

# INDUSTRIAL HEAT PUMPS

DEVELOPMENT PERSPECTIVES  
AND DEMONSTRATION ACTIVITIES

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BENJAMIN ZÜHLSDORF, PHD  
CENTRE PROJECT MANAGER

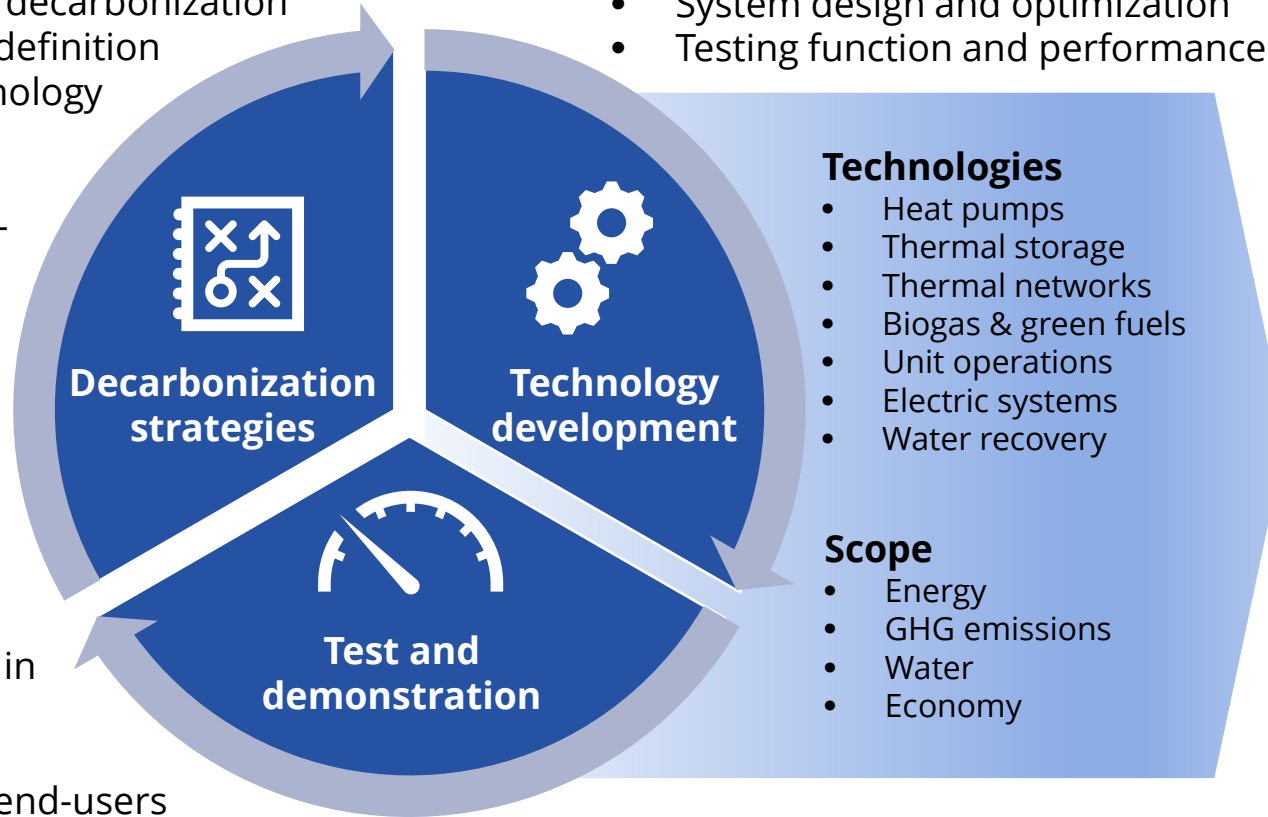


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# DECARBONIZATION OF INDUSTRIES AT DTI

- Holistic consultancy approach supporting process industries in their decarbonization
- Process Analysis & Target definition
- Conceptualization & Technology Overview
- Roadmap development
- Support during implementation

- Validation of technologies in full scale
- Industrial heat pump lab
- On-site demonstration at end-users



- Component development
- System design and optimization
- Testing function and performance

## Collaboration partners

- Technology suppliers (system manufacturers, OEMs, ...)
- Process equipment manufacturers
- End-users from various industries (Food & beverage, Pulp & paper, chemicals, minerals, utilities, industry symbioses, ...)

