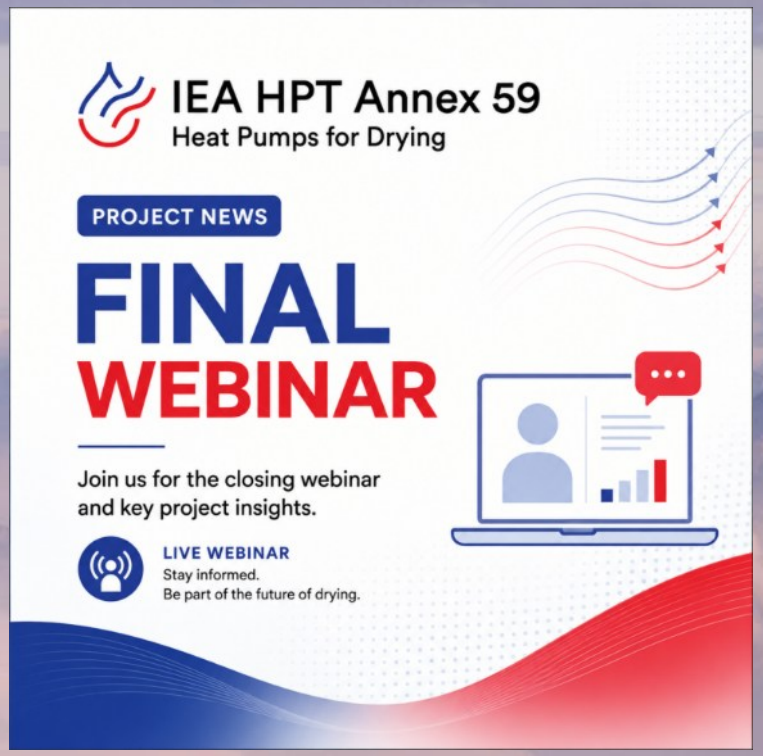

Project Partners

Heat pumps for industrial drying processes – An overview of realized use cases

Final Webinar, IEA HPT Annex 59 Heat Pumps for Drying
10 June 2026, Online

Dr. Cordin Arpagaus
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Institute for Energy Systems IES
www.ost.ch/ies

OST Eastern Switzerland University of Applied Sciences

IES Institute for Energy Systems

Content

- Realized Demonstration Cases
- Representative Cases – Success Factors
- Summary – Key Takeaways

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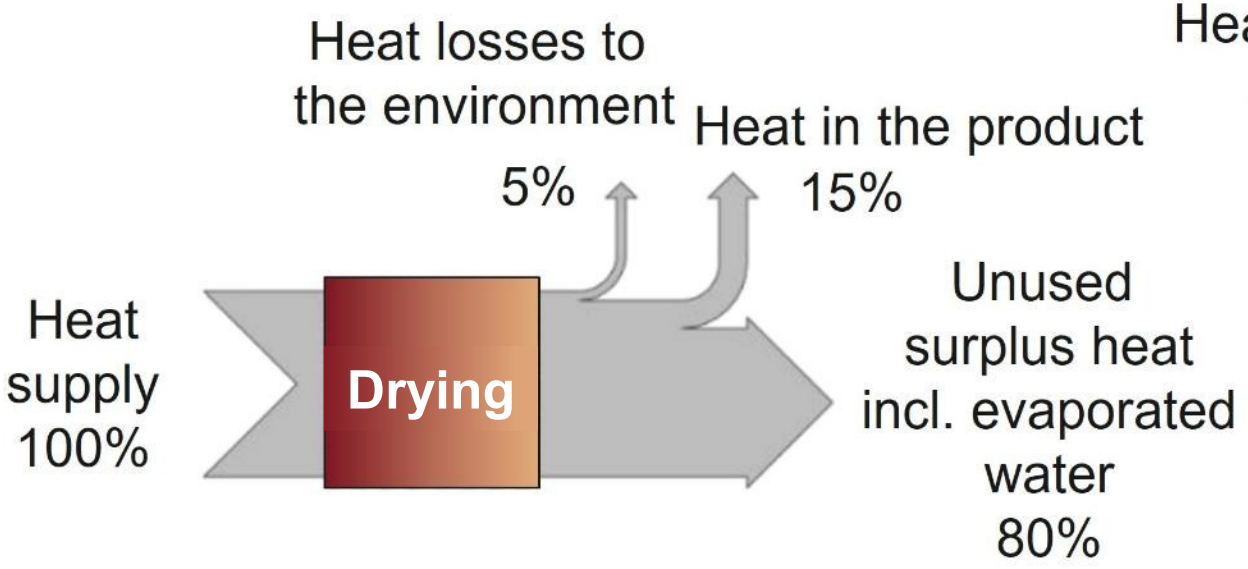
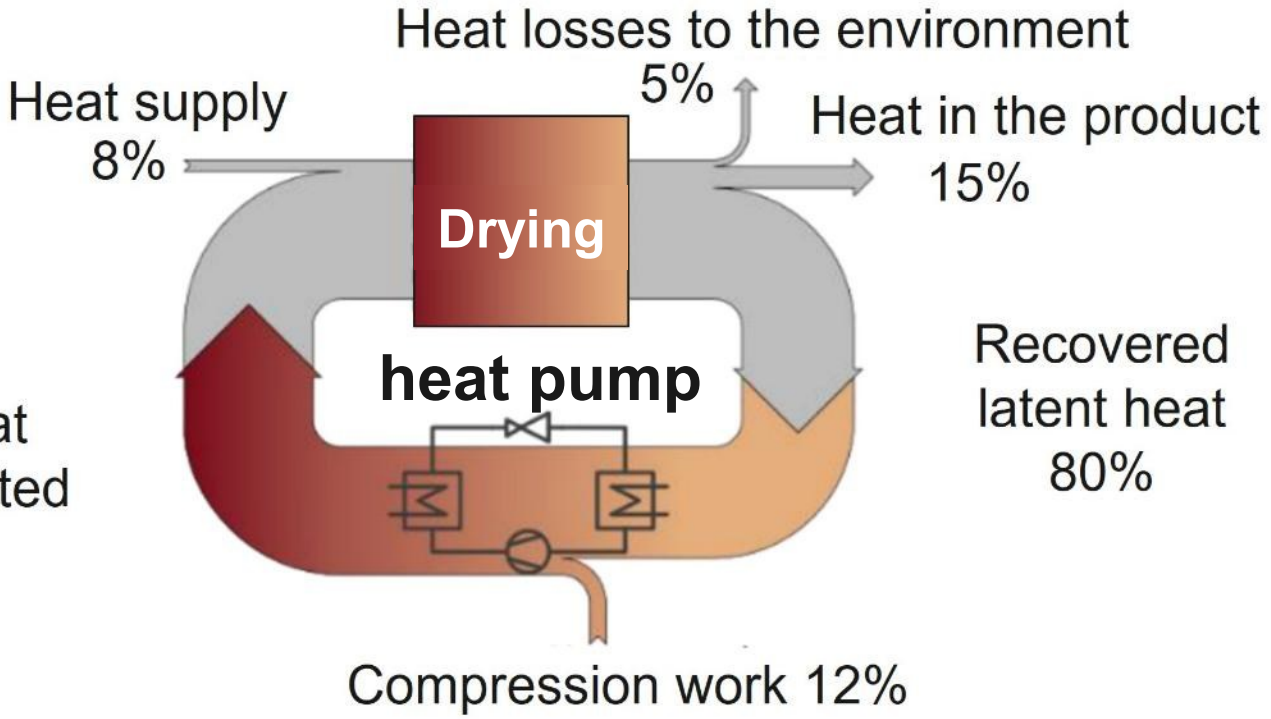
Heat pump integration enables energy savings of up to 80% through heat recovery

- Comparison of conventional (left) and heat pump-assisted drying (right)

Open cycle



Closed cycle



Source: Lauermann et al. (2023) and IEA HPT TCP Annual Report (2025)

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10 Demonstration Cases from IEA Project 59

IEA HPT Projekt 59
Case studies

Industry	Company	Country	Link
Paper pulp drying	Dalkia, EDF		Datasheet 01
Air-dried beef *(Bündnerfleisch)*	Micarna		Datasheet 02
Feed drying	Arla Foods		Datasheet 03
Feed drying	Cargill-Ewos		Datasheet 04
Animal feed/food drying	Felleskjøpet		Datasheet 05
Fish meal production	Pelagia Måløy		Datasheet 06
Brick drying II	Wienerberger		Datasheet 07
Brick drying I	Wienerberger		Datasheet 08
Starch drying	AGRANA		Datasheet 09
Biomass drying	Lindum		Datasheet 10

The case studies demonstrate successful application in the food, feed, ceramics, and biomass sectors

