AGENCE DE L'ÉNERGIE POUR L'ÉCONOMIE AEnEC

Pompes à chaleur haute température pour applications industrielles

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OST Ostschweizer Fachhochschule

Wettstein Kältetechnik


OST
Ostschweizer
Fachhochschule

résumé avec liens:

Frédéric Bless, PhD

Sédunois (-Moix)

Depuis 2015 à Buchs (SG) travaillant sur les PACs

OST

Pompe à Chaleur

Centre de Pompe à chaleur certifié

PACs résidentielles
Etude de terrain

Système de refroidissement

Buildings

IES Institut für Energiesysteme

(Agri-)PV

Decentralized Energy Supply

Electric & Thermal network

Energy Supply

Power Electronic

Thermal Management

Test Rig Development

Mobility

PAC Industrielle

Analyse énergétique

Efficiency

Industrie

OST

IES | Institut für Energiesysteme

IES-EES	IES-TES	WPZ
		


Les pompes à chaleur fonctionnent comme les frigidaires - simplement à l'envers
D'accord. Et maintenant ?
TIPP:
SELBST GEBAUT
NEUE HEIZUNG
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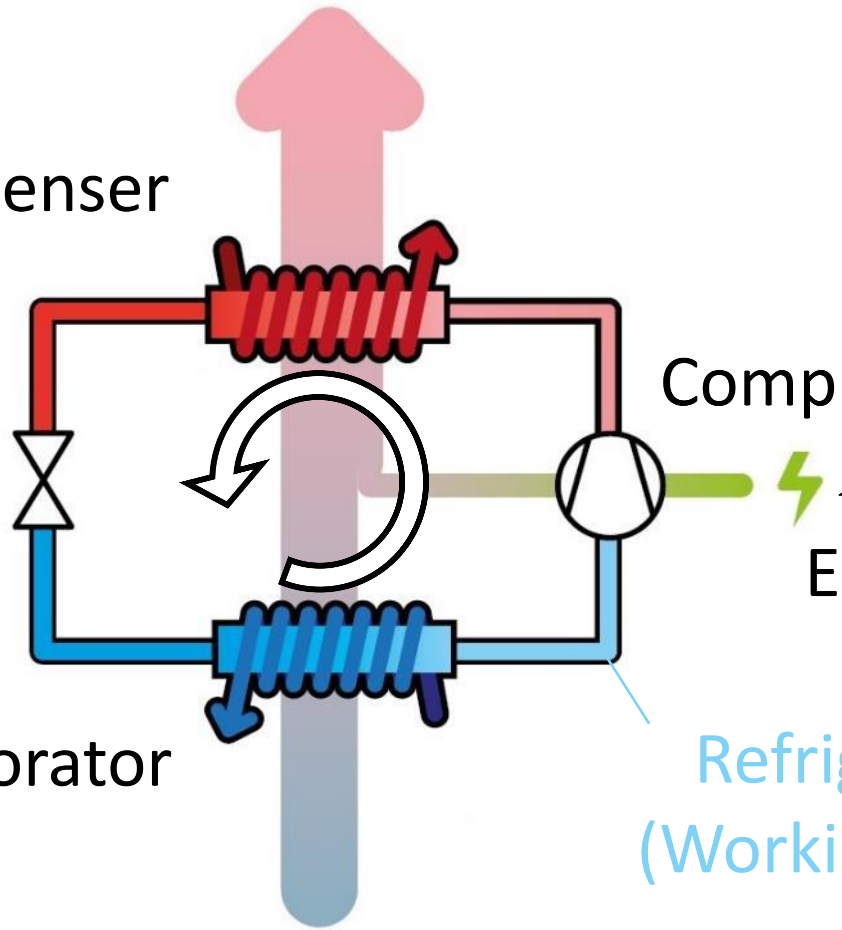
www.hannes-mercker.de

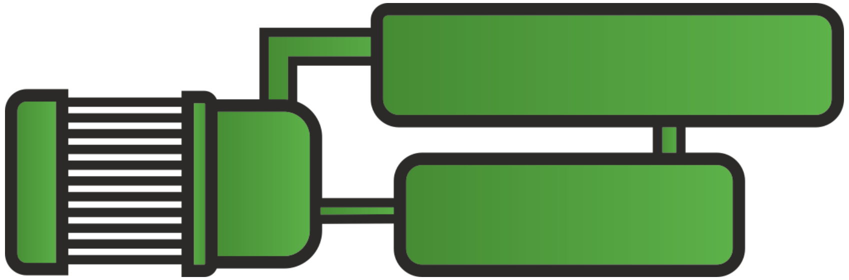


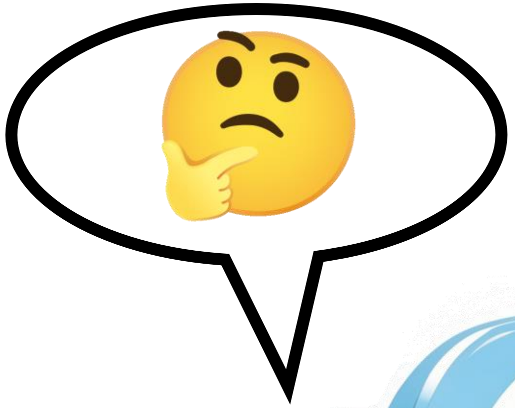
COP (Coefficient of Performance)

$$COP_H = \frac{\dot{Q}_H}{P_{el}}$$

UNE PAC EST-ELLE UNE BONNE SOLUTION ?

DANS LE SECTEUR INDUSTRIEL





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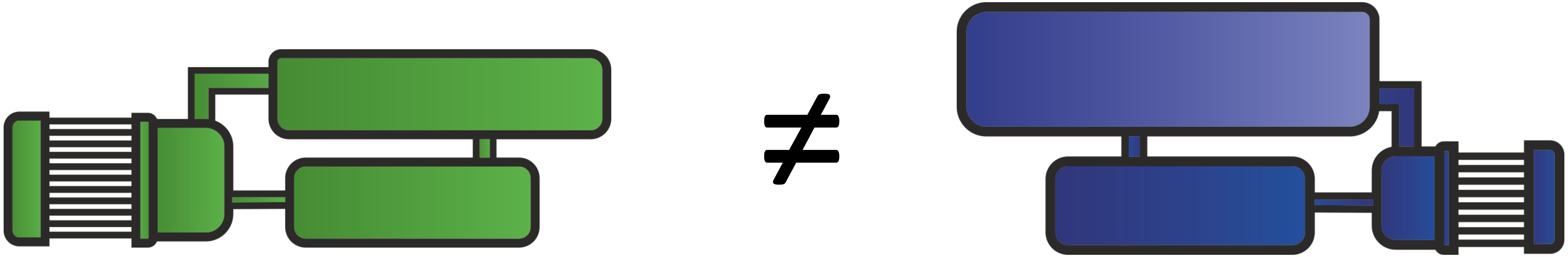
La **variabilité** des systèmes de pompe à chaleur peut **troblâ***



*troublé en patois

La variabilité des systèmes de pompe à chaleur est surprenante

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La variabilité des systèmes de pompe à chaleur est surprenante malgré un nombre de composants limités

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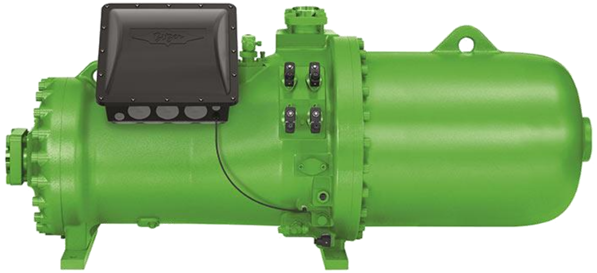