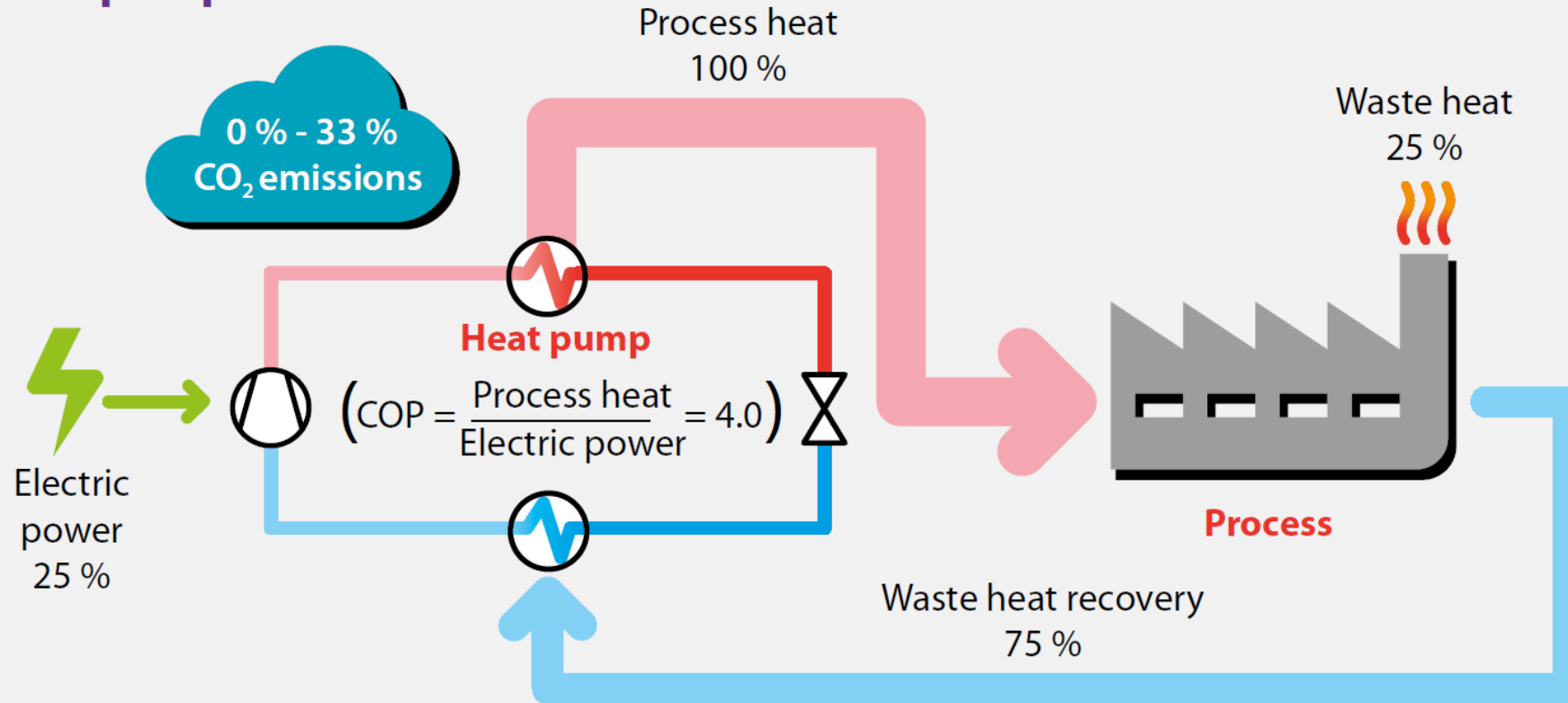


# HTHP APPLICATION POTENTIAL

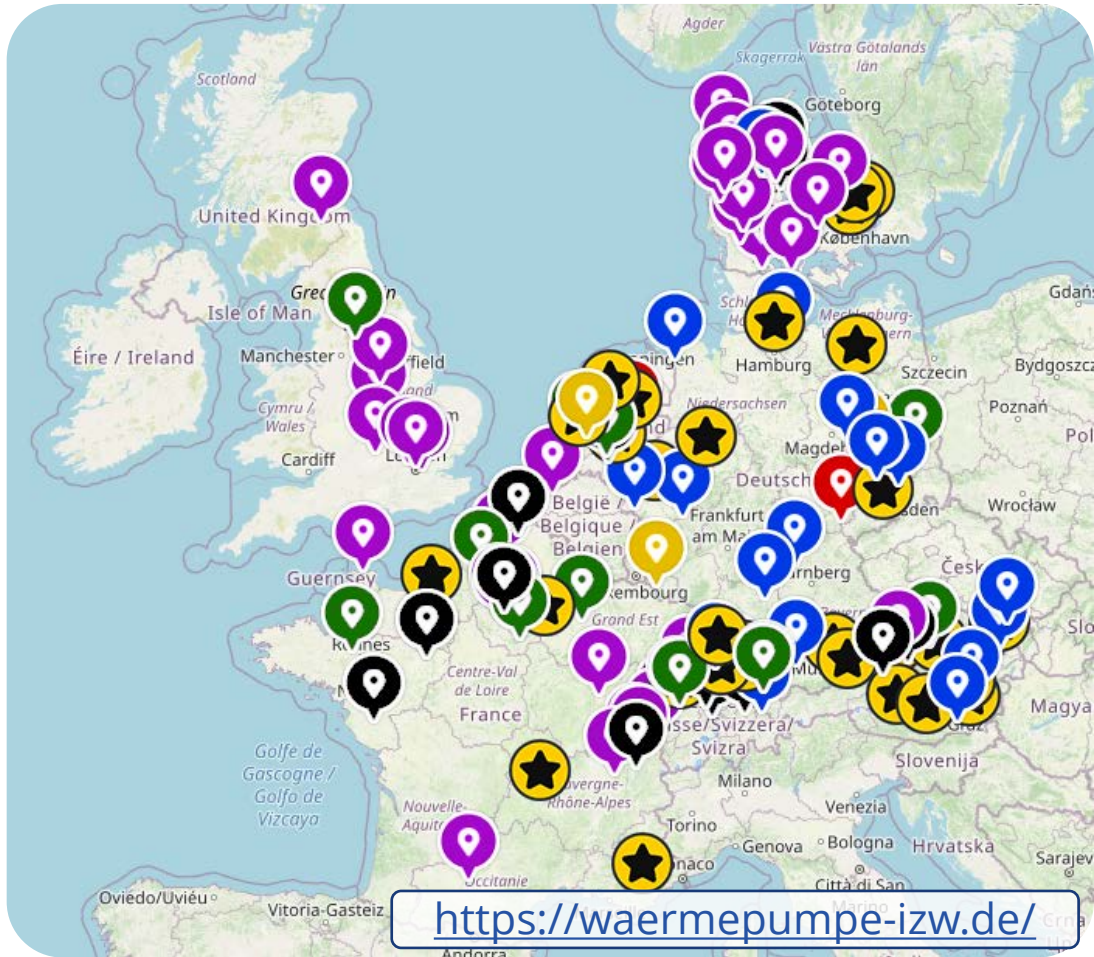


# INDUSTRIAL HEAT PUMPS FUNCTIONING PRINCIPLE

## Heat pump driven



# PROVEN PRINCIPLES



- > 300 cases in IEA HPT Annex 48
- Proven technology < 100 °C
- Proven principles > 100 °C





# INDUSTRIAL PROCESS HEAT DEMAND – EU28

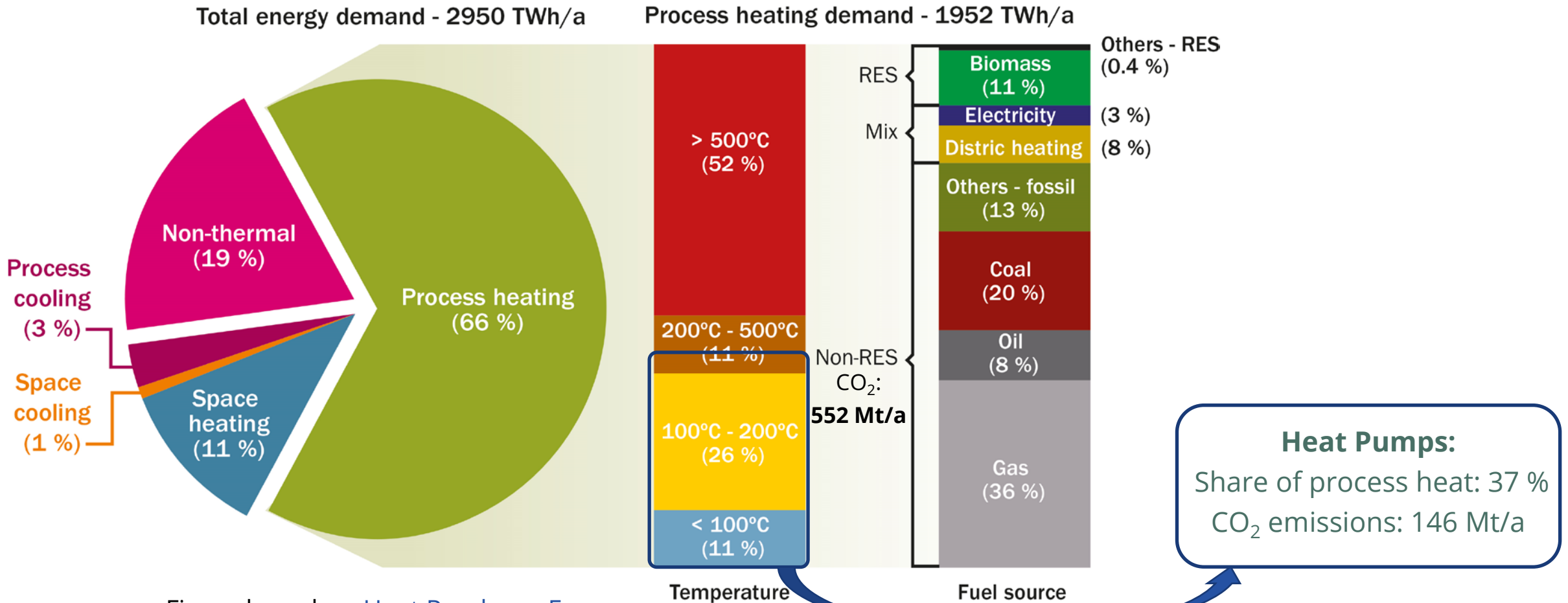


Figure based on [Heat Roadmap Europe](#)