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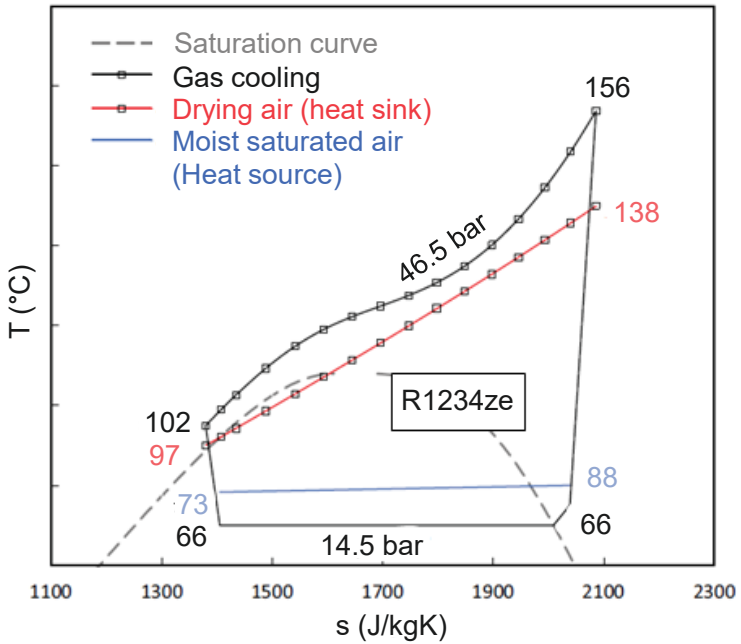
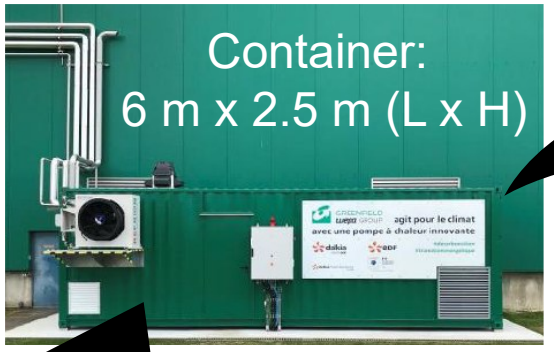
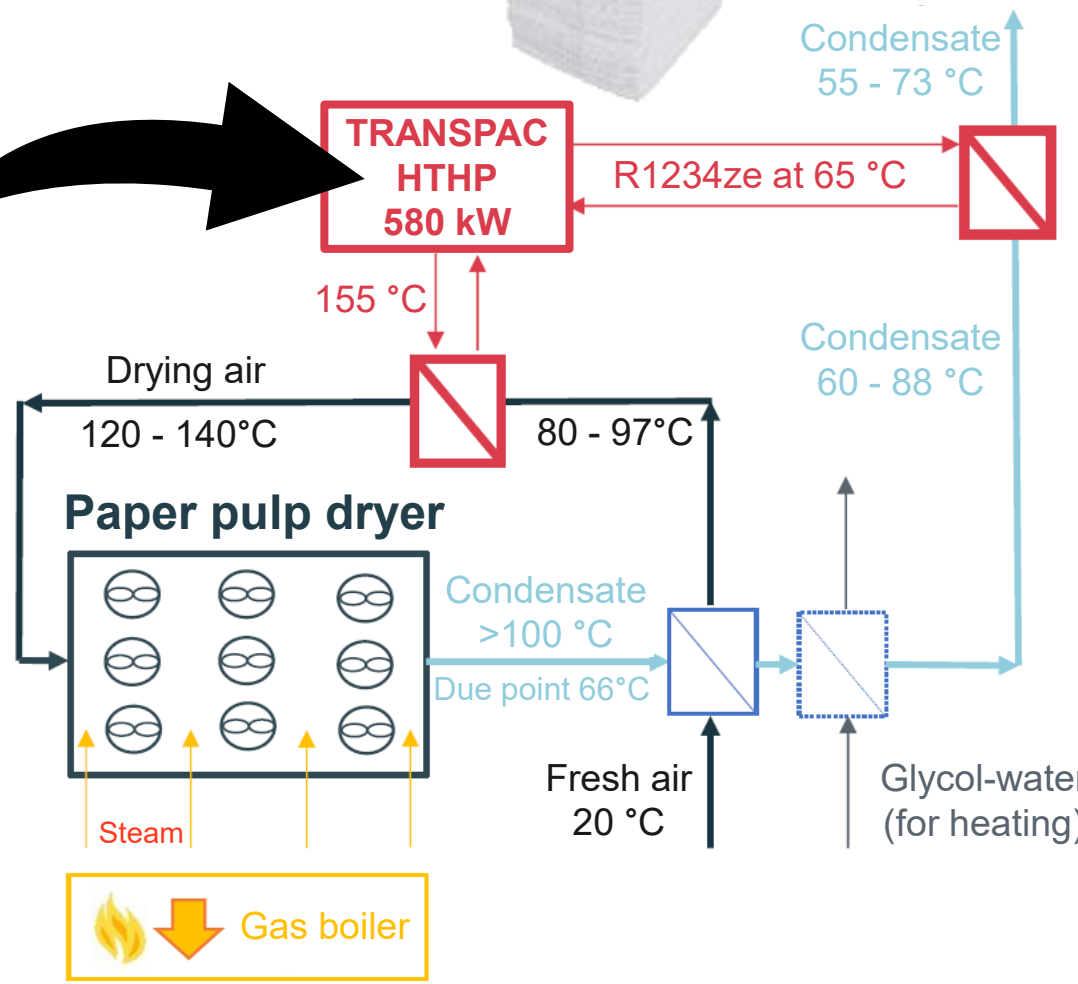
Transcritical HTHP (TRANSPAC) for pulp drying

WEPA Greenfield

COP > 3.5 at
Heat source 70 °C
Drying air 140 °C







Sources:
Dalika Groupe EDF (2024): https://www.dalkia.fr/sites/default/files/2024-04/CP_Dalkia_Transpac_PAC-THT_VDef.pdf und https://www.youtube.com/watch?v=w9kA4mOAqM4
EDF (2024): https://www.edf.fr/groupe-edf/inventer-l-avenir-de-l-energie/rd-un-savoir-faire-mondial/toutes-les-actualites-de-la-rd/transpac-la-pompe-a-chaleur-haute-performance-au-service-d-une-industrie-decarbonee
Pierrot und Varlet (2024): https://www.alliance-allice.com/fr/fire-2024-decouvrez-notre-programme-autour-de-la-chaleur-industrielle-decarbonee
Gachot (2024): https://energyefficiencyhub.org/wp-content/uploads/2024/01/EMAK12-EDF-Decarbonisation-of-Industry.pdf

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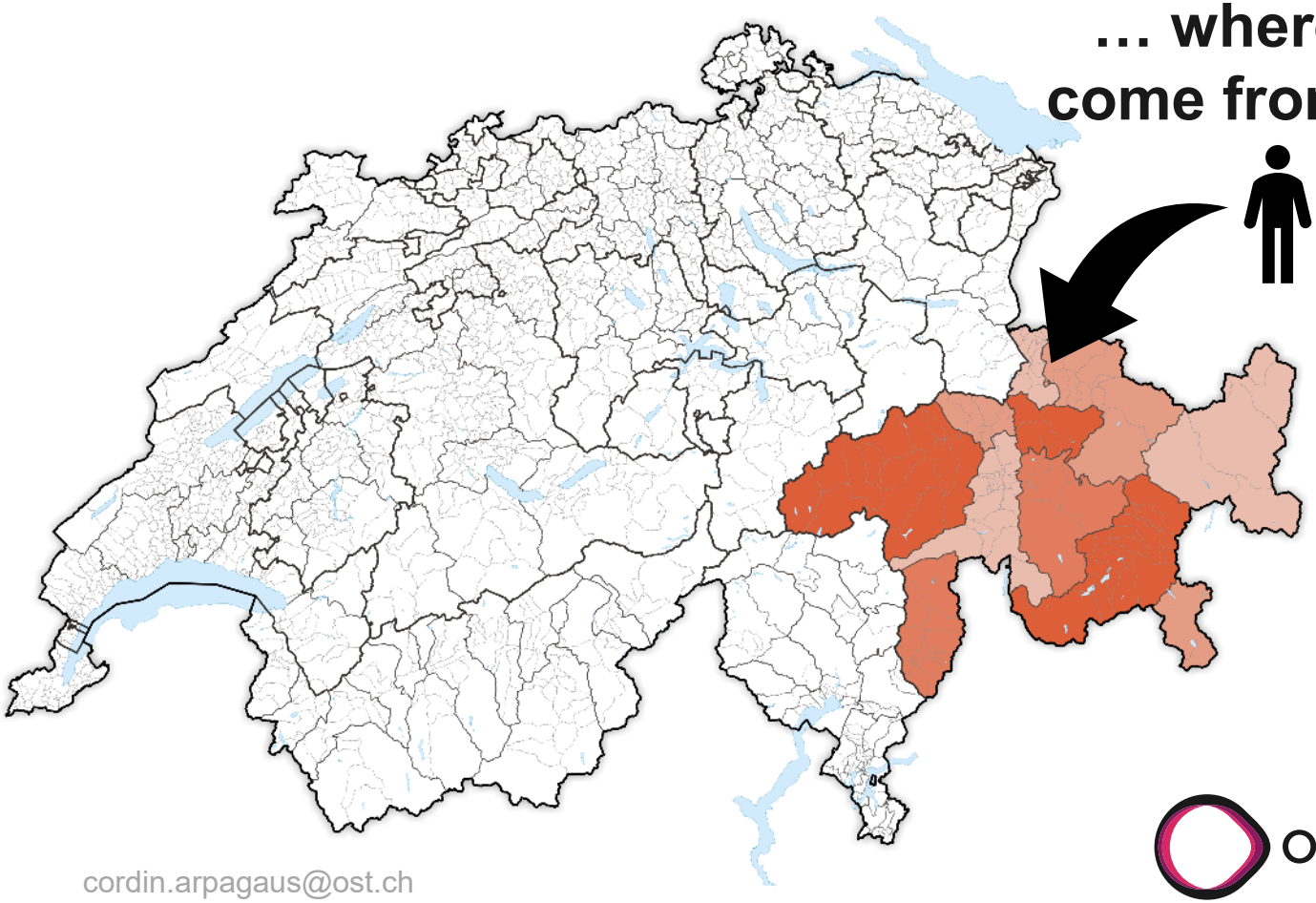
Air-dried beef *(Bündnerfleisch)* – cold drying

Good to know:

- Air-dried beef from **Canton of Grisons**

… where I come from ☺



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Air-dried beef *(Bündnerfleisch)* – cold drying

Good to know:

- Air-dried beef from **Canton of Grisons**
- **Protected Geographical Indication**
- Dried at altitudes **above 800 m above sea level**
- Duration: 3–6 months, 45–55% weight loss
- **Annual production: approx. 2,500 t**, requires approx. 5,000 t of fresh meat
- **Main drying: 12–18 °C, 70–80% relative humidity, controlled air circulation**
- **Sweating phase: 21–26 °C to develop flavor**

