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Joining Forces to Encourage High-Temperature Heat Pumps in Swiss Industries

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The IEA HPT Annex 58 HTHP-CH project regroups multi-disciplinary experts around the shared objective of promoting the integration of high-temperature heat pumps (HTHP) in the Swiss industries. Available products with supply temperatures above 100 °C show a slow adoption rate despite the key role forecasted and necessary to reach international CO2 reduction roadmap targets. This study investigates the integration of HTHP applied to three industrial case studies. The assessment based on Pinch analysis is led alongside the development of supporting tools and guidelines.

Introduction

After pioneering in the development and commercialization of heat pumps (HP), Switzerland is currently lagging to uptake this technology in the industrial sector. Yet the HP market is well established in the country with a 74% share of the heat production units sold in 2023, mostly smaller capacities for domestic applications (87% of HP under 20 kW) [1]. With market-available high-temperature heat pumps (HTHP) for heat production above 100 °C and allowing for steam generation, the lack of products is no longer a barrier. There is, however, still a need to broader disseminate knowledge about HTHPs and their adequate integration.

The HTHP-CH project [2] has been launched by specialists from OST (Eastern Switzerland University of Applied Sciences), EPFL (Ecole Polytechnique Fédérale de Lausanne), HEIG-VD (Haute Ecole d’Ingénierie et de Gestion du Canton de Vaud) and CSD Engineers. The objectives are to provide tools and inform on HTHP integration. Three national case studies with industrial partners contribute as concrete examples. A solution generator for optimal HTHP integration following Pinch analysis principles and suggestions for the best heat pump design as well as a pre-assessment tool are in development. The project is involved in IEA Annex 58 on HTHP, facilitating international exchange and serving as a national relay.

Market review

The range of industrial HTHP on the market has grown steadily in recent years. Figure 1 presents 33 products with heat supply temperatures above 100 °C producing pressurized water or steam [2]. They are shown sorted by their maximum heat supply temperature and heating capacity, ranging from about 10 kW demonstrators to 70 MW units. This synthesis is based on information collected in the IEA HPT Annex 58 [3] covering closed-cycle as well as open-cycle HP for mechanical vapor recompression (MVR). Please note that suppliers provided the information without third-party validation and that the technology readiness level (TRL) varies between products.