# INDUSTRIAL HP APPLICATION POTENTIAL

## HIGH POTENTIAL


Industry Sectors

 Food & Beverage  
**123 TWh/a**


 Pulp and Paper  
**230 TWh/a**

 Chemical  
**119 TWh/a**

 Machinery  
**41 TWh/a**

 Non Metallic Minerals  
**43 TWh/a**

Transitioning industry to the **USE** of **RENEWABLE** electricity

**200°C** 

Heatpumps for **DECARBONIZATION** of the **LOW TEMPERATURE** heat supply in industry

**RE-USE** of industrial waste heat, leading to **INCREASED** process **EFFICIENCY**

Potential to cover **37%** of the process heat in industry

Possible **CO<sub>2</sub>** emission **REDUCTIONS** of **146 Mt/a**

**REDUCING** final energy consumption by **487 TWh/a**

[White Paper: Strengthening Industrial Heat Pump Innovation – Decarbonizing Industrial Heat](#)

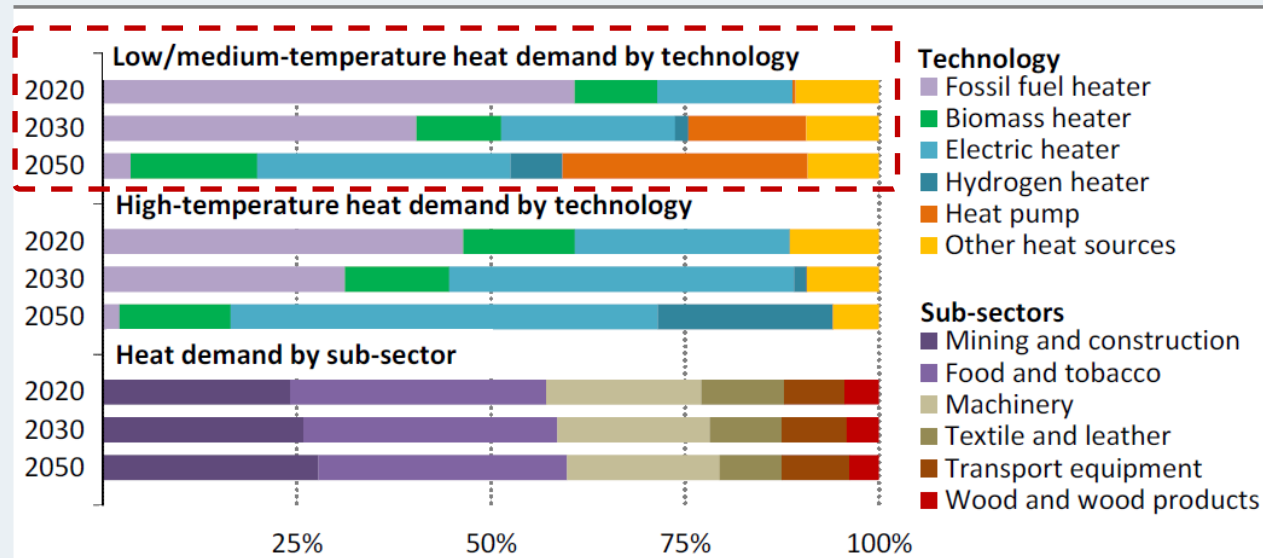
& [Webinar](#)



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# ELECTRIFICATION AND ENERGY EFFICIENCY ARE KEY FOR REACHING SUSTAINABILITY TARGETS

**Figure 3.20** ▶ Share of heating technology by temperature level in light industries in the NZE



IEA. All rights reserved.

*The share of electricity in satisfying heat demand for light industries rises from less than 20% today to around 40% in 2030 and about 65% in 2050*

Source: "Net Zero by 2050 – A Roadmap for the Global Energy Sector, International Energy Agency, 05/2021, <https://www.iea.org/reports/net-zero-by-2050>

- IEA estimates that natural gas will be steadily phased out by heat pumps and electric heaters, especially for temperatures up to 200 °C to 250 °C
- Developed countries must go first and be front runners
- The Danish industry should reduce emissions by 1.9 mio. tons of CO2 per year. **25 %** are to be obtained by "Electrification and heat pumps", mainly implemented between 2025 to 2030 ([Klimarådet](#))
- EU discusses an end of fossil fuel use for processes <200 °C by 2027 in the [RED III, art. 21](#)





# THE ROAD TOWARDS IMPLEMENTATION



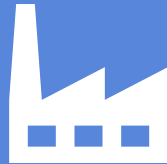
## Technology Awareness

- Commitment to sustainability and decarbonization
- Potentials, limitations and characteristics of the technology
- How to exploit the potentials?
- Variety of stakeholders involved



## Technology Development

- Component and system development
- Testing and demonstration
- Variety of technologies
- Collaborative effort



## End-user adoption

- Technology adoption life cycle
- Retrofitting of industries for HP-based heat supply
- Decarbonization strategies



## Boundary conditions

- Cost for fuels and GHG
- Regulatory frameworks
- Subsidies & incentives
- Market developments