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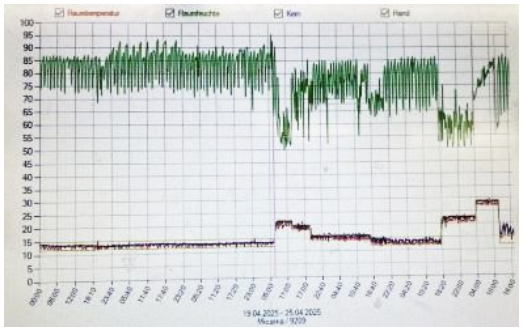
- Location: Micarna SA in Tinizong (GR)
- Supplier: Kältering AG / Enex srl (IT)
- Plant engineer : Brasser Kälte AG (Rhäzüns, GR)
- Photos: C. Arpagaus, 25 April 2025

Air-dried beef *(Bündnerfleisch)* – cold drying



Booster R-744

HP R-744

200 kW cooling capacity 80 kW heating capacity

330 kW useful waste heat

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Spray drying is a very energy-intensive process because of hot air generation and large airflow

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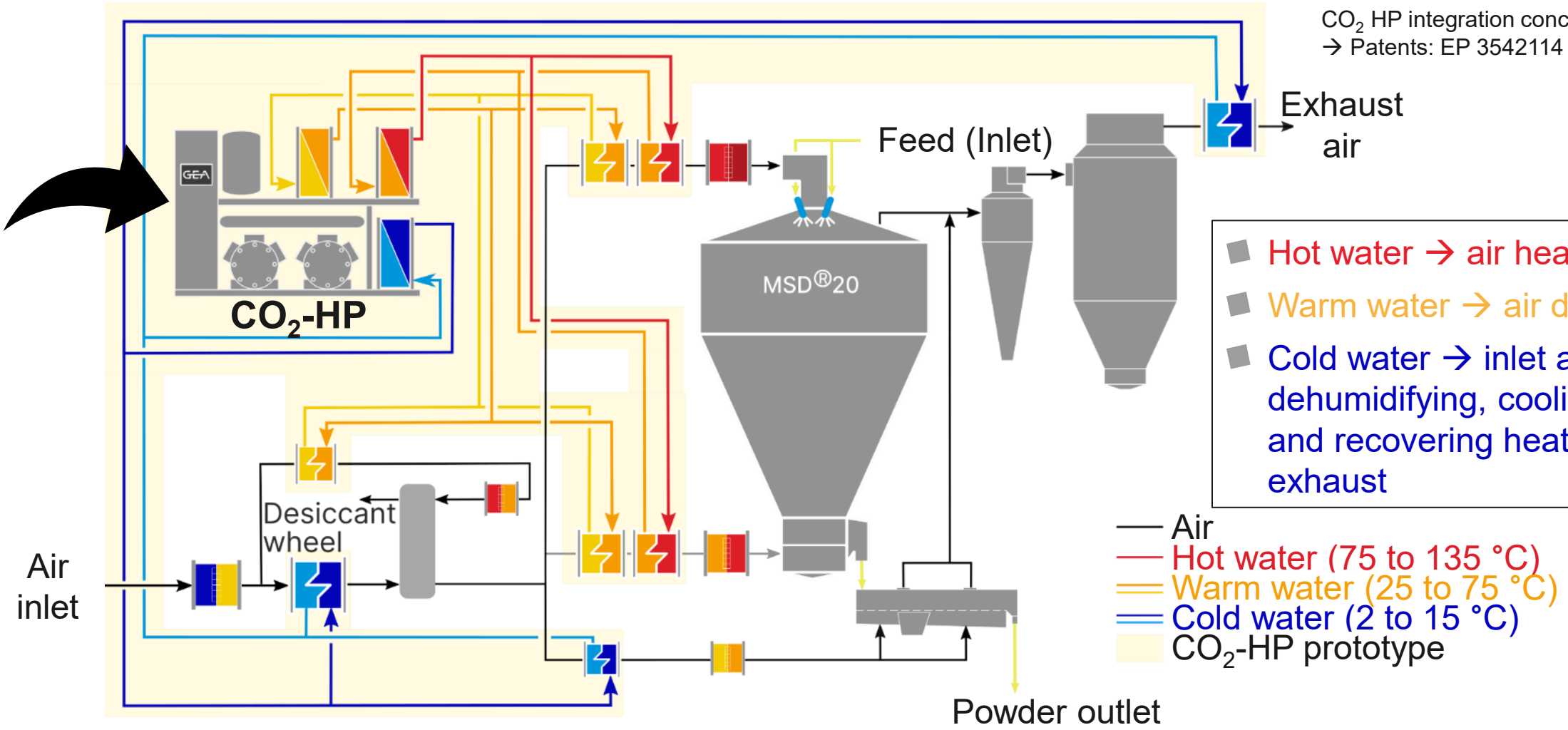
Transcritical CO_2 Heat Pump for Spray Dryer – GEA AddCool®

CO_2 HP integration concepts
→ Patents: EP 3542114 B1, WO 2018/091049



- Hot water → air heating
- Warm water → air desorption of air
- Cold water → inlet air dehumidifying, cooling fluidizer air, and recovering heat from dryer exhaust

Source: Bellemo, L., Krauthammer, E., Gerritsen, J., Hoffmann, K., Overgaard, J.S. (2020): Integration of a high temperature CO_2 heat pump into a spray drying process, 22nd International Drying Symposium (IDS 2020), Worcester, Massachusetts, USA

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GEA AddCool® – Transcritical CO_2 Heat Pump for spray dryer

CO_2-HP prototype integrated into the GEA spray drying test center in Søborg (DK)

- **Heating capacity (90 kW)**
- Hot water (130 °C)
- Warm water (75 °C)
- Chilled water (2 to 10 °C)
- COP of 2.8
- Connected to GEA MSD® 20 spray dryer (1,800 kg/h)

Source: Bellemo, L., Krauthammer, E., Gerritsen, J., Hoffmann, K., Overgaard, J.S. (2020): Integration of a high temperature CO_2 heat pump into a spray drying process, 22nd International Drying Symposium (IDS 2020), Worcester, Massachusetts, USA

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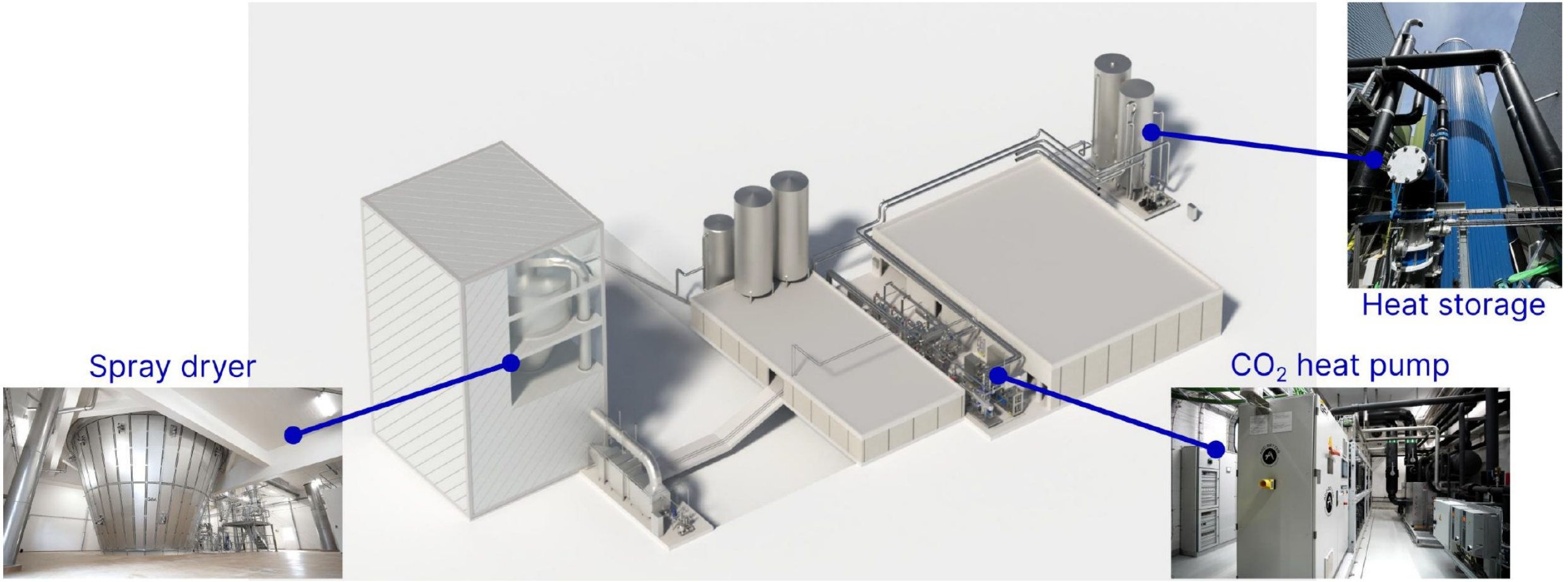
GEA AddCool® at Arla Foods AKAFA (Svenstrup facility, DK)



Source: Bergamini, R., Martinez-Maradiaga, D. (2026): Decarbonizing Industrial Spray Drying with High-Temperature Heat Pumps: Insights from the GEA AddCool® Demonstrator at Arla AKAFA, HTHP Symposium 2026, 21-22 January 2026, Copenhagen, Denmark, https://hthp-symposium.org/hthp-symposium-2026

