Grant Agreement No.: 723576

DryFiciency

Waste Heat Recovery in Industrial Drying Processes

H2020-EE-2016-2017-PPP
Valorisation of waste heat in industrial systems (SPIRE PPP)

Guidelines on Lessons Learned and Training materials

D6.9

This is a Deliverable of WP 6.

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INDEX

Statement of originality: This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through **appropriate** citation, quotation or both.

NOTES: For comments / suggestions / contributions to this document, contact: Coordinator of DryFiciency project at Veronika.Wilk@ait.ac.at. For more information on the project DryFiciency, link to www.dryficiency.eu

List of abbreviations

AGA	Agrana
AIT	Austrian Institute of Technology GmbH
HP	Heat pumps
HTHP	High temperature heat pumps
IHP	Industrial heat pumps
MVR	Mechanical Vapor Recompression
SCS	Scanship
WBG	Wienerberger

EXECUTIVE SUMMARY

Deliverable D6.9 *Guidelines of Lessons Learned, and Training Materials* reports on the training and knowledge sharing formats, tools and materials developed to broadly spread the results, lessons learned, and experiences gained from the projects' development and demonstration activities. The target groups to be profoundly informed and trained comprise especially energy managers, energy consultants, plant planners & engineer, but also policy makers on various levels. The formats developed and applied include five DryF online seminars, the DryFiciency training program consisting of three modules, and nine DryFiciency YouTube videos.

1 INTRODUCTION

In industrialised countries 12 to 25% of the industrial energy consumption is attributable to industrial drying. Most of this energy is based on the use of fossil fuels with no or little utilization of waste heat streams.

Industrial heat pumps (IHPs) are an efficient heat recovery technology in an early phase of market diffusion gaining increasingly attention from both policy makers and industrial end-users. Stringent environmental legislation ("European Green Deal"), a more favorable gas and electricity price ratio as well as rising prices for carbon dioxide emission certificates are the driving forces behind this development. In a recent market study by Global Market Insight, the European IHP market valued at over US$ 180 million in 2020 was estimated to register more than 6% CAGR between 2021 and 2027 to reach a projected value of US$ 300 million in 2027.[1]

In the DryFiciency project, **three novel high temperature heat pump (HTHP)** systems were developed under the lead of the coordinator AIT and **demonstrated first-time in industrial environment** with supply temperatures of **up to 160°C** thereby utilizing waste heat streams from **three drying processes** in **three industrial sectors**.

Food industry: A novel closed loop heat pump technology was implemented for **drying** of **starch** from potato, wheat, and corn at a production site of Agrana Stärke GmbH (www.agrana.com) in Pischelsdorf, Austria.

Ceramic sector: An innovative closed loop heat pump was implemented for **green brick drying** by Wienerberger AG (www.wienerberger.com), the largest brick producer worldwide, in a brick production plant in Uttendorf, Austria.

Waste management industry: An improved MVR drying technology for **sludge** respectively **biomass drying** was installed together with an innovative open loop heat pump in a land-based waste management system in Drammen, Norway.

[1] Global Market Insights, Europe Industrial Heat Pump Market, Regional Outlook 2027, April 2021 https://www.gminsights.com/industry-analysis/europe-industrial-heat-pump-market

The **main innovations** on the **closed loop heat pump systems** comprise:

Two advanced compressor technologies: modified screw compressors by Bitzer Kühlmaschinenbau GmbH (www.bitzer.de) used in the heat pump application at Agrana Stärke GmbH for starch drying and a novel piston compressor technology developed by Viking Heat Engines (www.vikingheatengines.com), which was taken over by Heaten AS (www.heaten.no) in 2020 implemented in the brick drying application at Wienerberger allowing heat supply temperatures up to 160°C.

A **unique synthetic lubricant** for high temperature applications developed by FUCHS (www.fuchs.com) for both compressors being sufficiently viscous and chemically stable with the refrigerant selected, Opteon™ MZ from Chemours, at elevated temperature levels.

Opteon™ MZ from Chemours (www.chemours.com), R1336mzz(Z), a synthetic refrigerant based on HFO (hydrofluoro-olefin), was developed for high temperature applications with heat supply temperatures of up to 160°C prior to the project. It shows a low GWP (Global Warming Potential) of 2 and a number of favourable characteristics, such as non-flammability and non-toxicity. It is also not subject to the EU legislation to control F-gases (so called F-gas regulation).[2]

The **design** of the **closed loop refrigeration cycle** was developed by AIT, who was also responsible for an appropriate process control system for the two air drying processes as well as for the monitoring of the performance of the two novel HP systems.

The **main innovation** on the **open loop heat pump system**, commonly referred to as Mechanical Vapour Re-compression (MVR), which uses water (R718) as refrigerant, includes:

Advanced, **low-cost**, **oil-free turbo-compressor technology** from ROTREX AS (www.rotrex.com) originating from the automotive sector, which was further developed to reach condensation temperatures of up to 155°C.

Advanced, MVR dryer technology improved in terms of capacity and efficiency of more than 75% while reducing energy consumption by 70%, was developed by Scanship AS (www.scanship.no)

The **design** of the **MVR system** was elaborated and implemented in close cooperation by EPCON (www.epcon.no) and SINTEF (www.sintef.no) considering the boundary conditions of the drying application at Drammen. SINTEF and ECPON were also responsible for an efficient process control and the integration of the MVR system into the drying process and the monitoring of the system performance.

[2] https://ec.europa.eu/clima/policies/f-gas/legislation_en

2 DIFFUSION OF INDUSTRIAL HEAT PUMPS

Although technologically mature when it comes to supplying heat up to 120°C for some time, IHP technology diffusion is still in an early stage with only few heat pumps (HPs) installed in the industrial sector reaching that elevated temperature level.

Recent research by AIT has shown, that there are only 20 demo respectively pilot installations known using compression HP systems at supply temperature levels of above 100°C, although the first two HTHPs were reportedly already installed in Japan in 2012 providing process heat up to 125°C and 120°C to chemical processes.

Figure 1 depicts the HTHP pilots known. Their heating capacities - displayed by the length of the bars - range from 50 kW supplying 130°C process heat (blue dot) up to a 6000 kW HTHP planned to be installed in an Italian DH-network to supply heat up to 120°C. The highest heat sink temperature - up to 180°C – is planned to be achieved by a 500kW HighLift HP developed by the Norwegian SME Olvondo to be installed at Astra Zeneca in Sweden in 2021.

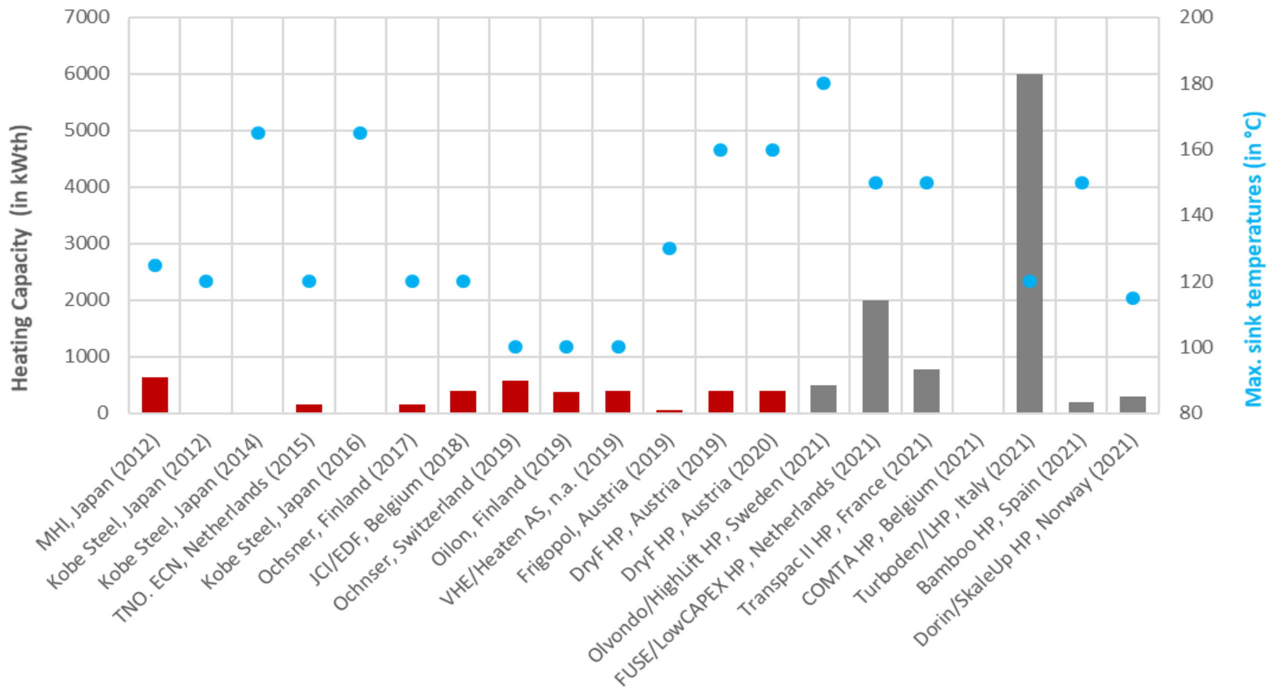

Figure 1 Overview of compression HTHP installations known worldwide (AIT research)

Besides economic reasons such as long pay back periods due to an unfavourable gas-electricity price ratio and low prices for carbon dioxide emissions, a broad market penetration of IHPs in general, and HTHPs in particular, has been hampered up to now by:

- Lack of heat pump technologies allowing supply temperatures of above 120°C.
- Low level of awareness on technical possibilities amongst industrial end-users, but also relevant intermediaries such as energy consultants, plant designers and engineers.
- Limited knowledge on the match between IHP and process demands.
- Limited knowledge on integration of IHP in industrial heat processes.
- Lack of data on heat consumption especially in manufacturing companies not belonging to the energy-intensive industries.

- Lack of trust on reliability and security of the technology due to low numbers of pilot & demo plants, and finally
- Lack of training and events supporting the spread of knowledge on IHPs in general, and HTHPs in particular.

These **limiting factors** already collected in other R&I projects[3] also **reflect the experience gathered by the DryFiciency consortium** in the framework of interviews and WS held with industry associations and the projects' external experts, surveys conducted online or during webinars/the final conference, but also in multiple conversations with interested stakeholders addressing consortium members either at events or by addressing the project coordinator by email dryficiency@ait.ac.at.