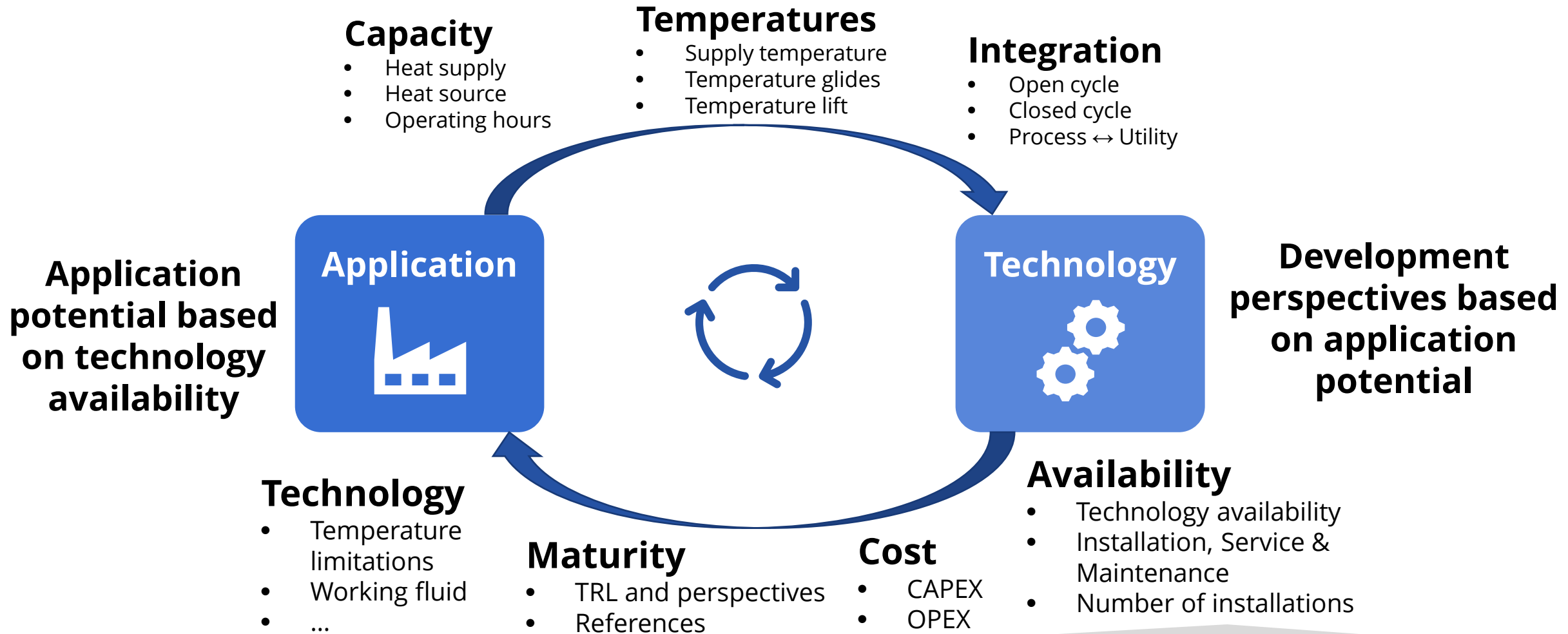


## Market deployment

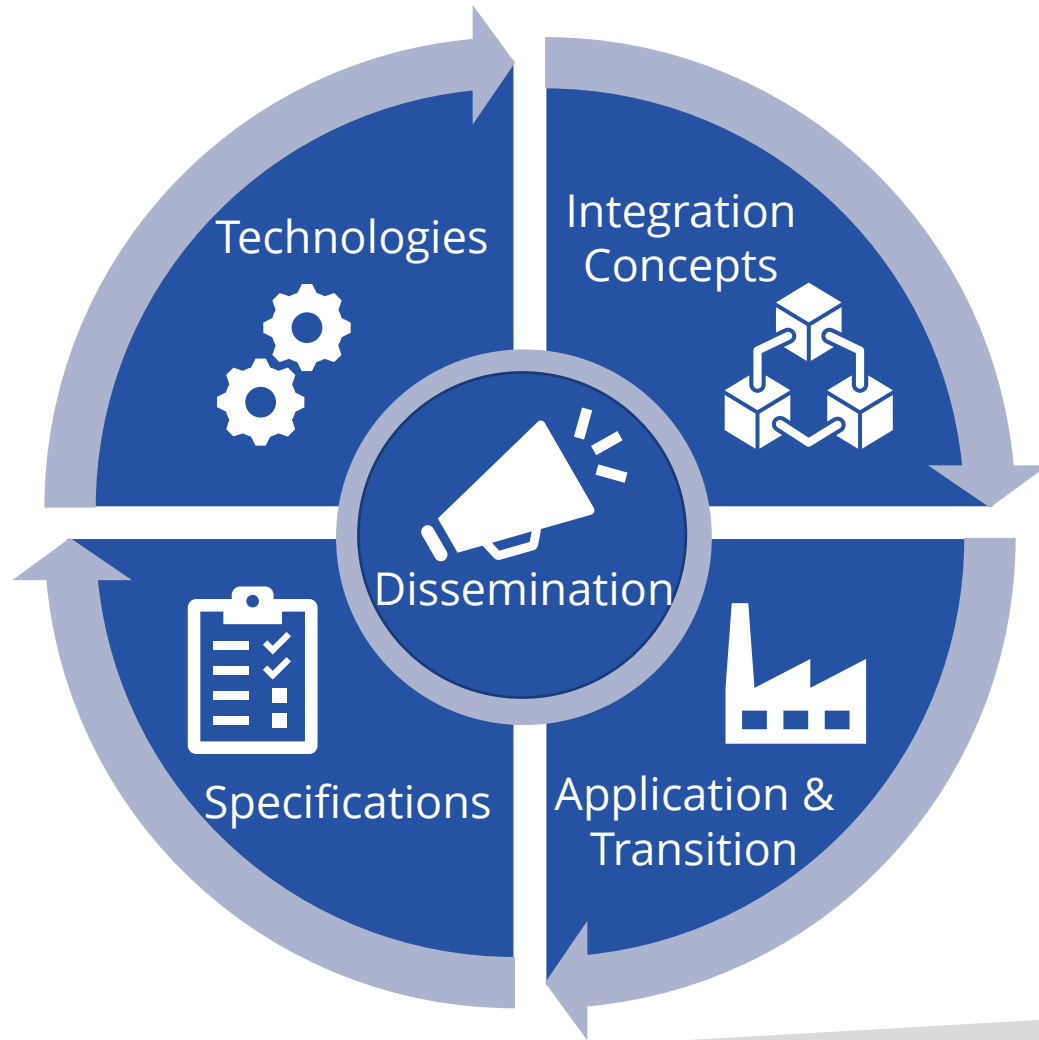
- Technology implementation within commercial projects
- Learning curve for operators and suppliers
- Supply chain covering considerable volumes
- Business models



# POTENTIAL & TECHNOLOGY AVAILABILITY



# IEA HPT ANNEX 58 ABOUT HTHP



- Heat pump technologies with supply temperatures above 100 °C
- Participants: **Denmark (Operating Agent)**, Austria, Belgium, Canada, China, France, Japan, Germany, Netherlands, Norway, South Korea, Switzerland, US
- 01/2021 – 12/2023
- <https://heatpumpingtechnologies.org/annex58/>



# HTHP TECHNOLOGY DEVELOPMENT PERSPECTIVES



# ANNEX 58 – TECHNOLOGY REVIEW



**Annex 58** High-Temperature Heat Pumps

## Screw compressor high-temperature heat pump

Rank®



**Figure 1: Rank® HTHP and compressor**

Rank® HTHP systems can be used since we have different standard adapted to the heat load. Our HT sized using our software if applications. The main Rank® industrial processes (chemical, or district heating.

Our HTHP prototype has been sink and source temperature lab-scale prototype varied based on the temperature lift. H designed for clients could re

The development status is p but our commercial dep installing our technology applications.

Compact HTHP systems a technology; therefore, th a thermal oil heat transfe heat coming from water i used as intermediary cir coils, among others

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.

**Annex 58** High-Temperature Heat Pumps



**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.

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, 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 required 5.2 to 13 m<sup>2</sup> / 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 information 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)

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

- 34 Technology descriptions
- Key information includes:
  - Performance data
  - Capacity range
  - Max. temperatures
  - Working fluid
  - Compressor type
  - Spec. investment cost
  - TRL
  - Expected lifetime
  - Size & footprint
- Project examples

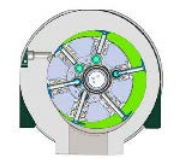
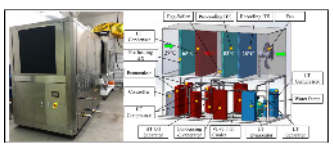
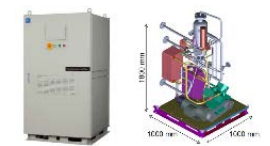