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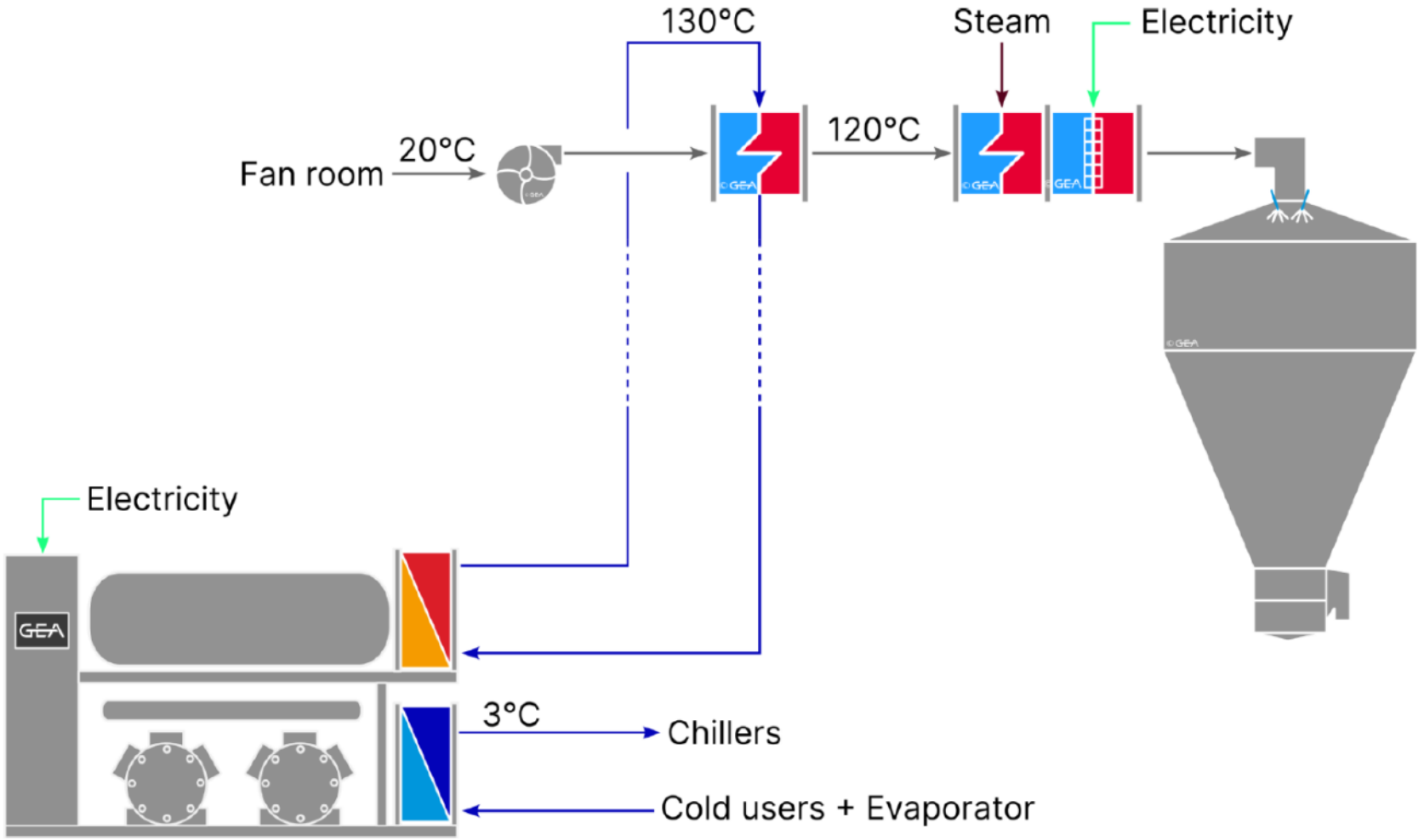
GEA AddCool® at Arla Foods AKAFA (Svenstrup facility, DK)



- **Arla Foods AKAFA = global dairy producer (milk powder)**
- Integrated GEA AddCool® system into a GEA MSD® 315 spray dryer
- **Heating capacity (900 kW)**
- Total COP of 3.6

Source: Bergamini, R., Martinez-Maradiaga, D. (2026): Decarbonizing Industrial Spray Drying with High-Temperature Heat Pumps: Insights from the GEA AddCool® Demonstrator at Arla AKAFA, HTHP Symposium 2026, 21-22 January 2026, Copenhagen, Denmark, https://hthp-symposium.org/hthp-symposium-2026

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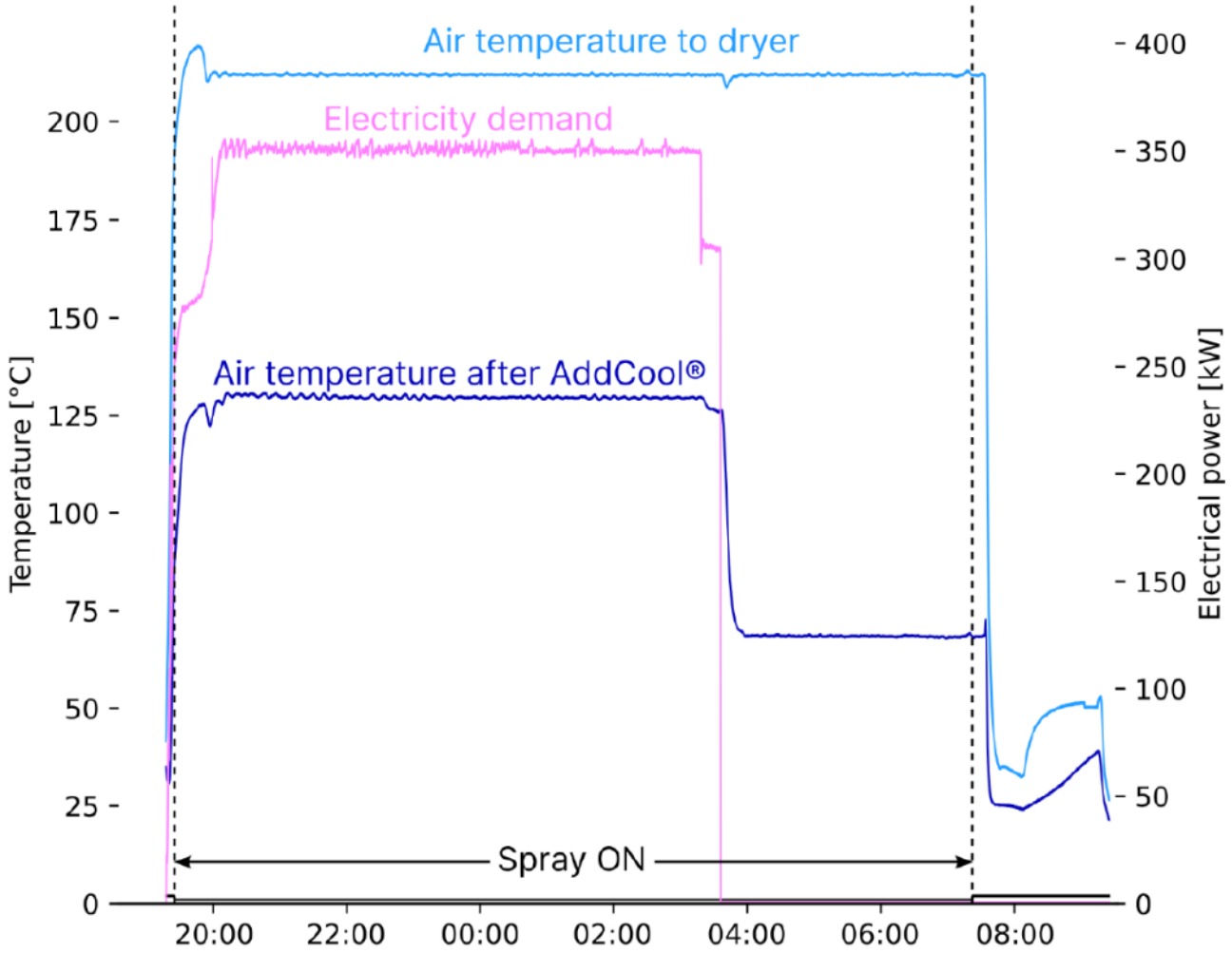
GEA AddCool® at Arla Foods AKAFA (Svenstrup facility, DK)



- Continuous monitoring since August 2024
- **Full operation in approximately 14 minutes**
- Annual reductions of approximately 1,500 t CO_2 and 670,000 Nm³ of natural gas

Source: Bergamini, R., Martinez-Maradiaga, D. (2026): Decarbonizing Industrial Spray Drying with High-Temperature Heat Pumps: Insights from the GEA AddCool® Demonstrator at Arla AKAFA, HTHP Symposium 2026, 21-22 January 2026, Copenhagen, Denmark, https://hthp-symposium.org/hthp-symposium-2026