Therefore, a number of knowledge-sharing and training activities developed, were not only focussed on the DryFiciency project and its heat pump demonstrators but beyond, to promote broad market diffusion of IHP technology. They are reported in section 4.

3 LESSONS LEARNED

The challenges encountered and to be dealt with during project execution were manifold. In the following, the **lessons learned** are described **in a more generalized way**.

- The **choice of components and materials** as e.g., safety valves or various compressor parts, which are compatible with the media used (refrigerant, steam) and which can withstand elevated operation temperature levels of above 150°C, is crucial and a challenging task. It is important to foresee enough time for profound analysis and testing.
- The **robustness of components & equipment** to be used in industrial environment has to be considered already in an early development stage. Novel components, such as a e.g., a compressor, might work nicely in lab environment, however there are a number of challenges when bringing it into the "real" world including dust, wet particles, etc. which are sometimes difficult to simulate to the full extent in lab environment.
- The **design** of the **heat pump** has to be chosen with great care. It has to be considered, that improvement work will most likely become necessary at the pilot installation. Therefore, all critical components prone to damages in such novel high temperature applications, such as e.g., compressors, need to be positioned in a way that they can be replaced with the lowest possible effort involved without compromising on the performance of the heat pump system and too much on the sizing of the heat pump installation as size matters especially when used for retrofitting.
- The **techno-economic "sweet spot"** between the heat pump and the sizing of the dryer has to be identified first. As far as the heat pump is concerned, higher temperature lifts can be achieved by adding more compression stages, which reduces however the efficiency of the heat pump system. On the other hand, a certain temperature lift is required on the side of the dryer, to get the system running and achieve the gains in efficiency and sizing required.
- The **estimation of costs of pilot installations** is a challenging task and might request more funding than anticipated. Especially, the costs for possible repair and adjustment work are

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[3] E.g., IEA HPT 48 Industrial Heat Pumps, Second Phase (website); IEA HPP Annex 35 (website)

easily to be underestimated. Therefore, strong commitment of the industrial partners, especially the demo-partners, is required and has to be sought prior to project start.

- In a globalized world, **lead times for components & equipment** vary very much, and can become extremely long in case of a pandemic or any other disturbances in the international transport business. Therefore, their supply has to be secured as early as possible in the project.
- The **involvement of small, innovative, component** or **equipment suppliers** might put an innovation project at risk due to their limited staff resources and often also their financial proneness. Therefore, a “back-up solution” with a larger component / equipment provider is preferable.
- The **involvement of external experts** into an innovation project is of great value, as they bring in constructive advice as well as active promotion and references.

More details on **technical experiences** made and **lessons learned** in context with the **development work on component** and **system level** are published in two other deliverables, in D4.5 *“Interim report on the heat pump technologies developed”*, and D5.4 *“Final report on the heat pump technologies developed*[4]*”*, which will be published here.

[4] To be published on the DryFiciency website here.

4 TRAINING AND KNOWLEDGE SHARING ON LESSONS LEARNED

Considering the limiting factors for broad market introduction of IHPs the DryFiciency consortium designed various **training and knowledge sharing formats & tools** to broadly spread the results, and lessons learned in the projects' development and implementation activities to all target groups concerned keeping in-mind however at all times the economic interests of all project partners concerned, who invested also substantial own funds in this project, which proved challenging in various aspects.

These **knowledge transfer & training measures** included:

- DryF online seminar series conducted from 30.09.2020 to 21.04.2021
- DryF Final conference on 06.07.2021
- DryF training program (3 modules); online trainings conducted: 15.07.2021 to 19.08.2021

4.1 Online seminars and final conference

4.1.1 Main Goals

- To increase competence on HTHPs and overcome especially non-technical obstacles for its application such as e.g., lack of knowledge on technologies available and their technical limits, lack of know-how on successful demo installations, etc.
- To prepare for and facilitate rapid and widespread uptake of HTHP technologies post project by broadly informing on the project, its activities, and results.

4.1.2 Main target groups addressed

- Industrial end-users, policy makers, energy mangers & consultants
- Plant engineers & Heat pump manufacturers

4.1.3 Online Seminars

4.1.3.1 Online seminars for industrial end-users, policy makers, energy managers & consultants

This online seminar aimed at showing best practice examples from both state-of-the art IHPs used in the food & beverage industry as well as in the animal health products facility with supply temperatures of up to 90°C as well as current research showcasing HT-HP research projects from the dutch RTO TNO and first operational experiences from the DryF demonstrator for starch drying at Agrana.
The presentations are available here.

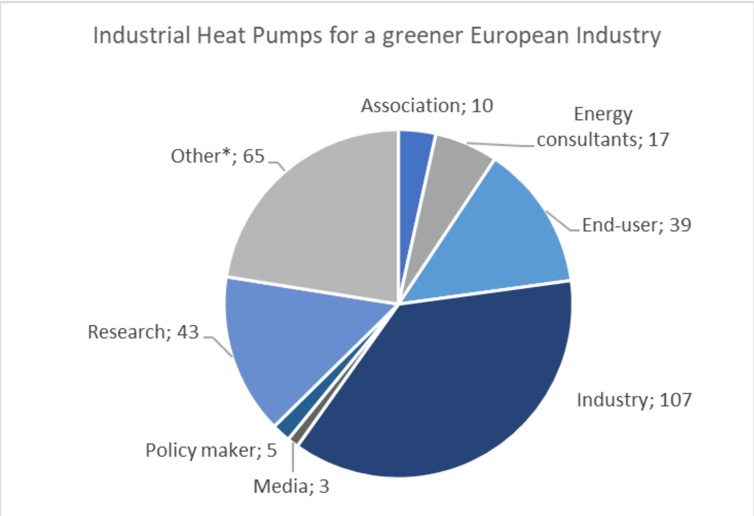
This online seminar aimed to stress the potential contribution of large HP technologies to the decarbonization of Europe's manufacturing sector. EEAB member Silvia Madeddu from PIK informed on the status of electricification of industry. DryF partners AIT and SINTEF informed a.o. on HP installations, challenges in development and integration as well as the potential impact of HT-HPs. The presentations are attached in section 5.3.

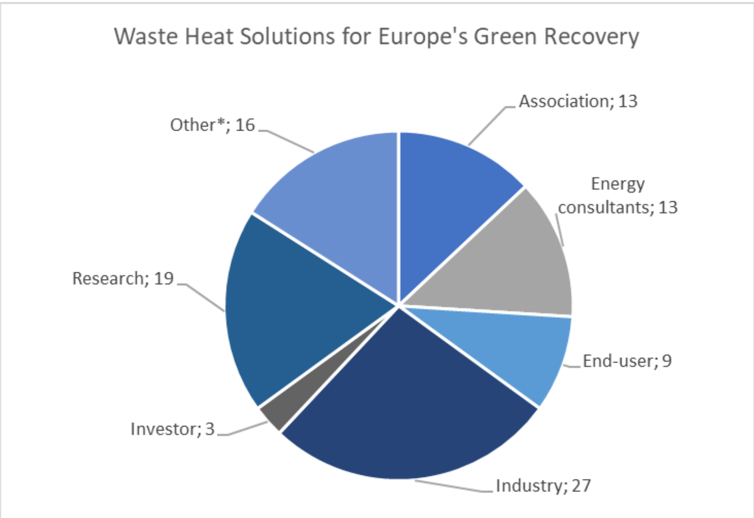
The recorded online seminar is available here.

This online seminar aimed at showcasing four projects dealing with energy efficiency including links to the industry either as supplier of waste heat or its user: energy cooperation in industry (R-ACS), recovery and re-use of urbane excess heat (ReUseHeat), re-use of low-temperature renewable energy sources in urban DHC-networks (REWARDHeat), and finally DryFiciency. The presentations are attached in section 5.3

The recorded online seminar is available here.

In total, **388 stakeholders participated** in the two seminars conducted in 2021. The following figures show an analysis of the audience in terms of professional background. “Industry” comprises heat pump manufacturers and components thereof as well as other technology suppliers. “Other” includes participants who identified themselves as “self-employed”.





4.1.3.2 *Online seminars for heat pump manufacturers & plant engineers*

The recorded online seminar is available here.

This seminar aimed at informing HP manufactures and plant engineers on the latest developments on component level, covering two compressor technologies, a novel lubrication oil and a new low-GWP refrigerant. DryF partners AIT, Fuchs, Chemours, Bitzer, Rotrex and Heaten reported on the development and adaption of their components for upgrading idle waste heat streams to process heat streams at temperature levels of up to 160°C. The presentations are attached in section 5.3

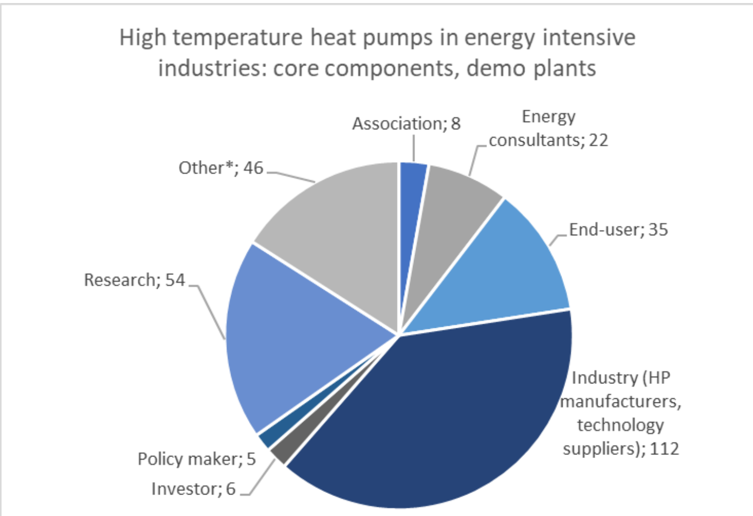
The recorded online seminar is available here.

This seminar aimed at informing HP manufactures and plant engineers on the latest developments and results of the three DryF demonstrators on system level. Demo partners Agrana, Wienerberger, and Scanship as well as the scientific partners AIT and SINTEF highlighting some of the projects' achievements

The presentations are attached in section 5.3

Besides, Veronika Wilk (AIT) regularly presented the projects' progress in the EHPA Working group on "Commercial Heat Pumps" and led – as did Michael Bantle (SINTEF) – individual talks with heat pump manufactures and plant engineers to discuss the uptake of the projects' results.