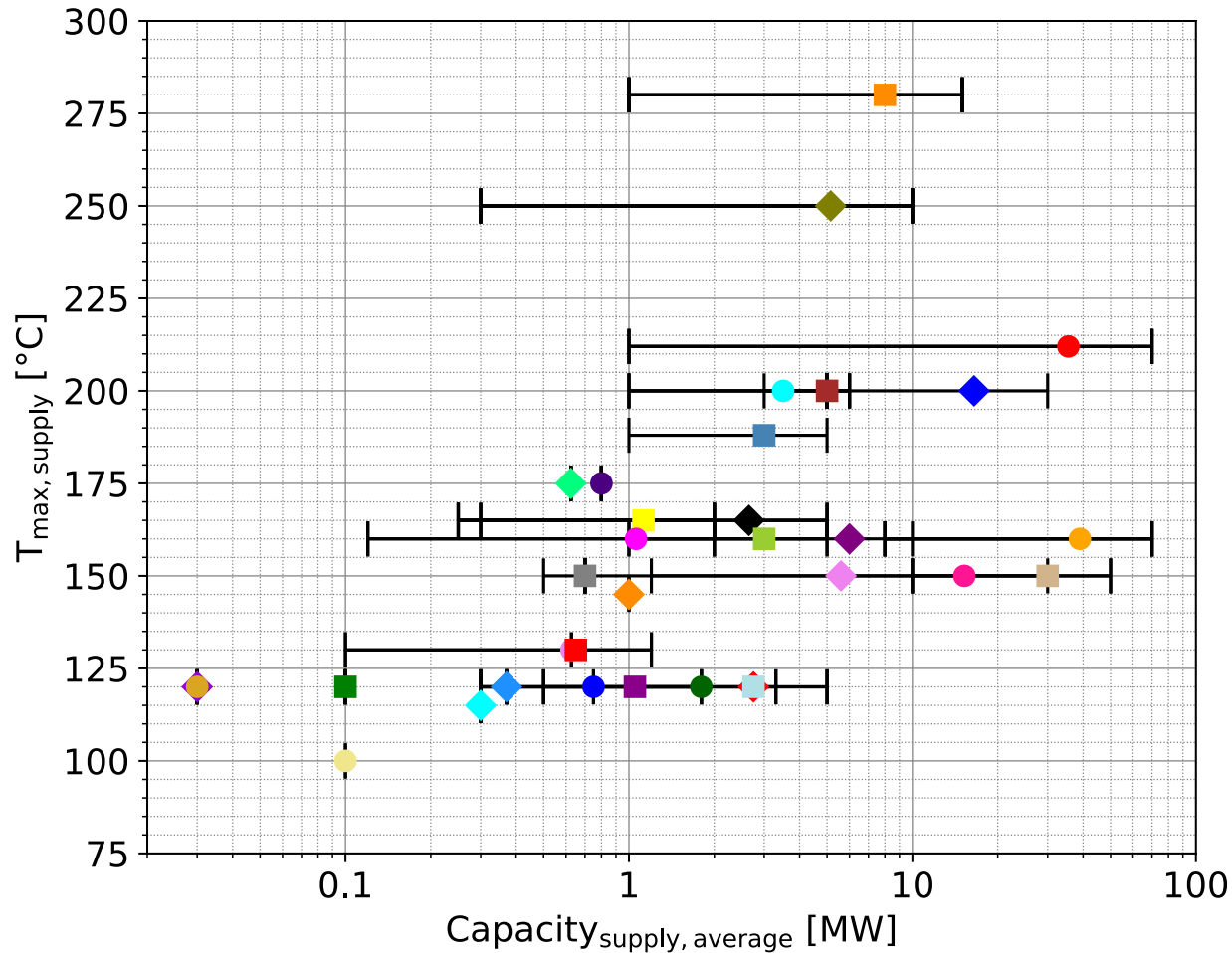
# ANNEX 58 – TECHNOLOGY REVIEW



# ANNEX 58 – TECHNOLOGY REVIEW



# MAXIMUM TEMPERATURE AS A FUNCTION OF CAPACITY



- Spilling
- Enerin
- Piller
- Olvondo
- Turboden
- Heaten
- ToCircle
- Kobelco (SGH-165)
- Kobelco (MSRC)
- SRM
- SPH
- Rank
- Weel & Sandvig
- Enertime
- Siemens Energy
- ecop
- Aneo Industry
- Epcon
- MAN Energy Solutions
- Mayekawa Europe (FC comp.)
- Mitsubishi
- GEA Refrigeration Netherlands
- Fuji Electric
- Emerson
- Mayekawa (EcoSirocco)
- Kobelco (SGH-120)
- Mayekawa Europe (HS comp.)
- Fenagy
- Hybrid Energy
- COMBITHERM GmbH
- Johnson Controls
- Skala Fabrikk
- Mayekawa (EcoCircuit)

## HTHP supplier technology review

<b>TRL level</b>	4-9
<b>Average specific cost</b>	200 €/kW - 1500 €/kW
<b>Capacity</b>	0.03 MW - 70 MW
<b>Max. supply temperature</b>	100 °C - 280 °C
<b>Availability</b>	Geographical dependent, e.g. between Europe and Japan
<b>Size of HTHP technology review</b>	34 different technologies with 85 performance use cases



# ANNEX 58 – DEMONSTRATION CASES



Annex 58

High-Temperature Heat Pumps

Refrigerant cycle designed as twin cycle for efficient operation over a wide range of operation conditions

**Operating experiences**

The DryEfficiency heat pump was operated for more than 4000 h covering a large range of operation conditions (heat supply temperatures from 104°C – 160°C, design point at 120°C). Compared to a natural gas burner providing the same amount of process heat, the DryEfficiency heat pump reduces end energy consumption by 2200 MWh/a, primary energy consumption by 1900 MWh/a, CO<sub>2</sub> emission by 590 t/a, resulting in 60500 €/a of energy cost savings. The increase in drying air temperature in the last zone of the dryer has beneficial effects on brick drying time and quality.

Figure 3: Measured COP of the DryEfficiency heat pump at Wienerberger

**Special learnings**

Challenges encountered during the development of the high temperature heat pumps included material compatibility (lubricant, refrigerant, sealing materials), mechanical design (vibrations), integrative infrastructure (e.g. pressure maintenance, flow measurement) and in the process control (e.g. start procedure, data transfer, measurement devices). DryEfficiency demonstrated the successful component development for high temperature applications such as compressors, the successful operation in industrial environment.

Contact in:

Stefan Puskas, stefan.puskas@wienerberger.com, +43 664 43 664 43 664

Veronika Wilf, veronika.wilf@wienerberger.com, +43 664 43 664 43 664

All information provided in this document is for informational purposes only. It is not intended to constitute an offer or a recommendation.

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Annex 58

High-Temperature Heat Pumps

**DryEfficiency - Industrial heat pump for a climate-neutral European industry**

Figure 1: DryEfficiency Heat Pump at Wienerberger brick production facility in Uttendorf, Austria

**Summary of demonstration case**

In the H2020 project DryEfficiency, high temperature heat pumps were developed and demonstrated to supply process heat with up to 160°C for industrial drying processes to increase energy efficiency and to lower CO<sub>2</sub> emissions. Wienerberger AG, the largest brick producer in the world, operates around 200 brick dryers. The DryEfficiency heat pump was integrated in the brick production process in Uttendorf, Austria, supplying heat for the drying process. A thermally driven heat pump uses hot air from the kiln and water at 90°C for the dryers. The DryEfficiency heat pump uses the hot water from the thermal heat pump as the heat source and provides hot air at up to 160°C for the last zone of the dryer, where higher temperatures are needed.