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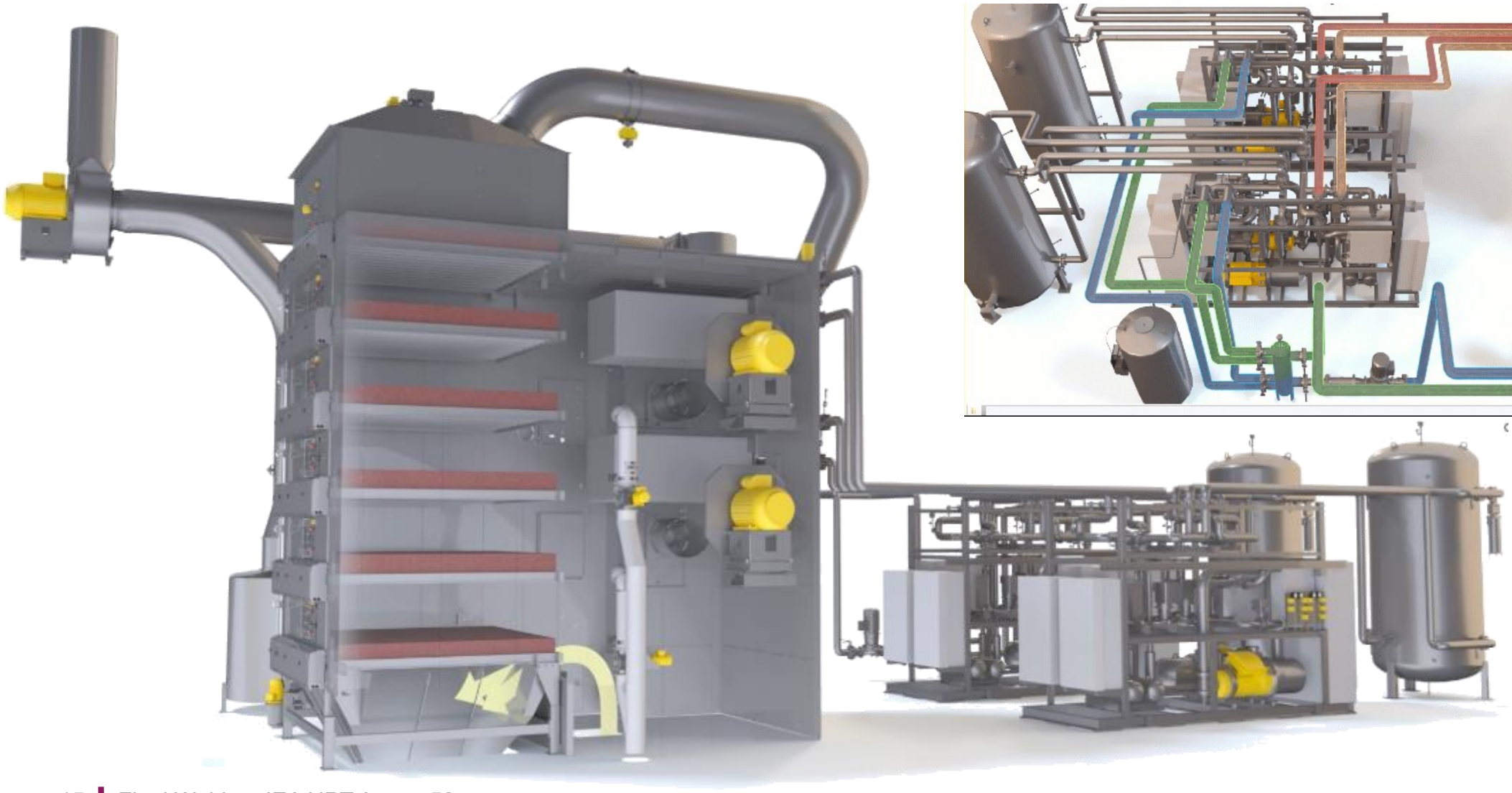
Electrified aquafeed dryer (e.g., salmon feed) at Cargill-EWOS



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Electrified aquafeed dryer (e.g., salmon feed) at Cargill-EWOS

- In partnership with **Combitherm GmbH**
- **4 x HWW 2/9583I** with **R1233zd(E)** for **120°C hot water**
- BITZER CSH2T screw compressors up to 125 °C condensation
- **COP ~ 2.8**
  - 2/3 at COP 2.4 (40 °C → 120 °C
  - 1/3 at COP 4.0 (40 °C → 90 °C)

Savings
- **3'000 tCO_2/a**
- **66% to 75% energy**

Cargill-EWOS in Bergneset (NO)

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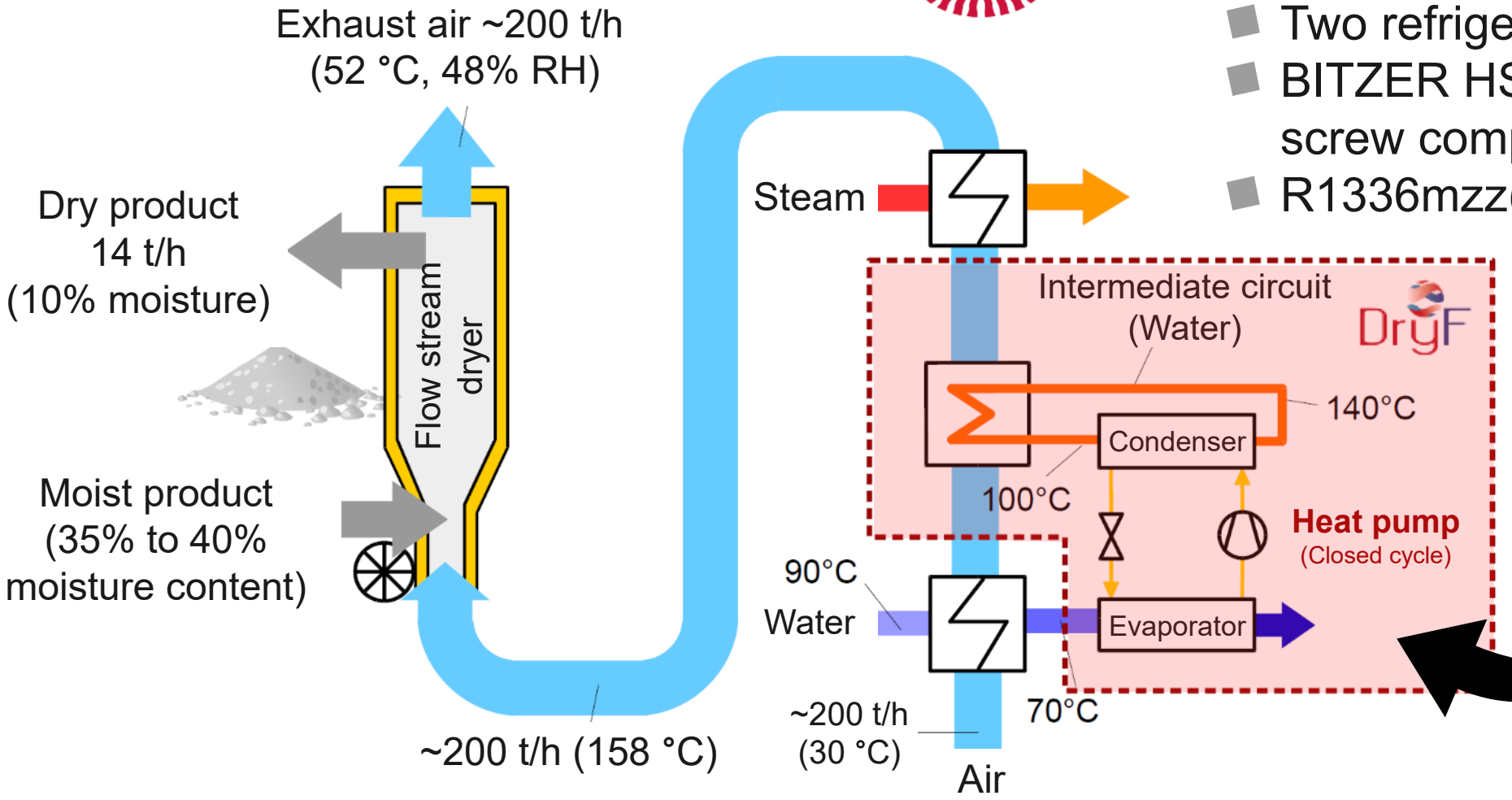
Starch drying at AGRANA



- EU Project DryFiciency
- Two refrigeration circuits
- BITZER HS Series semi-hermetic screw compressors
- R1336mzz(Z) Opteon MZ

AGRANA Stärke GmbH
in Pischelsdorf (AT)

Sources:
Wilk et al. (2021): Wärmerückgewinnung für Trocknungsprozesse mit Hochtemperatur-Wärmepumpen, WP-Tagung, BFH Burgdorf, 23. Juni 2021, https://www.fws.ch/wp-content/uploads/2022/09/Tagungsband_2021.pdf
Wilk et al. (2023): High temperature heat pumps for industry: Demonstration experience, *ICR2023, 26th International Congress of Refrigeration, August 21-25, 2023, Paris, France*, http://dx.doi.org/10.18462/iir.icr.2023.0712

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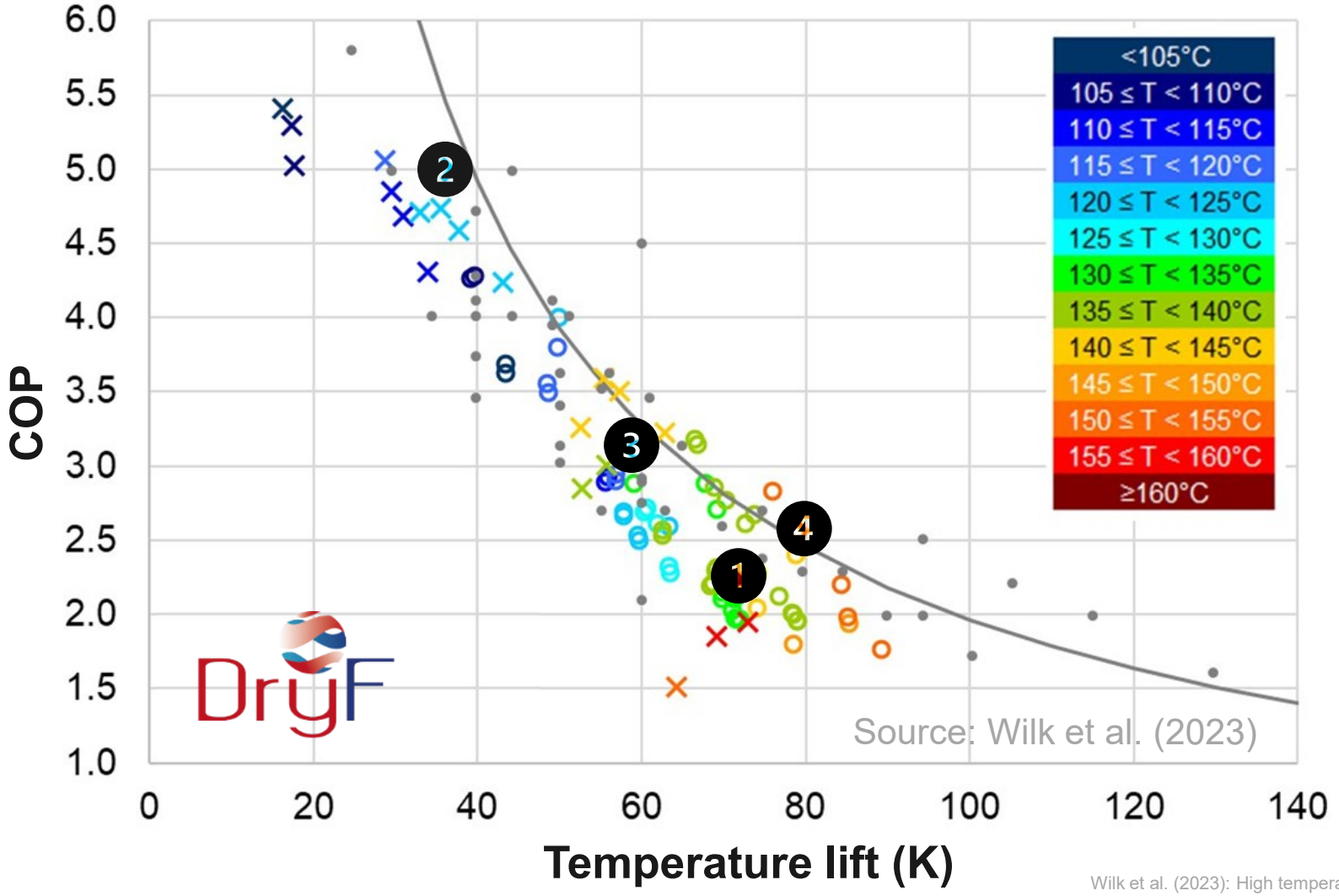
COP data from the operation of the demonstration plants



