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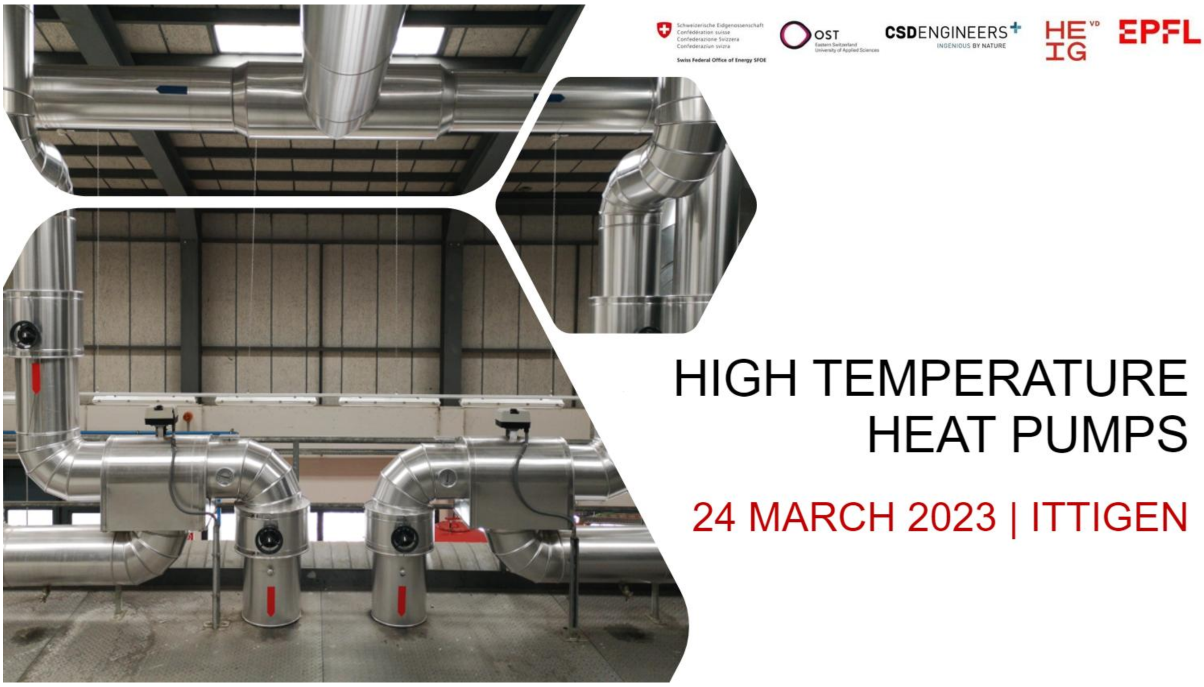
Swiss Federal Office of Energy SFOE
Energy Research and Cleantech Division

Deliverable dated 9 June 2023

Annex 58 HTHP-CH – Integration of HTHPs in Swiss Industrial Processes

Appendix 8

Minutes from the HTHP Workshop



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This is an appendix to the summary report on the project "Annex 58 HTHP-CH – Integration of HTHPs in Swiss Industrial Processes". The report and other appendices can be downloaded at https://www.aramis.admin.ch/Texte/?ProjectID=49514.

The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.

Contents

Abbreviations

DETEC:	Federal Department of the Environment, Transport, Energy and Communications
FOEN:	Federal Office for the Environment
HP:	Heat Pump
HTHP:	High-Temperature Heat Pump
MER:	Minimum Energy Requirements
OSMOSE:	OptimiSation Multi-Objectifs de Systèmes Énergétiques Intégrés (Multi-Objective Optimization of Integrated Energy Systems)
Rmd:	Rmarkdown file extension
SFOE:	Swiss Federal Office of Energy
SGHP:	Steam Generating Heat Pump

1 Context

The work carried out until now in WP1 covers the status of HTHPs in Switzerland and the collection of realized examples described in the Milestone Report M2 from 22 December 2022. In addition, more international demonstration cases and available technologies from HTHP suppliers have been gathered in the broader framework of IEA Annex 58 Task 1 participation.

An event was organized to disseminate this current state of the art on high-temperature heat pumps for the industry and get insight from the Swiss stakeholders.

2 Introduction

The workshop took place on 24th March 2023 in the DETEC building in Ittigen (Bern). Its goal was to learn and share on HTHPs and their role in the Swiss industry.

Held in English, the event consisted of a half-day of presentations on high-temperature heat pumps for the industry and workshops moderated by the HTHP-CH project partners. The first part of the day conveyed the current state of the art of HTHP and their integration into industrial processes. In the afternoon, work groups discussed socio-economical, technical, financial, and supporting tools.

Great networking and exchange opportunities for the diverse participants (industry, planners, manufacturers, academics, administration) were found during the lunch, coffee breaks and apéritif. CSD Ingénieurs lead the organization in close coordination with the project partners and SFOE, which lead to a successful event.

The targeted audience is composed of industrials, manufacturers, planners, and associations, as well as the teams of SFOE, FOEN, and SwissEnergy. Registrations showed good participation from each of these domains. One can find the participants list in Appendix 1. This document contains the names and companies of the persons who took part on-site (with a group number attributed) and those who followed the presentations online.

The realized overview of the current state of the art served as input to the presentations and workshops (Task T1.1). The goals of the event are as follows:

- Addressing the root causes of reluctance to implement HTHP: understand the decision-making process and identify ways to push for more implemented projects (lack of knowledge is addressed with the morning presentations)
- Gathering useful information to contribute to WP2, WP3, and WP4 to help define preliminary conditions and criteria to pre-assess the feasibility of a given HTHP project
- Presenting the tools that are being developed (pre-assessment / detailed integration)
- Developing strategies to promote the transition to a HTHP based heat supply in Switzerland by addressing the questions: what is missing, how to improve & encourage the market

3 Presentations

The first part of the workshop day was dedicated to disseminating the current state of technological developments of HTHPs for temperatures above 100 °C and related topics through the following presentations given by experts and industrials from the HTHP-CH project:

- Swiss national market for HTHPs
- Overview of the HTHP market and developments
- Sharing of methodology to approach HTHP integration (Pinch analysis for practice)
- Showing realized case studies with HTHPs

The program is illustrated in Table 1, and the presentations in pdf format as well as the video recordings, have been made available online at the following address:

- https://www.sweet-decarb.ch/events/event/high-temperature-heat-pump-event

Time	Title	Presenters
9:25	**Welcome**	Nicole Calame, CSD Ingénieurs
9:30	**Introduction by SFOE**	Carina Alles, SFOE
9:40	**Swiss National Market**	Cordin Arpagaus, OST
10:00	**Overview of HTHP technologies**	Frédéric Bless, OST Nicole Calame, CSD Ingénieurs
10:20	**Demonstration case studies from IEA Annex 58**	Eduardo Pina, EPFL Daniel Florez-Orrego, EPFL
10:40	*Coffee Break offered by SFOE in the aula*	
11:00	**Status of HTHP-CH case studies and preliminary integration ideas** • **Cremo, dairy company** • **ELSA, dairy company** • **Gustav Spiess, meat products company**	Laurent Giansetto, CREMO Stéphane Vesin, ELSA Christian Jansen, Gustav Spiess
11:40	**Pinch Analysis for practice and HTHP integration**	Pierre Krummenacher, HEIG-VD François Maréchal, EPFL

Table 1 : Morning program from the HTHP event

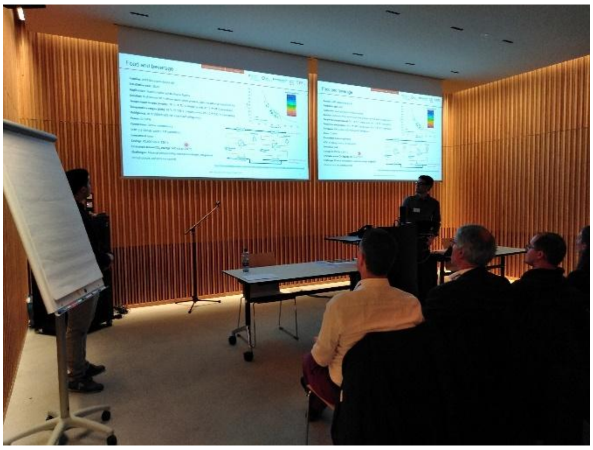


Figure 1: Pictures from the HTHP event in Ittigen (Photos © Sidharth Paranjape)

4 Minutes of the workshops

In the afternoon, the workshop allowed for active discussions on the following main topics:

- Socio-economical aspects
- Technical aspects
- Financial aspects
- Supporting tools

Feedback from the participants' experience, even for industrial applications at lower temperatures (>100 °C), provided insight on critical points and solutions. Moreover, the workshop outcomes will help outline the useful content the guideline should contain.

Time	Title	Moderators
13:30	**Goals of the workshops:** • Identify ways to help lift the various barriers, present tools and allow for knowledge exchange **Aspects addressed in the Workshops:** • social-economical, technical, financial, and supporting tools	• Pierre & Matthias • Cordin & Frédéric • Nicole & Loïc • Daniel & Eduardo
13:40	**Group work (30 min)** ***+ 5' switch room***	
14:15	**Group work (30 min)**	
14:45	*Coffee break offered by SFOE in the foyer*	
15:15	**Group work (30 min)** ***+ 5' switch room***	
15:50	**Group work (30 min)** ***+ 5' switch room***	
16:25	**In the plenum, presentation of workshop results by the moderators**	
17:00	*Closing workshop & Apéritif supported by CREMO and Gustav Spiess*	

Table 2: Afternoon program from the HTHP event

4.1 Workshop on socio-economical aspects

Moderators: Pierre Krummenacher (HEIG-VD) and Matthias Speich (ZHAW)

4.1.1 Topic 1: What sparks a HTHP project?

The first part of the workshop inquired about the drivers of HTHP adoption by industrial firms. To ensure that enough time would be allocated to the other two questions (for which more complex discussions were foreseen, and therefore more time was allocated), the questions were asked on the interactive website www.menti.com. Participants accessed the questions through their laptops/smartphones and selected answers from a list. This interactive survey consisted of two questions: first, participants were asked to choose the most important long-term factors influencing a firm's willingness to consider a HTHP project (Figure 2). Second, participants were asked to choose the most important short-term factors that trigger the decision to invest in a HTHP (Figure 3).