La variabilité des systèmes de pompe à chaleur est une chance

Procédé industriel

Pompe à chaleur

La variabilité permet d'optimiser le système à la demande

chaleur industrielle

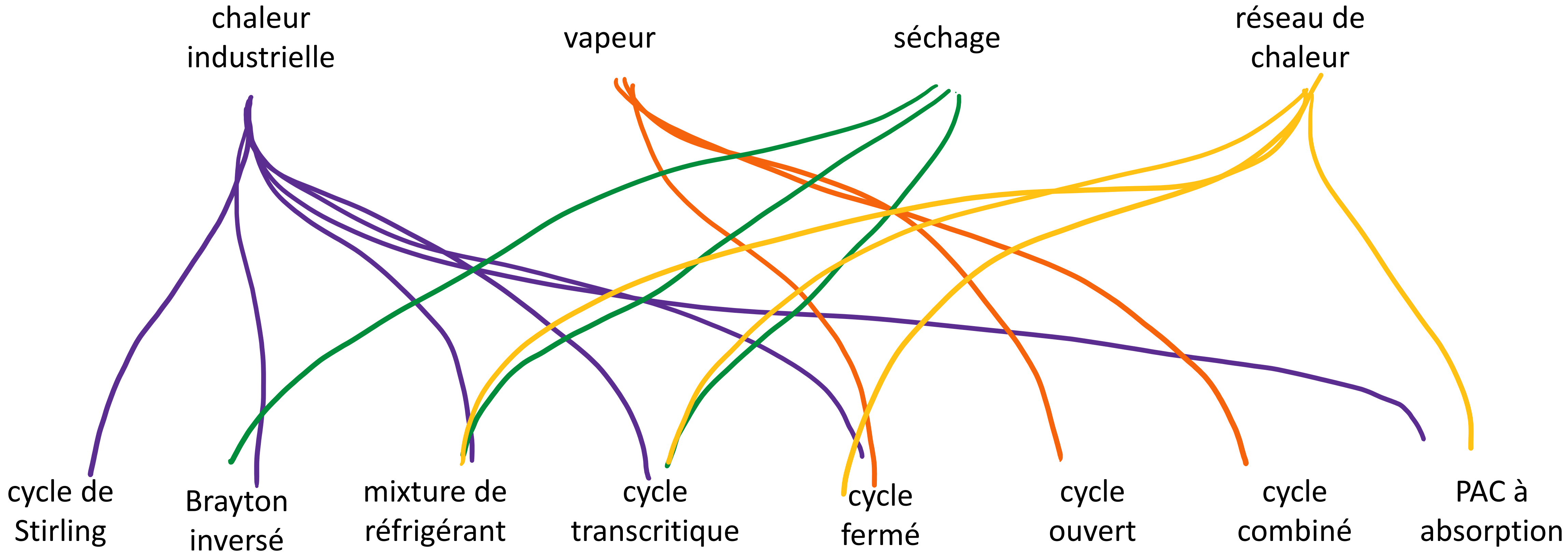
vapeur

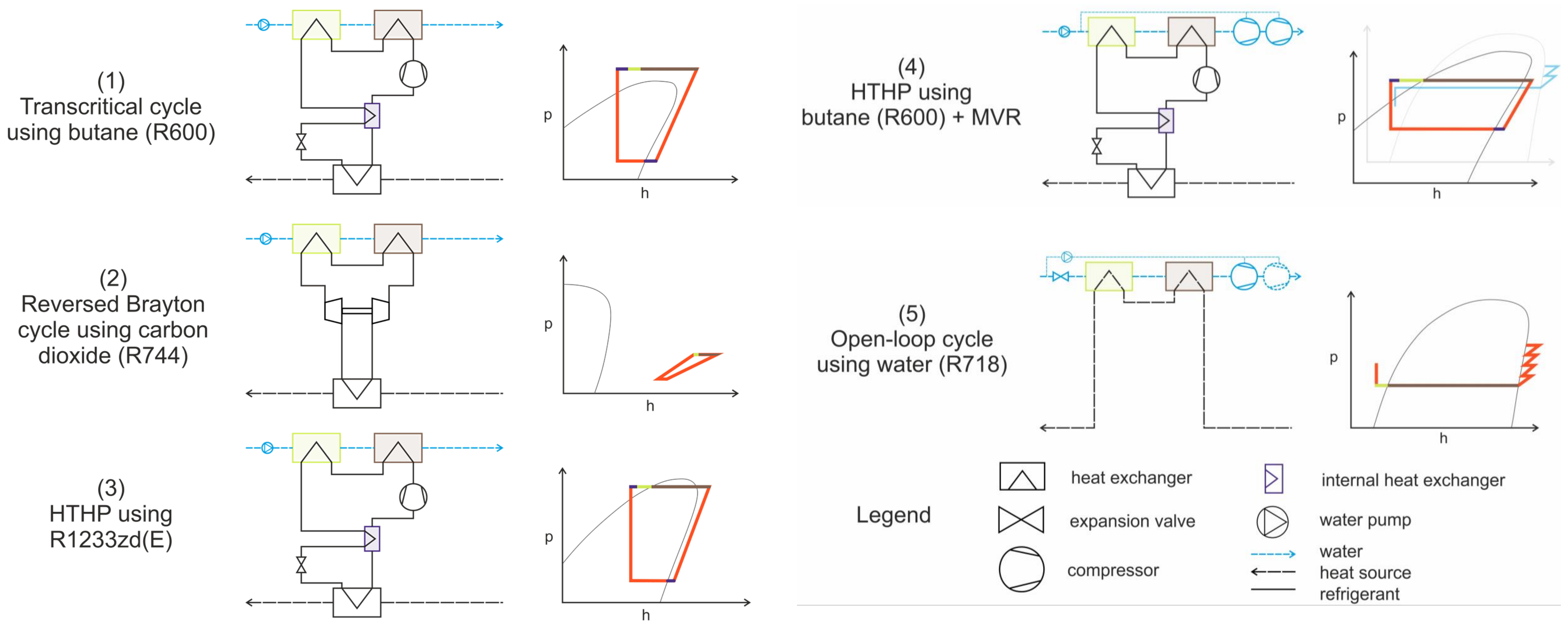
séchage

réseau de chaleur

Pompe à chaleur

La variabilité permet d'optimiser le système à la demande





(1)
Transcritical cycle
using butane (R600)
p
h
(2)
Reversed Brayton
cycle using carbon
dioxide (R744)
p
h
(3)
HTHP using
R1233zd(E)
p
h
(4)
HTHP using
butane (R600) + MVR
p
h
(5)
Open-loop cycle
using water (R718)
p
h
Legend
heat exchanger
expansion valve
compressor
internal heat exchanger
water pump
water
heat source
refrigerant

QUELLES SONT LES PRINCIPALES PROPRIETES DES POMPES À CHALEUR

DANS LE SECTEUR INDUSTRIEL

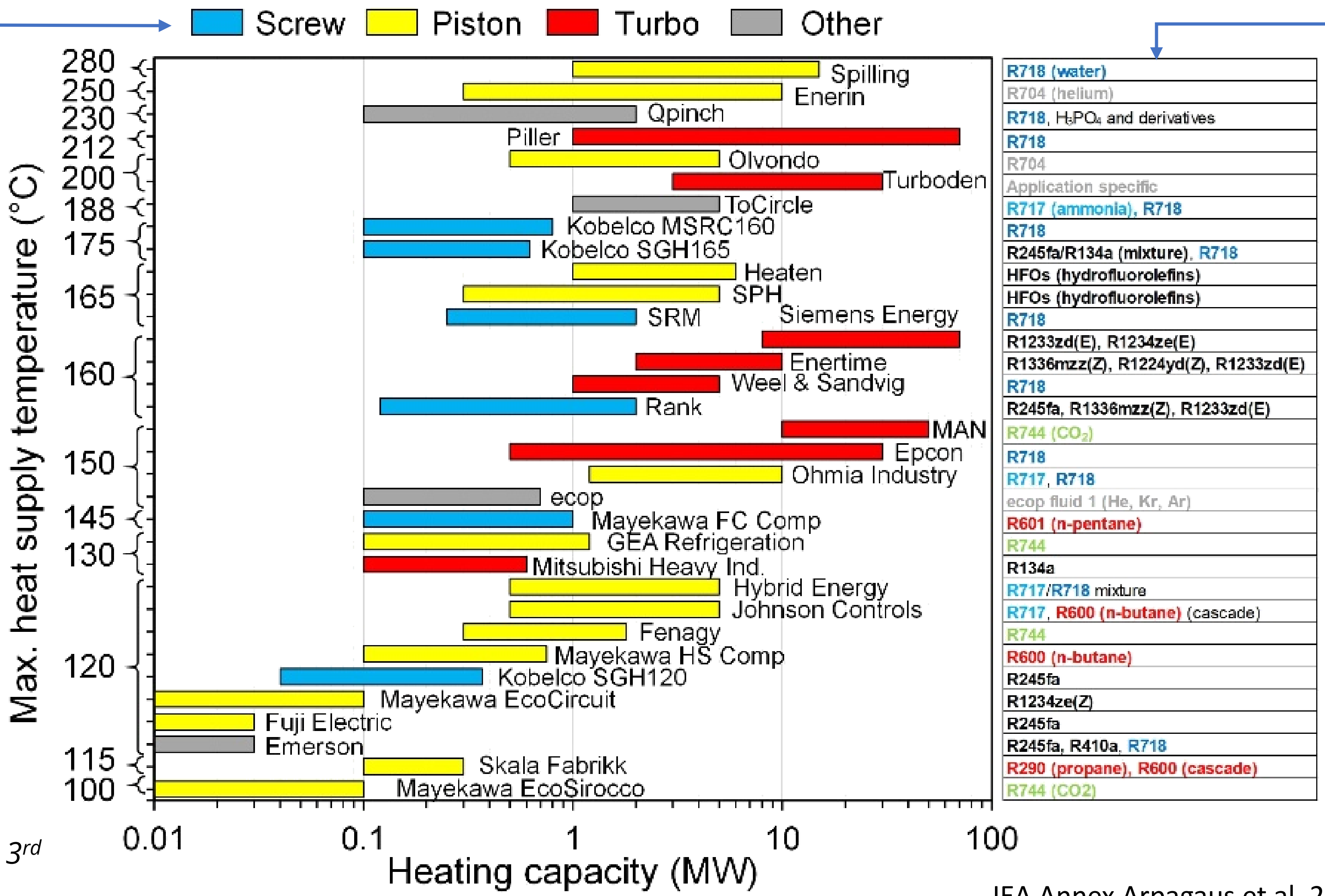
"Citius, Altius, Fortius – Communiter"

Les PACs industrielles peuvent atteindre jusqu'à ~70MW et 280°C*

*pour les compressions de vapeur (MVR)

Type de compresseur

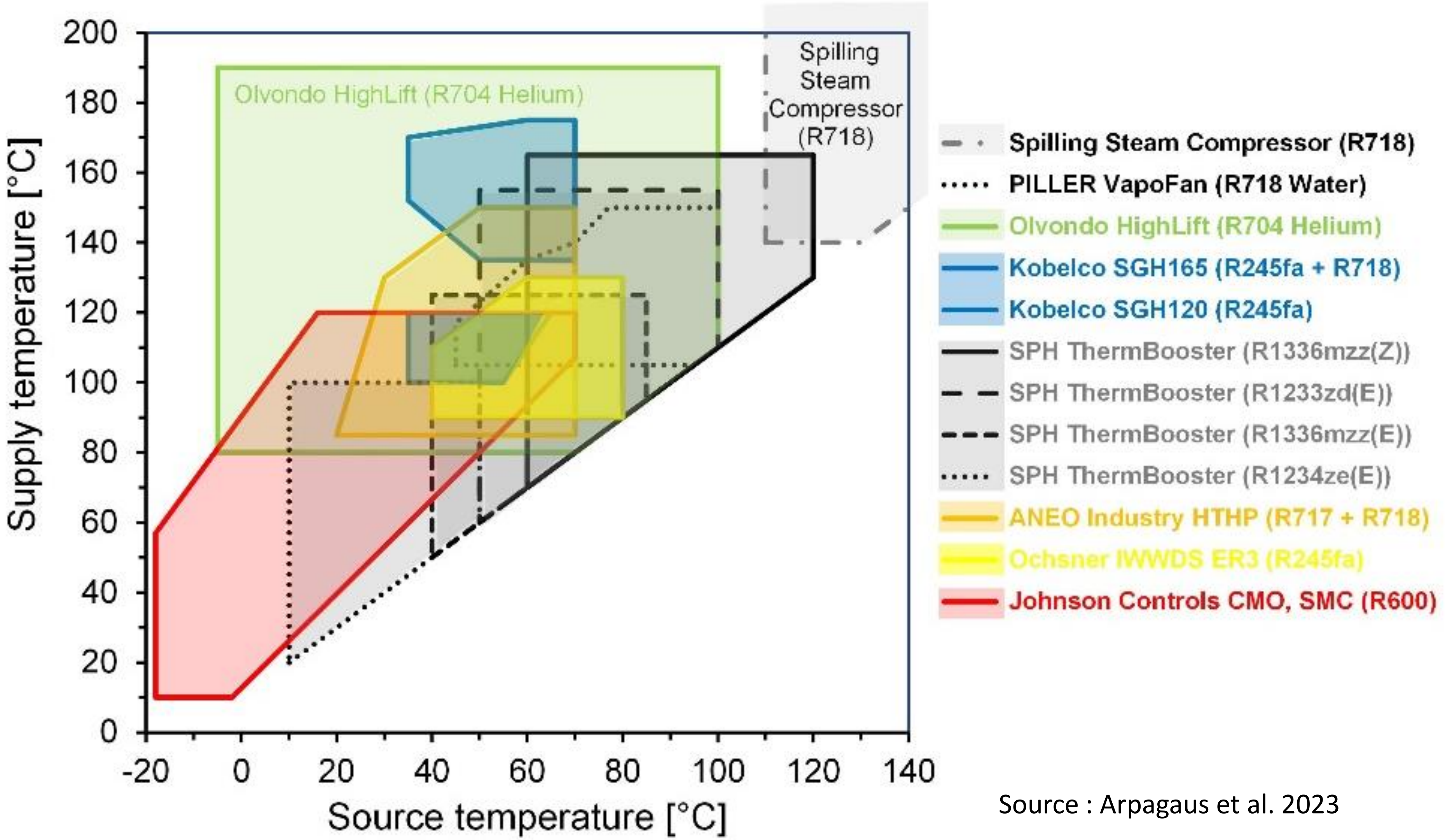
Réfrigérant



Information provided by technology suppliers without 3rd party validation

IEA Annex Arpagaus et al. 2022

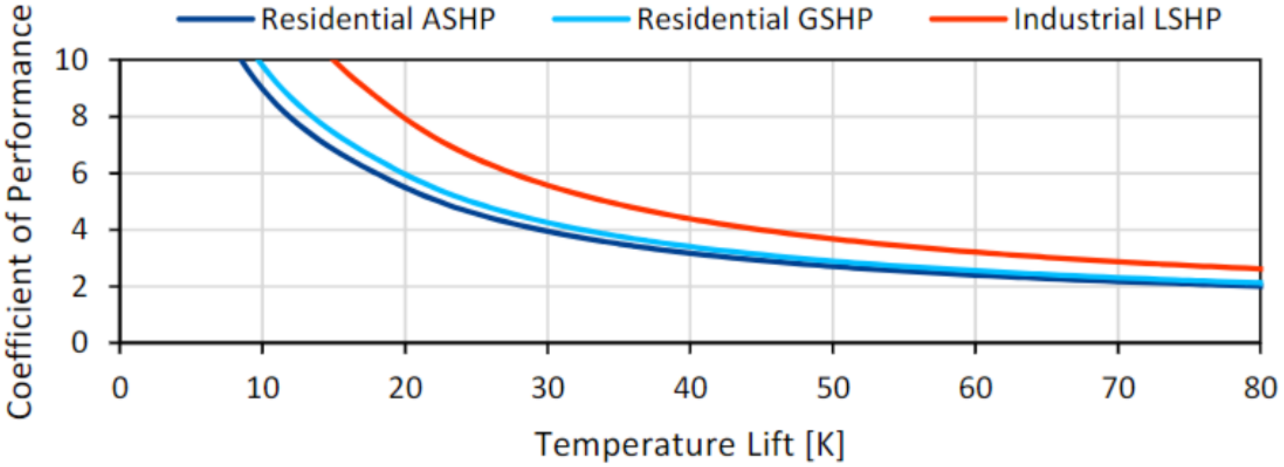
Les PACs sont limitées par le saut de température