Heat sink temperature

- × Wienerberger, Bricks
- ○ AGRANA, Starch
- — 50% Carnot (T = 120 °C)
- • Other industrial heat pumps

Arpagaus, C., Bless, F., Uhlmann, M., Schiffmann, J., Bertsch, S.S.(2018): High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials, Energy, 152, 985-1010, https://doi.org/10.1016/j.energy.2018.03.166

Each data point corresponds to
> 10 hours of stationary operation

$T_{Source,out}$	$T_{Sink,out}$	DT_{Lift}	COP	COP_{Carnot}	Carnot efficiency
[°C]	[°C]	[K]	[-]	[-]	[%]
(X) Wienerberger, brick drying					
89	160	71	2.2	1 6.1	36%
84	120	36	5.0	2 10.9	46%
(O) AGRANA, starch drying					
62	121	59	3.1	3 6.7	46%
73	153	80	2.7	4 5.3	51%

Wilk et al. (2023): High temperature heat pumps for industry: Demonstration experience, *ICR2023, 26th International Congress of Refrigeration, August 21-25, 2023, Paris, France*, http://dx.doi.org/10.18462/iir.icr.2023.0712

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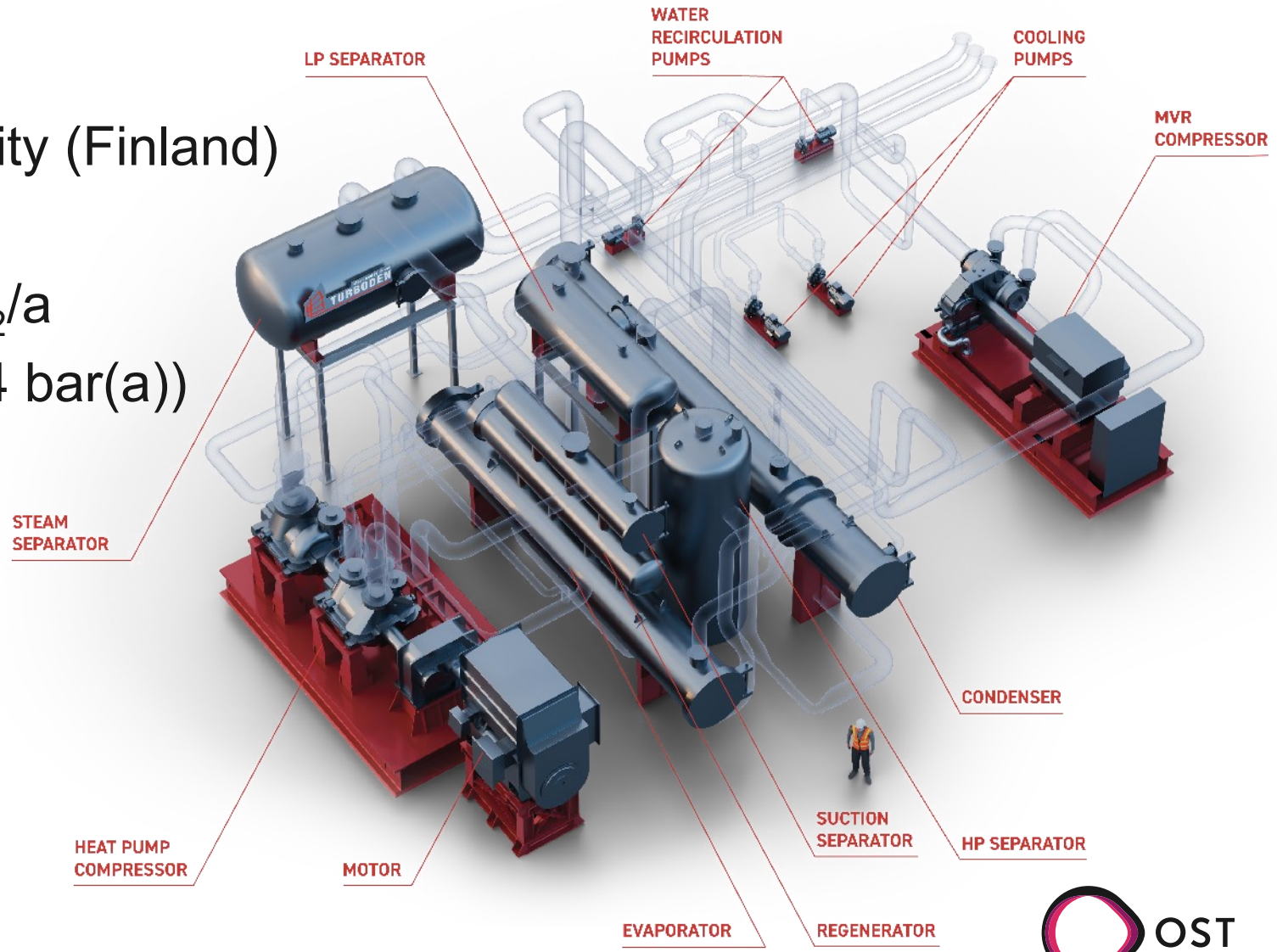
Largest Steam Heat Pump at Delfort Paper Mill

Success factors:

- Low-cost renewable electricity (Finland)
- Fully decarbonized steam
- CO_2 reduction >19’000 tCO_2/a
- 12.5 MW_{th}, 20 t/h steam (3.4 bar(a))
- 17/8 °C → 104/170 °C
- COP up to 2
- R600a (iso-butane)



delfort

clean energy ahead TURBODEN

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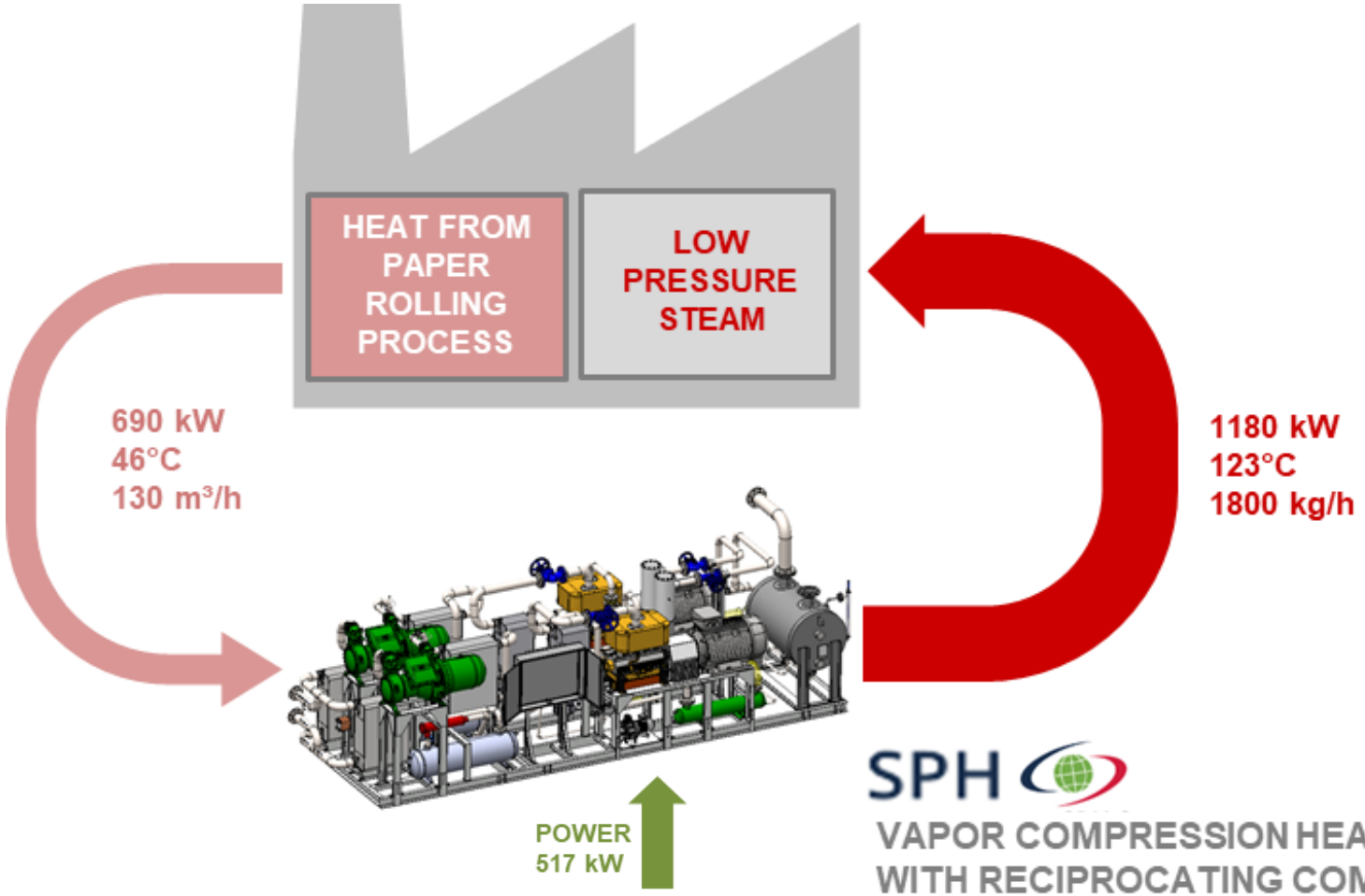
Push2Heat