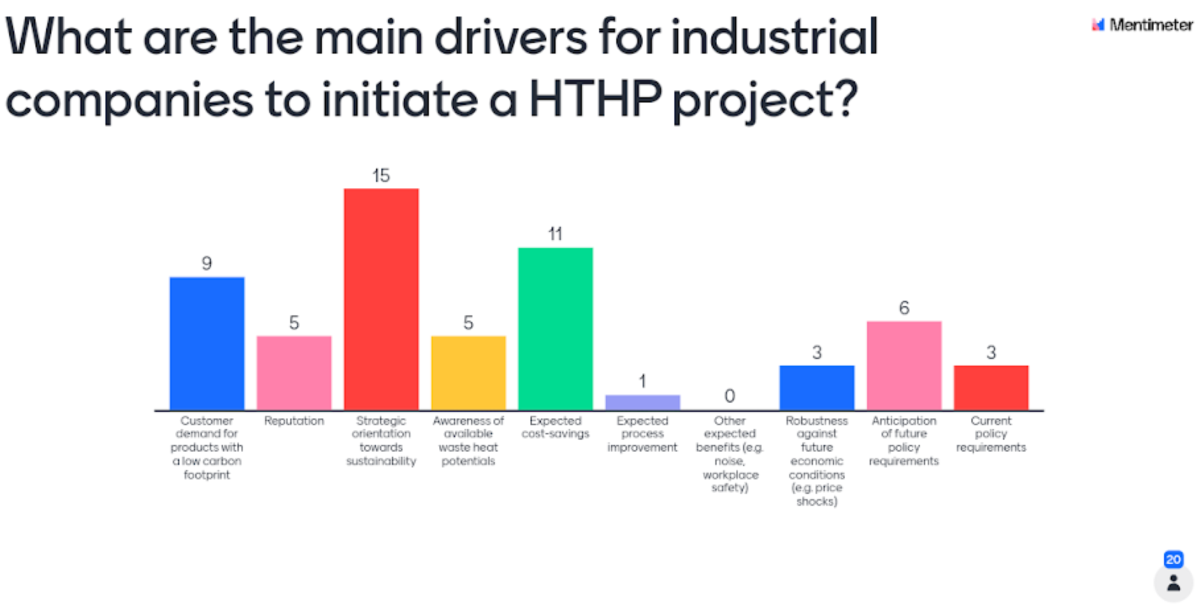


Figure 2: Results from the snap-survey on the drivers of HTHP adoption (long-term factors).

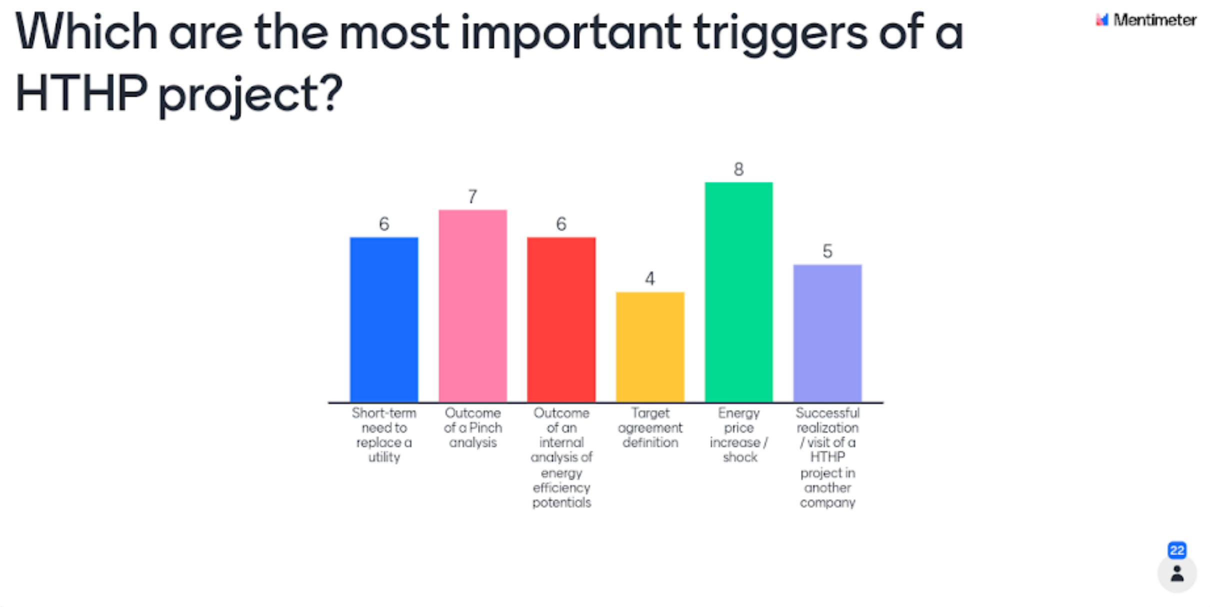


Figure 3: Results from the snap-survey on the drivers of HTHP adoption (short-term triggers).

In the discussion, participants were allowed to suggest factors not on the list. Two such factors were mentioned:

- Teenagers or spouses at home, influencing key decision makers' outlook on decarbonization.!
- Decarbonization: public commitment of the company

4.1.2 Topic 2: level / point of integration (process vs. utility)

Part 1: Discuss the level of integration (utility *versus* process level)

Selection/comparison/decision criteria:

- **Process level**: whenever there exists a process consuming a large share of the total heat (steam) consumption but also requires a long operation duration of the process for profitability
- **Utility level**: whenever there exists a cluster (collection) of steam consumers. Requires a suitable heat source. Preferred solution for e.g., SIP systems (concern about the quality of steam for HTHP integrated at the process level.
    - *Note: why this concern, since a white steam generator could be used?).*
- **Other criteria to consider**: heat demand fluctuation, required space (often limited or no space at all in the process area)

Requirements & benefits/drawbacks

- **Process level**: clear and detailed process understanding is needed to define design specifications. Tailor-made, process-specific design. Ensures better efficiency than integration at the utility level (thanks to smaller T lift)
- **Utility level**: easier to design & implement, less risky than process level integration w.r.t. to deviation from design conditions. "Poor" efficiency due to usually large T lift.

Implications of the level of integration on design and business model

- Process level:
    - Interaction/integration in processes → HP will typically be owned and operated by the industrial company (due to complexity and confidentiality issues).
    - Higher upfront costs.
    - Greater competition with other investment opportunities.
    - Design according to process requirements.
- Utility level: more suitable for contracting (easier to work with an ESCO who does not need to intervene at the process level).
    - Lower upfront costs with the contracting model.

Part 2: Which possibilities, benefits, and issues do you see for lowering the distribution network temperature, resp. For switching from steam to hot water?

There was little time for discussion; the outcome is:

Possibilities and conditions: lowering $T_{heating}$, and increasing $T_{cooling}$ is a general advice of an energy auditor. This can be achieved stepwise until problems appear at a process (i.e., the critical process)

- the question is, what do we do after? Do we try to analyze the reason for this limitation and try to get rid of it, or not?

Benefits: better COP, lower thermal losses, increased efficiency

Issues: reduced pressure means a smaller capacity of steam pipes; for water, decreasing T often decreases ΔT, hence decreased capacity (unless the mass flow is increased).

4.1.3 Topic 3: risks

This session aimed at identifying and categorizing the risks perceived by the customers (i.e., industrial companies) and the heat pump manufacturers (considered here to be the focal firm, i.e., the firm delivering the product to the customer) and documenting potential solutions to address them.

From the **customers' point of view**, the risks mentioned can be classified into three categories:

- Perceived low reliability of HTHP technology.
- Uncertain suitability of installed HTHP to modified operation conditions.
- Compliance risks arising from future policy changes.

From the **manufacturers' point of view**, the risks and challenges discussed in this session can be classified into two categories (following Adner & Kapoor 2010, http://dx.doi.org/10.1002/smj.821):

- Component challenges / risks: Challenges arising from the limited availability of suitable components (constrain the manufacturer's ability to improve their products).
- Complement challenges/risks: Challenges arising from the limited availability of products/services necessary to install and operate the HP (e.g., installation and design specification) or from quality issues or delays for these products/services.

Perceived low reliability of HTHP technology by industrial firms

- Fear that HTHP could impair the product quality/hygiene (if integrated at process level vs. food regulations!)
- Risk of reliability issues: compared to steam boilers, HTHP is perceived as potentially less reliable because:

- HPs (compared to steam boilers=«you know your system, you trust it») are intrinsically more complex (more components, many new compressor types, operation of the compressor is critical), hence the larger probability of component failure and decreased global reliability (TRL as low as the lowest TRL of HP components)
    - could manufacturers or independent actors provide sound data about the reliability of HP components, and compare these with the reliability of mainstream technologies (gas tubes and water tubes steam boiler (failure of the burner, …); need for reliable backup systems (depending on the application and low COP system, could an electrical heater be used temporally?) Not a good solution for blackout or load-shedding situations
- Lack of long-term reliability feedback of components operating in conditions not used in the past
    - in fact, systems like mechanical vapor recompression have decades of experience, not only for steam but for gas in general. So we can't say SGHP (if solely based on MVR, without an HP closed cycle) are new and more complex than steam boilers. It would also be interesting to get feedback from manufacturers of MVR systems applied in different sectors.
    - Heat pumps, in general, are sometimes marketed as a novel technology. Unfortunately, this represents a barrier to their diffusion: novelty implies complexity and low reliability. However, decision-makers in the industry need systems that are as easy to use and reliable as possible. Instead of novelty, manufacturers should highlight that heat pumps are a well-proven technology.

- Concerns that HP does not achieve the specified performances in practice:
    - Compared to steam boilers, HP's performances in general and HTHP, in particular, depend on more parameters that cannot be easily controlled: temperature and heat duty of both a heat source and heat sink, not to mention the fluctuations and the need for heat storage.
    - How to elaborate design specifications? Who is liable for defining and achieving the design specifications (e.g.in case the HP is implemented by an integrator which is not the manufacturer of the HP)
        - note that some companies (e.g., Epcon) do both the engineering of the integration and select/design the HP systems using proven HP/compressor technologies.
    - To manage these risks, the following questions should be answered:
        - How can it be proven, in the industrial operation context, that the HP achieves, or not, the design specifications?
        - How to foresee changes in operation conditions that could be detrimental to the performance of the HP or even make it unusable if, e.g., the heat source is beyond the temperature domain of the HP(see also below)?
        - How should these questions and interfaces be defined in the contract?
        - How many years should a guarantee last to prevent risk for the customer?