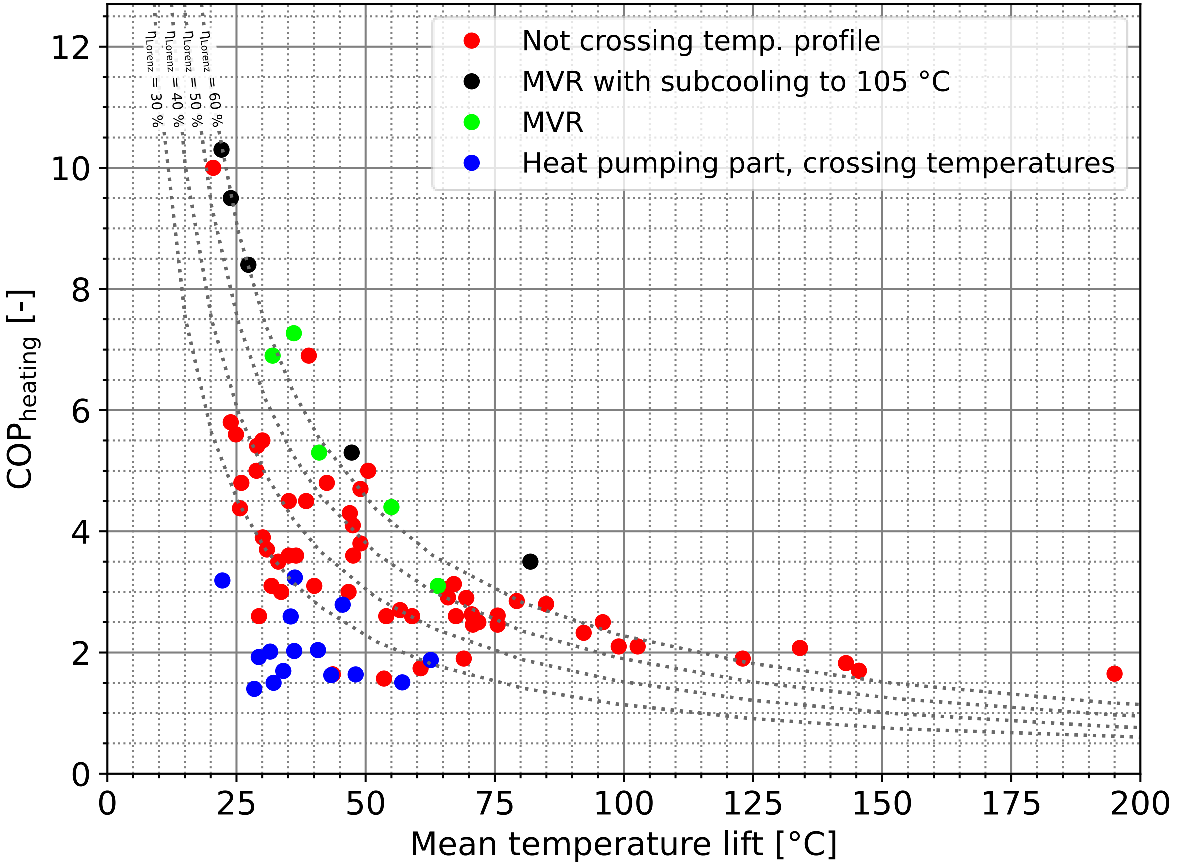
Source : Arpagaus et al. 2023

Leurs efficacités sont limitées par le saut de température

- COP = chaleur produite / energie consommée
- Plus grande échelle et contexte industriel = meilleure efficacité



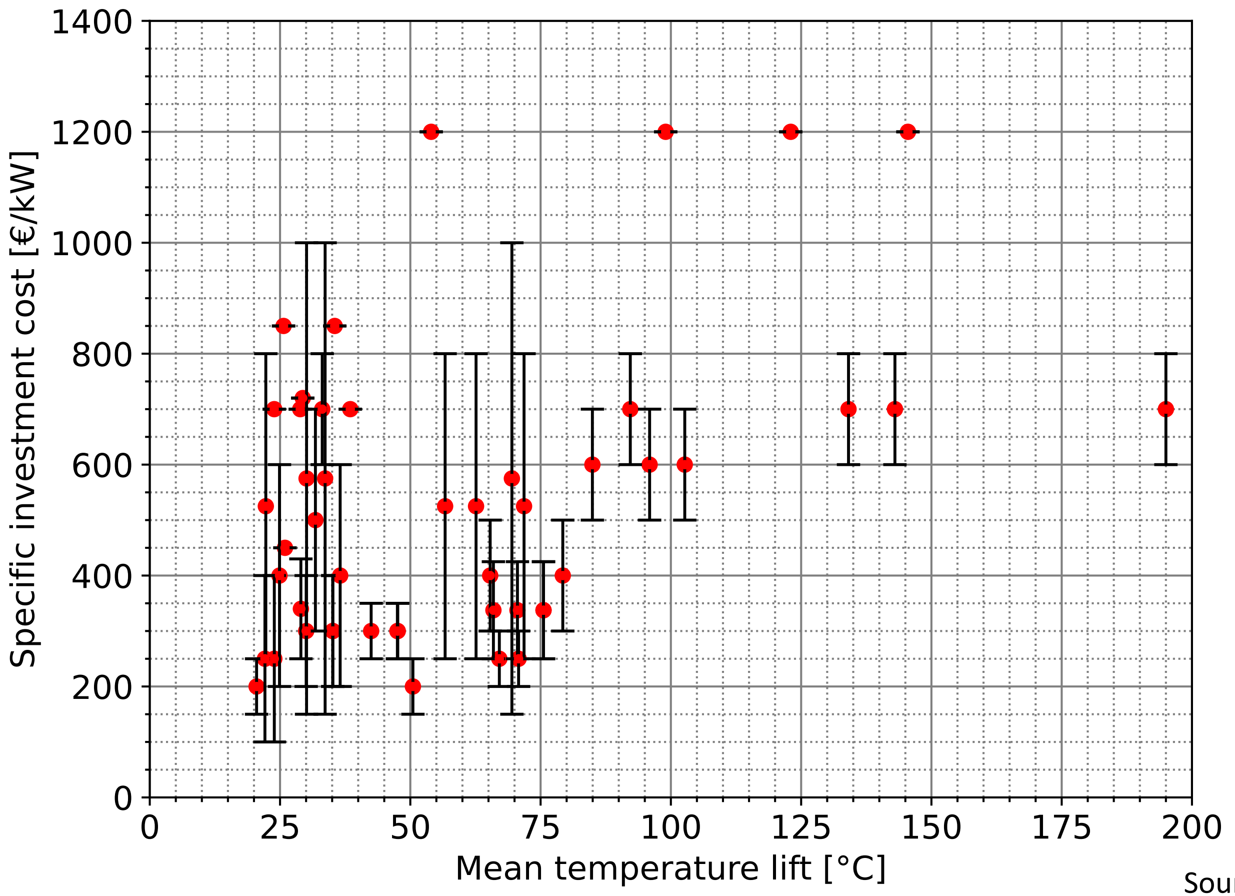
Source : Wolf and IEA Annex 35, 2014

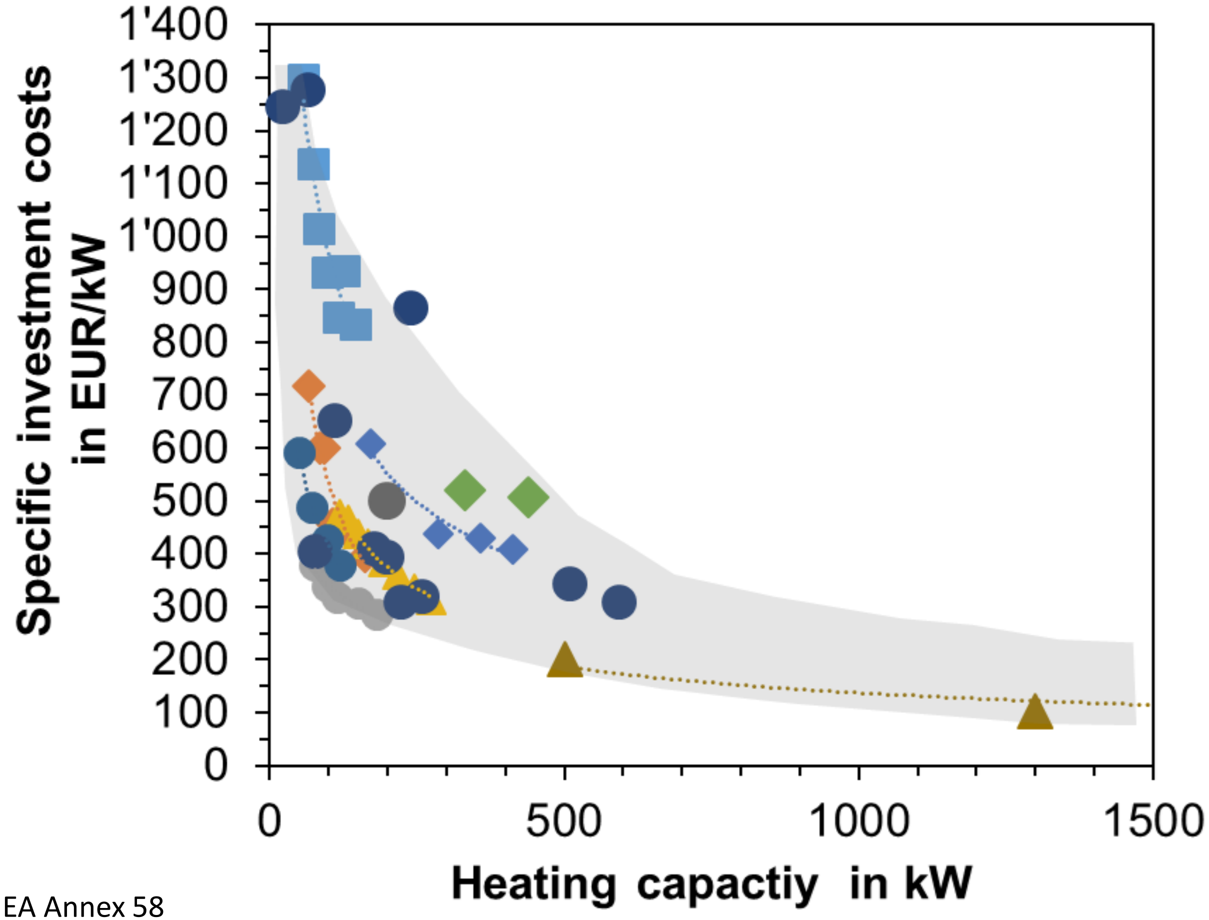


Source : IEA Annex 58, 2022

Le prix d'une PAC industrielle est difficile à estimer, surtout son installation.