EU Project – Paper industry – Felix Schoeller GmbH & Co. KG



FELIX SCHOELLER

Fraunhofer

Weissenborn, Germany

SPH

VAPOR COMPRESSION HEAT PUMP
WITH RECIPROCATING COMPRESSOR

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

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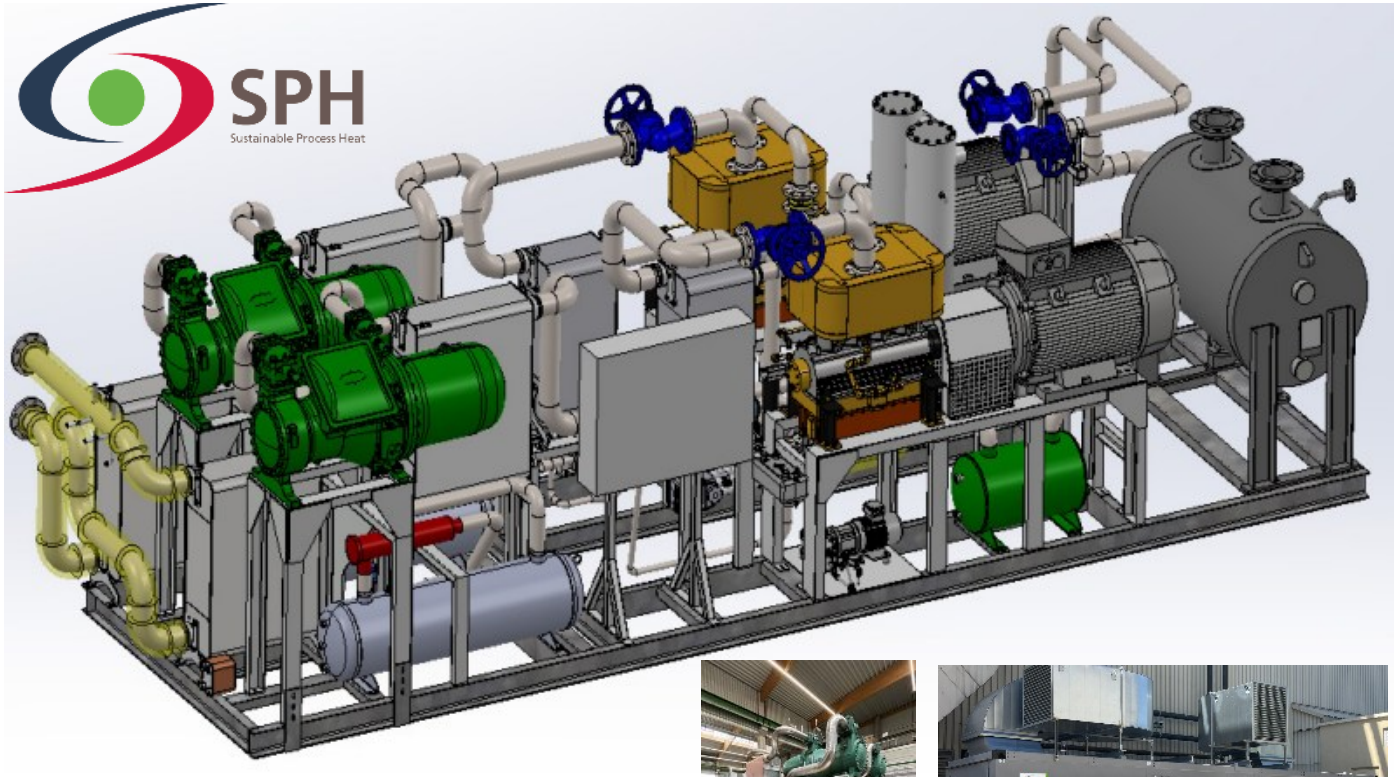

Link to Factsheet

Application	Paper drying process
Technology	HTHP cascade with 2 screw and 2 piston compressors
Heat sink	123 °C (2.85 bara) steam
Heat source	46 °C (exhaust air/water, heat recovery, 690 kW)
Heating capacity	**1.18 MW (1.8 t/h steam)**
Refrigerants	R515B & R1233zd
COP	2.3
Operating hours	4,000 h/a
Energy savings	2,400 MWh/a
CO_2 savings	230 tCO_2/a

Funded by the European Union

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Summary of Key Facts

Case Study	Product	Refrigerant	Capacity	Heat source	Heat sink	COP	Key Outcome
WEPA Greenfield	Pulp	R1234ze(E) (transcritical)	580 kW	~85°C waste heat	140 °C air	>3.5	First transcritical industrial HTHP, gas replacement
Micarna	Air-dried meat	R744 (CO_2)	80 kW HP + 330 kW recovery	Refrigeration waste heat	43 °C water	3–5	Simultaneous cooling, dehumidification and heating
Arla AKAFA	Milk powder	R744 (CO_2)	900 kW	Dryer exhaust air	Up to 120 °C	3.6	670,000 Nm^3 gas ~1,500 tCO_2/a reduction
Cargill-Ewos Bergneset	Fish feed	R1233zd(E)	3.3 MW (4 HTHP units)	Internal heat recovery	120 °C air	2.8	15 GWh/a energy savings 3,000 tCO_2/a reduction
Felleskjøpet Skansen	Feed pellets	NH_3 / H_2O (cascade)	1.5 MW	31 °C water ~65 °C exhaust air	120–130 °C steam	3.1–3.4	67% efficiency increase
Pelagia Måløy	Fish meal	NH_3 / H_2O (cascade)	4.4–4.5 MW	15–95°C waste heat	143–180 °C steam	3.5–6.5	7 t/h steam, 4,000 tCO_2/a reduction
Wienerberger I (DryFiciency)	Bricks	R1336mzz(Z)	279–400 kW	Dryer exhaust air	110–160 °C	2.2–5.0	Up to 84% energy savings, 80% CO_2 reduction
Wienerberger II (GreenBricks)	Bricks	R717 (NH_3)	3 x 1.2 MW	Dryer exhaust + kiln cooling air	90 °C	n.a.	Electrified brick production
AGRANA	Starch	R1336mzz(Z)	~500–800 kW	Process waste heat	Up to 160°C	2.7–3.1	Fossil fuel substitution in starch drying
Lindum	Dried biomass	R718 (H_2O)	500 kW	Moist drying exhaust air	125-140°C steam	4.5–8.7	Improved biomass quality and energy recovery
Delfort Paper Mill	Paper	R600a (iso-butane)	12.5 MW	Moist drying exhaust air	3.4 bar(a) steam	~2	Fully decarbonized steam >19'000 tCO_2/a reduction
Felix Schoeller	Paper	R515B, R1233zd(E)	1.18 MW	46 °C moist drying exhaust air	123 °C 2.85 bar(a)	2.3	2.4 GWh/a energy savings 230 tCO_2/a

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Key Takeaways

	Evidence from Cases
(A) Food & feed drying are the dominant industrial drying applications for heat pumps	*6 of the 11 case studies are related to food, feed, dairy, fish processing, or meat drying*
(B) HTHPs can now deliver process **steam**	*Pelagia (143–180 °C), Felleskjøpet (120–130 °C)*
(C) Natural refrigerants are becoming the preferred solution	*CO_2 (Arla, Micarna), NH_3 (GreenBricks, Pelagia)*
(D) Industrial heat pumps can cover almost the **entire drying temperature range**	*40–180°C across the cases*
(E) Large-scale is **already commercial**	*Up to 4.5 MW (7 t/h steam) & 12.5 MW (20 t/h)*
(F) Integration of heat recovery is crucial	*Cases recover waste heat from exhaust air, refrigeration systems, dryers, or process streams*

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Acknowlegements

sweet swiss energy research for the energy transition

DeCarbCH

DeCarbonisation of Cooling and Heating in Switzerland) (SI/502260) www.sweet-decarb.ch (2021-2028)

IEA HPT Project 68:
Industrial High-Temperature Heat Pumps (SI/502999) (2025-2029)

IEA HPT TCP Annex 59
Heat Pumps for Drying (SI/502606) (2023-2027)

Push2Heat
Pushing forward the market potential of heat upgrading technologies in the industrial sector

Funded by the European Union

Grant Agreement No. 101069689
www.push2heat.eu

ZIMBA
Zero-carbon Industrial heat production by aMmonia water aBsorption heAt transformer

Funded by the European Union

Grant Agreement No. 101146932
www.zimba-project.eu

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Backup

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Mit Unterstützung von energieschweiz

Continuing Education Course “Industrial heat pumps”

- **4-day course with OST certificate**
- **Module 1: General Overview**
- **Module 2: Economy and Market**
- **Module 3: Technology**
- **Module 4: Integration/Case Studies**
- **Practical Training in the Lab**
- **Excursion**
- **Online participation possible**