- Are there ISO or other international Standards that could apply to such HP issues? How do companies with long experience in the field (Epcon or other MVR systems companies (e.g., evaporators, etc.)) deal with such issues in their contracts?
- Could a template/framework/recommendations/checklists/procedure be prepared for industrial customers or engineering companies to elaborate and validate specifications and control performance at commissioning and later in operation? Recommendation for instrumentation/maintenance?

Concerns by industrial firms about the compliance of refrigerants with future environmental regulations.

- What is the acceptance/perception of customers as regards flammable refrigerants?
- IEA Annex on the safety of HP refrigerants/share experiences with refrigerants?

A manufacturer interested in entering the HTHP market stated: «Nobody has much experience; there is a lack of suitable / allowed compressor for NH_3» (comment: probably a limited view of the whole range of HTHP technologies).

Concerns by industrial firms about the flexibility of the HP system to be adapted to future changes, like a change of source and/or sink temperature (e.g., an increase of sinkT) or an increase or significant decrease of heat duty?

- As regards capacity, modularity (i.e., several identical units) could be a solution (probably neither possible nor economical for some types/technologies of HTHP)
- For changes in the source and sink temperatures? => Suitable design specifications? Impact of changes dependent on HTHP technologies?
- For integration at the utility level: wish of HTHP customers (for ease of engineering/implementation/comparison / etc.) to be offered by manufacturers standard/general purpose HTHPs (operating source and sink temperatures, heat duty ranges/classes)? Could this bring cheaper and more reliable, and better acceptance? For integration at the process level: tailor-made HTHP to best fit the process conditions (?)

Component risk/challenge for HTHP manufacturers

As described above, the manufacturer's ability to offer HTHP that satisfies the customers' needs depends on the availability of suitable components, with differences in TRL between components. Components with lower TRL or little feedback are sometimes perceived as less reliable by industrial firms. Since the failure of a single component may lead to failure or performance decrease of the whole HTHP, this decreases the acceptance of the whole product.

Complement risk/challenge for HTHP manufacturers.

The technology provider only sometimes executes feasibility studies, design specifications and installation of the HTHP. In such cases, the technology provider depends on the correctness of design specifications: if those were made based on a faulty assessment of the operation conditions, the technology provider risks being made responsible in case of failure or low performance. In addition to being a liability, this also represents a reputational risk for the technology provider.

4.2 Workshop on technical aspects

Moderators: Nicole Calame and Loïc Schüpbach (CSD Ingénieurs SA)

The goal of this workshop was to list as many key aspects as possible that should be addressed in a technical pre-assessment of HTHP projects. These key aspects were divided into themes that every group fully or partially addressed.

Figure 4 : Picture from the workshop on technical aspects

4.2.1 List of key aspects

The following key aspects have been identified, organized and commented on. There are very few points that generate a technical no-go, they mainly impact the financial feasibility.

#	Key aspects	Comment
	Heat source/sink	
1.01	Temperature admissible for a HTHP (source/sink)?	What are the temperatures of the sink and source? What temperature lift is expected on the HTHP? Discharge temperature of the compressor ok with the HTHP project? Out of compressor specification from the manufacturer? Within the range of dT with regards to heat production?
1.02	Waste heat or process cooling needs as a source? Other source?	Availability of a heat source? Advantage of a continuous process. Seasonality of the needs and available heat, 2-sides impact hot/cold. If you produce necessary cooling and heating at the same time, the efficiency is greatly improved.
1.03	Process optimized? Is the sink temperature level at its lowest?	Check the real need, not always use as high a temperature as asked for. Can the process technology be replaced?

1.04	Impact on the process?	It is related to #1.03. Longer heat-up time admissible with lower temperatures?
1.05	Distribution pipes size?	For example, lower steam temperature would require larger pipes. Heat capacity reduction for an existing steam distribution network.
1.06	Heat source and sink location?	Cost on circulating source/sink (piping, pumping). Heat losses to consider.
1.07	Heat storage required?	If the demand/source is variable. Directly related to the heat need. Yes for batch process
1.08	Media quality/state suited for heat exchangers?	Cross-contamination? Fouling?
1.09	Simultaneous or batch?	Non-simultaneity can be «created» (PV auto-consumption strategy for example). Process may be interrupted waiting for an available source. Need for a safety gap
1.1	Good knowledge of the process temperature needs	What is the real temperature demand for process? Are there pressure reducing valves for steam before HEX inlet?
1.11	HTHP capable of following the temperature fluctuations (source / sink)	The HTHP manufacturer shall provide a Tsource / Tsink graph with the allowed working area.
1.12	Flue gaz heat recovery?	Consider that some sources may not be available in the future.
1.13	Variation of the process installations (production and utility heat production)	Power load monotone graphic required
1.14	Stability of the production temperature	Related to source temperature
	Infrastructure requirements	
2.01	Sufficient electrical power installed? (introduction, from elec. supplier)	Cost of the project to add a transformer / Max Amps vs available Amps / Slow start available?
2.02	Enough space for an HTHP? Where?	Cost, new building/technical room needed? / Including free space for maintenance and space for heat storage
2.03	Structural requirements? (static calculations)	Heat pumps are heavy and dense machines.
2.04	Level of vibration allowed ?	Sensitive process close by?
2.05	Level of noise allowed?	Possibility to add a sound dimming construction?
2.06	Distribution networks to build/modify?	1 HP for several processes to manage and guarantee supply temperature? Multi-level network existing: advantage for HP if yes. Greenfield projects easier. Network can swing in temperature and impact other processes. Buffer helps to avoid fluctuations / Not always possible technically to add a network

2.07	Refrigerant fluids requirements (ATEX / Inflammable / Toxicity / compatibility with materials / oil)	Regulations to be followed.
2.08	Hybrid system with gas boiler	Redundancy, footprint, regulation aspects
2.09	Distance between production and use	See 1.06
2.10	GWP of the refrigerant / charge of refrigerant	What happens in case of a leak? Internal guidelines for natural refrigerants only?
2.11	Timing of the project - planning phase	Use lot of time convincing clients. Is the timing right for the company?
2.12	Measurements and knowledge on the process as to place the HP wisely	Closest to process? Pinch analysis for optimal placement
2.13	Adapting the refrigerant to the glide of the process	Chose a refrigerant mixture with non-constant temperature for heat exchange, allows glide on the source side in the evaporator / Difficulty in adjusting the mixture composition
2.14	Controlling and automation system	Key to good operation / Integrated in the HP, MCRG
2.15	How to use the storage right?	Need storage simulation for HP project (cold and hot) / Consider stratification. For start-up and non-continuous process
2.16	Area where HP installed - district cooling/heating?	Synergies with other processes, plants? Sharing of resources with third party ok? Contracts can be very complex by networking with various companies.
2.17	Ownership of the infrastructure	If you don’t own the place? / Existing contract for 10 years for fixed steam capacity supply: no interest in changing to HP / Linked to the business model (selling energy), constraints on modifying infrastructure
Redundancy strategy		
3.01	Keeping actual heat source as backup? For how long?	Boilers can notoriously be maintained and used (following regulations and inspections) way longer than the life expectancy (20 years). Beware of heat-up duration.
3.02	Trust in the selected HTHP’s reliability?	Do you wish to be part of the pioneers (funds may be interesting), or will you wait until the HTHP is in common use?
3.03	Assessment of risk of heat production shutoff?	Classic exercise for manufacturing companies.
3.04	Importance of financial impact of heat production shutoff?	Classic exercise for manufacturing companies.
3.05	Number of compressors per machine? Replacement of one compressor during operation?	To check with the supplier

3.06	Redundancy guaranteed during maintenance?	Shutdown aligned to maintenance periodicity?
3.07	Renewable redundancy? Impact of long-term activation on CO2 emission goals.	Commonly requested now by clients. For example, with electrical boilers and renewable electricity procurement.
3.08	Design make-up system, start-up system and back-up	All to be considered
3.09	Start by reducing the needs.	First, optimize, then install an HTHP. It will also reduce the need for backup.
3.1	Redundancy is to be evaluated based on the criticality of the process, and backup for selected parts of the process.	Exothermal process, critical points?
3.11	Speed of available backup steam, heat-up time?	Need to keep the steam boiler hot at all times?
3.12	200% power availability?	May be required if valuable/sensitive product.
3.13	For how much time must the redundancy be defined	2h, 8h? Time to finish process or batch, for example.
3.14	Direct electric back-up	Emergency backup only by law. Could be an opportunity for HTHP with existing electric introduction
3.15	Back-up costs	Less maintenance and energy consumption (hot standby) with electrical boilers than gas boilers.
3.16	Generator in case of black-out	What happens if there is a black out? Shall the installation be shut-off or saved with expensive back-up fuel generators? May require inertia wheels/batteries to compensate for the power-up delay of the generators.
	Technical requirements / constraints for the HPHT operation	
4.01	Minimal working duration of the HTHP?	Check with the supplier – usually 20min
4.02	Heat-up duration?	Storage? Direct heating?
4.03	Quality of the streams?	Corrosive? Droplets?
4.04	High variations in demand?	Keep the temperature as constant as possible.
4.05	High variations of the source or sink temperatures?	Variation of temperature and demand in % capacity and gradient %variation/time. All scenarios (start-up, climate effect, etc.) must be considered
4.06	Shut off duration without maintenance?	Check with supplier
4.07	Precision of the output temperature?	Compressors with inverters?
4.08	Continuous operation?	Check with supplier
4.09	The characteristics asked for must be sure (URS, user requirement specifications) and confirmed by supplier	Guarantees mandatory. Define indicators and measurements allowing verification