Johannes Rath, CTO at Wienerberger Building Solutions: "Sustainability has always been at the core of the Wienerberger world. As part of the DryEfficiency research project, together with AIT, we were able to set another milestone in the direction of decarbonisation of the brick industry and create a prime example of how innovations from research can be brought to market quickly"

It is a closed loop vapor compression heat pump, the development and demonstration work included:

- The use of the synthetic low GWP refrigerant R-1336mzz(Z) by Chemours
- 8 piston compressors designed for high temperature applications by Viking Heat Engines
- Fine-tuned, synthetic lubricant working stable with the refrigerant by Fuchs Schmierstoffe

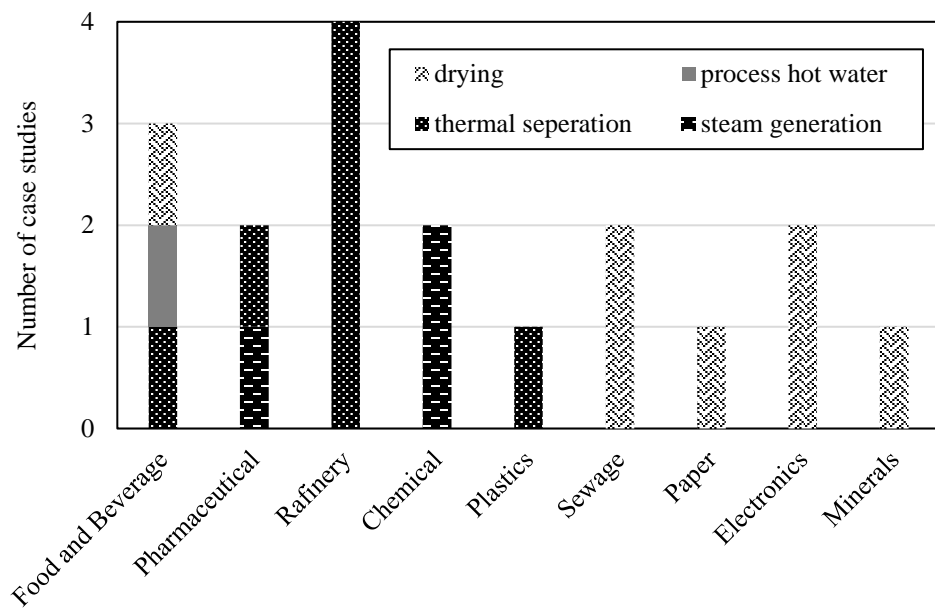
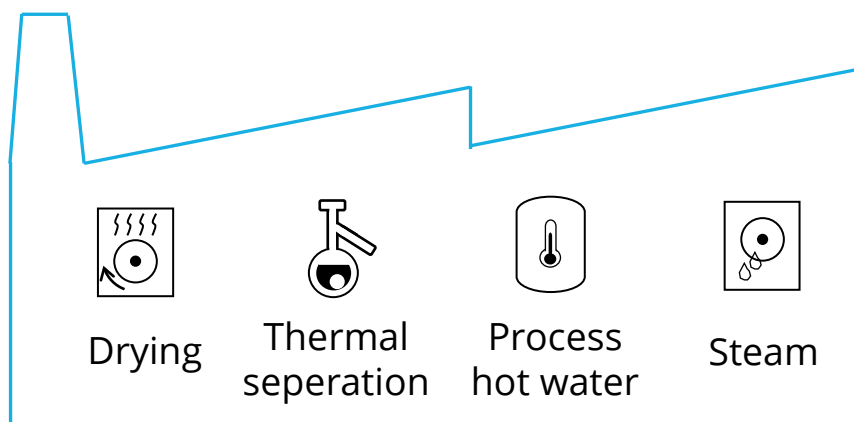
Figure 2: Layout of the DryEfficiency heat pump

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

- 16 two-paged descriptions of HTHP demonstration cases prepared.
- Includes key information on:
  - Performance in design point
  - Operating hours
  - System manufacturer
  - Installation year
  - Working fluid
  - Compressor technology
  - Investment cost
  - Energy savings
  - Estimated annual CO<sub>2</sub> savings



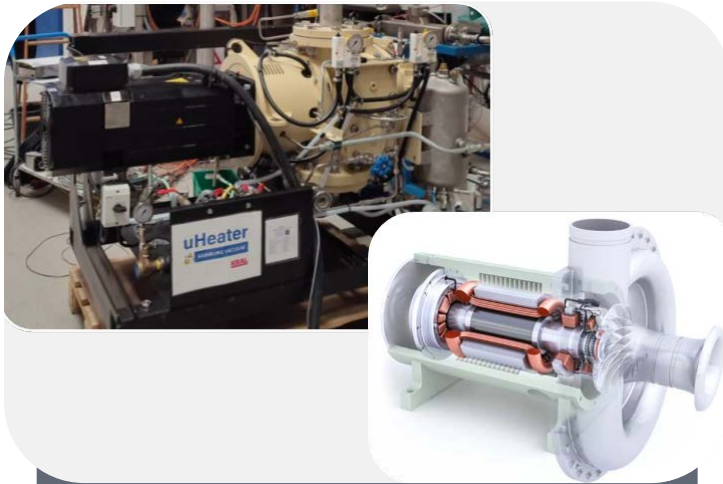
# DEMONSTRATION CASES OVERVIEW



No.	Supplier	Industry	Process	Heat source			Heat sink			HP Type	Refrigerant	Compressor	Capacity [kW]	COP <sub>H</sub>	Op. hours [h/a]	Ref.
				Unit Operation	T <sub>out</sub> [°C]	T <sub>in</sub> [°C]	Unit Operation	T <sub>out</sub> [°C]	T <sub>in</sub> [°C]							
1	n. a.	beverage	alcoholic distillation	product cooling	75	78.3	distillation	140	n. a.	MVR	n. a.	n. a.	350	5.2	n. a.	[1]
2	Mayekawa	electronic	coil drying	electro-painting cooling	25	30	drying	120	20	CCHP	R744	piston	89	3.1	n. a.	[1]
3	AMT/AIT	food	starch drying	waste heat	72	76	drying	138	96	CCHP	R-1336mzz(Z)	screw	374	3.2	4,000	[2]
4	Olvondo	pharmaceutical	recooling	recooling heat	34	36	steam generation	183	178	Stirling HP	R704	piston	2,250	1.7	6,100	[2]
5	Kobelco	sewage	sludge drying	exhaust drying air	93	93	steam generation	160	160	MVR	R718	twin-screw, roots blower	675	2.9	n. a.	[2]
6	Kobelco	refinery	bioethanol distillation	process cooling	60	65	distillation	115	110	CCHP + Flash Tank	R245fa	twin-screw	1,850	3.5	n. a.	[2]
7	MHI	electronic	coil drying	waste heat	50	55	drying	130	70	CCHP	R134a	centrifugal	627	3.0	n. a.	[2]
8	Piller	plastics	thermal separation	exhaust vapour	60	60	steam generation	131	126	MVR	R718	turbo (8 blowers)	10,000	4.4	8,000	[2]
9	AMT/AIT	minerals	brick drying	exhaust drying air	80	84	drying	121	96	CCHP	R-1336mzz(Z)	piston (8 compr.)	296	5	4,000	[2]
10	Spilling	pulp and paper	pulp drying	exhaust vapour	105	133	steam generation	201	n. a.	MVR	R718	piston (4 LT-, 2 HT-cylinders)	11,200	4.2	7,500	[2]
11	Spilling	chemical	chemical	exhaust vapour	105	152	steam generation	211	n. a.	MVR	R718	piston (4 LT-, 2 HT-cylinders)	12,000	5.3	7,500	[2]
12	Rotrex, Epcor	sewage	sludge drying	surplus steam	100	n. a.	steam generation	146	n. a.	MVR	R718	turbo (2 stages)	500	4.5	n. a.	[2]
13	SkaleUP	dairy	process hot water (re)cooling		12, 0	20, 5	process hot water	115	95	CCHP	LT-C: R290, HT-C: R600	piston	300	2.5, 2.3	6,500	[2]
14	QPinch	chemical	steam production	exhaust vapour	120 - 145		steam generation	140 - 185		heat transformer	H <sub>2</sub> PO <sub>4</sub>	heat-driven	2,900	0.45	2,500	[2]
15	Huayuan Taimeng	refinery	ethyl-benzene	waste heat	95	120	steam generation	152	n. a.	heat transformer	LiBr-H <sub>2</sub> O	heat-driven	7,553	0.48	n. a.	[2]
16	Shanghai Nuotong	beverage	alcoholic distillation	air	n. a.	18.9	steam generation	120	90	CCHP + Flash Tank + MVR	LT-C:R410a, HT-C:R245fa	screw	180	1.85	n. a.	[2]
17	Huayuan Taimeng	refinery	alkyl-benzene	waste heat	86	127	steam generation	150	n. a.	heat transformer	LiBr-H <sub>2</sub> O	heat-driven	5,100	0.48	n. a.	[2]
18	Shandong Zhangqiu Blower	refinery	ethanol distillation	exhaust vapour	76	n. a.	steam generation	116	n. a.	MVR	R718	centrifugal	n. a.	7.68	7,000	[2]