In German:

Day 1: September 3, 2026
Day 2: September 4, 2026
Day 3: October 1, 2026
Day 4: October 2, 2026

In English:

Day 1: April 23, 2026
Day 2: April 24, 2026
Day 3: October 1, 2026
Day 4: October 2, 2026

Target group:

- Energy managers
- Planners
- Consultants
- Energy suppliers
- Plant manufacturers
- Heat pump suppliers

Registration Link

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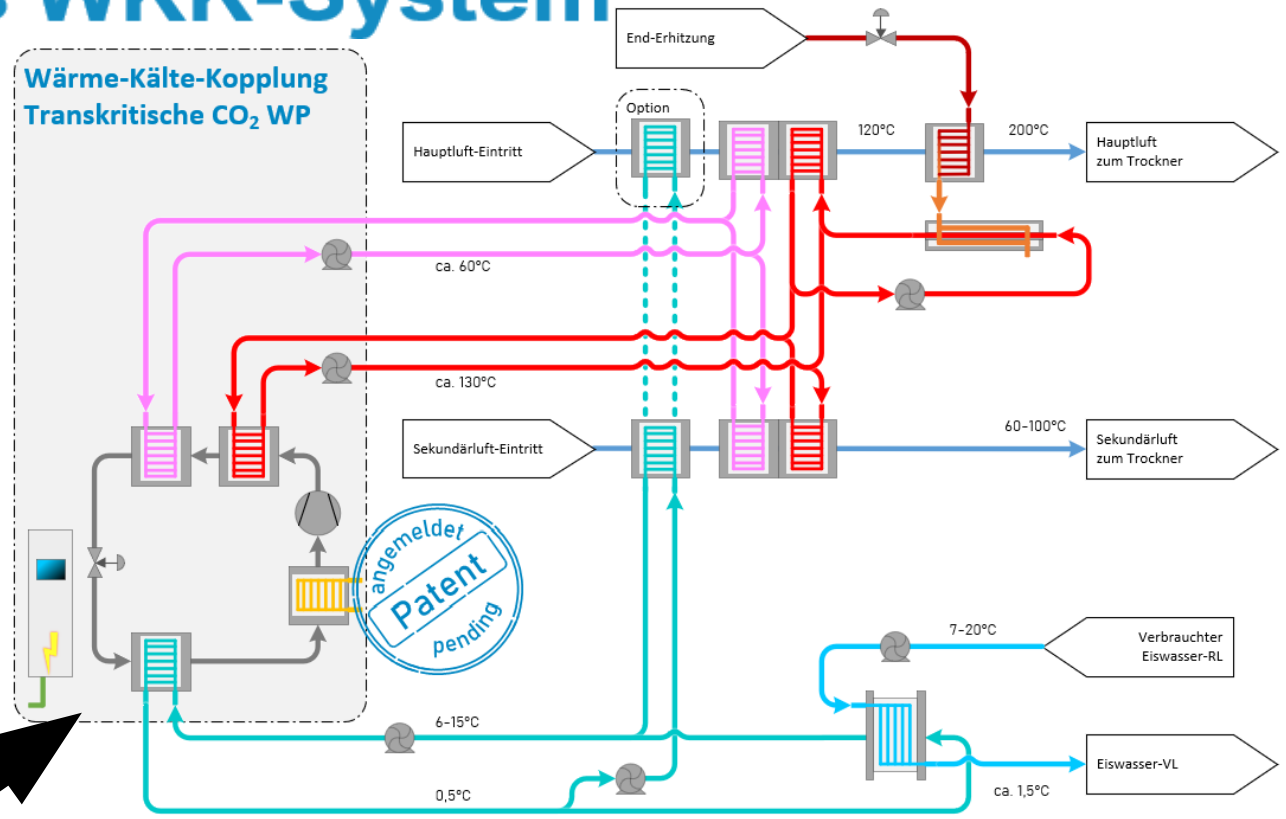
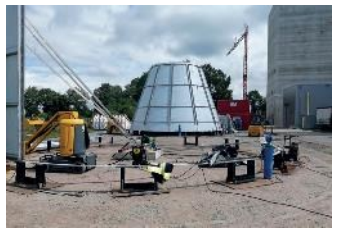
Spray dryer with Lübbers WKK-System

- Transcritical CO_2 heat pump
- Simultaneously generating:
  - Hot water up to 130 °C
  - Warm water at 60 °C
  - Ice water at approx. 0 °C
- Total COP of 5.2
- 1.9 MW_{el} power consumption
- 6.3 MW process heat
- 4.0 MW process cooling



Lübbers

7 heat pump units, each with 6 compressors in parallel



Ammerland dairy in Dringenburg (DE)

- Up to 120 °C with CO_2 HP
- 200 °C with natural gas
- 66% natural gas savings

Images courtesy of Lübbers Anlagen- und Umwelttechnik GmbH
https://www.industrie-waermepumpe.de
https://www.bulkgids.nl/wp-content/uploads/2023/10/Bulk_6-2023_Lubbers-LR.pdf

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HeatBooster HBL4 W/W at BENEO to support the drying processes of rice products (since November 2024)

HEATEN —— beneo connecting nutrition and health

4-Cylinder version of HeatBooster HBL4 W/W

Photo courtesy of Heaten Germany GmbH

- **BENEO produces plant-based ingredients for food, animal feed, and pharmaceuticals**
- **Application:** Drying of rice components
- **Heat source:** Wastewater at ~ 20 °C
- **Heating capacity:** >1 MWth with a temperature lift of approximately 100 K (4-cylinder compressor)
- **Benefits:** Reduced CO2 emissions, no cooling tower required, saves water, and simplifies infrastructure
- Scale-up **possible:**

V4 – up to 2 MW

V16 – up to 8 MW

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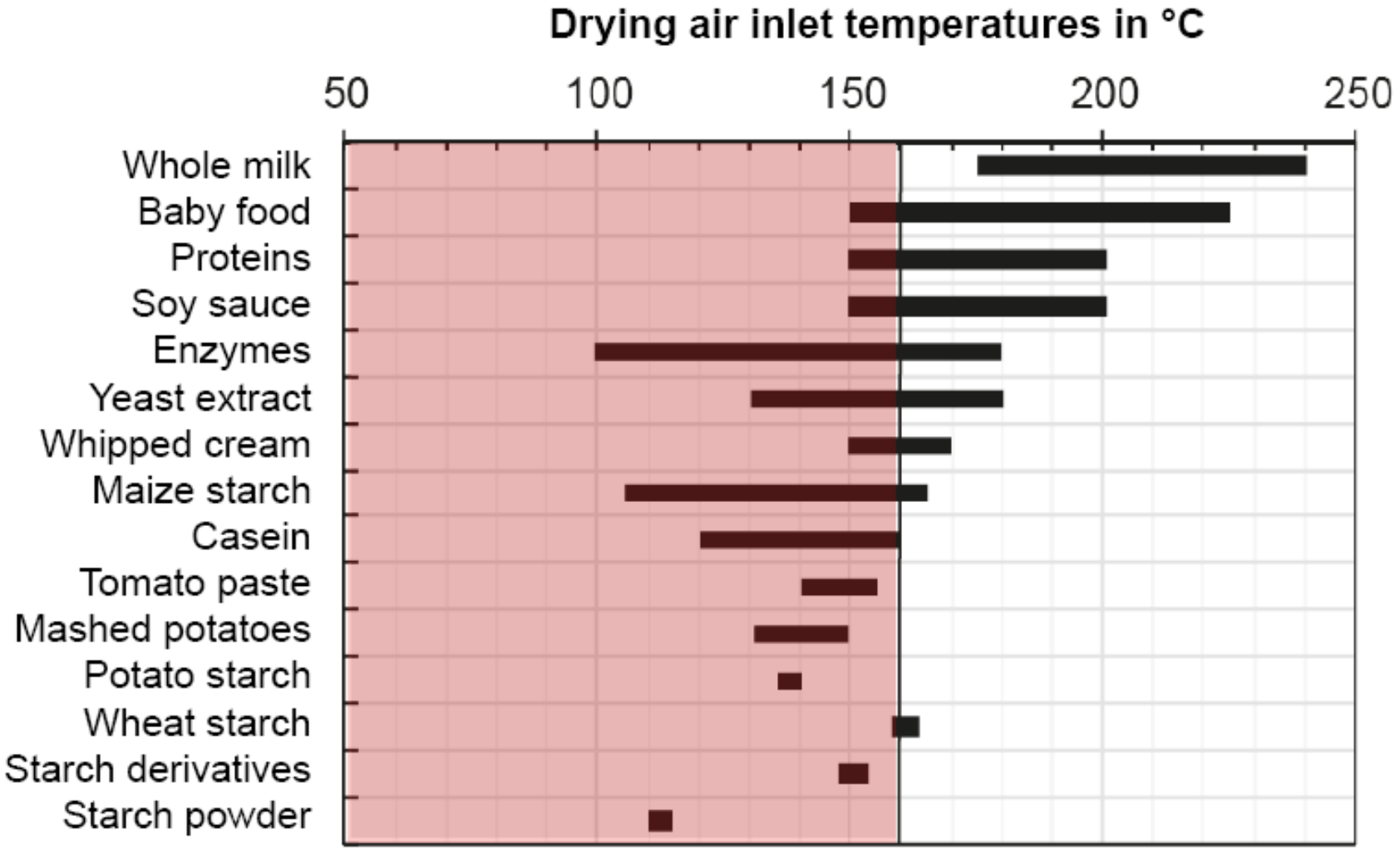
Spray drying temperatures of various foodstuffs



Own figure, Data Source: Masters, K. (2002): Spray Drying in Practice, SprayDryConsult International ApS, Denmark

The red area indicates the range that current high-temperature heat pumps (HTHPs) could cover up to 160 °C.

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