4.1	Regulation	Interaction with existing heat production system? Allowing best efficiency of the HTHP? Be aware that a HP is not as flexible in use as boilers.
4.11	Decoupling the HP from the process with intermediate water loop	COP will drop, but avoids contamination in heated stream
4.12	Boundary conditions with steam-HTHP clearly established for roles repartition	Who manages what? Customer or supplier? Modifications on existing equipment? Impact on warranties for other equipment?
Safety		
5.01	Main technical requirements?	Enclosure, ventilation, detection, alarm shall be specified. Related to refrigerant gas selected.
5.02	Evaluation of risks?	Global risk analysis including OPAM, PED, SUVA, OPAIR, MACHINE, ATEX.
5.03	Regulation compliance?	Pre-validation of project by local authorities. Study including notified bodies and specialists already at the start of the project
5.04	Impact on the production process	Disturbance of process / Linked to the two sides. What happens in case of failure? Shut off strategy?
5.05	Toxicity and flammability of the refrigerant	To be considered in 5.02.
Maintenance		
6.01	Internal maintenance staff trained for part of the routine checks?	What is routine check? Boundaries to be defined with supplier.
6.02	Long term maintenance contract concluded with the supplier?	Highly recommended.
6.03	Periodicity of maintenance?	To be defined with supplier
6.04	Ensuring safe maintenance?	To be defined with supplier
6.05	Location of supplier?	Impact on reactivity in case of issues.
6.06	Access?	Enough space provided? Routine checks without using ladders guaranteed?
6.07	Spare parts?	Depending on the redundancy strategy. May be interesting to add storage of key components at the suppliers facility in the maintenance contract.
6.08	Reaction time? Remote controlling available?	Can be specified in maintenance contract. With financial penalties in case of delay. Some products can't wait 18hr for chiller not working and delicate product waiting for the repair.
6.09	Who performs the maintenance?	Internal : better vs long reactivity time from some suppliers / External : not equally good at aligning to planned maintenance breaks

4.3 Workshop on financial aspects

Moderators: Frédéric Bless and Cordin Arpagaus (OST)

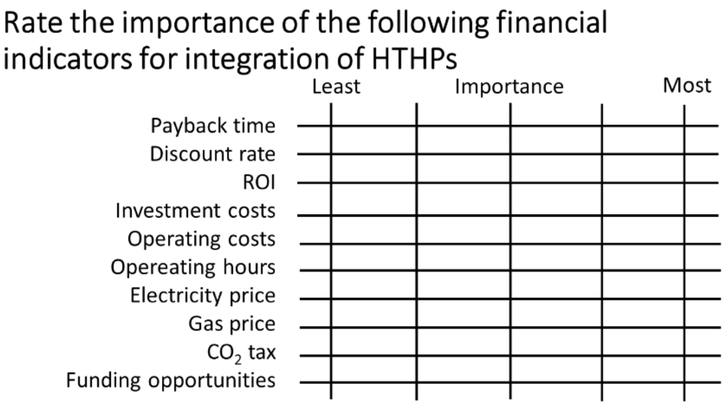

Figure 5 : Pictures from the workshop on financial aspects

4.3.1 **Introduction and goal of the workshop**

- Goal of the workshop was to clarify and discuss financial aspects for HTHPs and get feedback of the main financial indicators used.
- The workshop was organized in 4 parts:
  - Importance of various economic indicators for HTHP integration (flipchart)
  - Economic competition with alternative renewable heating solutions (multiple-choice answers)
  - Discussion of financial aspects (post-it's clustered on the wall)
  - Discussion of business models applied for HTHPs
- Timetable: 5 min goals, 30 min discussion, 5 min summary

4.3.2 Importance of various economic indicators for HTHP integration

- The participants of the 4 groups were asked to rate the importance of various financial indicators for the integration of HTHPs. A flipchart was prepared to rate the indicators by markers.



- The results depended on the group (see photographs below)

- The main findings were as follows:
  - The most important indicators mentioned by all groups were: payback time, ROI, operating costs, electricity and gas prices, and discounting.
  - Less important were investment costs and funding opportunities.

Figure 6 : Results of importance of various economic indicators for HTHP integration

4.3.3 What alternative renewable heating solutions are in economic competition with HTHPs?

- The participants were asked about alternative renewable heating solutions in economic competition with HTHPs.

What alternative renewable heating solutions are in economic competition with HTHPs?

	Yes	No
Biomass	☐	☐
Cogeneration	☐	☐
Electrical steam boiler	☐	☐
Electrical (air) heater	☐	☐
Solar thermal	☐	☐
Other:	☐	☐
Other:	☐	☐

Remarks: ....

- The results (table) clearly show that the largest competition is biomass, followed by cogeneration, solar thermal, electrical steam boiler, biogas, and electrical (air) heater.

Table 3: Results of alternative renewable heating solutions

What alternative renewable heating solutions are in economic competition with HTHPs?		
n=26 (participants)		***Comments***
Biomass	24	*availability*
Cogeneration	11	*and carbon capture*
Solar thermal	9	*not in Switzerland, complimentary*
Electrical steam boiler	8	*size small, depending on the temperature*
Biogas	7	
Electrical (air) heater	4	*depending on the temperature*
Green hydrogen	2	*synthetic fuels, as energy carrier*
Geothermal	2	
Others	3	*direct heat recovery, thermal storage, direct waste heat use*

4.3.4 Discussion of financial aspects

- Goal of this exercise was to clarify and discuss financial aspects for HTHPs and get feedback from the participants. Post-its were clustered on the wall and some possible answers were discussed. The results with the post-it's grouping is shown in the next photograph.

Figure 7 : Postits of the discussion of financial aspects

The most relevant questions and answers on the economic aspects of HTHPs were:

- Important economic aspects discussed : gas availability, the total cost of energy production, energy price (electricity price with long-term contracts, gas price more short-term, gas day-by-day trading), energy price ratios (cost of energy vs overall OPEX), CO_2 tax expectations for the future, maintenance costs (gas/HP variations or fixed), operation hours/year, etc.
- How much a HTHP costs? → See specific investment costs curve
- What are typical cost multipliers to calculate the HTHP integration? What is the cost multiplication factor for a whole project? → the multiplication factor can be 1 to 4 times the HTHP equipment costs
- What are the maintenance costs? → typically, a few % of the investment per year, maintenance and safety aspects need to be considered, like ammonia detection, risk of toxicity and flammability (hydrocarbon refrigerants)
- What is the efficiency (COP) of a HTHP? → use as a 2nd Law efficiency (Carnot efficiency) of about 45% for closed-cycle heat pumps and 65% for MVR (mechanical vapor recompression), the OPEX is related to efficiency (i.e., thermodynamics, COP vs. temperature lift function)
- What subventions and funding possibilities are available? → EnergieSchweiz offers financial support for process heat, SFOE offers P&D projects, etc. see also the presentation from Carina Alles: https://www.sweet-decarb.ch/fileadmin/downloads/Presentations_File/02_SFOE_Introc.pdf
- Does the budget include a performance guarantee / qualified operating personal / insurance?
- Are there possibilities for cross-sectoral approach (e.g., district-heating close-by, sell/buy heat from external)?

4.3.5 Business Models for HTHPs

- Finally, there was a discussion of business models for HTHPs. The main findings and results of the submitted conference paper were shortly presented (see next graphs).
- *Paper: Arpagaus, C., Paranjape, S., Nertinger S., Tietz, R., Bertsch, S.: Review of Business Models for Industrial Heat Pumps, Proceedings of ECOS 2023, 36th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, 25-30 June 2023, Las Palmas de Gran Canaria, Spain*
- Feedback from the participants:
    - The company Walter Wettstein AG is a heat pump producer and sells their heat pumps directly to the customer, including 5 years of maintenance
    - EWZ or 360° are energy contractors and would buy the HTHP plant and sell the energy (heat as a service) (EWZ sells for example refrigeration energy to ice rings)
    - Potential end users like Gustav Spiess AG and ELSA would buy the HTHP and order maintenance contracts
    - Cremo also wants to be the owner of the heat pump (buy), otherwise energy contracting with an energy contractor. Important is to have a reliable heating solution.
    - Lonza would buy the heat pump (ownership) and has in-house maintenance people for the primary energy production and distribution. In canton Valais, the water amount from the Rhone River for cooling is limited. If the CAPEX is large (big project) then energy contracting is an option.
    - Carina Alles pointed out that the business model depends on the company (buy the own heat pump or licensing it)
    - Stefan Renz explained that many companies like in the Basel area mandate a company for the utilities (outsourcing the services). There is a facility manager involved in energy utilities. This way the discount rate for investment project in energy can be 4%, in comparison to a chemical company with a 10% discount rate.
    - One group of participants especially emphasized the need for modular heat pumps (standardized modules so that reliability increases)

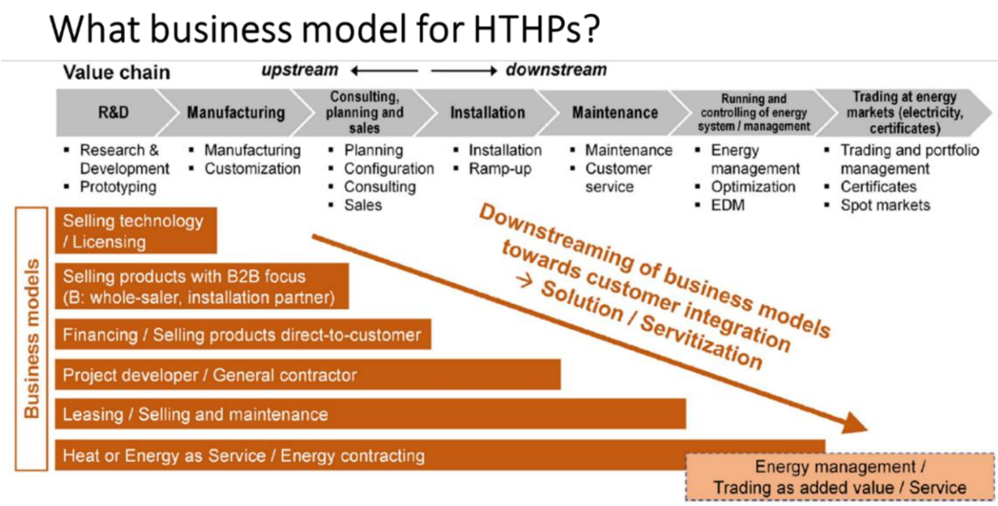


Figure 8 : Results of importance of various economic indicators for HTHP integration