- Specific investment cost = coût de la machine sans intégration et installation
- Outils d'aide à l'installation se trouve sur www.sweet-decarb.ch -> Further Info -> DeCarbonization tools





Source : IEA Annex 58

RECHERCHES ET FUTURE DES POMPES À CHALEUR

DANS LE SECTEUR INDUSTRIEL

Les sujets de recherches sur les PACs industrielles sont:

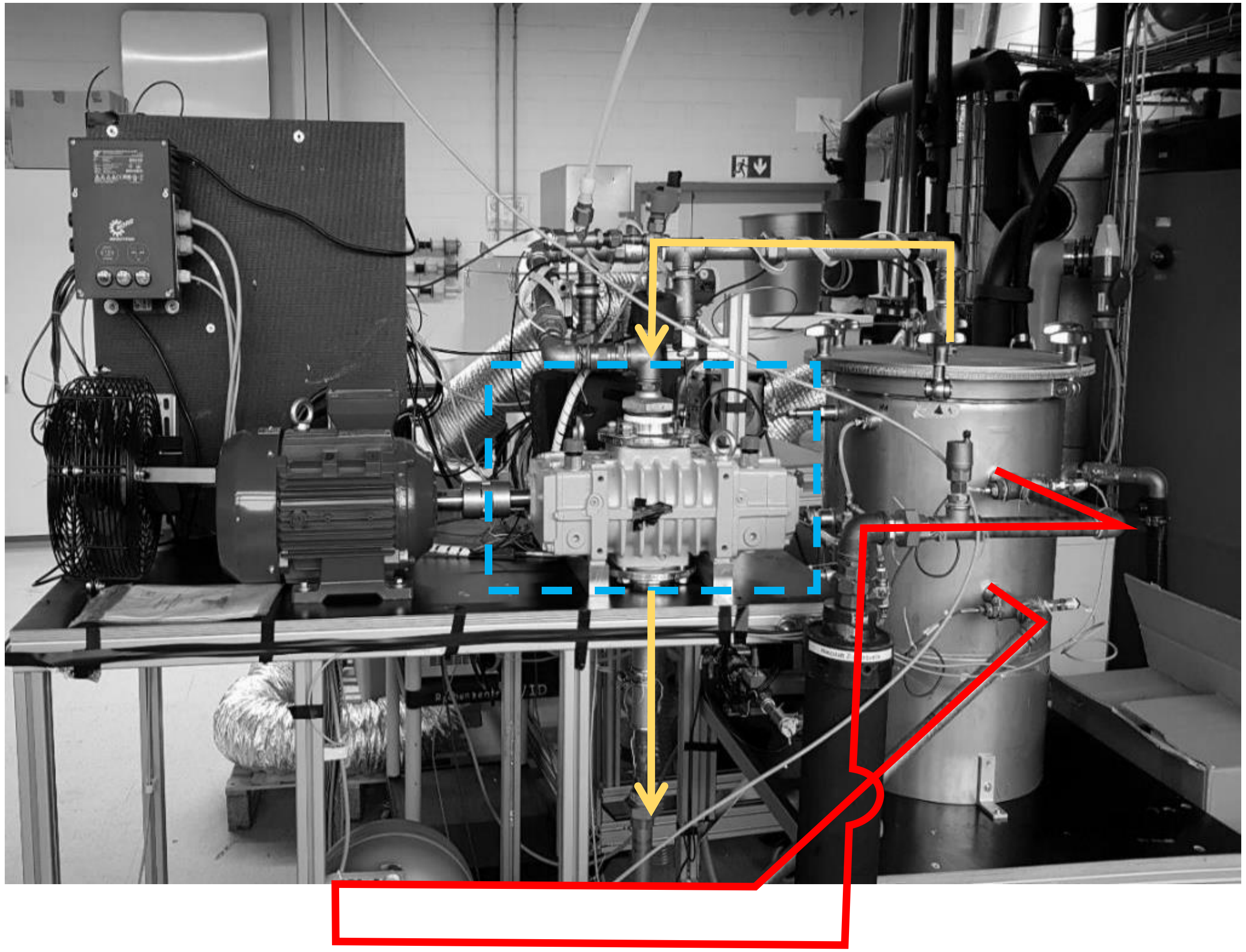
- PACs à hautes températures
- PACs générant de la vapeur
- PACs utilisant des réfrigérants à faible GWP et/ou naturels
- PACs de grandes puissances (≥ 1 MW)

OST
Eastern Switzerland
University of Applied Sciences

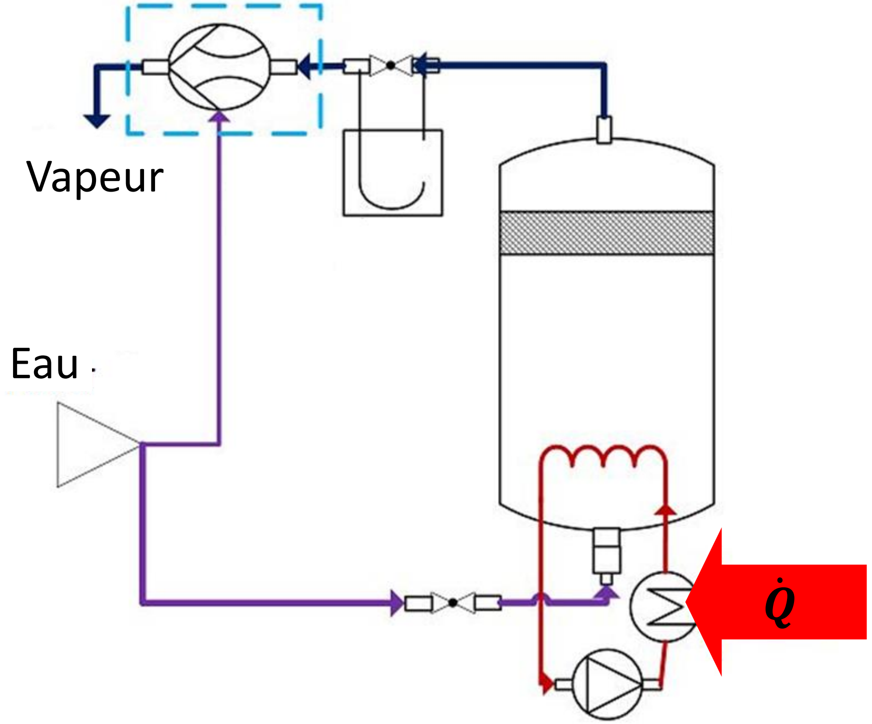
Sélection de projets R&D en Suisse sur le sujet des PACs à haute températures:

Project	Partners
SCCER EIP – Swiss Competence Center for Research in Energy, Efficiency of Industrial Processes (InnoSuisse, Swiss Innovation Agency, 2013-2020), www.sccer-eip.ch	ETHZ, EPFL, EAWAG, EMPA, HSLU, OST, FNHW, UNIGE
IEA HPT TCP Annex 48 – Industrial Heat Pumps (Second Phase) (2017-2019), ARAMIS description (Project No. SI/501782), www.heatpumpingtechnologies.org/annex48 and www.waermepumpe-izw.de	EPFL, OST
Methods for developing integrated industrial heat pump systems considering existing and novel components, SFOE, 2016-2019), Description, Report, Refrigerant Selection Tool	EPFL
SGHP – Steam-generating heat pump (InnoSuisse, 2020-2023)	OST, EPFL
SWEET DeCarbCH – Decarbonization of Cooling and Heating in Switzerland (SFOE, 2021-2028), ARAMIS description, (Project No. SI/502260), www.sweet-decarb.ch	UNIGE, ETHZ, OST, HSLU, ZHAW, EMPA, Industrial partners
IntSGHP – Integration of steam-generating heat pumps in industrial sites (retrofit) (SFOE, 2021-2023), ARAMIS description, (Project No. SI/502292)	OST, Industrial partners
Case studies of industrial and high-temperature heat pumps (Swiss Federal Office of Energy, 2018-2022)	OST, Industrial partners
High-efficiency, high-temperature heat pumps with temperature glide (Bridge Discovery, SNF, Swiss National Science Foundation, 2022-2025), SNF description (Grant number 203645)	ETHZ, OST, Industrial partners
DeCarb-PUI –Decarbonization of industrial processes through redesign of the process-utility interface, SFOE, P+D project, 2021-2024), ARAMIS description (Project No. SI/502298)	HEIG-VD, HSLU, Industrial partners
HTHP-CH – Integration of HTHPs in Swiss Industrial Processes (2021-2025), ARAMIS description (Project No. SI/502336), www.heatpumpingtechnologies.org/annex58	OST, HEIG-VD, EPFL, CSD, Industrial partners

Générer de la vapeur avec un compresseur à pression < 1 atm



- 34.2 kg/h vapeur at 115 °C
- Proof of concept

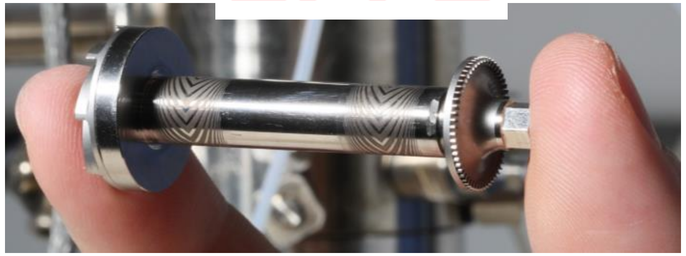


Projet de recherche – PAC générant de la vapeur

Innosuisse (42533.1 IP-EE)

Variable	Target value
$T_{Sat,steam,Turbo}$	148 °C (4.5 bar)
$T_{Sat,steam,HP}$	111 °C (1.5 bar)
$T_{Sink,in}$	100 °C
$T_{Source,in}$	50 °C
$\dot{Q}_{HP}$	115 kW
$\dot{m}_{steam}$	50 g/s

EPFL



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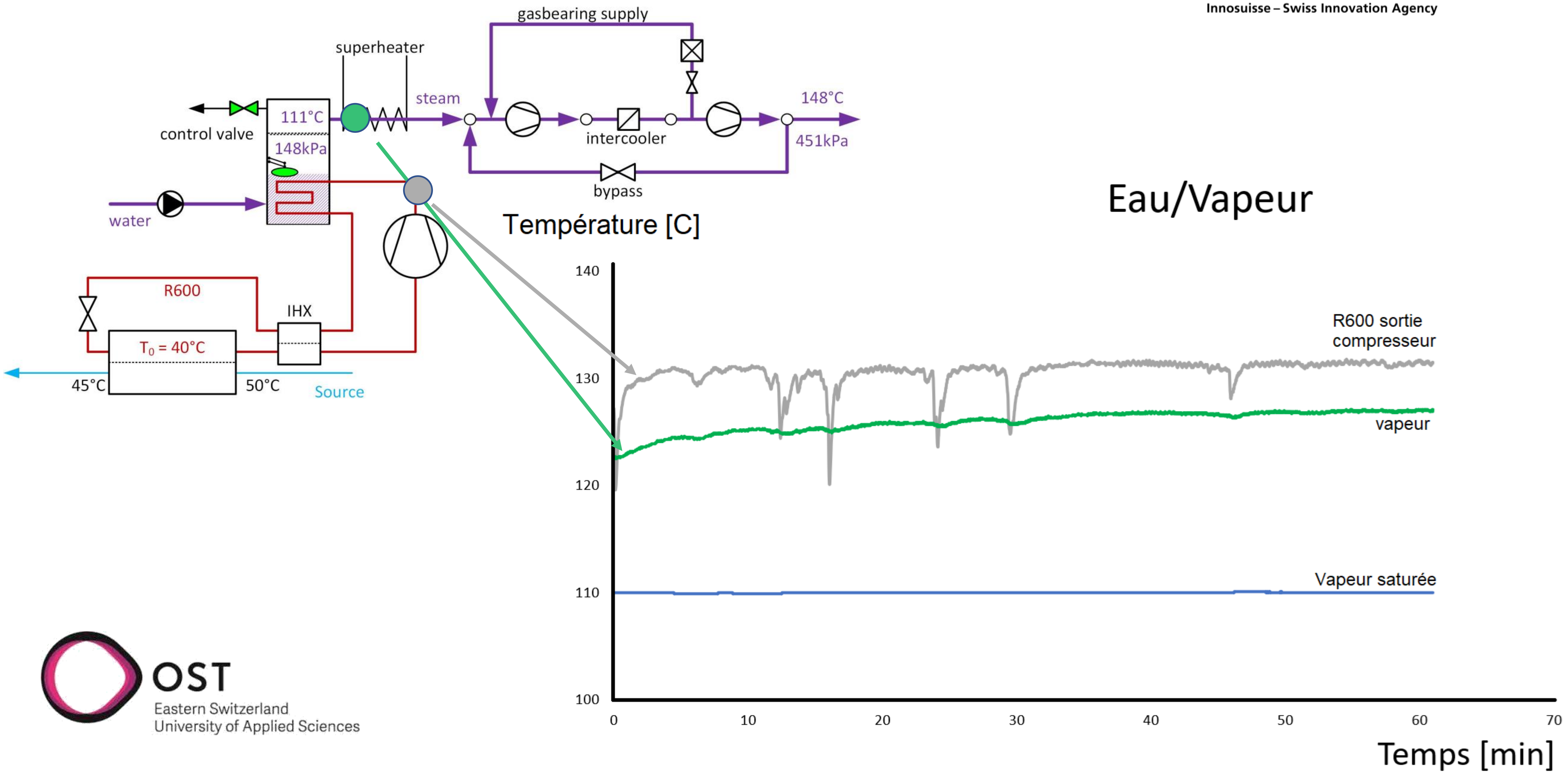
Projet de recherche – PAC générant de la vapeur