In total, **288 stakeholders participated** in the online seminars set-up especially for heat pump manufacturers & plant engineers in 04/2021. The following figure shows the professional background of the participants. As evident, the events were also well received in the research community[5].

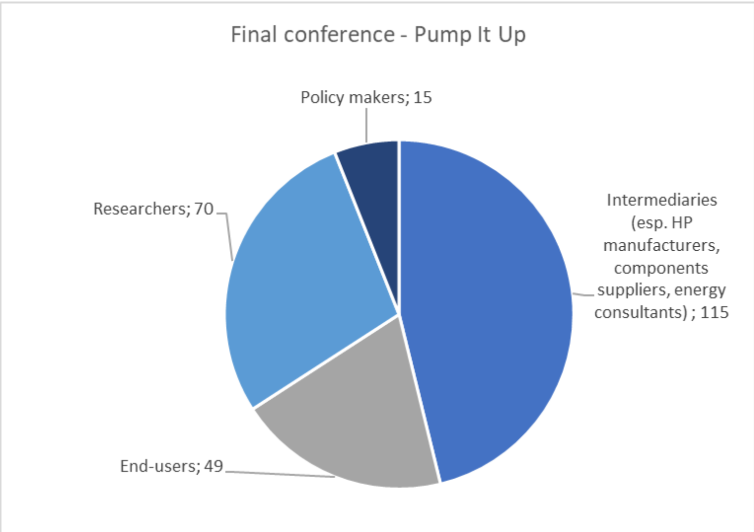


[5] *Other includes participants who identified themselves as "self-employed".

4.1.4 Final conference

This online conference showcased the results from DryFiciency from lab to reality. The conference was opened with an input from IEA show-casing the importance of IHPs as future heating technology, DryF partners AIT, SINTEF and EPCON presented the work conducted, challenges encountered in development and operation of the novel heat pump solutions, the main results and impact achieved as well future steps required to fully commercialise the systems.

In total, **245 stakeholders** from +200 companies/organisations based in 32 countries participated in the projects online conference, which set up as a hybrid event. The following figures shows their professional background.



The recorded conference is available [here](). The presentations are attached in section 5.3

4.2 DryF training program on IHPs

4.2.1 Main goals

- To prepare for and facilitate rapid and widespread uptake of IHP technologies post project with focus on closed loop DryF^{TM} HPs.
- To increase awareness, competence and know-how of various target groups thereby overcoming non-technical obstacles such as lack of knowledge on technologies available and their technical limits, know-how on successful demo installations, etc.
- To secure high quality planning, engineering, integration, and maintenance work required for further promoting the use of IHPs especially at elevated temperature levels.

4.2.2 Target group

The training program developed in the DryFiciency project addresses all relevant professionals along the value chain. However, the main target group comprises:

- Energy managers employed at potential industrial end-users, but also freelancers.
- Plant engineers/planners and constructors as well as heat pump manufacturers.
- Process engineers.

Besides, the following groups are addressed:

- Staff of energy agencies, personnel of public funding agencies, energy service contractors, or energy consultants dealing with energy and environmental topics.
- Students at the technical universities such as e.g., Vienna University of Technology, Institute for Energy Systems and Thermodynamics.

4.2.3 Training program

The training program developed by AIT consists of three modules, which are briefly described in terms of target group, requirements, duration, content, learning objectives, skills acquired, and methods to be used in the following.

4.2.3.1 Module 1: Introduction to IHPs

Target group	This introductory module primarily targets all (future) professionals dealing with industrial energy efficiency and environmental topics, who wish to gain an overview of the potential and benefits of industrial heat pumps (IHPs) with a focus on high temperature heat pumps (HTHPs). This includes non-technicians such as staff of energy agencies and public funding agencies, energy service contractors, and consultants, but also future technical professionals (students) and all technicians addressed by the other two modules.
Requirements	None
Duration	2 hours
Content	• Current industrial energy demand and energy sources used. • Industrial energy and environmental targets. • Application potential of IHPs and especially HT-HPs (sectors, processes, barriers/obstacles)

	• Best practices examples of IHPs and ongoing research activities on HT-HPs focusing on DryFiciency. • Costs and benefits of IHPs and HT-HPs.
Learning objectives	• Know relevant energy and environmental targets. • Know potential applications for IHPs, especially HT-HPs and their boundary conditions. • Know ongoing research activities & fields • Know best practice and demo examples of IHPs and HT-HPs. • Know environmental impact of IHPs and HT-HPs. • Know CAPEX and OPEX of IHPs.
Skills acquired	No special technical skills but a good overview of IHPs, the technologies available, their potential and applications focusing especially on HT-HPs.
Methods used	• Web-based training in German and English • Lecture in classroom (on demand) • Videos of DryFiciency demo sites • Factory tour to the Agrana use case (on demand)
Certificate	Certificate of Participation
Training material	The training material developed is attached in section 5.2 in both English and German.

4.2.3.2 Module 2: Components and Specifications of IHPs

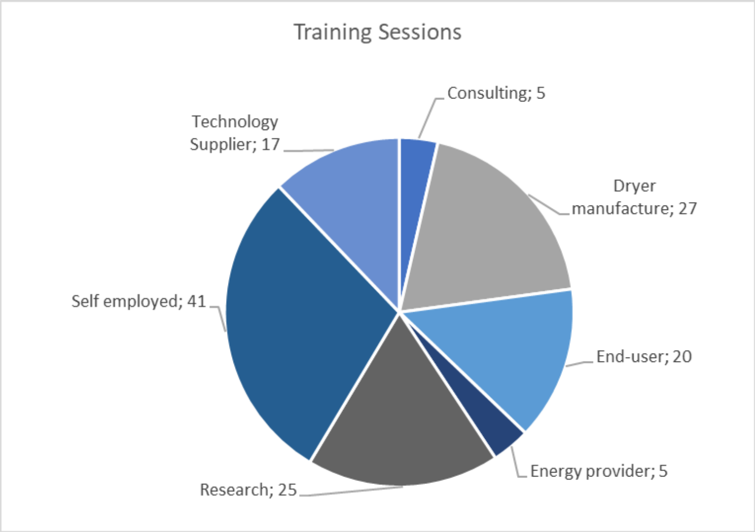
Target group	This module targets professionals dealing with planning, designing or operating industrial energy efficiency and heat recovery technologies, who wish to extend their knowledge and skills to IHPs and especially HT-HPs and their use in industrial processes focusing on drying and dehydration. This includes process engineers, energy managers and industrial plant planners/constructors.
Requirements	• Knowledge in thermal energy technologies • Knowledge in relevant industrial processes • Knowledge on refrigeration technologies and working principles
Duration	4 hours
Content	• Industries & processes suitable for IHPs • Components for IHPs with focus on HTHPs • Refrigerants and refrigeration oils to be used in high temperature heat recovery applications. • Properties of IHPs • Planning of integration and dimensioning of IHPs with focus on high temperatures and drying / dehydration processes. • Best practice examples and demo plants
Learning objectives	• Know requirements for components, lubricants and working fluids used in IHPs at elevated temperature levels. • Know requirements for the application of IHPs, esp. HTHPs. • Know processes suitable for HTHPs. • Know relevant regulatory requirements and standards. • Be acquainted with planning principles for IHP.
Skills acquired	• To be able to calculate the efficiency of IHP (COP, SCOP…)

	• To be able to calculate the required power and temperatures of IPHs with respect to the properties of the industrial processes concerned.
Methods used	• Web-based training in German and English • Lecture in classroom (on demand) • Videos of DryFiciency demo sites • Factory tour to the Agrana use case (on demand)
Certificate	Certificate of Participation
Training material	Is not publicly available.

4.2.3.3 Module 3: Installation, Commissioning, Operation and Maintenance of IHPs

Target group	This module targets professionals dealing with integration, commissioning and maintenance of industrial energy efficiency and heat recovery technologies, who wish to extend their knowledge and skills to IHPs and especially HT-HPs. This includes especially process engineers, energy managers, heat pump integrators.
Requirements	• Knowledge in thermal energy technologies • Knowledge in relevant industrial processes • Knowledge on refrigeration technologies and working principles
Duration	2 hours + ½ day each for factory tour to demo-sites
Content	• Personnel requirements (legal issues, required skills) • Safety and security requirements • Specifics of installing, commissioning and operating IHPs • Typical failures of IHPs • Specifics of maintaining IHPs
Learning objectives	• Know legal issues in regard to integration, commissioning and maintenance of IHPs with focus on HTHPs. • Know relevant safety and security regulations. • Know required maintenance intervals and indications for malfunctioning of IHPs.
Skills acquired	• To be able to integrate IHPs analogously to conventional heating units with respect to their specific properties. • To be able to commission IHPs or to support the commissioning by the plant constructor. • To be able to perform respectively coordinate maintenance works of heat pumps on-site.
Methods used	• Web-based training in German and English • Lecture in classroom (on demand) • Videos of DryFiciency demo sites • Factory tour to the Agrana use case (on demand)
Certificate	Yes. Certificate of Participation.
Training material	Is not publicly available.

In total, **140 stakeholders** from **+40 companies/organisations** participated in the first training sessions. Each of the modules was offered twice. Module 1 on 15.7. and 05.08.; Module 2 on 22.07. and 12.08. and Module 3 on 29.07. and 19.08.2021. They were planned to be hold in a classroom setting to allow for more personal interactions but were finally conducted via MS Teams due to COVID-19. The following chart shows the professional background of the participants. Nearly 50% of the trainees participated in all three Modules; about one third did two, and only one fifth took part in one training Module only



In future, the trainings will be offered by AIT in both formats, with classroom lectures to be conducted on demand. The trainings will be offered in both German and English, depending on the demand.

In a next step, the training material (PowerPoint slides) developed will be updated with the input received by the participants of the first training sessions and will then be integrated into AITs certified training program for intermediaries, which will be continuously further developed by integrating the results and lessons learned from other IHP demo-projects as e.g., the H2020 BAMBOO project, where a HTHP is to be demonstrated in a steel plant, or the nationally funded NEFI project Leap, where innovative integration measures based on HP systems for low-pressure steam supply are being developed and demonstrated two industrial processes.