Table 4: 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

4.4 Workshop on supporting tools

Moderators: Daniel Florez-Orrego and Eduardo Antonio Pina (EPFL)

Comments gathered during the workshop on Supporting Tools

The workshop was very productive as it was possible to offer an overview of the supporting tool currently developed at IPESE-EPFL. In this way, it was useful to get feedback from the participants regarding their expectations about how they interpret a supporting tool should operate. Overall, the comments were positive, as most people were interested in knowing the framework behind the tool, including software integration, and provided positive feedback on how it could be improved based on their day-to-day needs. A few participants still needed to be completely enthusiastic about the proposed environment. Some of them see supporting tools (other than Excel or PowerPoint) as more comprehensive but also need help applying them on a daily basis. Indeed, a tool that calculates thermodynamic properties, performs energy integration, supports decision-making through the display of shareable reports and can be deployed online is possibly more than what practitioners want to use daily. Yet, it may also be born in mind that, due to the lack of this kind of tools, the industrials have not always made the better decisions in terms of energy management, incurring oversizing, wrong integration, and environmental burden,

Other comments are discussed below:

- Focusing on the **end-users' needs**. In this regard, there should be an effort to educate end-users about the importance and benefits of process integration techniques in industrial processes.
    - Some participants expressed certain disdain about the tools, expressing that before proposing a tool, developers of engineering tools (in general) should first "understand the core business" and "focus on real-life" demands, rather than looking for "academic" applications. In this context, there is a typical need to bridge the gap between industry and academia.
- Generating and **evaluating alternatives**, or "good options":.
    - The evaluation of alternatives should encompass different levels, beginning with the process itself (e.g. whether the existing operating conditions are appropriate or not, or if the energy requirements have been defined from the beginning). It is necessary to have a perspective that includes long-term energy scenarios.
    - Cost is clearly an important element.
    - It is important to show the advantage of the HTHP technology over the "competitors", such as gas boilers. This would involve understanding the end-users' decision making process, which goes beyond purely economic and technical aspects.
    - Include uncertainty and sensitivity analysis. Sankey diagrams. Error measurement.
    - The flexibility of the proposed solution is an important issue because often the process needs to be operated within wide ranges.
- Improving **data management** because they feel they must deal with a huge amount of data from their processes. A training session on how to extract data from their database (.csv files), organize it in a structured way and input it in the supporting tool
- **Challenge the status quo: Excel**.
    - Some participants acknowledged preferring to use Excel because it is "simpler" and "easier" for practitioners in the industry, and because "it is the tool that has been used for years".

    - Some participants were concerned that anything other than Excel would be too complex for their day-to-day work and would require considerable time to learn.
    - Given that Excel is widespread in the industry, it would be interesting to add some kind of connection to it in the new tool. This could facilitate end-users' opt-in as well as some degree of compatibility.
- The **cost of the supporting tool** was also a frequent concern, as enterprises won't be willing to spend money to use costly licenses and vendor software, as they think are not used as much as in academia. As soon as it has been stated that the supporting tool would be open source, most of them changed their mind to be more open to understand how the maintenance, the obtainment and the data safety is managed by the servers that house the engine of the supporting tool.
- Another "fear" is associated with the **fast changing environments** in the industry 4.0. They worried about the emergence of more and more supporting tools that promise helping engineers. It has been explained that the idea of the supporting tool is rather to ease the manipulation and visualization of the data, the centralization of the information, and a way of allowing the different actors (from suppliers up to managers) to have access to updated information that is not located in a multi-version file in one directory of a specific employee.
- Those enthusiastic about the supporting tools asked for a catalogue with **guidelines on specific components**, and not necessarily the whole energy systems.

5 Results from the survey

Twenty persons have fully answered the survey that has been prepared to get more insight. The following sections give a synthesis of the results for each question.

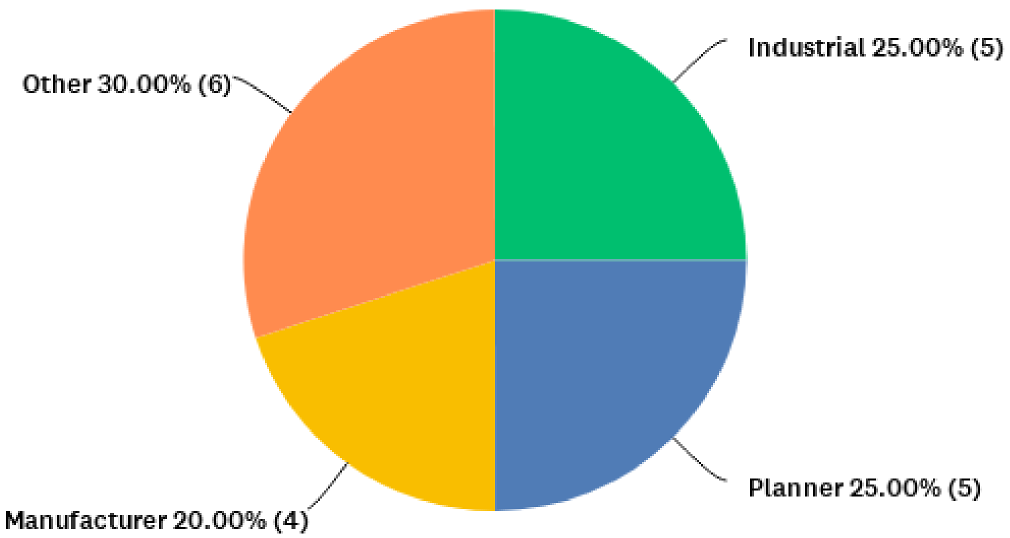
5.1 Contact E-mail

14 persons shared their e-mail addresses hence agreeing to be contacted in case of questions.

- marc.gruenig@scheco.ch
- elia.stieger@dmeag.ch
- Simon.rime@groupe-e.ch
- teutloff@lemonconsult.ch
- beat.nussbaumer@eicher-pauli.ch
- philippe.huber@truttmannag.ch
- badertscher.reto@ch.sika.com
- raphael.gerber@heim-ag.ch
- basile.laurent@cimo.ch
- andreas.genkinger@fhnw.ch
- blandine.maisonnier@cimo.ch
- stefan.flueck@hslu.ch
- annamaria.mosetto@vd.ch
- cordin.arpagaus@ost.ch

5.2 In what domain do you work with respect to HTHPs?

The repartition of the participants is given in the figure below.



From the category “other” 3 are from the research field, and the other 3 answered consultant, education and regulatory aspects (government).

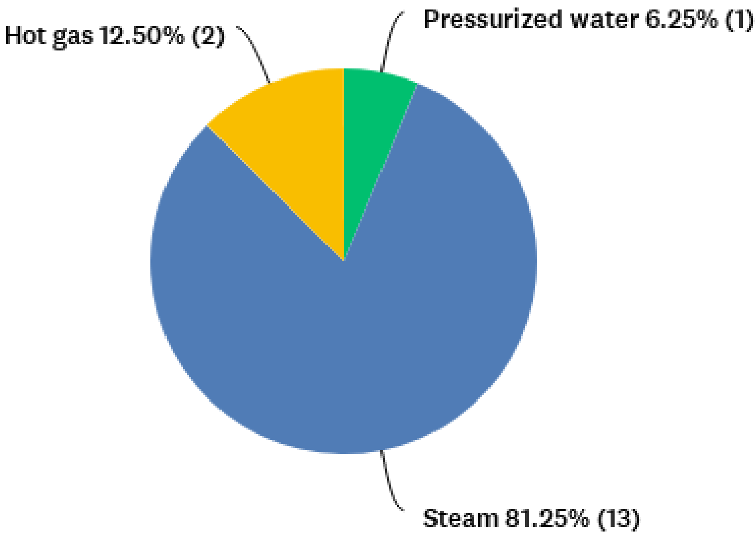
5.3 What is your role and position?

Hereafters are the replies:

- Head Technology Group (Verfahrenstechnik)
- Group Leader
- CEO
- Technik
- Project leader feasibility
- Energy efficiency engineer
- Pro
- Projektleiter - Industrie und Grossbauten
- Sen.Projektleiter
- Designer / Project manager
- Sustainability/Engineering Manager
- Development engineer
- Ing. Energie et Environnement
- Lecturer
- Energy engineer / project manager
- Researcher, project manager
- Energy efficiency engineer
- I am responsible for the industry-mobility section of the energy efficiency division in the Direction de l'énergie of the Canton de Vaud
- Senior Research Engineer

5.4 Which medium is most interesting to supply heat at >100°C?

Steam has been selected as the most interesting heat distribution media with over 80% of the votes.



5.5 Why?

As a justification, the following arguments have been given:

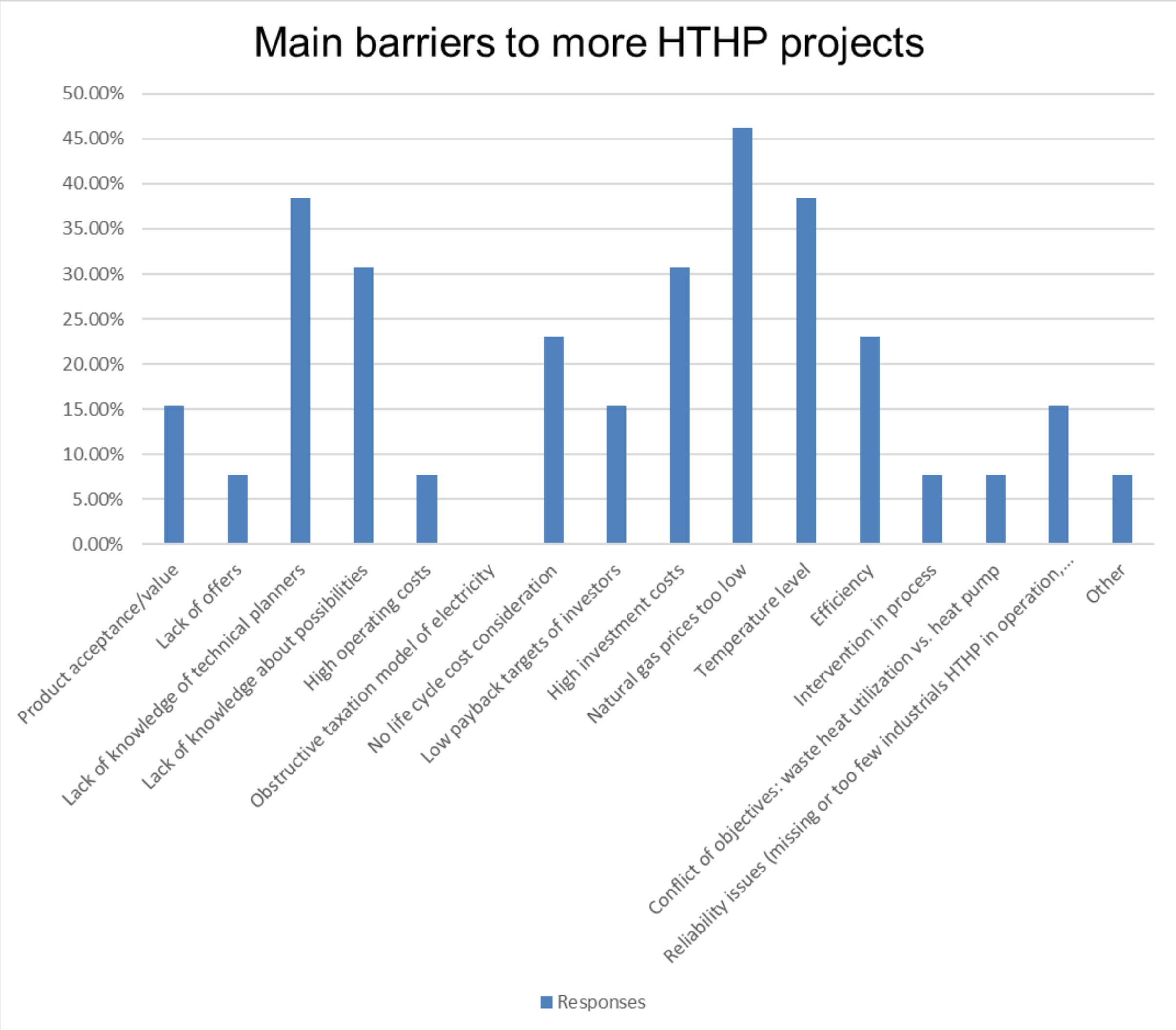
- Replacement of fossil-based steam generation
- Because this is (alas) still requested by the equipment manufacturers
- It allows for the use of proven technologies
- The steam system is already in operation (heat distribution and process units)
- Widely used as the main heat transfer fluid in existing industrial plants, especially for process steam requirements
- Steam is currently the main energy carrier in industry; however, hot air is also important for drying processes and pressurized water is also important for processes below 100 °C.

5.6 What thermal capacity would be most suitable for a HTHP unit? Specify why or for which field or application. Fill as many as you want.

The table below shows an overview of the votes. 500 kW and 10 MW units have the highest potential according to the participants. Some state that industrial needs can also exceed this highest value. Application examples given are synthesized for each power range.

Power per unit	Voted suitable	Comments or application examples			
100 kW	42.86%	Our product range, small food production	Small production processes which are steam-based	Nicht typisch	Medium sized residential/industrial building. Most of the time HT needs are small
500 kW	64.29%	Kleine Molkereien	Replacement of steam in production plants, nutrition, diary, chemistry	Distillation, heating dryers	
1 MW	50.00%	Small size food industries	Dairy, chemistry	Heating reactors	
2 MW	28.57%	District heating networks	Mediuml size food industries		
10 MW	57.14%	Overall capacity	for steam supply to a chemical site (global need ~100MW)	Large size food industries as well as pharma	Mean consomption of steam on our site is above this value. If we want to replace gas boiler by HTHP unit 20 MW would be a minimum.

5.7 Give 3 reasons why there aren't more HTHP projects



5.8 Propose key actions or elements to push the implementation of HTHPs

Knowledge:

- Promotion of technologies
- Information about the state of the art, spreading knowledge
- Demonstration of implemented systems and operating plants / Flagship projects
- Training of energy consultants and planners
- Build up know-how and train customer for long term thinking
- Create guidelines to implement heat pumps optimally

Products:

- Availability of products
- Standardized Products (cost reduction)
- Efficient systems with high COP
- Natural refrigerants

- Simple and reliable heat pumps
- For energy recovery

Investments:

- Incentives or subsidies for customers and producers
- Support fast implementation to avoid investments into less optimal energy solutions that block industrial heat pump adoption in future years
- Increase in CO2 tax
- Incentive on electricity taxes
- Tax reductions

Other measures

- Restriction of fossil fuels
- Decarbonized electricity supply
- Create tools for Life Cycle Environmental Impact

5.9 Which source of information would you consult for HTHP questions?

- Manufacturers / technology provider
- Online database
- Energy planner, specialized engineering offices
- Book by Cordin Arpagaus
- Symposium and conference proceedings
- IIR Fridoc
- Papers from universities
- Google
- Literature

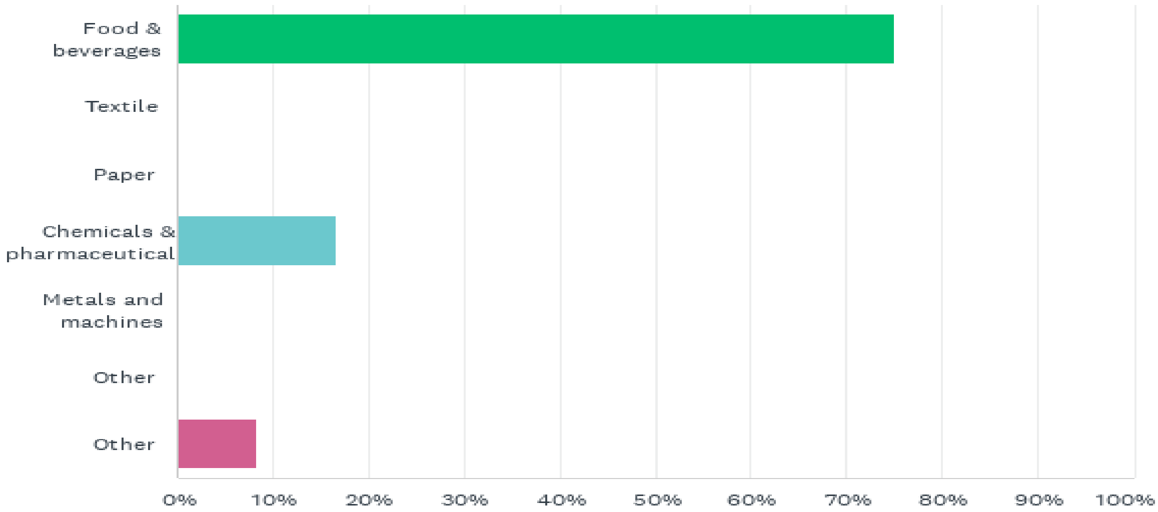
5.10 Did you realize a project with (HT)HP in the industry? Do you currently have a potential project?

100% of the 12 persons who answered the question said “yes” and the other 8 skipped it.

5.11 For which application?

- Spa and sauna
- Printing industry
- Printing and food industry
- Diverse Processes
- R744/CO2-Heat pumps
- Steam generation and thermal oil heating (160-200°C)
- Steam 6 bar(g) generation
- 6/12 bar steam production
- Heat supply in chemical process and food industry
- Industrial facilities, heat recovery, natural gas replacement
- Food processes, milk products, cleaning-in-place, sausages cooking, spray drying, distillation.

5.12 What industrial sector do you consider as most promising for HTHP?



5.13 Why?

- They have the greatest need
- Because we need to
- Usable temperature range, Less CO2
- Many cleaning and sterilization processes with temperatures not much above 100°C.
- Because their industry is familiar with process engineering, safety and environmental assessments
- Need lower temperature for their processes
- Level of temperature
- Many companies in Switzerland. Processes that take place at a high temperature level and are now heated with steam.
- Steam needs and waste energy availability
- Low-temperature process heat requirement <200 °C

5.14 Is there a specific topic you would like to be addressed during the workshop?

- Environmental danger of synthetic refrigerants, esp. to water bodies
- What are the physical limitations for higher efficiency? What is the maximal theoretical COP for generation of Steam? Is there currently pilot and large scale example?
- Are there heat pump models for 165 - 192 degrees?
- Up to which temperature range can one confidently recommend a customer at present.
- What are the needs of guidelines and training of qualified personnel able to implement industrial heat pumps optimally?

6 Conclusions

The workshop on HTHP was held at the SFOE in Ittigen on 24 March 2023 with 70 participants from different backgrounds. The first part of the workshop day was dedicated to disseminating the current state of the art of HTHPs for supply temperatures above 100 °C. Several experts from OST, EPFL, HEIG-VD, CSD, SFOE, and industry partners CREMO, ELSA, and Gustav Spiess presented the latest advances for HTHP applications, the Swiss national market, HTHP products with various technical readiness level (TRL) (IEA HPT Annex 58), process integration methodology (Pinch analysis), and realized case studies examples. Different facets of industry decarbonization were discussed which provided an opportunity to expand knowledge and exchange ideas with other professionals from different industrial sectors.
The presentations are now available for download from the SWEET DeCarbCH website (https://www.sweet-decarb.ch/events/event/high-temperature-heat-pump-event).
Representatives from SFOE were present to answer questions about funding programs and funding opportunities for target agreements, P&D projects, and net-zero schedules. Several aspects proved to be very important for successful process integration of HTHPs:

- Rethink and reduce: Exploiting optimization potential is the first step and always makes ecological and economic sense.
- Process analysis: Using data collection and bottleneck analysis, map the process and check where heat recovery and the installation of a heat pump can reduce primary energy requirements.
- Planning the energy system with the involvement of the heat pump supplier.

In the afternoon, 4 workshops provided opportunities for active discussions and feedback on socio-economic, technical, and financial aspects, and supporting tools for HTHP integration. The main conclusions of the workshops are as follows:

Socio-economic aspects:

The discussion on the drivers for HTHP adoption highlighted the role of institutional factors on the side of industrial companies (e.g., companies for whom sustainability is a core value may be more willing to take on additional risks and transactional costs to find suitable solutions for clean energy supply) as well as customers (e.g. demand for products with a low carbon impact). While they cannot be seen as representative, these results point to companies with a strong sustainability motivation and/or under customer pressure for low-carbon products as a lead market for technologies such as HTHP.