Innosuisse (42533.1 IP-EE)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Innosuisse – Swiss Innovation Agency



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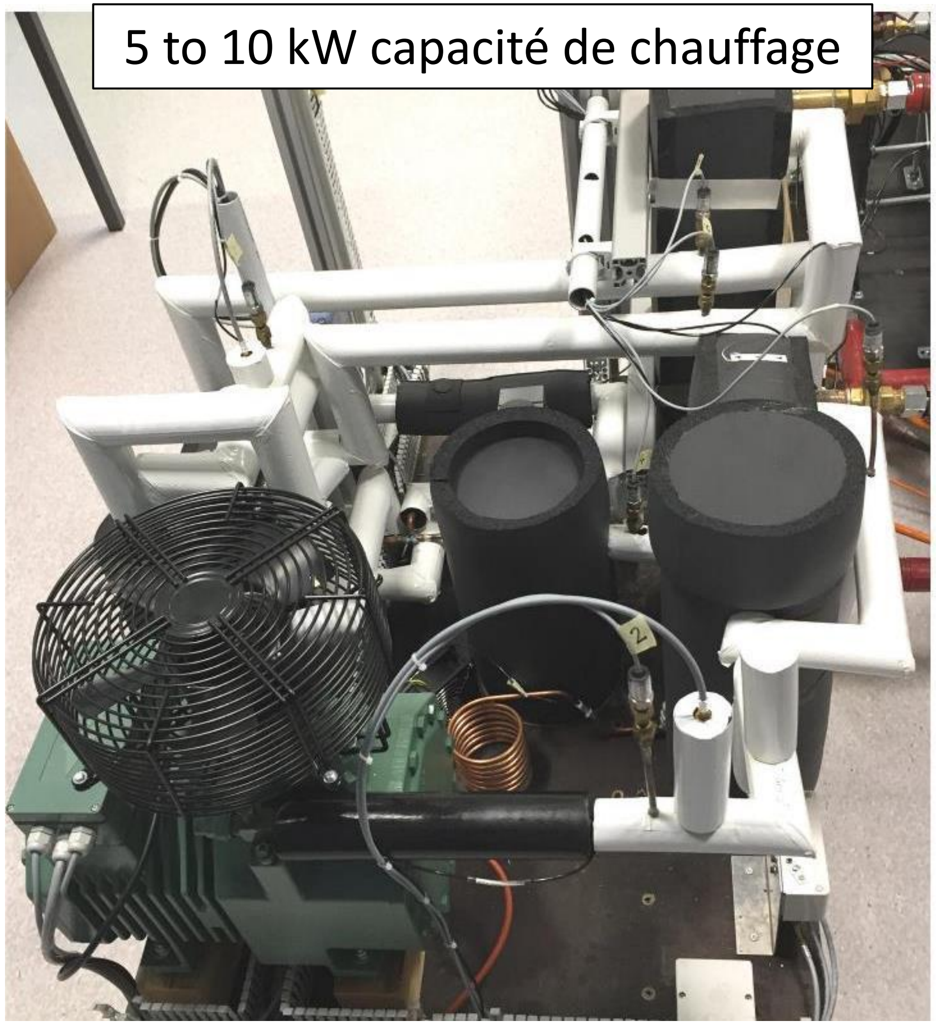
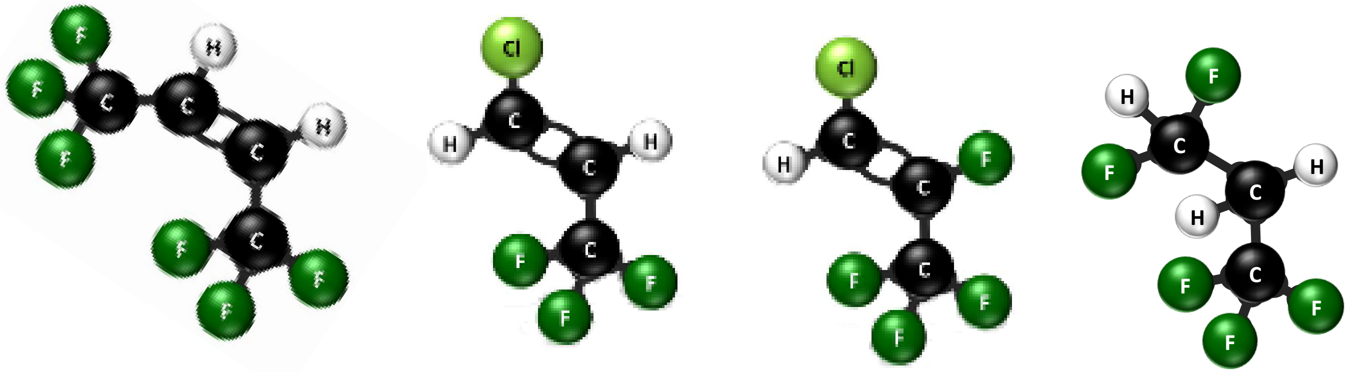
PACs à haute temperature jusqu'à 150°C et test des réfrigérants HFO/HCFO





R1336mzz(Z) R1233zd(E) R1224yd(Z) R245fa

HFO: Hydrofluorolefine, HCFO: Hydrochlorfluorolefine

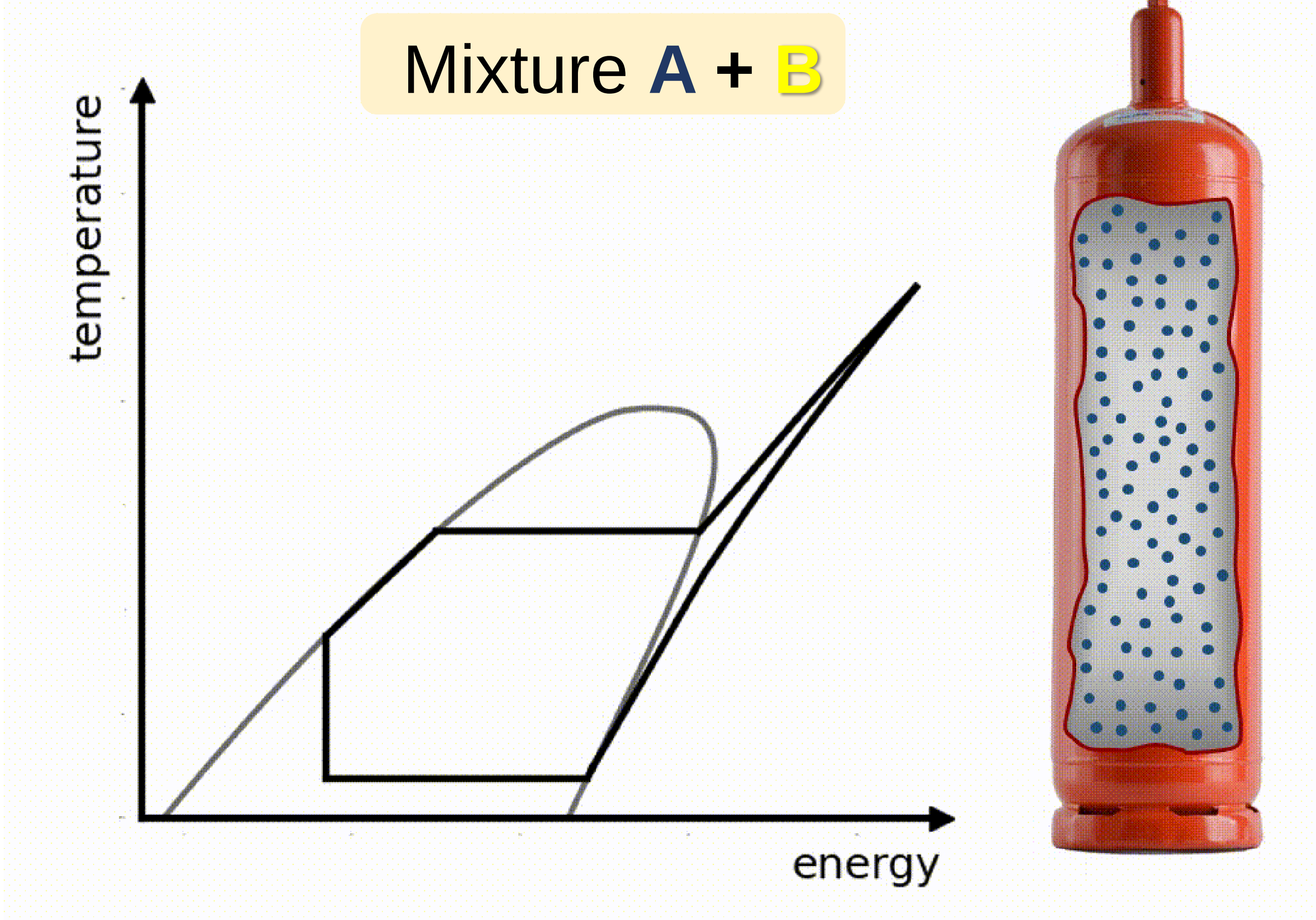
Properties:

- Low GWP
- Zero/near zero ODP
- Short atmospheric life
- Not flammable
- Not toxic

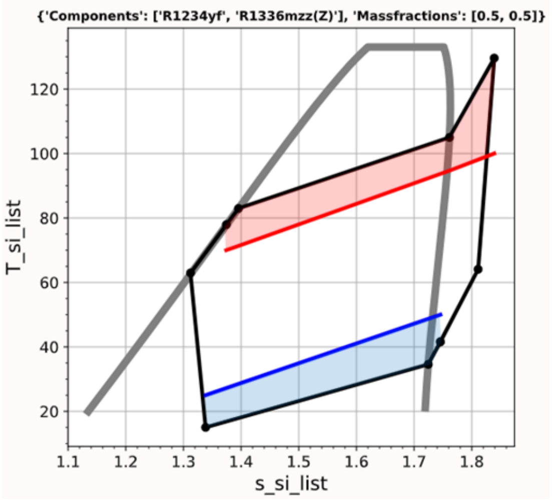
Refrigerant	ODP	GWP_{100}	SG
R1336mzz(Z)	0	2	A1
R1233zd(E)	0.00034	1	A1
R1224yd(Z)	0.00023	0.88	A1
R245fa	0	858	B1