The future training sessions will also include exams and – besides a certificate of participation – corresponding DryF certificates for process engineers, energy managers and industrial plant planners/constructors. DryF shall be established as quality label for both, efficient HTHPs and qualified installation and operation.

The training schedule for 2022 is to be found here soon.

5 MATERIALS FOR CAPACITY BUILDING

In the following, the tools and materials developed for capacity building are compiled.

5.1 YouTube Videos

The video on the project results is available [here](#)

The video on the demo plant for brick drying is available [here](#)

The video on the Demo plant for sludge drying is available [here](#)

The video on the demo plant for starch drying is available [here](#)

The video on lessons learned in the open loop HP development is available [here](#)

The video on the major challenges in commercialising the open loop HP is available [here](#)

The video showing the view of client of the open loop HP is available here

The video on future R&D required on the open loop HP is available here

5.2 DryF Training program – Module 1

In the following, the training materials for Module 1 is provided in both English and German.

Module 1

High Temperature Heat Pumps for Industrial Use

AIT
Dr. Michael Lauermann

Grant Agreement No 723576 - Energy Efficiency
Innovation Action H2020-EE-2016-2017
www.dry-f.eu

1

Agenda

- Energy & environmental targets for industry
- Market for high temperature heat pumps
- Barriers & Opportunities
- Applications and their potential
- State of the art high temperature heat pumps
- Ongoing research activities with focus on DryFiciency project

Grant Agreement No 723576 – Energy Efficiency

2

Introduction AIT

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3

BMK

1.400 employees

Austria's largest RTO

8 Centers

Applied Research

Infrastructure Systems

System Competence

Federation of Austrian Industries (through VFFI)

Next Generation Solutions

4 Subsidiary Enterprises

LKR, NES, SL, Profactor 51%

167 m EUR total revenue

Tomorrow Today

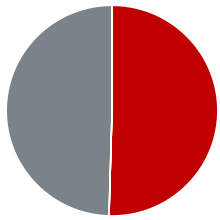
as of YE 2018

Grant Agreement No 723576 – Energy Efficiency

4

AIT Austrian Institute of Technology

OWNERSHIP STRUCTURE



50.46 %

REPUBLIC OF AUSTRIA
Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology

49.54 %

FEDERATION OF AUSTRIAN INDUSTRIES
(through VFFI)

1.400

EMPLOYEES

167 m EUR

TOTAL REVENUES
as of YE 2019

90,4 m EUR	Contract research revenues (incl. grants)
49,8 m EUR	BMK funding
22,8 m EUR	Other operating income, incl. Nuclear Engineering Seibersdorf
4,0 m EUR	Profactor (51% of 7,9 m EUR)

Grant Agreement No 723576 – Energy Efficiency

AIT Austrian Institute of Technology GmbH

AIT Austrian Institute of Technology

Seibersdorf Labor GmbH

Nuclear Engineering Seibersdorf GmbH

Energy	**Health & Bioresources**	**Digital Safety & Security**	**Vision, Automation & Control**
Mobility Systems	**Low-Emission Transport**	**Technology Experience**	**Innovation Systems & Policy**

Grant Agreement No 723576 – Energy Efficiency

Focus of the centers

Energy	Health & Bioresources	Digital Safety & Security	Vision, Automation & Control
• Electric Energy Systems • Integrated Energy Systems • Photovoltaic Systems • Digital Resilient Cities • Sustainable Thermal Energy Systems	• Biomedical Systems • Bioresources • Digital Health Information Systems • Molecular Diagnostics	• Security & Communication Technologies • Sensing & Vision Solutions • Data Science & Artificial Intelligence • Cooperative Digital Technologies	• Assistive & Autonomous Systems • Complex Dynamical Systems • High-Performance Vision Systems

Mobility Systems	Low-Emission Transport	Technology Experience	Innovation Systems & Policy
• Dynamic Transportation Systems • Transportation Infrastructure Technologies	• Electric Drive Technologies • Light Metals Technologies Ranshofen	• Experience Contexts and Tools • Experience Business Transformations	• Digital Innovation • Foresight & Institutional Change • Policies for Change

Grant Agreement No 723576 – Energy Efficiency

Climate & Energy

Trends & Targets

Grant Agreement No 723576 – Energy Efficiency

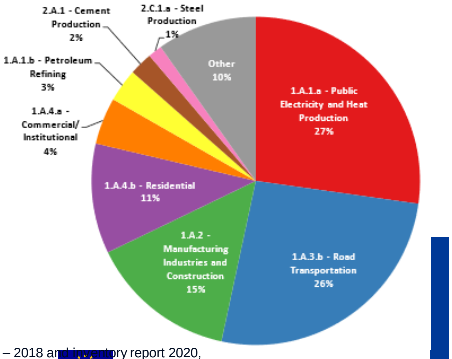
Climate & Energy
Facts

"Business as usual will lead to a global warming of about 4° C until the year 2100" (UN IPCC)

Industry in EU-27 accounts for:

- **25%** on **final energy consumption.**
- **15%** of **GHG emissions** originating from fossil fuel consumption for energy generation.

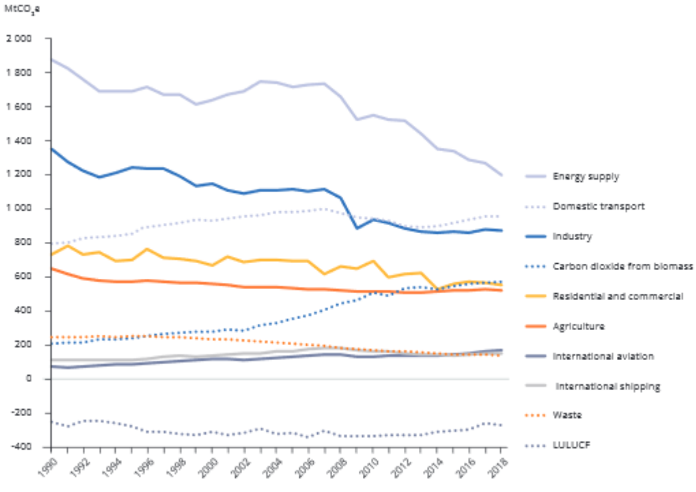
Sectoral GHG emissions in EU-28 by IPCC sector (2018)



Sources: IPCC (2020) Annual European Union greenhouse gas inventory 1990 – 2018 and inventory report 2020, EEA https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2020/ghg-dashboard-01

Grant Agreement No 723576 – Energy Efficiency

Climate & Energy
Development of EU GHG emissions by sector (1990-2018)



Source: EEA, Trends and drivers of EU greenhouse gas emissions, EEA Report, No. 03/2020

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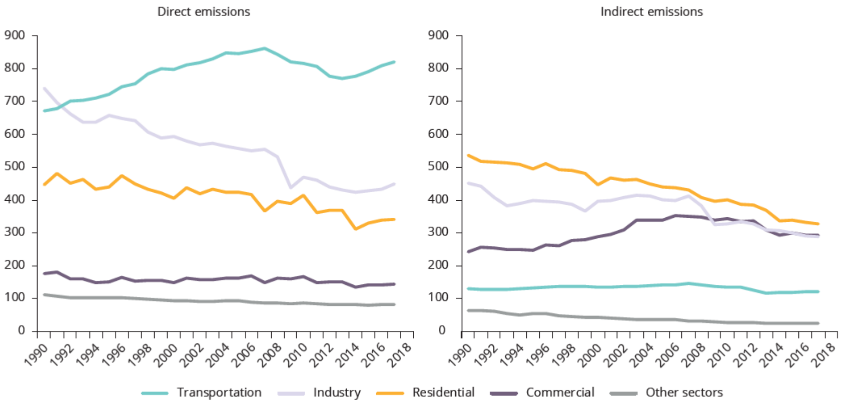
Energy-related GHG emissions by sector (1990-2017)



Source: EEA, Trends and drivers of EU greenhouse gas emissions, EEA Report, No. 03/2020

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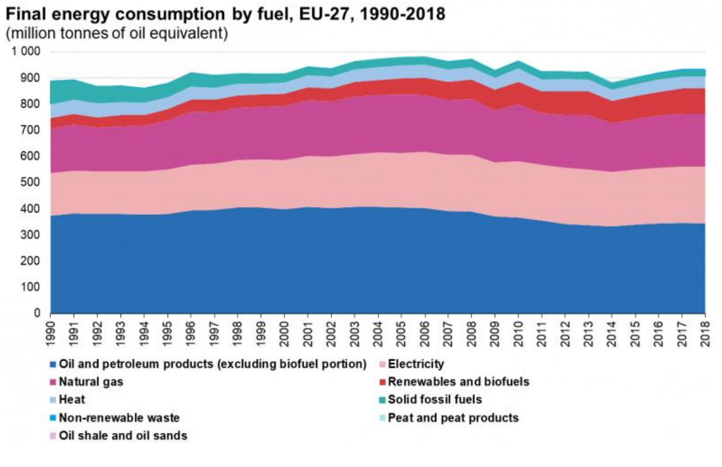
Development of EU-27 final energy consumption by fuel (2000-2018)



Source: Eurostat, Statistics Explained, Link

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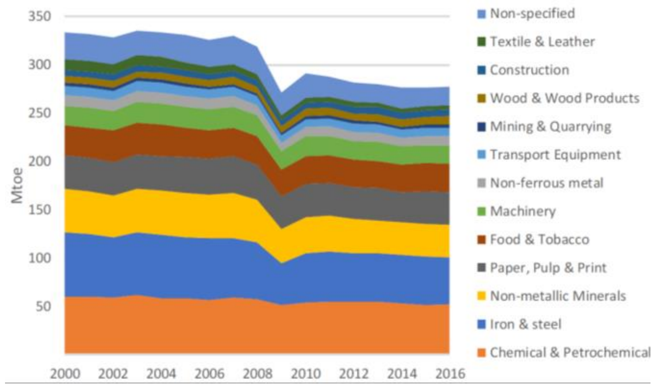
Development of EU final energy consumption by industry sectors (2000-2016)



Since 2007, **10 out of 13 industrial sectors** experienced a decrease in final energy consumption

Source: Eurostat Energy Balance May 2018, http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb

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Targets

- Cut in **GHG emissions** (comp. to 1990 levels) by **40%**
- At least **32%** share of **renewable energy** consumption (upward revisions clause for 2023)
- **Improvement** in **energy efficiency** at EU level of at least **32.5%**
- Support completion of internal energy market by achieving existing electricity interconnection target of 10% by 2020 (view to reaching 15% by 2030)