# ONGOING DEVELOPMENT & DEMONSTRATION ACTIVITIES BY DTI



## Steam compression system

- Spindle compressor: High pressure ratio and  $T_{\text{lift}}$
- 2-stage turbo compressor: high flows and  $T_{\text{lift}}$  up to 50 K
- Full-scale test: 2023
- On-site demo: 2024



## Hydrocarbon system

- Butane (R600)  $\rightarrow$  120 °C
- Isopentane (R601a)  $\rightarrow$  160 °C
- Bock piston compressors
- Full-scale test: 04/2023
- On-site demo: Early 2024



## CO<sub>2</sub> system

- CO<sub>2</sub> (R744)  $\rightarrow$  180 °C
- Bock piston compressors
- Single-stage with ejectors
- Full-scale test: 2023
- On-site demo: Early 2024

<http://suprheat.dk/>



# ONGOING DEVELOPMENT & DEMONSTRATION ACTIVITIES BY DTI



## HC cascade system

- Iso-Butane (R600a) → 120 °C
- Iso-Pentane (R601a) → 160 °C
- Frascold screw compressors
- 500 kW in drying process
- Full-scale test: 2023
- On-site demo: 2024
- <https://interheat.dk/>



## HC & steam system

- Butane (R600) → 120 °C
- Water (R718) → 160 °C (steam)
- SRM screw compressors
- 1 MW process heat (source DH)
- Full-scale test: 2023
- On-site demo: 2024
- <https://interheat.dk/>



## Pentane system

- Pentane (R601) → 145 °C (steam)
- GEA screw compressors
- Single-stage
- 4 MW for sugar production
- On-site demo: 2024
- <https://spirit-heat.eu/>