Projet de recherche – Mélanges de fluides frigorigènes pour des grandes pentes de température (SNF Bridge Discovery, 203645)

One mixture → **many** options



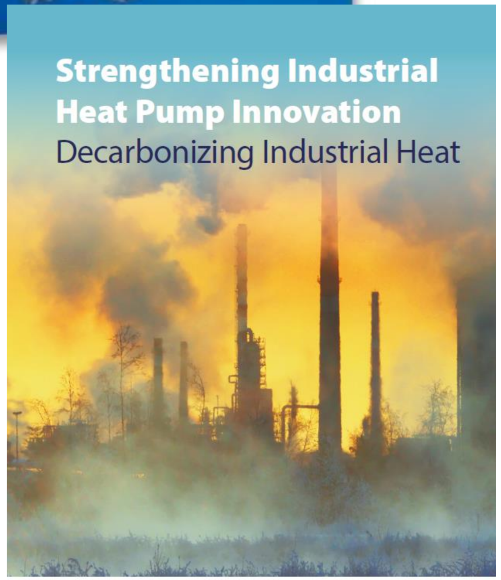
High **flexibility** in **T-levels** and **T-glide**



Animation from Swiss Bridge Project: High-efficiency high-temperature heat pumps with temperature glide

ETH zürich

Références



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Défis à relever pour favoriser la pénétration des pompes à chaleur industrielles sur le marché

icons generated by IA – Adobe Firefly

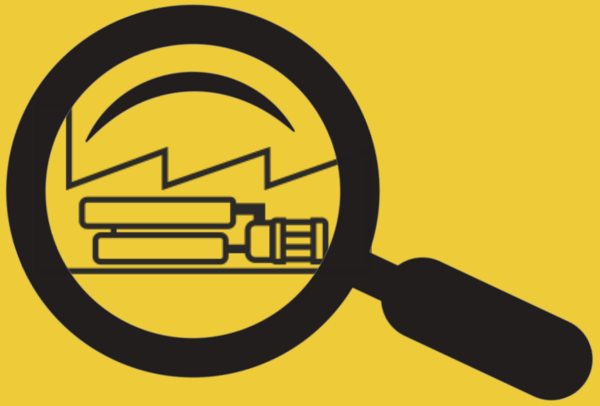
1. **Manque de connaissance des possibilités techniques** et du potentiel d'application économiquement réalisable parmi les utilisateurs, les consultants, les investisseurs, les planificateurs, les fabricants et les installateurs.
2. **Manque de connaissances sur l'intégration** des pompes à chaleur dans les processus industriels existants (modernisation)
3. **Conception en usine ou sur mesure** (économies d'échelle)
4. **Périodes d'amortissement** plus longues que pour les chaudières à gaz ou à mazout (rapport entre le prix de l'électricité et celui du gaz)
5. **Concurrence entre les technologies de chauffage** (énergies fossiles et autres technologies renouvelables tel que le biomass)
6. **Besoin de stockage de chaleur** pour compenser le décalage entre la demande et l'offre (par exemple, pompe à chaleur pour la charge de bande, chaudière à gaz pour les pics de chauffage)
7. **Manque de compresseurs disponibles** pour les températures élevées et de réfrigérants à faible potentiel de réchauffement planétaire (PRP) et sans potentiel d'appauvrissement de la couche d'ozone (PACO).

Aide financière pour les industries Suisse

Funding program	Pinch Analyses	Heat Pumps for Process Heat	Klimaprämie (Climate bonus)	Pilot and Demonstration (P&D projects)
Program manager	**EnergieSchweiz** (SuisseEnergie)	**EnergieSchweiz** (SuisseEnergie)	**Energie Zukunft Schweiz**	**SFOE**
Financing	SFOE	SFOE	KliK Foundation	SFOE
Amount	• Pre-analyses: **max. 60% of total costs** • Pinch analyses: **max. 40% of total costs**	• **Max. 40% of additional costs** compared to conventional technology (e.g., oil or gas boiler)	• **0.18 CHF/kWh heat** • **About 360 CHF/kW heat** at 2’000 h annual operation	• **Up to 40% (60%) of non-amortizable supplementary costs**
Funding criteria	• Using PinCH-Software • Trained experts • Publication of findings (summary, final report)	• Industrial process heat • Payback > 4 years • Funding request before construction starts	• Replacement of oil/gas boiler with HP • Order not yet placed • CO_2 savings to be transferred to Energie Zukunft Schweiz	• Application potential • Innovation content • Pilot: TRL 4 to 7 • Demonstration: TRL 7 to 9 • Publication of findings (final report)

EXAMPLE D'INTÉGRATION DE POMPE À CHALEUR

DANS LE SECTEUR INDUSTRIEL



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PACs industrielles à **haute température:**

(IEA Annex 58)

https://heatpumpingtechnologies.org/annex58/task1/

- Rapport publié récemment
- Information de fournisseurs internationaux
- Liste et description de démonstration en cours ou planifiées

Annex 58 High-Temperature Heat Pumps

Screw compressor high-temperature heat pump

Rank®

Figure 1: Rank® HTHP and compre

Summary of technology

Rank® is a worldwide recognized company in the design and manufacture of Organic Rankine Cycles for different capacities and applications. Now, Rank® is using this valuable experience in extreme conditions to develop high-temperature heat pumps (HTHP) that can produce renewable heat up to 160 °C.

New Rank® HTHP systems are based on a single-stage cycle with an internal heat exchanger (IHX). However, a two-stage cascade cycle with IHXs can be assembled for covering larger temperature lifts.

The compressor is electrically driven, is based on a screw technology with a frequency inverter to be adapted to the customer's actual operation. The compressor is based on direct drive, avoiding gears or pulleys, minimizing the maintenance, and increasing electrical efficiency. Moreover, magnetic coupling ensures tightness and a-voids the possibility of leakage.

Lubrication used for the proper operation of the compressor is polyolester oil (POE oil) of a specific viscosity, fully compatible with organic working fluids and able to work at high temperatures while keeping the optimum properties.

IEA Technology Collal
Heat Pumping Techn

Annex 58 High-Temperature Heat Pumps

www.heatpumpingtechnologies.org/annex58/

Figure 2: Rank® modular solution

Our machines operate through an automatic, efficient managing system without human intervention. Real-time data transmission via the internet allows predictive maintenance by server data analysis, online supervision (PC, mobile phone, tablet, etc.), and remote configuration of working parameters.

Table 1: Performance for the single-stage cycle with IHX HTHP prototype (experimentally measured in lab. prototype, not fully optimized for specific purpose)

$T_{source,in}$ [°C]	$T_{source,out}$ [°C]	$T_{sink,out}$ [°C]	$COP_{heating}$ [-]
84	70	103	5.9
101	70	122	4.6
102	72	130	4.0
115	70	130	3.7
100	90	160	3.0
116	95	160	2.8

Table 2: Case study for production of thermal oil.

$T_{source,in}$ [°C]	$T_{source,out}$ [°C]	$T_{sink,out}$ [°C]	$T_{sink,out}$ [°C]	$COP_{heating}$ [-]
100	70	130	110	3.6
100	80	130	110	4.5

Project example

A perfect application for our HTHP systems is district heating networks (DHN).

DHN are present in urban and industrial environments where each user is connected and uses heat at a given temperature. Heat is distributed at a particular temp-erature, but users' needs can differ.

HTHPs present in the installations of each client can upgrade the heat at useful levels with a high COP (2.6 to 5.9), adapting the temperature glide of the heat sink.

HTHPs, which local renewable energy sources can power and promote decarbonization in industries connected to district heating networks, independently of the distribution temperature, avoiding the need for fossil fuel boilers.

FACTS ABOUT THE TECHNOLOGY

Heat supply capacity: 120 kW to 2000 kW

Temperature range: useful heat inlet 80 °C to 120 °C and outlet 100 °C to 160 °C / heat source inlet 60 °C to 100 °C and outlet 40 °C to 80 °C

Working fluid: adaptable to the application R245fa, R1336mzz(Z), R1233zd(E)

Compressor technology: Screw

Specific investment cost for installed system without integration: 200-400 € per kW_t, but it varies between temperature levels and applications

TRL level: TRL 7 – prototype demonstration

Expected lifetime: 20 years (with the possibility of hiring Service to extend lifetime and ensure the highest energy performance)

Size: weight 5.5 to 8 tons / surface requried 5.2 to 13 m² / height 2.2 to 2.5 m

Contact information

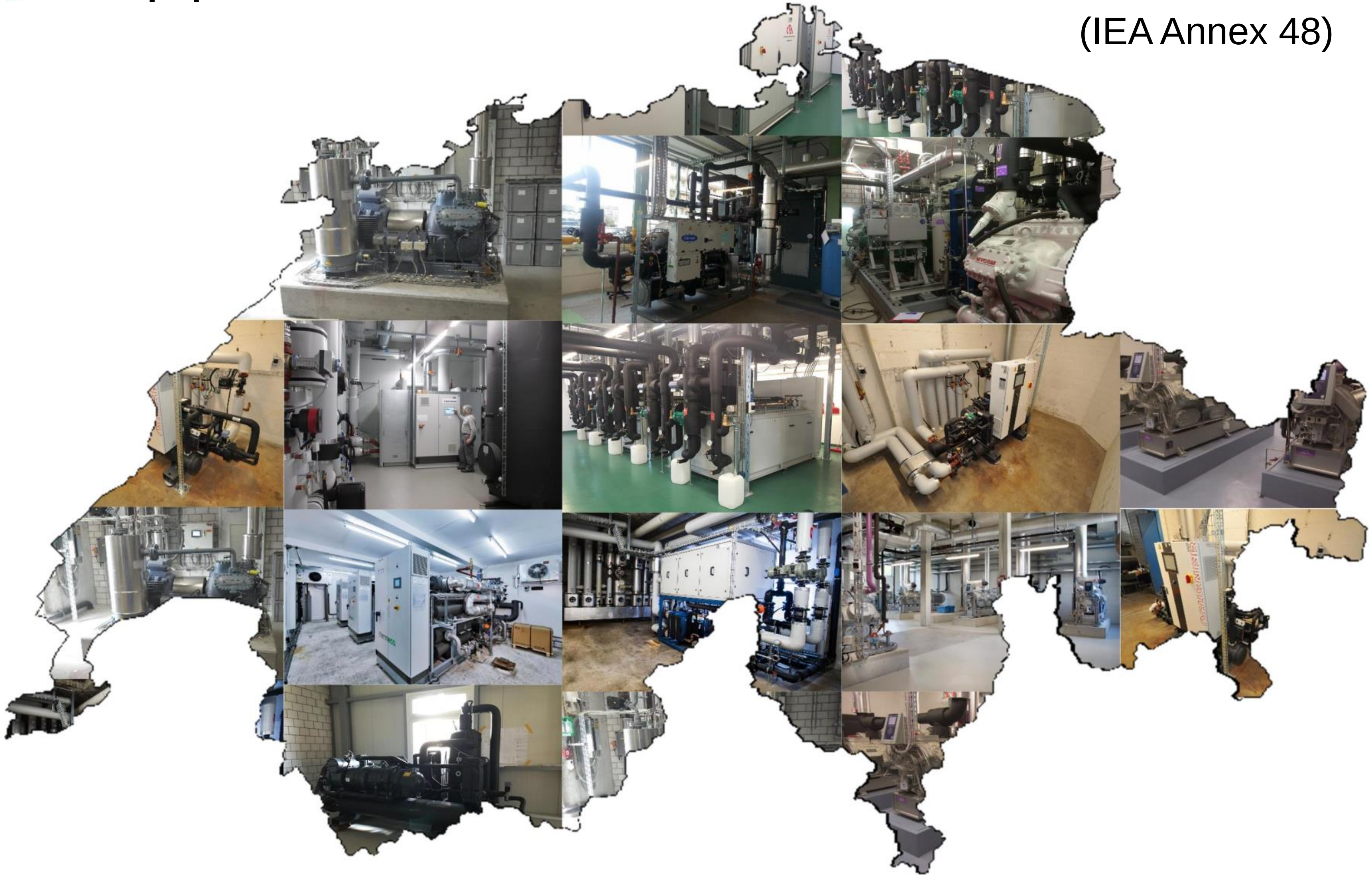
Rank ORC, s.l.
info@rank-orc.com / sales@rank-orc.com
+34 964 69 68 59

All information were provided by the supplier without third-party validation. The infomation was provided as an indicative basis and may be different in final installations depending on application specific parameters.