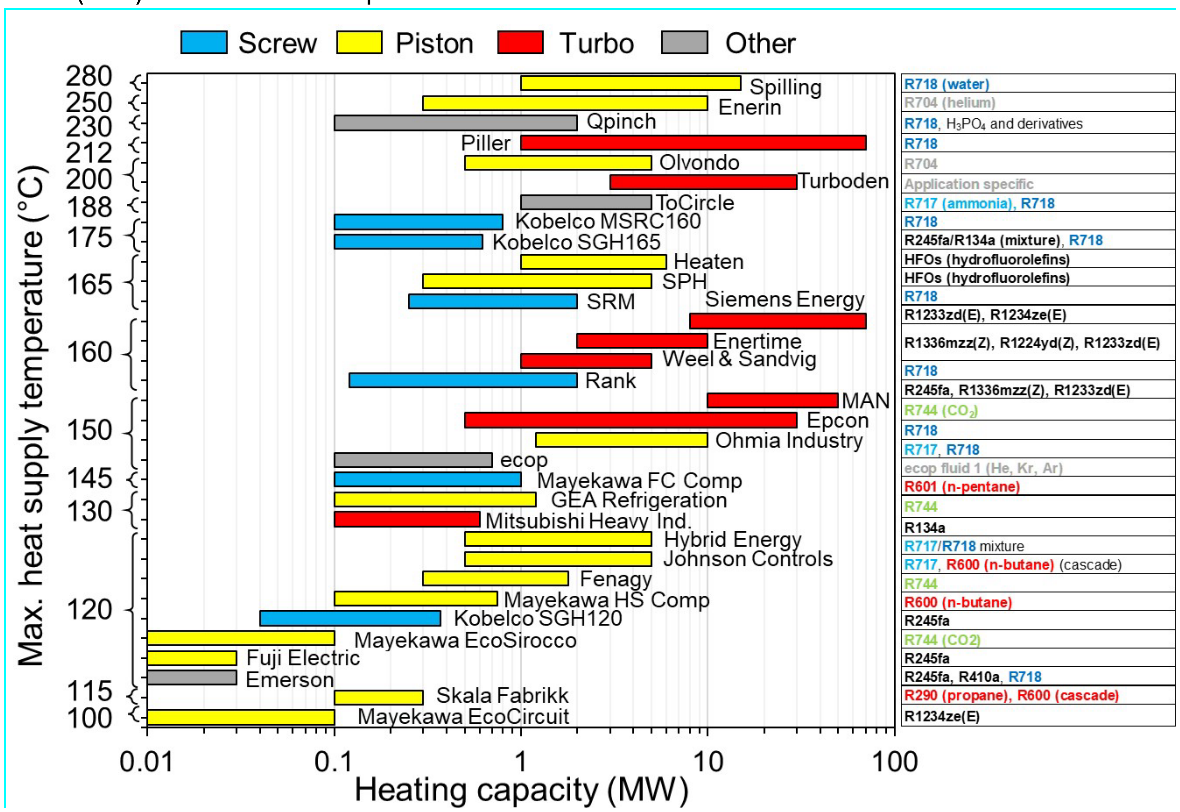

Figure 1. Industrial HTHPs products sorted by maximum heat supply temperature (>100 °C) and heating capacity. The compressor technology is color-coded. The table indicates the refrigerant [2].

Case studies

Three industrial companies support the HTHP-CH project by giving access to their process data. In a global improvement approach, and not merely by adding a heat pump according to intuition or to replace warm utilities, Pinch Analysis are being performed. The effort needed to gather the information translates into optimized heat recovery opportunities identification and adequate placement of the HTHP, hence lowering the process's overall energy need.

ELSA (Estavayer Lait SA) is Switzerland's largest dairy on a single site, processing around 260,000 t/a of milk into a wide range of dairy products. The main heat treatments are pasteurization and sterilization ranging up to 155 °C. In addition, a cleaning-in-place process requires large amounts of water and an important steam consumption at 4.5 bar(a). A wood chip boiler and natural gas boilers currently generate process steam. To save energy and water, waste heat from the ammonia chillers at 20 °C or drain water at 50 °C, could be used as a heat source for a HTHP. This solution has yet to be confirmed. The company benefits from a favourable electricity-to-gas price ratio.

Cremo SA processes milk into various dairy products. Today, heat is supplied by two 5 MW gas-fired steam boilers and a district heating network (105 °C / 80 °C). As a future reduction of the district heating operating temperatures to 80 °C / 60 °C is envisioned, a large-scale HTHP is considered to upgrade the supplied heat temperature. Another potential integration point for a HTHP has been identified in the TIXOTHERM™ drying plant, which produces milk permeate powder and consumes 10% to 15% of the total steam demand. For the latter, Figure 2 (left) shows the calculated Composite Curves of a preliminary assessment, indicating a Heat Recovery (HR) potential through direct heat transfer of about 600 kW between air flows and a Pinch temperature of around 70 °C. Furthermore, the corresponding Grand Composite Curve shows the impact of an integrated HTHP providing 940 kW of heat at 120 °C using 523 kW at 38 °C, with a COP of about 2.3. Finally, Figure 2 (right) shows the Composite Curves with integrated HTHP. The example demonstrates a potential reduction of the Hot Utility (HU) by 100% (from 940 to 0 kW) for this drying unit and 47% (from 1,204 to 634 kW) of the unused waste heat. A challenge is the low evaporation temperature (large temperature lift of 82 K), and the probably insufficient evaporation capacity if the waste heat is to be recovered exclusively from the drying process. Therefore, additional waste heat sources must be identified.

Gustav Spiess AG in Berneck (SG) produces meat products such as sausage, ham, and bacon. Today, a gas boiler provides 6 to 8 bar(a) steam to the pasteurization and cooking/smoking cabinets. Process data is currently being acquired for this site to perform a Pinch analysis and adequate dimensioning of a steam-generating heat pump using waste heat from the chillers.