Source: IPCC (2018) http://www.ipcc.ch/report/sr15/

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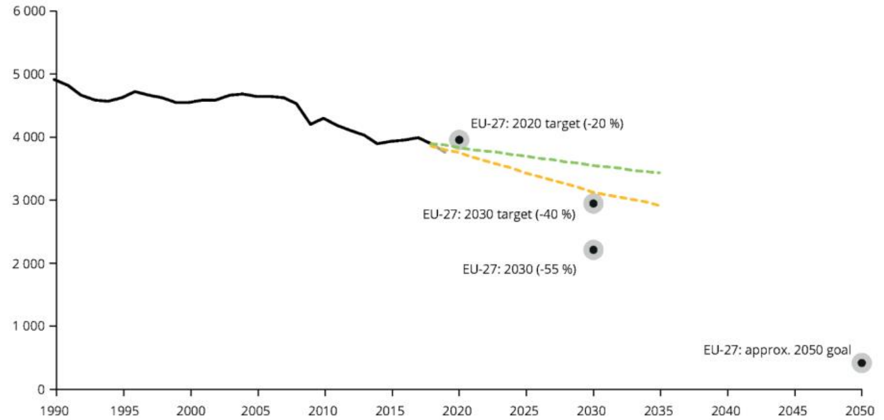
Climate & Energy

GHG emission targets, trends & projections



Source: EEA, Total greenhouse gas emission trends and projections in Europe, https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-7/assessment

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19

Climate & Energy

Potential contribution of Industrial Heat Pumps to EU targets

EU Target 32,5% energy efficiency goal for 2030

END ENERGY EFFICIENCY	7-18%
PRIMARY ENERGY EFFICIENCY	2-6%

Waste heat recovery means a more efficient use of energy in industries.

EU Target 40% CO_2 emission reduction for 2030

ALL SECTORS	3-7%
MANUFACTURING SECTOR	14-35%

Waste heat recovery means significant contributions from the industry.

Potential contribution of the DryFiciency project

Assumptions: 50% of all drying processes in EU are equipped with DryF HP (average COP: 3; heat source: 70, Heat sink: 140, replacement of natural gas burners with thermal eff. of 95%

Source: DryFiciency

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20

Market for High Temperature Heat Pumps

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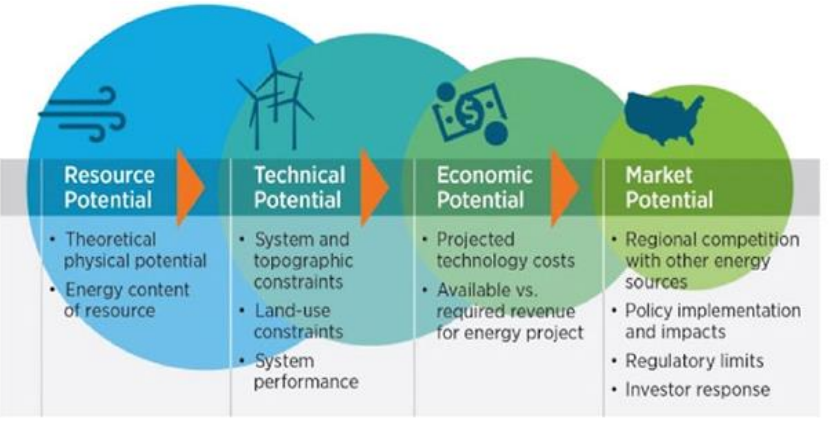
22

Market potential



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23

Economic Feasibility of HTHPs

Advantageous conditions for IHPs include:

- High ratio of gas to electricity price
- High CO_2 prices (depending on carbon intensity of electricity)

Boundary conditions for the calculation of the economic market potential

	Unit	In 2020 S1: "*Baseline*"	In 2025 S2: "*Future*"
CAPEX Reference technology (gas boiler)	€/kW	100	100
CAPEX Integration of reference technology	€/kW	100	100
CAPEX Heat pump	€/kW	500	375*
CAPEX Integration heat pump	€/kW	500	375*
CO_2-price	€/t	25	80
Changes in energy prices (Basis: Eurostat, 2019S1)	-	0%	+20%
Max. payback time	a (Jahre)	5	5
Full load hours	h/a	5256	5256

- 25% reduction by public subsidies
- and cost reductions of the HP-technology (economies of scale).

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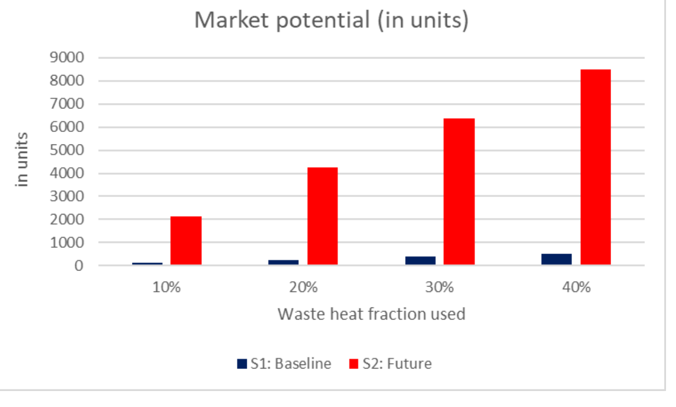
Market potential for HTHPs in Europe

Sales in Units (conservative estimations based on waste heat fraction used)



Upper limit
8481 Units

Lower limit
130 Units

Source: AIT own calculations based on research work of G. Kosmadakis

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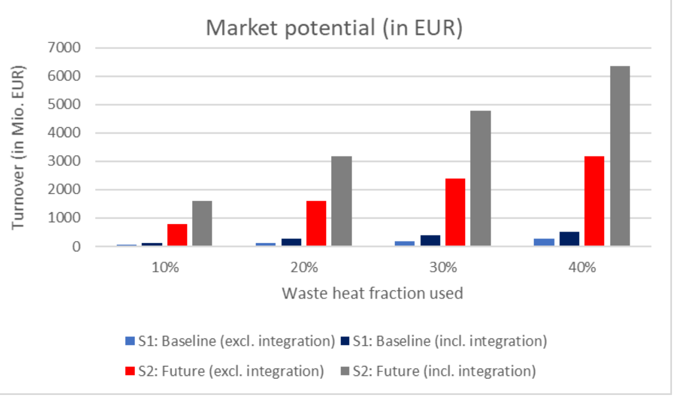
Market potential for HTHPs in Europe
Sales in EUR (conservative estimations)



Upper limit
6361 (3180) Mio. €

Lower limit
130 (65) Mio. €

Source: AIT own calculations based on research work of G. Kosmadakis

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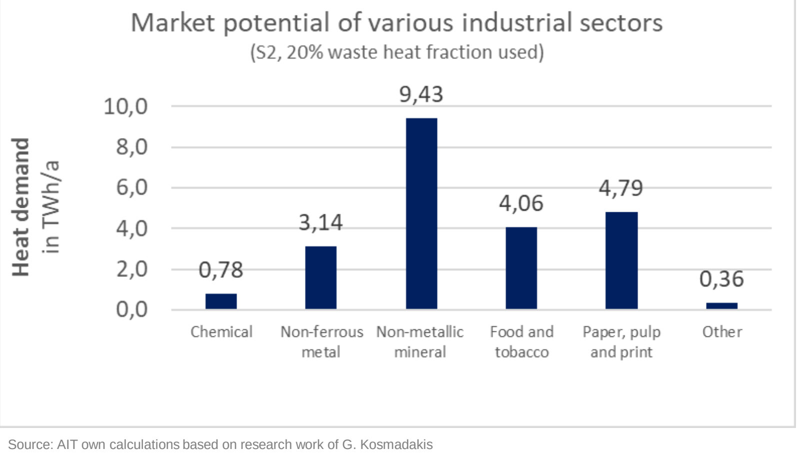
28

Market potential for HTHPs in Europe
Industrial sectors



Source: AIT own calculations based on research work of G. Kosmadakis

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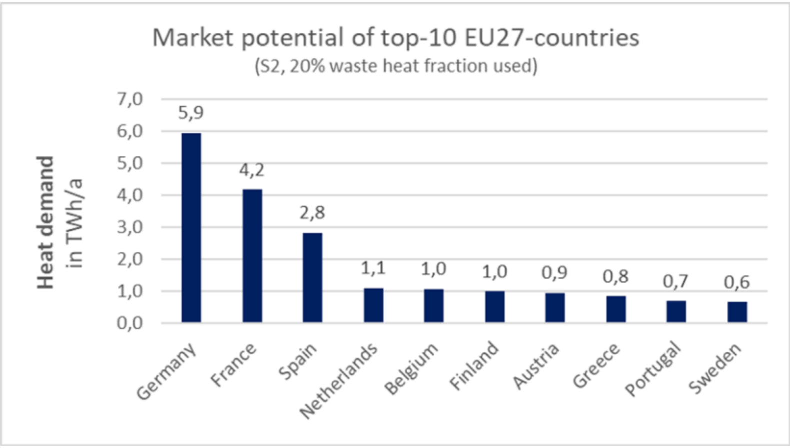
29

Market potential for HTHPs in Europe
Top 10 EU-27 countries



Source: AIT own calculations based on research work of G. Kosmadakis

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Industrial Heat Pumps
Market barriers

- **Low level of awareness** of technical possibilities and economically feasible applications among users, consultants, investors, plant designers, producers, and installers**.**
- **Lack of knowledge** on processes and integration of technology => cost-intensive tailor-made design.
- **Missing data on heat consumption** in companies => expensive and time-consuming measurements required.