IEA Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

PACs industrielles en Suisse: applications et études de cas.

(IEA Annex 48)



Final report: https://www.aramis.admin.ch/Dokument.aspx?DocumentID=66033

Examples de **réalisation** de PACs à haute temperature en **Suisse**

Cheese factory Gais Appenzell
(process water 90 °C)

OCHSNER
ENERGIETECHNIK

Slaugtherhouse Zurich
(hot water 90 °C for cleaning)

engie

Sauna NEST EMPA
(hot water up to 120 °C)

scheco kühlt wärmt klimatisiert

Sélection de **fournisseurs de PACs** à haute temperature en **Suisse** (listes non exhaustive)

Scheco AG	https://www.scheco.ch
Walter Wettstein AG Kältetechnik	https://www.wwag.ch
Zero-C	www.zero-c.ch
Friotherm AG	https://www.friotherm.com
MAN Energy Solutions	https://www.man-es.com
SSP Kälteplaner	https://www.kaelteplaner.ch
CTA	https://www.cta.ch

Si vous désirez **collaborer** ou avez des **questions** sur le sujet n'hésitez pas à nous écrire.

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Si vous désirez **apprendre plus** sur le sujet

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MAS Energiesysteme

- 5 CAS Kurse
- Berufsbegleitend
- 1 Tag pro Woche (Mo oder Fr)
- 14 Wochen
- Start Februar/September,

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Masterarbeit
12 ECTS

CAS Erneuerbare Energien
12 ECTS

CAS Elektrische Energiesysteme
12 ECTS

CAS Energie digital
12 ECTS

CAS Energie und Wirtschaft
12 ECTS

CAS Wärmepumpen/Kältetechnik
12 ECTS

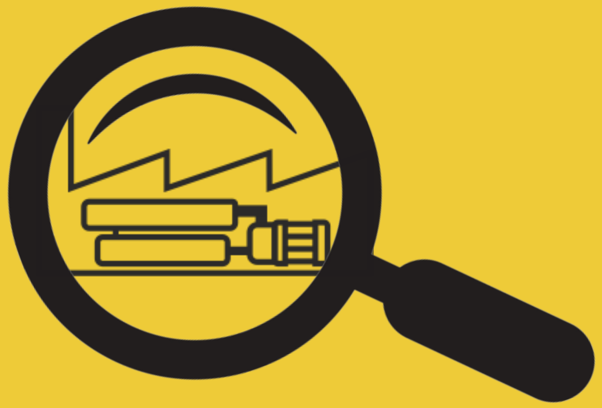
→

Master of Advanced Studies in Energiesysteme

Total 60 ECTS

MERCI

CONTINUONS AVEC DES CAS CONCRÊTS



Wettstein
Kältetechnik

icons own & Adobe Stock

Back-up slides

Bref résumé avec liens:

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PACs industrielles en Suisse: applications et études de cas. (IEA Annex 48)

Company, Location	Industry / Sector	Application	Integration level	Capacity (kW)	Temperature range (°C)		No.
Slaughterhouse, Zurich	Food	Hot water, cleaning water	Process	800	20	90	CH01
Chocolate factory Maestrani, Flawil	Food	Hot water, heating, cooling	Process	276	17	70	CH02
Cheese factory, Gais Appenzell	Food	Hot water, heating	Process	520	18	92	CH13
Kambly SA, Trubschachen	Food	Hot water for biscuit production	Process	471	20	65	CH23
Kellermann AG, Ellikon an der Thur	Food	Hot water for greenhouse heating	Plant	1'000	6	65	CH19
Hilcona AG, Schaan	Food	Hot water for fresh convenience foods	Plant	507	31	67	CH29
Nutrex, Busswil bei Büren	Food & Beverages	Vinegar fermentation and pasteurization	Process	194	30	70	CH15
GVS Schaffhausen Landi	Food & Beverages	Process/hot water, heating, cooling	Plant	63	37	95	CH14
Bachem AG, Bubendorf	Pharma	Heating and cooling of peptides	Process	480	14	70	CH26
R134a heat pump, Geistlich Wolhusen	Pharma	Hot water, heating	Plant	606	2	67	CH08
Mifa AG Mibelle Group, Frenkendorf	Home Care and Nutrition	Hot/cold water, heating, cooling	Plant	885	35	70	CH25
Härterei Gerster AG, Egerkingen	Metals	Process heat for hardening process	Plant	260	17	65	CH17
Georg Fischer AG, Grüsch	Machinery	Heating for production of plastic valves	Plant	382	8	65	CH20
Feldschlösschen, City of Rheinfelden	District heating, brewery	Hot water, district heating	Plant/Network	1'350	16	81	CH27
Champagne, Biel	District heating	Hot water, heating	Network	650	11	63	CH03
St. Jakob, Basel	District heating	Hot water, heating	Network	181	0	65	CH04
Laurana, Thônex	District heating	Hot water, heating	Network	338	14	63	CH09
Les Vergers, Meyrin	District heating	Heating of residential buildings	Network	5'000	12	50	CH10
City of Lausanne	District heating	Hot water for residential buildings	Network	4500	6	68	CH16
Casino Aarau	District heating/cooling	District heating and cooling network	Network	1'975	9	70	CH24
Kokon Corporate Campus, Ruggell	Wellness and restaurant	Hot water, heating	Building	341	10	35	CH22
Swiss Army, CO_2 HP Payerne	Military	Tap water and facility heating	Building	60	9	45	CH18
Swiss Army Troop building, Matt	Military	Hot water, heating	Building	270	8	60	CH21
ARA Altenrhein	Waste water treatment	Hot water for sewage sludge drying	Plant	2'840	8	65	CH28
Waste water treatment plant, Zürich	Waste water treatment	Hot water	Plant	410	7	50	CH11
Bad Zurzach	Thermal bath	Hot water	Plant	550	29	55	CH12

Quelques details de PACs industrielles de haute température

Object, location	GVS Landi, Schaffhausen-Herblingen	Resilux Schweiz AG, Bilten	Bachem AG, Bubendorf
Application, temperatures, heating capacity	Cleaning of bottles and wine tanks, heating/hot water 37 °C/ 80 to 95 °C, heating capacity 63 kW	Production of PET blanks 50 °C / 90 to 95 °C (hot water), heating capacity 400 kW	Space heating/hot water up to 70 °C, cooling capacity 480 kW, heating capactiy 640 kW
Operating data	Over 3 years of operating data via online software at 1-min resolution, remote access, hydraulic integration	Operating data of 2 units with integration into extruder process and cooling systems	Operating data from process control system (reference is refrigeration), trending data since 2020
Heat pump	Ochsner ISWHS 60ER3, economizer cycle, screw compressor, ÖKO 1 (R245fa)	2x Viking HeatBooster HBS4, piston, R245fa	Sabroe HPO 28 VSD, Ammonia (NH_3)

Zum Einstieg

Wege zur Dekarbonisierung der Prozesswärme

Biomasse-zu-Wärme

71 PJ/a nachhaltig (BFE, CH)
(19.7 TWh/a)

82 PJ/a Prozesswärme
(22.8 TWh/a)

Wichtiger Rohstoff

Nur für Hochtemperatur-Wärme

Wo immer möglich!

Strom-zu-Wärme

1 kWh

Wärme-pumpen	Direkt-heizung	Synthetische Brennstoffe
2 bis 4 kWh	1 kWh	0.5 bis 0.7 kWh

Maximale Temperatur

Datenquelle: ETHZ, OST

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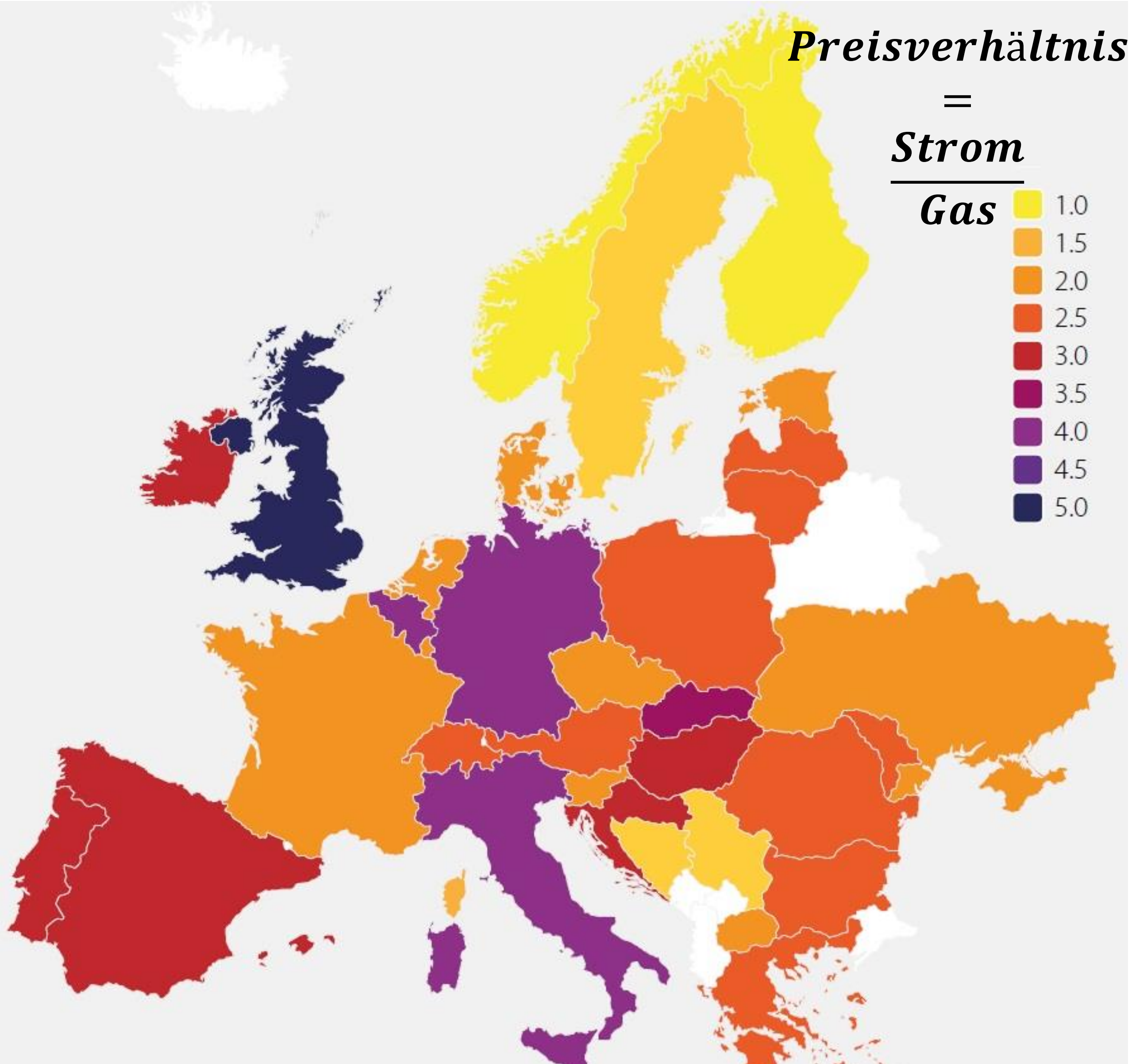
Die Marktattraktiviät

hängt vom Preisverhältnis zwischen Strom und Gas ab

- Die Dekarbonisierung erfordert verstärkte Nutzung von **Strom aus erneuerbaren Energien**
- **Elektrizität ist** in vielen europäischen Ländern **teurer** als fossile Brennstoffe