- A discussion of the level of HTHP integration (utility vs. process level) revealed that whenever there exists a cluster of steam consumers the utility level is used. A general advice was to lower the heating temperature at a site (e.g., from steam to hot water circuits) and increase cooling temperature levels to improve efficiency. Other integration criteria considered were heat demand fluctuations and limited space in the process area.
- The risks perceived by the end users (i.e., industrial companies) were mainly:
    - low reliability of HTHP technology,
    - uncertain suitability of installed HTHP to modified operation conditions, and
    - compliance risks arising from future policy changes.

From the heat pump manufacturers' point of view, a potential risk exists when the design specifications are established by a different company. If the design specifications are based on a faulty analysis, the HTHP may malfunction and fail to reach the announced performance, which represents a liability and reputational risk for the manufacturer/installer.

Technical aspects:

A checklist was developed and discussed in the technical workshop giving an overall picture of aspects to be considered for heat pump implementation projects in an industrial context. Key aspects were identified and organized by themes, such as:

- Heat source and sink (14 key aspects),
- Infrastructure requirements (17),
- Redundancy strategy (16),
- Technical requirements and constraints for the HPHT operation (12),
- Safety (5),
- Maintenance (9)

For all aspects some comments and hints were given to address the issues.
There are very few points that generate a technical no-go for HTHP integration into industrial processes, they would mainly impact the financial feasibility.

Financial aspects:
The main conclusions from the financial workshop were as follows:

- The most important indicators mentioned by all groups were: payback time, ROI, operating costs, electricity and gas prices, and discounting.
- Less important were investment costs and funding opportunities.
- The results of a multiple-choice questionnaire survey (24 participants) showed that the largest competition of HTHP technology is biomass (24 responses), followed by cogeneration (11), solar thermal (9), electrical steam boiler (8), biogas (7), and electrical (air) heater (4).
- Important financial indicators are gas availability, total cost of energy production, energy price (electricity price with long-term contracts, gas price more short-term, gas day-by-day trading), energy price ratios (cost of energy vs overall OPEX), CO2 tax expectations for the future, maintenance costs (gas/HP variations or fixed), operation hours/year, etc.
- Finally, a discussion on business models for heat pumps revealed that heat pump manufacturers typically sell their heat pumps directly to the customer, including maintenance. Some energy contractors would buy the HTHP plant and sell the energy (heat as a service). Potential end users would buy the HTHP (ownership) and order maintenance contracts. Important is to have a reliable heating solution.

Supporting tools:
The workshop on supporting tools revealed in particular that some participants acknowledged preferring to use Excel because it is “simpler” and “easier” for practitioners in the industry for daily use, and because “it is the tool that has been used for years”. Given that Excel is widespread in the industry, it would be interesting to add connection to it in the new tool. This could facilitate end-users’ opt-in as well as some degree of compatibility. In addition, a supporting tool which is open source (no license) would be appreciated.

Survey:
Finally, the results of a survey with 16 questions were summarized and discussed. In total, 20 persons have answered the survey. The main findings from the answers are:

- 81% rated steam as the most interesting medium to supply heat at >100 °C
- HTHP units with 500 kW and 10 MW thermal capacity are seen to have the highest potential
- The main barriers to more HTHP projects are the gas price which is too low and the lack of knowledge of technical planers on current possibilities
- Food & beverage is the most promising sector for HTHPs
- Proposed key actions or elements to push the implementation of HTHPs
    - Increase knowledge on products and HTHP integration, give examples of running systems
    - Increase availability of (standardized) products with high efficiency and natural refrigerants
    - Financial incentives and subsidies, increase in CO2 tax
    - Decarbonize electricity supply and restrict fossil fuels

7 Next steps

The planned activities included the preparation of these minutes and the dissemination of the workshop results on the Sweet DeCarbCH website which have been realized. Moreover, to valorize the outcomes from the workshop, an article is to be published in the IEA magazine (CSD) and the establishment of a “risk-matrix” to mitigate international hurdles to implementing heat pumps is also foreseen (OST / ZHAW).

8 Appendix

Appendix 1 – List of participants to the HTHP presentations and workshop from 24th May 2023

Appendix 2 – Minutes from the advisory board meeting from 30.03.2023

High Temperature Heat Pumps Event | 24 March 2023 | Ittigen

Last name	First name	Company	Workshop group
Organisation team			
Arpagaus	Cordin	OST	Moderator
Bless	Frédéric	OST	Moderator
Calame	Nicole	CSD ENGINEERS	Moderator
Florez-Orrego	Daniel	EPFL	Moderator
Krummenacher	Pierre	HEIG-VD	Moderator
Pina	Eduardo Antonio	EPFL	Moderator
Schüpbach	Loïc	CSD ENGINEERS	Moderator
Speich	Matthias	ZHAW	Moderator
Participants			
Alles	Carina	BFE	Group 2
Alonso	Laura	Tecnalia Research and Innovation	
Arduini	Dimitri	Merck Serono	
Badran	Bassam	RISE	
Barras	Irène	OFEN	Group 1
Bertsch	Stefan	OST	Group 2
Betancur Arboleda	Luis Alonso	Unidades Tecnológicas de Santander	
Bever	Paul-Michael	OST	Group 1
Blumenthal	Patrick	Lonza AG	Group 2
Blunier	Adrian	Walter Wettstein AG	Group 4
Botelho	Jose	Takeda	Group 4
Burger	Felix	Lonza AG	Group 1
Caha	Tomáš	Exergie	
Chauvet	Gabriel	Groupe E	Group 2
Chereau	Loic	Chemours Sarl	
Dany	Harald	Atlas Copco Energas GmbH	
Dominic	Meyer	KAPAG	
Eckmann	Andreas	BFE	Group 3
Faessler	Jerome	Geothermie Suisse	
Festa Rovera	Paride	TBF + Partner AG	Group 2
Flück	Stefan	Hochschule Luzern	Group 2
Gheondea	Sabin	Chemours Sarl	
Giansetto	Laurent	Cremo	Group 2
Goffin	Philippe	Weisskopf Partner GmbH	Group 3
Grünig	Marc	Scheco AG	Group 1
Gubser	Marc	P+p project	Group 2
Gummin	Ingolf	DSM Nutritional Products	
Hoyos	Jose	Etat de Vaud	Group 3
Huber	Philippe	Truttmann AG	Group 2
Jansen	Christian	Spiess Berneck	Group 1
Jansen	Ørjan	AMOF Fjell	
Janssen	Thomas	Feldschlösschen Supply Company AG	
Kami	Eduardo	Petrobras	
Kauffeld	Michael	Hochschule Karlsruhe	
Läubli	Daniel	KLINGER Gysi AG	Group 4
Laurent	Basile	CIMO	Group 3
Leiser	Alain	Ensolutions.ch	Group 3
Leumann	Pascal	Stadt Zürich	

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Liechti	Martin	Thermische Netze Schweiz	Group 3
Liukaitiene	Giedre	CSD ENGINEERS	
Maisonnier	Blandine	CIMO	Group 2
Maréchal	François	EPFL	Group 4
Märsmann	Marco	Bell Schweiz AG	
Martin	Thibault	Aporia	Group 4
Mathys	Andre	IndustriePlan	Group 1
Maurer	Frédéric	BFE	Group 4
Moia	Emilio	Jacobs Italy	Group 3
Mosetto	Annamaria	Canton de Vaud, Direction de l'énergie	Group 2
Mota Babiloni	Adrian	Universitat Jaume I	
Müller	Alain	KLINGER Gysi AG	Group 1
Nussbaumer	Beat	eicher+pauli Bern AG	Group 4
Paranjape	Sidharth	OST	Group 4
Peña	Xabier	Tecnalia Research and Innovation	
Philippe	Huber	Truttmann AG	Group 2
Pinto	Matteo	KAPAG Kälte-Wärme AG	
Rebillard	Clement	Groupe E	Group 4
Renz	Stephan	BFE / Beratung Renz Consulting	Group 1
Rime	Simon	Groupe E	
Rosenthal	Günther	Lonza AG	
Scuffi	Luca	CSD ENGINEERS	
Soltermann	Martin	Lonza AG	Group 3
Steiger	Martin	Emmi Schweiz AG	Group 1
Steinmann	René	Truttmann AG	Group 3
Stieger	Elia	DM Energieberatung AG	Group 1
Van Hattem	Dolf	Studio Caramelli S.r.l.	
Vautherot	Martin	Merck Seronon	
Vesin	Stéphane	ELSA Estavayer Lait SA	Group 3
Widmaier	Philip	ETHZ	Group 4
Wirz	Men	BFE	

Survey about high temperature heat pumps (HTHP) for industrial applications

https://fr.surveymonkey.com/r/W5P8GX6

Minutes HTHP-CH Project:

Advisory Board Meeting & HTHP Workshop Debriefing

Date / Time / Location	**March 30, 2023 / 10:15-16:30 / Online MS Teams Meeting**	
Participants:	**OST-IES:** **HEIG-VD:** **EPFL-IPESE:** **CSD:** **Industrial Partners:** **Advisory Group (SFOE):**	Frédéric Bless, Cordin Arpagaus Pierre Krummenacher Daniel A. Flórez-Orrego, Eduardo Pina, François Maréchal, Nicole Calame-Darbellay, Fabrice Rognon - Carina Alles, Stephan Renz, Frédéric Maurer
Lead / Protocol:	Cordin Arpagaus	
Attachments:	-	

<u>Note:</u> Documents shared within the HTHP-CH project are confidential and must not be shown to anyone outside the HTHP-CH members without the consent of all involved partners. A corresponding project agreement has been signed between all project partners.