Sources: Laue et al., (2014), IEA Annex 35: Application of Industrial Heat Pumps. Final Report, Part 2, p. 2, Arpagaus, C. et al. 2018: High temperature heat pumps: Market overview, state of the art, research status, refrigerants and applications. Energy 152, p. 985-1010

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Industrial Heat Pumps
Market barriers

- **Long payback periods** of >3 yrs.
- **Competing heating technologies** generating high temperature using fossil fuels at low energy prices (electricity to gas-price ratio).
- **Lack** of **pilot & demonstration plants** of HTHPs results in **lack of trust** on feasibility & performance; reliability of process is more important than energy savings.
- **Lack of training** and events supporting the spread of knowledge on HTHPs

Sources: Laue et al., (2014), IEA Annex 35: Application of Industrial Heat Pumps. Final Report, Part 2, p. 2, Arpagaus, C. et al. 2018: High temperature heat pumps: Market overview, state of the art, research status, refrigerants and applications. Energy 152, p. 985-1010, T. Nowak, (2018), Feedback from Meeting with Industry Associations

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Industrial Heat Pumps
SWOT Analysis

Strengths
- Maturing technology & widening range of available products
- Documented references available
- Large energy efficiency gain and GHG emission reduction
- No local pollutant emissions

Weaknesses
- Relatively high CAPEX
- Relatively complex process integration

SWOT

Opportunities
- Large technical potential
- Enforcement of climate change mitigation politics
- Increasing ETS carbon prices
- Supportive regulations and subsidies
- Decarbonizing electricity mix

Threats
- High electricity prices and low fossil fuel prices
- Short payback periods expected
- Lack of knowledge among planners and energy managers

Sources: Wolf, S. (2018): Presentation on „Market for High Temperatur Heat Pump Applications“, 2nd EEAB Meeting DryFiciency project

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High Temperature Heat Pumps (HTHPs)

State-of-the Art

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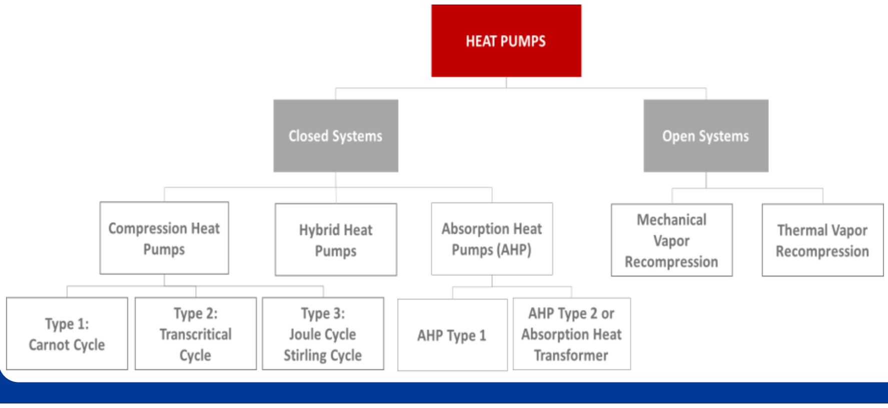
34

High Temperature Heat Pumps

Definition & Classification

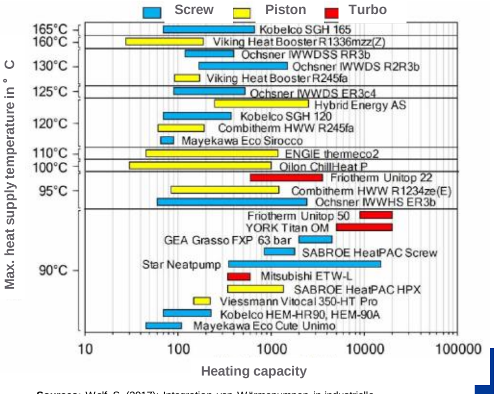
No uniform definition. According IEA HPT Annex 56 High Temperature Heat Pumps are capable of supplying heat of 100˚ C and above.



35

Industrial Heat Pumps
Commercially available systems

- Compression heat pumps are the most common type.
- 19 HP manufactures known commercially offering HTHPs
- Heat output up to max. 165 ° C (Kobelco = cascading system, available only in Japan);
- Heat output up to 120° C SoA in Europe
- Heating capacity up to 20 MWth
- Low GWP refrigerants partially in use.
- 1 and 2-stage closed loop cycles are the most common heat pump designs.



Sources: Wolf, S. (2017): Integration von Wärmepumpen in industrielle Produktionssysteme. Dissertation, Universität Stuttgart; Arpagaus, C. et al. 2018: High temperature heat pumps: Market overview, state of the art, research status, refrigerants and applications. Energy 152, p. 985-1010 , AIT research

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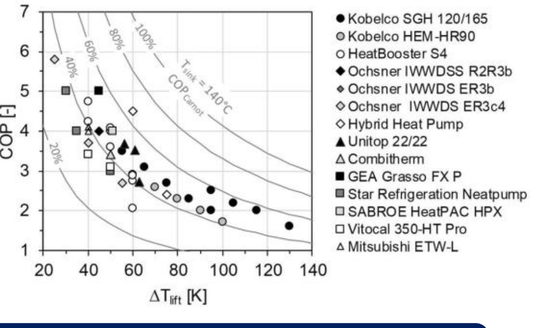
Industrial Heat Pumps
Efficiency

- Carnot efficiencies of available IHPs range between 35% and 60%.
- Carnot efficiency increases with heating capacity and peaks at the designed temperature lift.



Non standard applications require customizable heat pumps to reach maximum efficiency.

Sources: Wolf, S. (2017): Integration von Wärmepumpen in industrielle Produktionssysteme. Dissertation, Universität Stuttgart; Arpagaus, C. et al. 2018: High temperature heat pumps: Market overview, state of the art, research status, refrigerants and applications. Energy 152, p. 985-1010

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High temperature heat pumps

Ongoing research activities

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38

HTHP Research & Innovation

Main research groups

Intensive research activities on compression heat pump technology in various countries

Country	Research institutes
Austria	AIT Austrian Institute of Technology GmbH Graz University of Technology
Denmark	DTI Danish Technological Institute DTU Technical University of Denmark
France	EDF
Japan	CRIEPI Central Research Institute of Electric Power Industry
Norway	NTNU Norwegian University of Science and Technology, SINTEF Energy Research
Switzerland	NTB University of Applied Sciences of Technology Buchs
Spain	University Politecnia de Valencia
The Netherlands	TNO (formerly ECN)

Source: AIT Research

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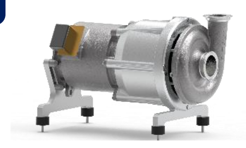
39

HTHP Research & Innovation

Main research topics

COMPONENT LEVEL

- Novel / adapted compressor technologies
- Novel lubricants working well with new HFO or natural refrigerants
- Improved material properties of components e.g. sealings, heat exchangers,…
- More cost-efficient components



Source: Rotrex A/S

SYSTEM LEVEL

- Various heat pump configurations (cascade systems with different working fluids, with/without intercoolers, …)
- Large scale demo & pilot installations

Source: SINTEF

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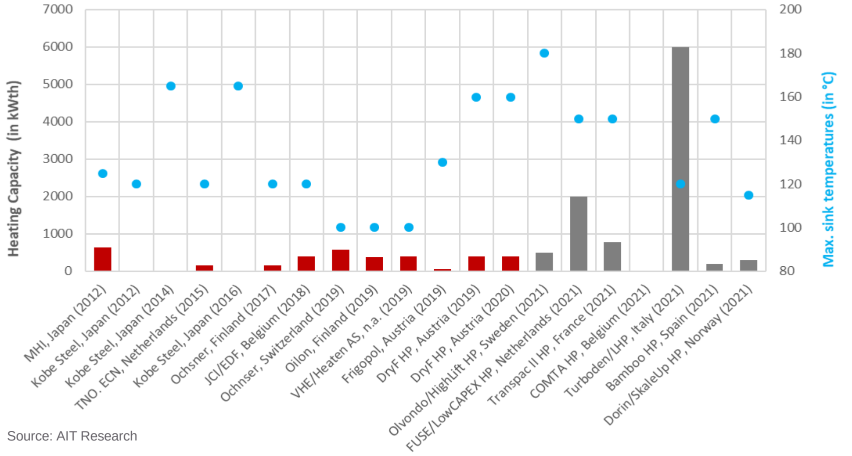
HTHP Research & Innovation

Demo & pilot installations known



Source: AIT Research

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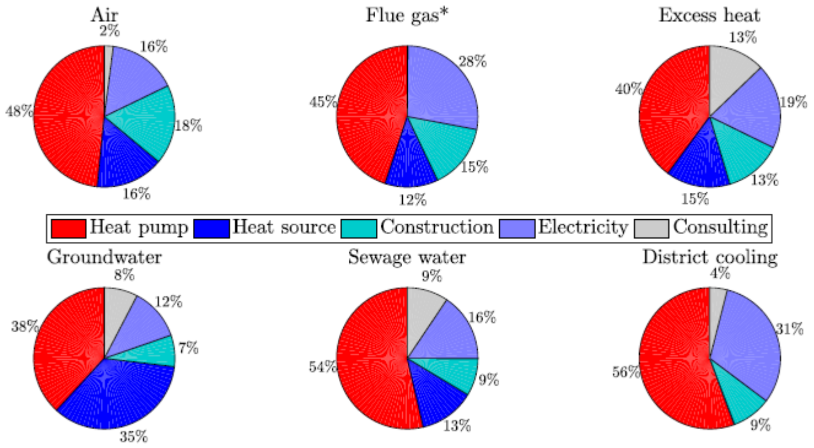
CAPEX of IHPs



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Distribution of specific investment costs (SEC)

Distribution of total SEC in €/kW of a HP using excess heat as heat source	Heating capacity		
	≤ 500 kW	≤ 1000 kW	≤ 4000 kW
Heat Pump Unit (40%)	520	388	288
Heat source (15%)	195	145.5	108
Construction (13%)	169	126.1	93.6
Electricity (19%)	247	184.3	136.8
Consulting (13%)	169	126.1	93.6
Specific total investment costs	**1300**	**970**	**720**

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SEC for different working principles

Working principle	SEC in €/kWth
Low Temp. Compression HP (up to 90°C)	800 to 2000
High Temp. Compression HP (up to 140°C)	2000 to 5000
Chemical/Absorption HP	1500 to 3000
Steam compression	100 to 150
MVR based HP	200 to 600

Source: Navigant, Verkenning uitbreiding SDE+ met industriële opties, 2019; M. Marsidi, Factsheet Industrial High Temperature Heat Pumps, 2018, https://energy.nl/wp-content/uploads/2019/06/Industrial-high-temperature-heat-pump-2.pdf, accessed 2 December 2020.

