-assessment, feasibility of switching refrigerants*	Possibility to use different refrigerants and maintain a high degree of efficiency	In some industries, particular references may act as a do-or-die criterion
CA: Corporate strenghts and positioning	**Turn-key solutions and interoperability ("Ease of use") [8, 12, 18]**	Capability to manage technical systems and infrastructure, including IT systems, remote maintenance and optimization, and interoperability with existing energy management software.	*Self-assessment*	One-stop shop: single face to the customer Service levels provides; Ease of use and integration of software	Interoperability and integrability with/ in the process landscape of customer acts as a key criterion
	Time-to-market / Speed	Average time from contract to commission/running	*Months*	Delivery time is key	Customers' needs' urgency
	Financial strength [18]	Assessment of own financial strength, e.g., to enable high-volume projects, scale fast, and pre-financing of projects	*Rating A-D*	The healthier the finances of the tech provider, the more trustworthy for customers and partners (e.g. suppliers)	Capability to handle big projects, accounts Capability to pre-finance projects Access to PPA/HPA/HaaS
	Staff / Man-Power	Size of team to address different and/or large-scale projects	*Headcount*	Man power	Capability to handle big projects, accounts
	Proofs-of-concepts / signature projects (Trust) [21]	Number of successfully done projects / proof-of-concepts	*Number (projects), volume (MW), sold units*	References and signature projects are key for sales of innovative, non-mainstream solutions	track record decreases uncertainty and increases conversion rate
	Sales Capabilities / Ecosystem / One-Stop-Shop [11]	Self-assessment of sales power, experience, and capacity for tenders (both private and public)	*Self-assessment, regarding tenders: Go-/No-Go*	Capacity and capability to acquire multiple customers from multiple industries	*Consultancy and sales with significant industry know-how are needed (EPC+), less for Haas (for sales purposes)*
	Service Capabilities / Ease of Use [11]	Capability to stick to sophisticated service level requirements, e.g., from multinational companies	Self-assessment, feasibility to SLA (national, EU, worldwide)	Offered service levels across countries and industries	Companies, particularly multinational Companies, seek service levels, sometimes as condition sine qua non

Table 2:Criteria for Competitive Advantage.