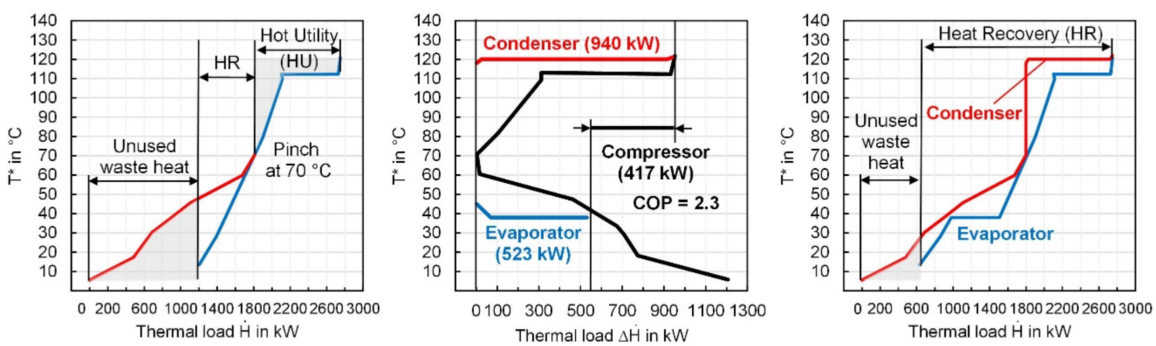

Figure 2. Composite curves (left) and Grand composite curve (center) of the current drying process from Cremo showing the potential HTHP integration. The resulting Composite curves (right) show increased heat recovery and reduced waste heat.

Preliminary evaluation tool

A preliminary economic evaluation of the case studies was performed with a calculation tool developed in MS Excel, illustrated in Figure 3. It assumes that the gas boilers' investment is depreciated and that it remains for production redundancy or other use (start-up, peak loads). The tool helps to quickly evaluate the economic feasibility as a “go/no-go” decision to further evaluate a potential HTHP project:

- First, the efficiency of the HTHP is estimated using the temperature lift and a COP correlation.
- Next, the investment costs of the HTHP are evaluated based on specific investment costs, the heating capacity and a cost multiplication factor accounting for planning and integration (typically between 1.5 to 4.0 depending on the complexity of integration).
- Then, the annual cost savings are calculated considering the electricity cost to operate the HTHP, the maintenance costs of the HTHP using a multiplication factor on capital cost, saved fuel costs, and possible refunds of CO_2 reduction.
- After that, the payback period of the investment is evaluated using the investment costs and the expected annual cost savings resulting from the investment.
- Finally, the discounted payback periods (DPP) is computed.

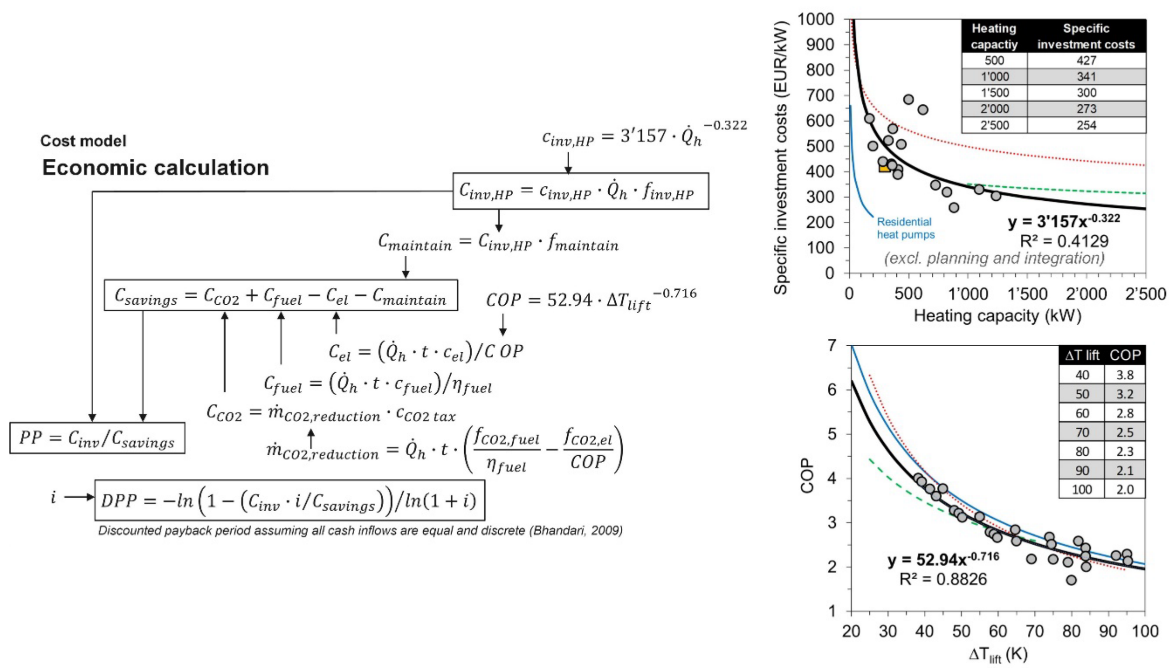

Figure 3. Economic calculation, COP, and specific investment costs to derive the payback period for HTHP integration.