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Operating expenses (OPEX) of IHPs

OPEX = energy costs + general operating costs*

***incl. costs for maintenance, servicing & monitoring HP operation**

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Profitability of IHPs

Simple pay back method

$$PBP = \frac{CAPEX\ or\ total\ investment\ costs}{Average\ annual\ net\ cashflow}$$

Discounted pay back method

$$DPBP = ln\left(\frac{1}{1-\frac{CAPEX \cdot r}{Net\ annual\ saving}}\right)/ln(1+r)$$

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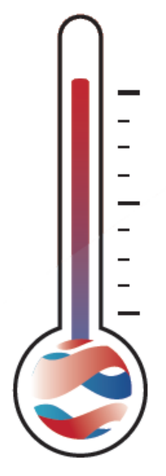
DryFiciency – Waste Heat Recovery in Industrial Drying Processes

Research & Innovation Action
Duration: 09/2016 – 08/2021
Budget: € 6,3 Mio.
EU-contribution: € 4,98 Mio.



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Challenge

12 to 25 %

of **final energy consumption in industry** is used for **drying & dehydration** processes.

Processes are currently primarily **fossil-fired** and generate large volumes of **low grade waste heat** that is not or only minimally utilized.

Industrial drying offers large potential for improved energy efficiency, reduction of fossil carbon emissions, and increased competitiveness by introducing advanced energy efficiency technologies.

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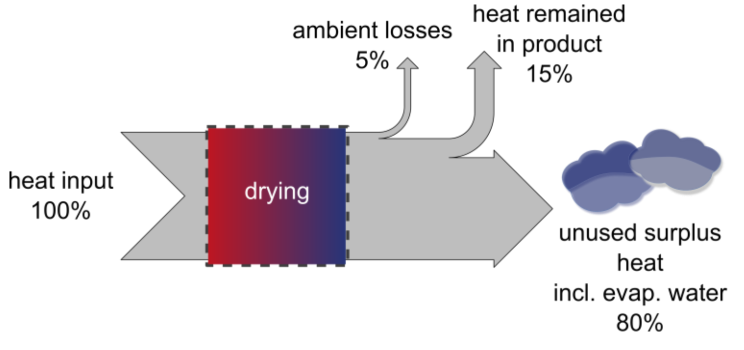
Motivation



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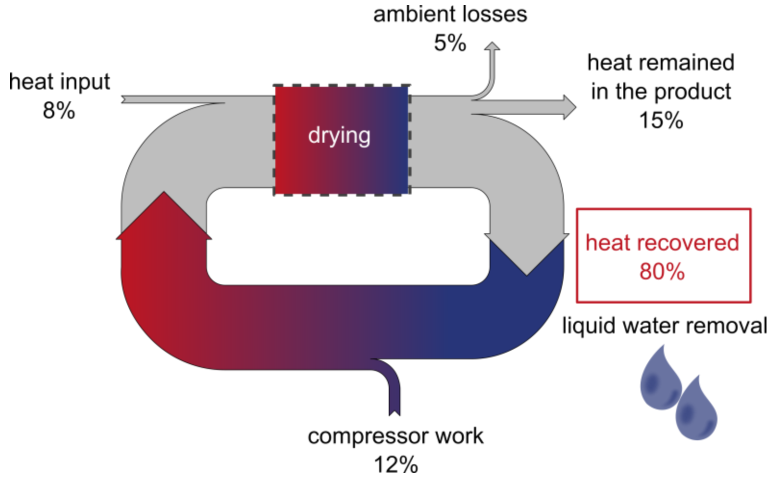
Motivation



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Research Approach

2 heat pump systems

- closed loop heat pump
- open loop heat pump

3 demonstration sites

- Wienerberger (Austria)
- Agrana (Austria)
- Scanship (Norway)

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Key Goals

ENERGY EFFICIENCY — up to 80%

PRODUCTION COSTS — up to 20%/kg

CO_2 EMISSION — up to 75%

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52

DryFiciency Consortium

Closed Loop Heat Pumps		Open Loop Heat Pump
AIT	2 RTOs	SINTEF
Bitzer, HEATEN	3 compressor manufacturers (2 SME)	ROTREX
Chemours, FUCHS	1 refrigerant manufacturer 1 lubricant manufacturer	
	1 plant engineer/ system expert (1 SME)	EPCON
Agrana Stärke, Wienerberger	3 end-users	SCANSHIP

2 experts on dissemination & exploitation (1 SME)

ehpa, RTDS Association

53

Technical Objectives

- Develop **viable solutions for upgrading idle waste heat streams to process heat streams** at higher temperatures up to 160°C
- **Key elements** of the solution are **three advanced high temperature vapour compression heat pumps**
  - » two **closed loop heat pumps** for air drying processes
  - » one **open loop heat pump** for steam driven drying processes

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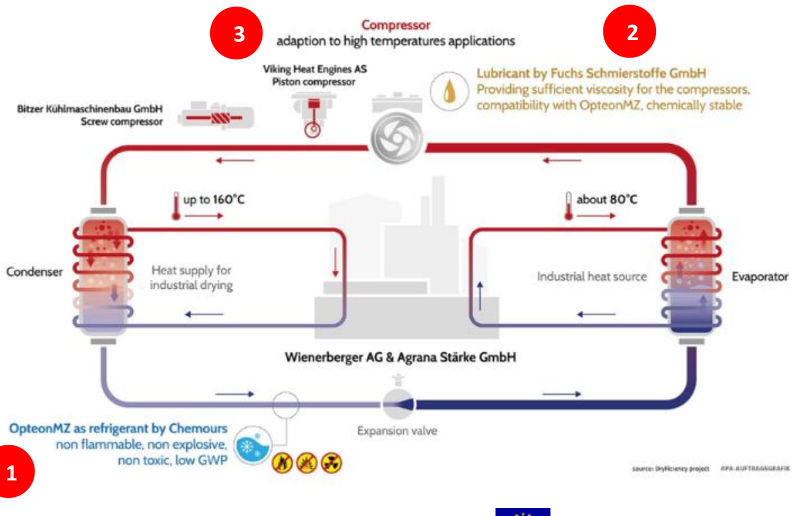
Innovations: Closed loop Heat Pumps



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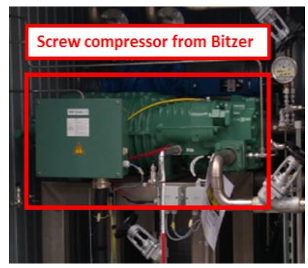
Innovation: Modified Screw Compressor

- **modified semi-hermetic screw compressor** based on Bitzer's' proven HS series
- for suction gas temp. up to 100° C and **discharge temp. up to 160° C**
- **two-shaft rotary displacement** design with high efficiency profile geometry
- swept volume of 300 m³/h at 60 Hz operation frequency
- Optimized for parallel operation with up to 6 compressors



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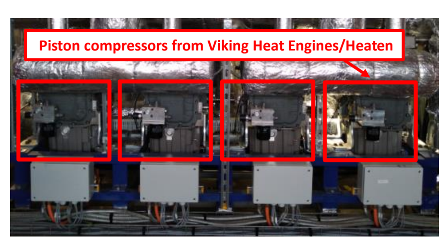
56

Innovation: Novel Piston Compressor

- **novel piston compressor** by Viking Heat Engines (taken over by Heaten A/S) and AVL based on a proven, heavy-duty design
- engineered to operate at very **high internal temp.** and pressures (**up to 215 ° C**).
- One compressor has a swept volume of 55 m³/h at 60 Hz.



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57

Innovation: Novel Lubricant

- **unique synthetic lubricant** for high-temperature heat applications
- designed for **high temp. (up to 160˚ C)** and **max. pressure of 18 bar**
- chemically stable when operated with OpteonMZ (HFO-1336mzz-Z) from Chemours
- was enhanced with additives to prevent degradation of both, lubricant and refrigerant

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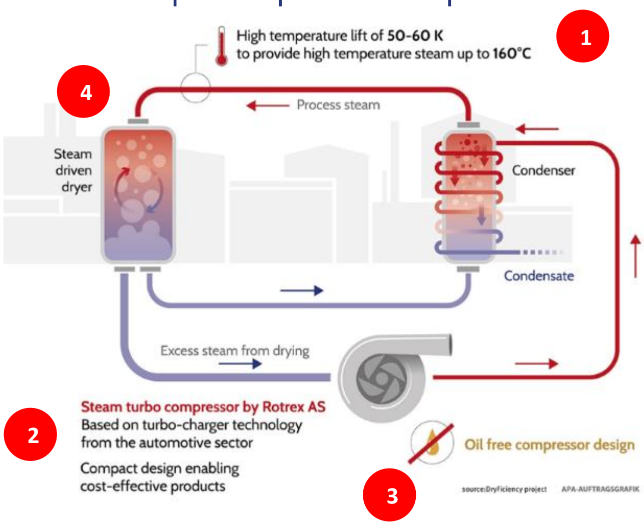
58

Innovations: Open loop Heat Pump



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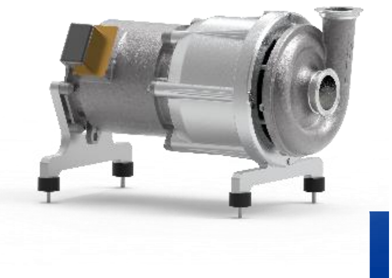
59

Innovation: Steam Turbo Compressor

- **Novel steam turbo compressor** developed by ROTREX A/S and SINTEF based on a **proven traction drive** concept from the automotive industry
- Oil-free
- Rotational speed up to 80.000 rpm for an impeller size of 15 cm

ROTREX™



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Innovation: MVR Drier Technology

- **Adapted MVR drier** designed for large temperature difference (60K instead of 20K) with improved properties
  - Larger capacity
  - Improved motor
  - Improved design for easier maintenance
  - Improved drier paddles for increased heat transfer