Für kleine industrielle Endverbraucher mit:
2 bis 20 GWh/a



Quelle: De Boer et al. (2020): [Strengthening Industrial Heat Pump Innovation, Decarbonizing Industrial Heat](), White Paper, 14. Juli 2020

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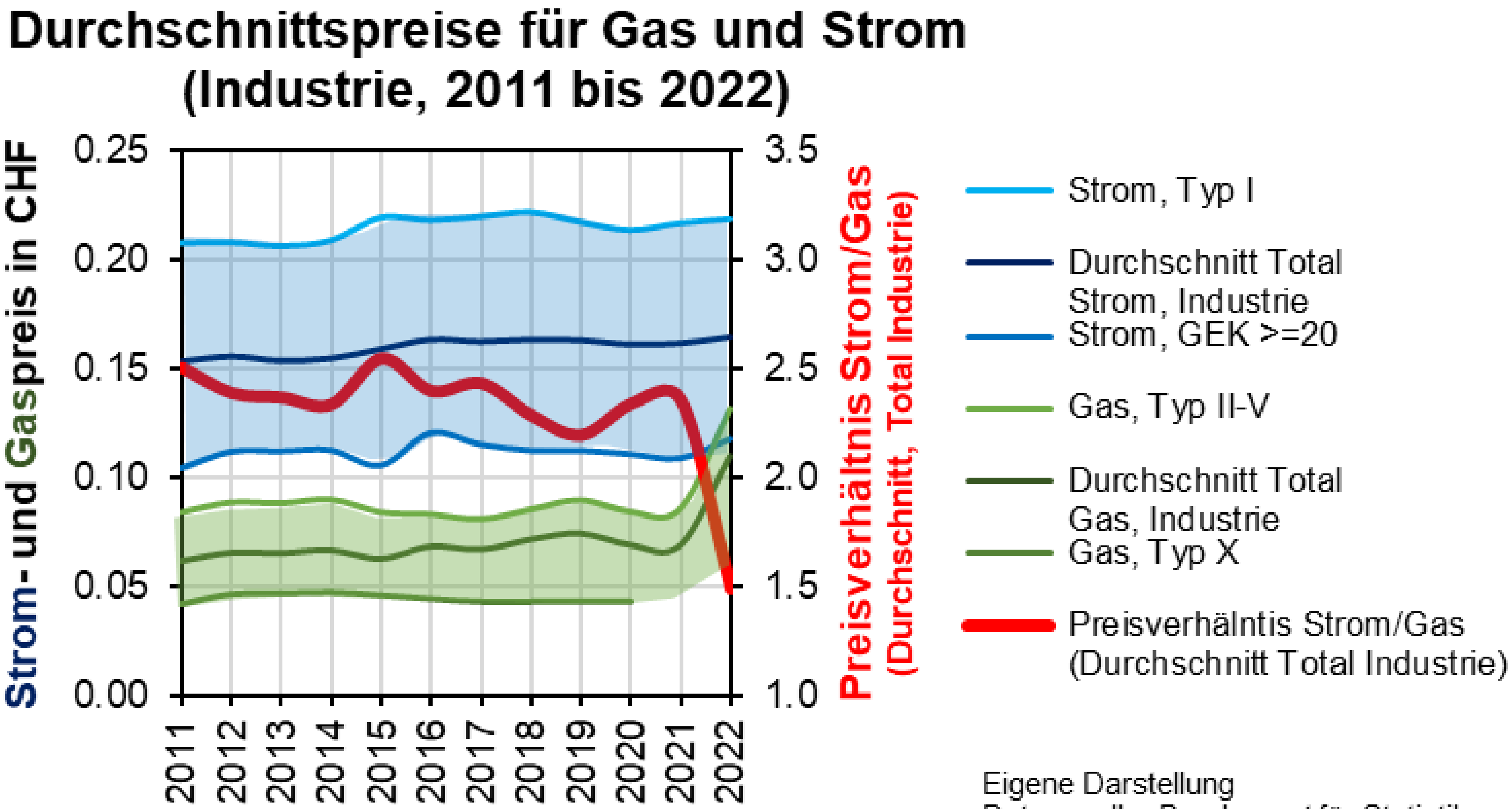
Marktattraktiviät

Preisverhältnis Strom/Gas in der Schweizer Industrie



Eigene Darstellung
Datenquelle: Bundesamt für Statistik

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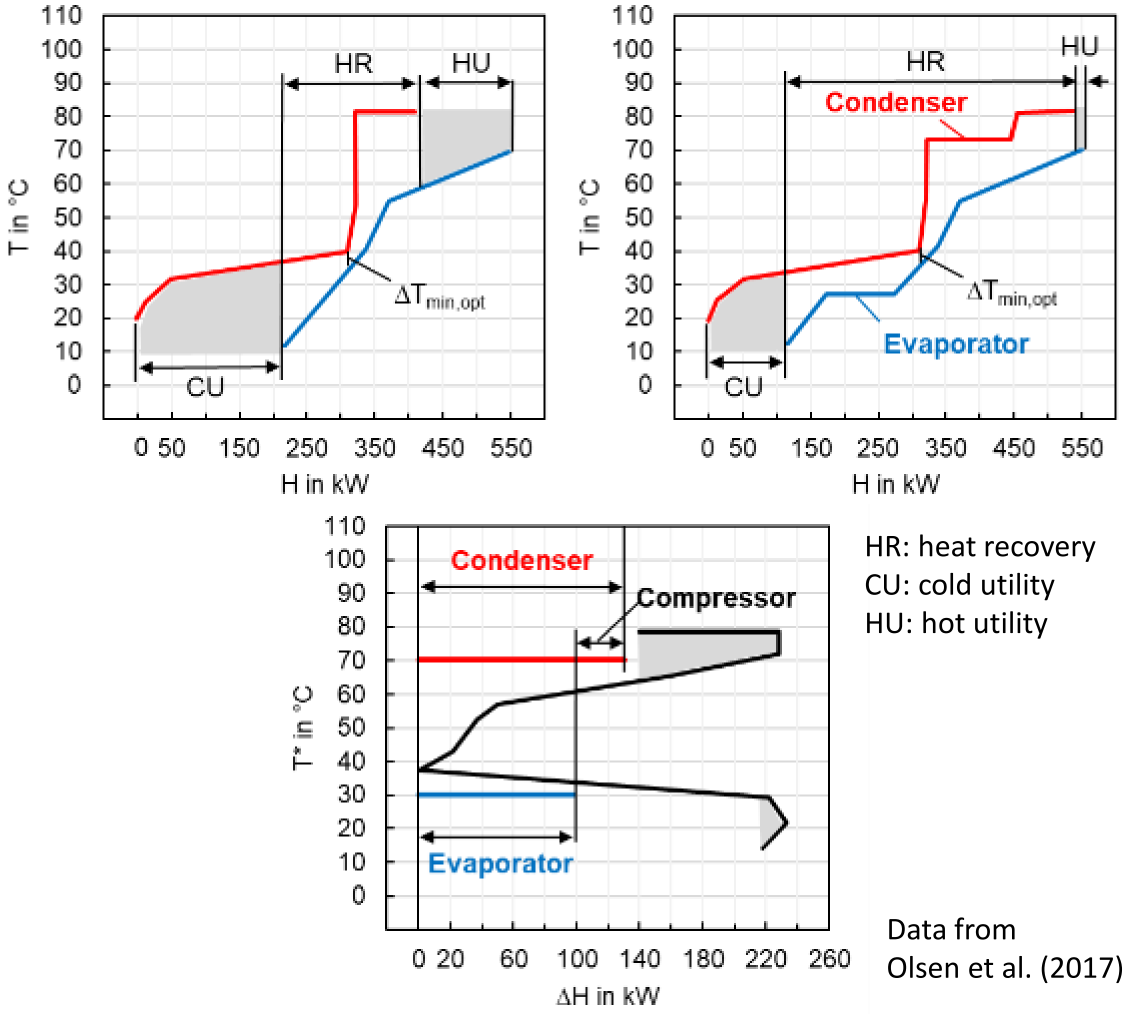
Integration von HTWP in industrielle Prozesse

Fragestellungen

1) Gibt es Prozesse mit **Wärmebedarf**?
2) Gibt es Prozesse mit **Kühlbedarf**?
3) Wie hoch ist die erforderliche **Wärmeversorgungstemperatur**?
4) Sind ausreichend **Wärmequellen** für hohe Wärmebereitstellungstemperaturen vorhanden?
5) Hat die Wärmequelle etwa dieselbe **Größenordnung** wie der Wärmebedarf?
6) Ist die Wärmequelle etwa zur gleichen **Zeit** verfügbar wie die Wärmesenke?
7) Wie gross ist das **Wärmerückgewinnungspotenzial** (WRG)?
8) Wie ist das **Betriebsprofil** der Wärmepumpe (Laufzeit, Teillast, Schwankungen)?

Pinch Analyse
Fallbeispiel – Süßwarenherstellung



HR: heat recovery
CU: cold utility
HU: hot utility

Data from Olsen et al. (2017)

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Energieeinsparungen und Reduzierung der CO_2-Emissionen

Fallbeispiel	Energieeinsparungen	Reduktion der CO_2 Emissionen
Schlachthaus Zürich	2'560 MWh fossile Brennstoffe	**30%** (510 t CO_2/a) *(520 t CO_2/a*)*
Schokoladenfabrik Maestrani	*882 MWh Gas**	179 t CO_2/a (2013 bis 2020)
Fernwärme Champagne	*3'054 MWh Gas**	620 t CO_2/a
Fernwärme Laurana	1'435 MWh fossile	**42%** (1'746 t CO_2/a)
Käserei Gais Appenzell	1'500 MWh Gas	*305 t CO_2/a**
GVS Landi Getränke	26'000 L Öl/a	**40%** *(69 t CO_2/a*)*
Nutrex AG Fermentation	bis zu 65'000 L Öl/a	310 t CO_2/a *(bis zu 172 t CO_2/a*)*
Härterei Gerster AG Metalle	**80%** (800 MWh Gas)	160 t CO_2/a *(162 t CO_2/a*)*
Kellermann Gemüse	*4'729 MWh Gas**	960 t CO_2/a
Kambly SA Biscuits	**25%** *(493 MWh Gas*)*	**90%** (100 t CO_2/a)
Fernwärme Casino Aarau	**40%** bis 2035	n.v.
Mifa AG Home Care & Nutrition	**20%** *(4'729 MWh Gas*)*	**60%** (960 t CO_2/a)
Bachem AG Biotech	*1'478 MWh Gas**	300 t CO_2/a
Feldschlösschen Bier	**75%** (11'160 MWh fossile)	*2'265 t CO_2/a**
ARA Altenrhein Abwasser	*14'778 MWh Gas**	3'000 t CO_2/a

- **Der Ersatz von Gas- und Ölkesseln durch WP führt zu signifikanten Energieeinsparungen und Reduktion der CO_2-Emissionen**

**Annahme CO_2 Emissionsfaktoren (BAFU, 2019)*
Gas: 0.203 t CO_2/MWh, Öl: 0.00265 t CO_2/L Öl

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