Preliminary calculations from 2022 using the simplified evaluation tool led to payback periods of 2.0, 3.7, and 3.3 years [2] and a non-definitive HTHP point of integration. The cost multiplication factor for planning & implementation, which depends on the complexity of the HTHP integration, leads to significant uncertainty. Overall, the concerned processes analysed showed important annual energy savings of 55%, 60%, and 66%, and CO_2 emission reductions of 71%, 75%, and 98%, respectively, given the Swiss electrical mix CO_2 emission factor. The estimated COP varies between 2.0 and 2.7. Favourable conditions are lower electricity prices, higher fuel prices, longer operating time, and to a lesser extent CO_2 tax and increasing capacity.

Solution generation tool
EPFL is developing a web-based tool for optimal integration of HP into industrial processes [4]. The ROSMOSE platform determines the minimum energy requirements and operating costs of a process based on the Pinch Analysis methodology. Inputs needed are the hot and cold heating demand profiles, mass and electricity flows, and economic data. Outputs are delivered in a formatted report, including the integration and sizing of utilities (HP and competing technologies, for example biomass boiler or natural gas) and comparison of optimized solutions. The tool computes the evaporation and condensation temperature levels, compressor technology and best thermodynamically suited refrigerant for the HP generating the most economically competitive solution. Relevant KPIs such as cost, CO_2 emissions or efficiency can be also determined.

National workshop
A successful event was organized by the project team to raise awareness and knowledge on HTHP and get insight from the Swiss stakeholders. Around 70 participants from the industry, planners, manufacturers, academics and administration took part on site. A half-day of presentations was followed by four workshop roundtables [5].

The main conclusions on financial aspects were that the investment cost of the machine alone is less relevant (as are the funding opportunities) than payback time, ROI or total cost of energy production. A list of points of attention was generated on various technical aspects. As for HTHP products capacities, the range from 500 kW to 10 MW has been regarded as adequate, and steam-producing machines would be preferred a priori. Companies with a strong sustainability motivation and/or under customer pressure for low-carbon products are a lead market for HTHP. The perceived risks by end-users are linked to the suitability of installed HTHP to modified operating conditions, compliance risk to future policy changes and reliability.

Proposed key actions to push the implementation of HTHPs were:

- Increase knowledge and trust about HTHP by giving examples of running systems,
- Increase the availability of products (standardized / with natural refrigerants),
- Increase in CO_2 tax or restrict fossil fuels, and
- Decarbonize the electricity supply.

Conclusions
There is an urge to decarbonize the Swiss and international industrial heat production, and high-temperature heat pumps (HTHP) constitute an adequate and efficient solution. HTHPs provide heat by upgrading thermal energy at lower temperature levels, hence simultaneously reducing the cooling needs.

The objectives of the HTHP-CH project are to provide tools and communicate knowledge and visibility to promote the insightful integration of HTHP helped by 3 industrial case studies.

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References

[1]. Swiss professional association for heat pumps (FWS), market statistics for 2023.
   a. https://www.fws.ch/download/statistik-2023/

[2]. Arpagaus et al. 2023. "Integration of High-Temperature Heat Pumps in Swiss Industrial Processes (HTHP-CH)". Proceedings of 14th IEA Heat Pump Conference, Chicago, USA. https://www.hpc2023.org/wp-content/uploads/gravity_forms/3-7075ba8a16c5f78b321724d090fb2a34/2023/05/0494_HPC2023_Full_Paper_Arpagaus_v02.pdf

[3]. IEA HPT Annex 58 on HTHPs: Task 1 Technologies - State of the art and ongoing developments for systems and components, 2022, Website. https://heatpumpingtechnologies.org/annex58/task1/

[4]. Dardor et al. 2023. “ROSMOSE: A Web-based Optimization Tool to Aid Decision-making for the Design and Operation of Industrial and Urban Energy Systems”. Proceedings of the 36th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems (ECOS), Las Palmas de Gran Canaria, Spain, 25-30 June, 2023.

[5]. HTHP-CH conference and workshop day presentations, 24 March 2023, Ittigen, Switzerland. https://www.sweet-decarb.ch/events/event/high-temperature-heat-pump-event

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