# END-USER ADOPTION

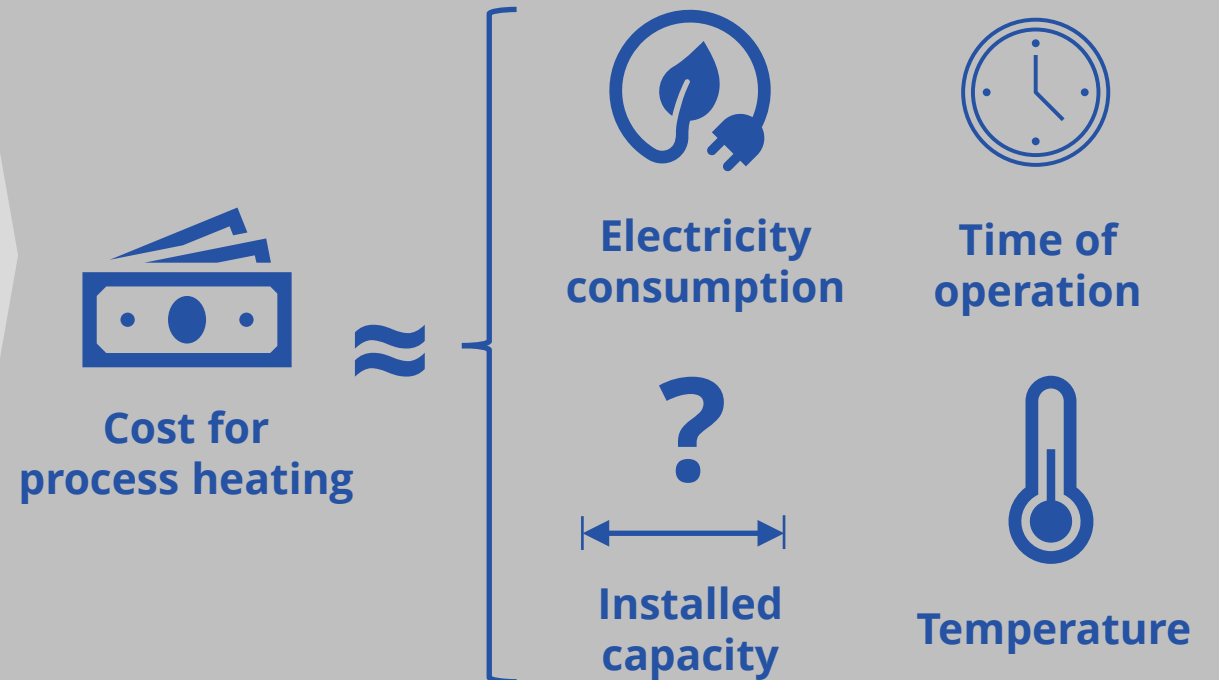


# BUSINESS CASES

## Fossil-fuel based process heating



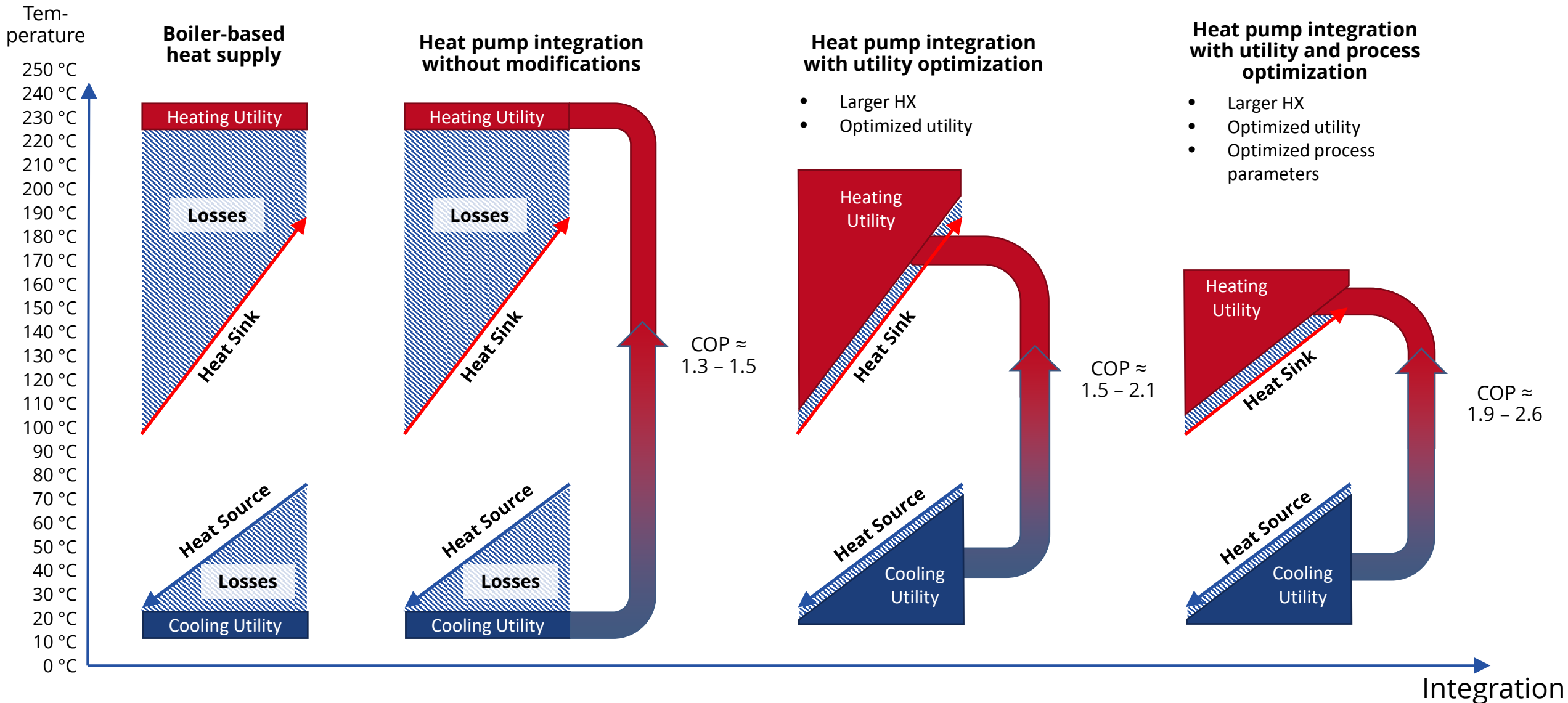
## Heat pump-based process heating



# TEMPERATURE DEMANDS & LEVEL OF INTEGRATION

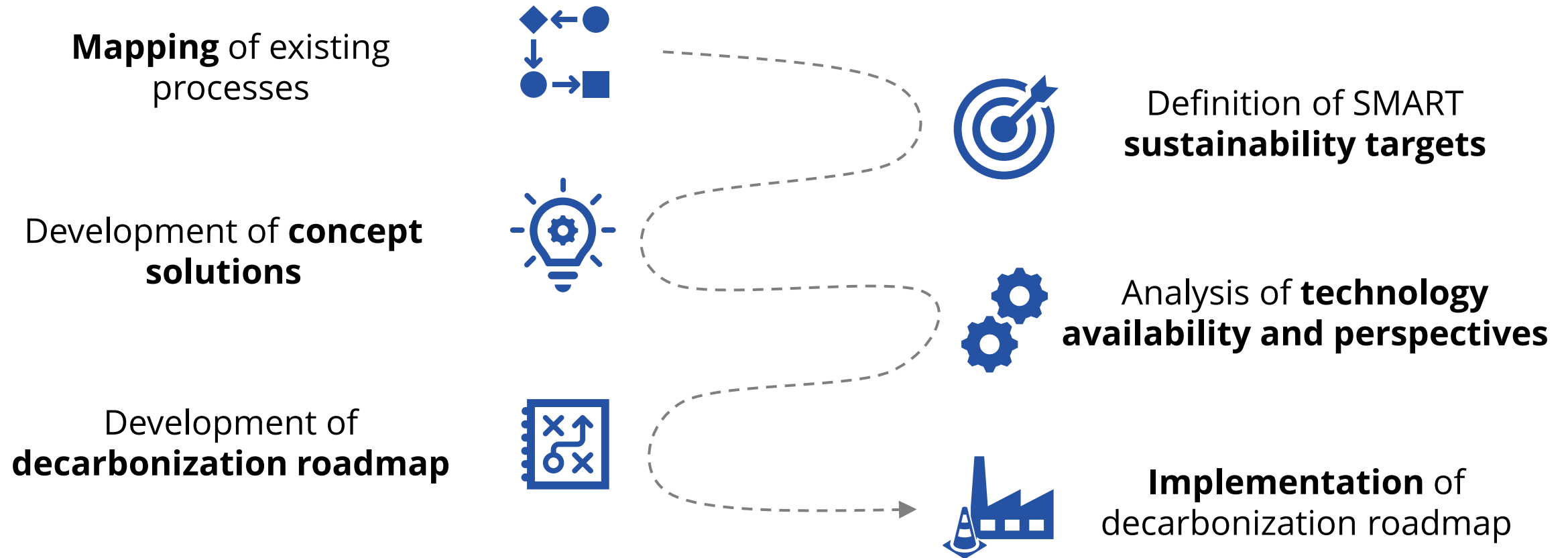


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# DEVELOPMENT OF DECARBONIZATION STRATEGIES



# PERSPECTIVES





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Heating Capacity	Temperature	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
200 kW to 10 MW	< 120 °C	Prototypes available		Full-scale demonstrators available		Various HP Technologies commercially available		Established as preferred technology					
		Prototype developments		Technology advancement, upscaling		Optimization of efficiency, cost, ...		Standardization, further improvements and novel applications					
		Test and demonstration of prototypes		Full-scale demonstrations in industrial environment		Commercial deployment of systems							
	120-160 °C			Prototypes available		Full-scale demonstrators available		Various HP Technologies commercially available		Established as preferred technology			
		Prototype developments		Technology advancement, upscaling		Optimization of efficiency, cost, ...		Standardization, further improvements and novel applications					
		Test and demonstration of prototypes		Full-scale demonstrations in industrial environment		Commercial deployment of systems							
	> 160 °C					Prototypes available		Full-scale demonstrators available		Various HP Technologies commercially available		Established as preferred technology	
				Prototype developments		Technology advancement, upscaling		Optimization of efficiency, cost, ...		Standardization, further improvements and novel applications			
				Test and demonstration of prototypes		Full-scale demonstrations in industrial environment		Commercial deployment of systems					
>10 MW	< 120 °C			HP Technologies commercially offered		First demonstrations realized		Established as preferred technology					
		Technology transfer to HP applications		Technology advancement, upscaling		Optimization of efficiency, cost, ...		Standardization, further improvements and novel applications					
		Integration studies with end-users		Full-scale demonstrations in industrial environment		Commercial deployment of systems							
	> 120 °C					HP Technologies commercially offered		First demonstrations realized		Established as preferred technology			
		Technology transfer to HP applications		Technology advancement, upscaling		Optimization of efficiency, cost, ...		Standardization, further improvements and novel applications					
				Integration studies with end-users		Full-scale demonstrations in industrial environment		Commercial deployment of systems					

# CONCLUSIONS, OUTLOOK & TAKE-AWAYS

## Conclusions

- High-temperature heat pumps have a considerable potential
- Variety of technologies and manufacturers required
- Process integration and decarbonization strategies are key

## Outlook

- Large up-take of heat pumps in industry & district heating < 100 °C
- Establishing HTHPs as reference technology for heat supply up to 150/160 °C
- Advancing the state of the art for technologies >150 °C
- Creating awareness at variety of stakeholders

## Take-aways

- **Technologies must be developed and demonstrated at scale**
- **Industrial decarbonization is a long-term process and requires holistic strategies**
- **The HTHP technology supply and the market are global.**



# HTHP SYMPOSIUM



High-Temperature  
Heat Pump Symposium



- Focus on:
  - Technology developments and trends
  - Successful demonstration cases
  - Integration concepts
  - Market potential and demand
- Presentations & Exhibition area
- Save the date:  
**23<sup>rd</sup> & 24<sup>th</sup> of January 2024**
- <http://hthp-symposium.org/>



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# Benjamin Zühlendorf, PhD

Centre Project Manager

[bez@dti.dk](mailto:bez@dti.dk), +45 7220 1258



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