Topics:

1 HTHP Workshop Debriefing
2 Advisory Board Meeting

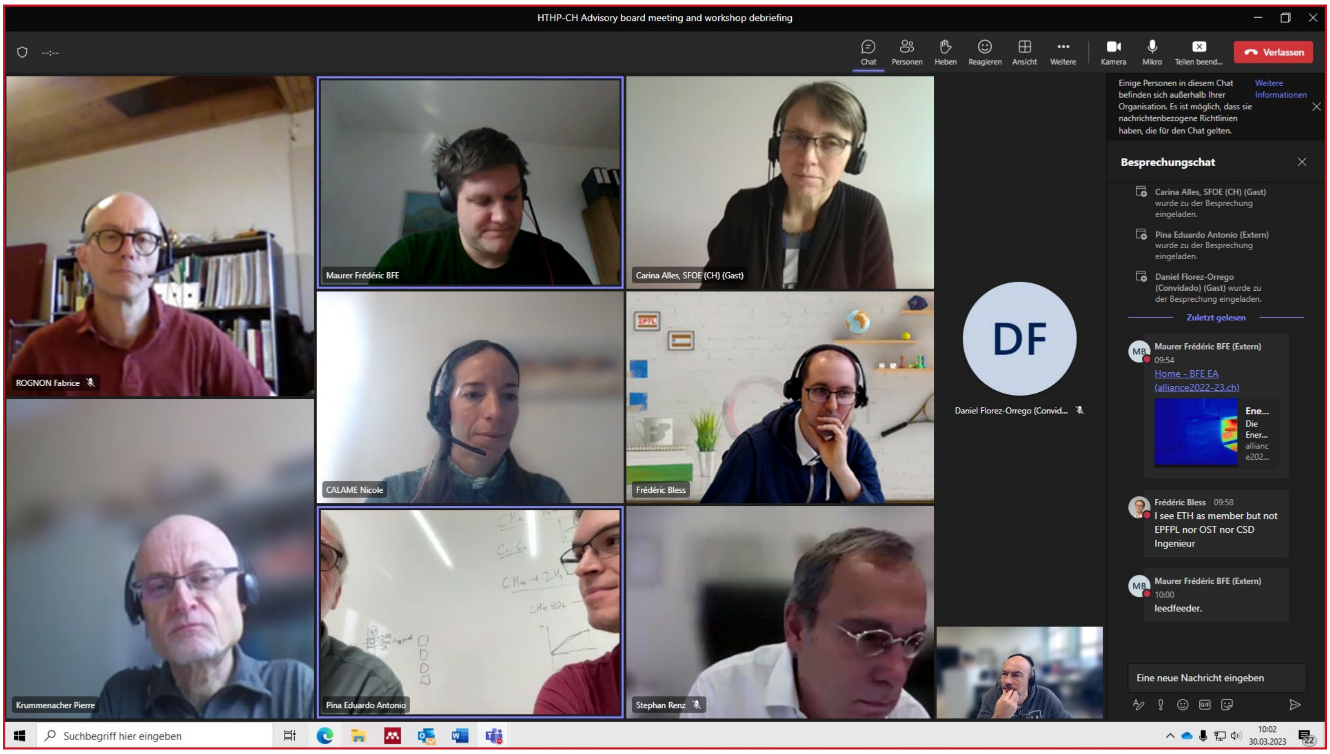

Figure: Screenshot of meeting participants

1 HTHP Workshop Debriefing

General feedback:

- Stephan Renz: positive feedback for the workshop, many people were attending (especially from industry), the presentations were well prepared, good discussions during breaks and lunch, and workshops in the afternoon were well prepared and organized with different measures (like mobile phone, screen, notes, flipcharts, etc.), with dedicated special workshops topics, it enabled lively activities
- Carina Alles: in general, positive feedback like Stephan Renz, many people attended, which enabled an open exchange of ideas and concerns, there was enough space for that
- Daniel Flórez-Orrego: the participants were interested in the evaluation tool. However, for daily use, a high-level tool would be required. The tool requires training, participants want to see alternatives. The tool should look more like an Excel program, however with access to thermodynamic data, “Pinch light” from a former EPFL time could be an option, create blocks and use copy and paste

Possible improvements for the next time workshop:

- Nicole Clame-Darbellay: the program was quite dense
- Stephan: it was difficult to motivate the people to start a discussion in the workshops, maybe one workshop less would have been OK, because it was a little bit overloaded
- Carina: The morning presentations could be better coordinated (e.g., funding programs with Cordin’s presentation), the variety of the workshops was good, and a general introduction to tools and methods would have been good for the preparation of the workshops in the afternoon
- Frédéric Maurer: need more people from the industry for dissemination, an idea would be to use the “Energiespar-Alliance” platform (this includes people from cities, branches, corporates, about 188 companies, 98 cantons, 309 members, https://alliance2022-23.ch/). This platform is used for the heat pump conference in Burgdorf 2023
- Fabrice Rognon: Think about how to help companies to develop heat pump products according to the requirements (e.g., risk mitigations, reliability), and think of other ways of subsidies (e.g., promoting heat pump development in Switzerland, e.g., Bulle, EnergieSchweiz, SFOE, national associations, pathways to the communes, approach the Energiespar-Alliance)
- Stephan: Have good application examples to convince heat pump integration (show energy security and economic feasibility by site visits, use the opening ceremony at the IEA HP conference Chicago as a platform for open discussion with industry on how to implement heat pumps, especially HTHPs)
- Frédéric Bless: Sound quality of speaker presentations was not always good (this makes it difficult to cut YouTube videos with good sound)

Next steps / ToDos:

- Summarizes all Workshops findings as Minutes (all), make out of it the Deliverable D1.2 (Nicole)
- Disseminate the workshop results via the SWEET DeCarbCH website, upload presentation slides, https://www.sweet-decarb.ch/events/event/high-temperature-heat-pump-event (Fred, Cordin)
- Disseminate the workshop results by an article in the IEA magazine (Nicole)
- Summary of questionnaire/survey results: 10 replies so far (biggest issues/barriers from industry: gas price is too low, see running examples, high investment costs, temperature level, etc.) (Nicole)
- Coordinate funding programs overview with SFOE, actual status, recheck funding support overview, report on innovation funding, brochure, update the overview (Irene, Fred, Carina, Cordin)
- Send “thank you E-mail” to the participants, incl. an advertisement (PDF flyer) for the “Wärmepumpen-Tagung Burgdorf” (14 June 2023) (CSD, Nicole)
- Video recordings of workshop presentations on YouTube (some have no good sound quality (OST, Fred)
- Send information by E-mail to “Energiespar-Alliance” platform (https://alliance2022-23.ch/) (Inform about recordings/PDFs HTHP-CH + IntSGHP Webinar + information for WP conference Burgdorf) (Lead-Feeder: who is visiting the webpage) (SFOE, Frédéric Maurer)
- Establish a “risk-matrix” to mitigate international hurdles to implementing heat pumps, including IEA HPT Annex 58 information (Cordin informs Matthias Speich from ZHAW)

2 Advisory Board Meeting

- The status of the HTHP-CH Annex 58 Project was reviewed.
- In particular, the status of the Deliverables (D1.2(a), D2.2, D2.3., D3.2, D5.1(b), D5.2(b), D5.3(b), D5.4) for the Milestone Report M3 which is due by 30 June 2023 (Q2/2023).
- The next activities planned per work package (WP) were discussed and defined as Next steps/ToDos.

Table 12: Deliverables for the Milestone Report M3 (Q2/2023): D1.2(a), D2.2, D2.3, D3.2, D5.1(b), D5.2(b), D5.3(b), D5.4.

Deliverables	Lead	Due date
D1.2(a): Minutes of two workshops	**CSD**, OST, EPFL	Q1/2023
D2.2: Integration concepts of HTHPs for 3 industrial Swiss case studies	**OST**, HEIG-VD, EPFL	Q1/2023
D2.3: Integration concepts of HTHPs mainly from IEA HPT Annex 58	**OST**, EPFL	Q2/2023
D3.2: Online tool for optimal heat pump integration in industrial processes	**EPFL**	Q2/2023
D5.1(b): Annual project reports for the SFOE, including an executive summary of each work package (WP1, WP2, WP3, WP4) and deliverables	**OST**, CSD, HEIG-VD, EPFL	Q4/2023
D5.2(b): Financial reports	**OST**	Q1/2023
D5.3(b): Contribution to Annex 58 reports together with other participating countries	**OST**, CSD, HEIG-VD, EPFL	Q4/2022
D5.4: Presentation of project results at the WP-Tagung in Burgdorf	**OST**, CSD, HEIG-VD, EPFL	Q1/2023

Milestone	Date	Description
M1	Q4/2021	Kick-off, go/no-go decision: Check whether project case studies from Switzerland are suitable for testing and validation the tool Check necessary data and information are available
M2	Q3/2022	Delivery of input data for HTHPs of the 3 Swiss case studies
M3	Q2/2023	Delivery of web-based tool for optimal heat pump integration in industrial processes
M4	Q4/2023	Delivery of design guidelines
M5	Q1/2024	All reports delivered

Next steps / ToDos:

- Summarize the minutes of the Advisory Board Meeting & Workshop debriefing (Cordin)
- **WP1/D1.2:** Summarize minutes of workshops and HTHP event (Nicole, 30 April)
- **WP2/D2.2 (integration concepts):**
  - Gustav Spiess (Pierre, Cordin): Start Pinch Analysis in April/May 2023 (data collection), online meeting on 11 April, organize site visit at Gustav Spiess on 30 May, establish process overview by Q3/2022
  - ELSA (Pierre): meeting with Stephan Vésin in April: collect representative data for the CIP systems (April/early-Mai (risk: lack of measured data)
  - Cremo (Pierre): meeting with Laurent Giansetto in April, check data collection (risk: lack of measured data to complete the list of streams)
  - Pierre to give an update on the case studies status to SFOE (Pierre, by end of April)
- **WP2/D2.3 (integration concepts from Annex 58):**
  - Review Annex 58 Task 1 report (Cordin, due date 14 April)
  - Contact Friotherm and ask for factsheets and integration concepts (Cordin, 30 April)
  - Participate in Annex 58 meeting in Aarhus (Denmark) (Cordin, 25-26 April)
  - Share Annex 58 deep dive presentations with HTHP-CH team (Cordin, 30 April)
- **WP3/D3.2:**
  - EPFL needs to work on the front end of the web-based evaluation tool, and integrate feedback from the HTHP workshop results (Daniel, mid of May)
  - Organize an online meeting with HTHP-CH team to present the “alpha version” of the web-based tool (Daniel, 23 May, online)
- **General:**
  - Write Milestone Report M2 by Q3/2022 and send to SFOE (ALL contribute their deliverables, OST finalizes the report)