SCANSHIP
for cleaner oceans

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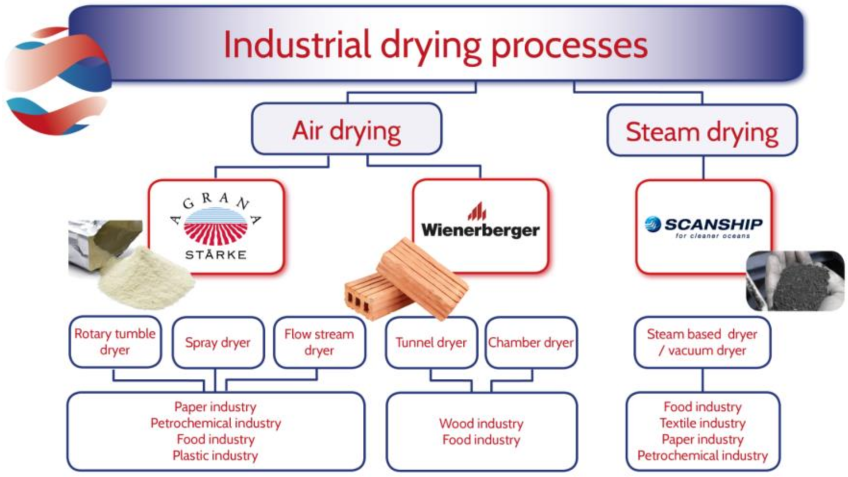
Industrial sectors targeted by DryFiciency



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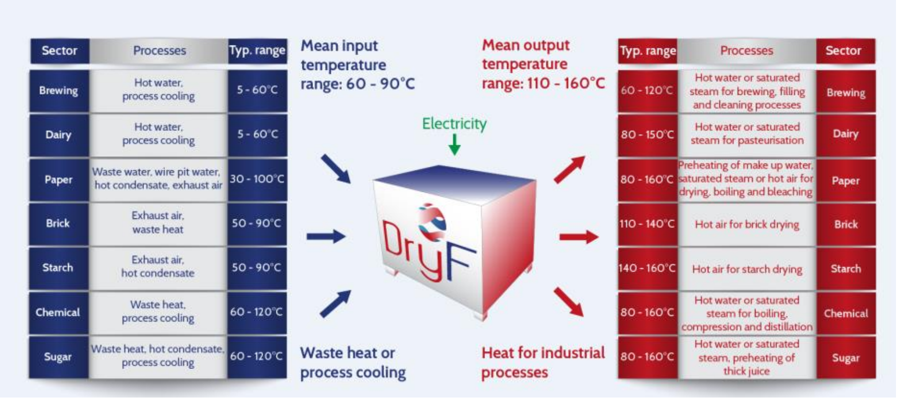
62

Industrial applications suitable for DryFiciency Heat Pumps



Sector	Processes	Typ. range
Brewing	Hot water, process cooling	5 - 60°C
Dairy	Hot water, process cooling	5 - 60°C
Paper	Waste water, wire pit water, hot condensate, exhaust air	30 - 100°C
Brick	Exhaust air, waste heat	50 - 90°C
Starch	Exhaust air, hot condensate	50 - 90°C
Chemical	Waste heat, process cooling	60 - 120°C
Sugar	Waste heat, hot condensate, process cooling	60 - 120°C

Typ. range	Processes	Sector
60 - 120°C	Hot water or saturated steam for brewing, filling and cleaning processes	Brewing
80 - 150°C	Hot water or saturated steam for pasteurisation	Dairy
80 - 160°C	Preheating of make up water, saturated steam or hot air for drying, boiling and bleaching	Paper
110 - 140°C	Hot air for brick drying	Brick
140 - 160°C	Hot air for starch drying	Starch
80 - 160°C	Hot water or saturated steam for boiling, compression and distillation	Chemical
80 - 160°C	Hot water or saturated steam, preheating of thick juice	Sugar

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63

Drying applications in DryFiciency

Closed Heat Pump Systems | **Open Heat Pump System**

STARCH DRYING	BRICK DRYING	SLUDGE DRYING
		
AGRANA Stärke GmbH Pischelsdorf (Austria)	Wienerberger AG Uttendorf (Austria)	Scanship A/S / Lindum A/S Drammen (Norway)

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64

Starch Drying @Agrana Stärke GmbH

FACTS

- **Compression heat pump** with Bitzer screw compressors
- **Heat source:** Waste heat (water) at 70° C
- **Heat supply:** hot air at 110 to 160° C

IMPACTS (Plan)

- **Savings on CO2 emissions:** approx. 500t/a
- **Savings on end energy:** 2.200 MWh/a

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65

DryF | AIT Austrian Institute of Technology TOMORROW TODAY

Brick Drying @Wienerberger AG

FACTS

- **Compression heat pump** with piston compressors from Viking Heat Engines A/S resp. Heaten A/S
- **Heat source:** Waste heat (water) at 70˚ C
- **Heat supply:** hot air at 110 to 160˚ C

IMPACTS (Plan)

- **Savings on CO_2 emissions:** approx. 2.900t/a
- **Savings on end energy:** 10.500 MWh/a

AIT Austrian Institute of Technology TOMORROW TODAY | Viking Heat Engines | Lubricants. Technology. People. FUCHS | Chemours

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66

DryF | AIT Austrian Institute of Technology TOMORROW TODAY

Sludge Drying @Scanship A/S

FACTS

- **MVR system** with turbo compressors from Rotrex A/S
- **Heat supply:** superheated steam up to 155 ˚ C

IMPACTS (Plan)

- **Savings on CO_2 emissions:** approx. 450t/a
- **Savings on end energy:** 1500 MWh/a

SINTEF | ROTREX | SCANSHIP for cleaner oceans | EPCON Evaporation Technology AS

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67

Project contacts

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Back-up slides

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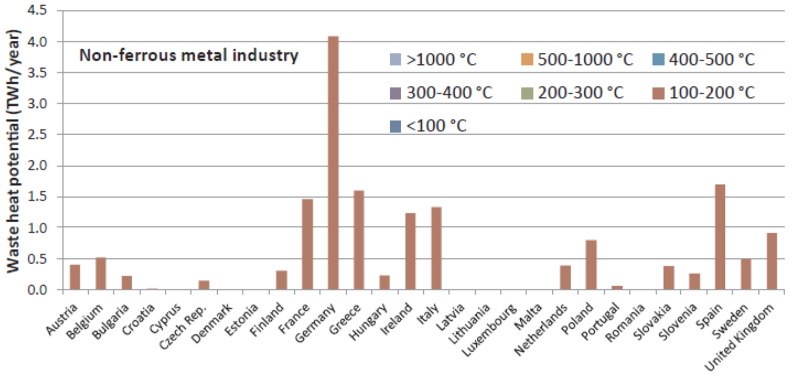
Waste heat potential: Non-ferrous metal (2015)



Source: Papapetrou (2018), Industrial waste heat: Estimation of the techncially available resource in the EU per industrial sector, temperature level and country

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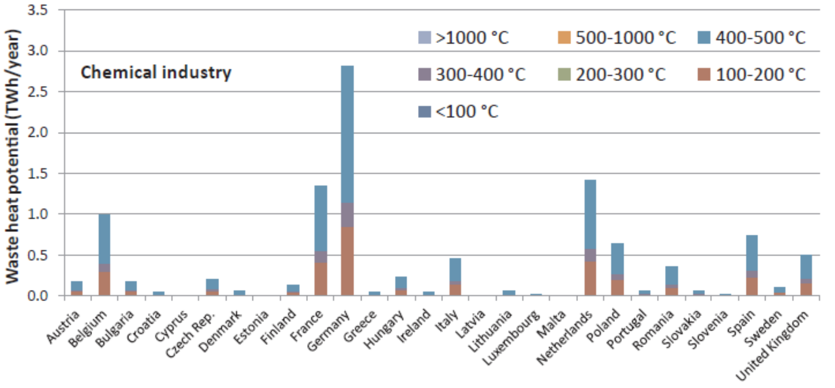
70

Waste heat potential: Chemical industry (2015)



Source: Papapetrou (2018), Industrial waste heat: Estimation of the techncially available resource in the EU per industrial sector, temperature level and country

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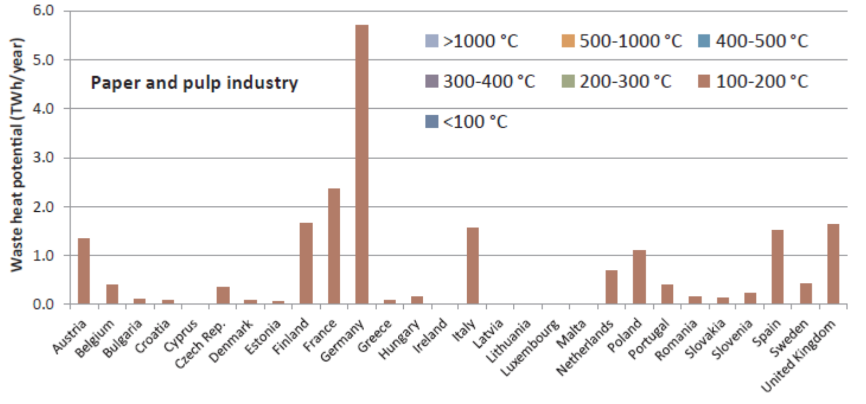
71

Waste heat potential: Pulp & Paper industry (2015)



Source: Papapetrou (2018), Industrial waste heat: Estimation of the techncially available resource in the EU per industrial sector, temperature level and country

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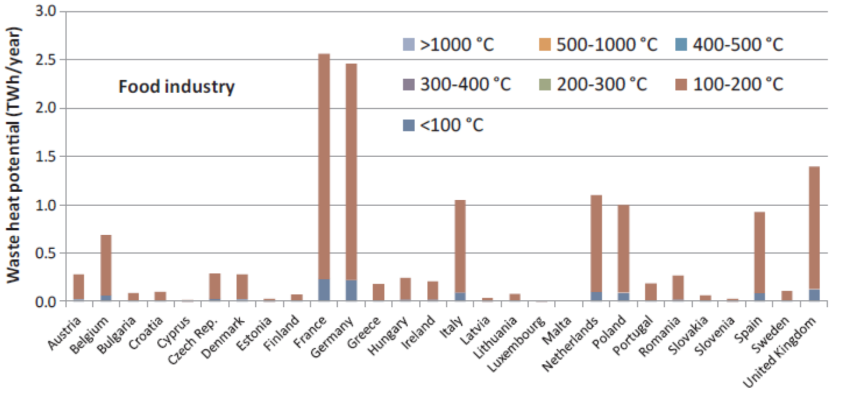
72

Waste heat potential: Food industry (2015)



Source: Papapetrou (2018), Industrial waste heat: Estimation of the techncially available resource in the EU per industrial sector, temperature level and country

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73

Modul 1

Hochtemperatur-Wärmepumpen für industrielle Anwendungen

AIT
Dr. Michael Lauermann

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Innovation Action H2020-EE-2016-2017
www.dry-f.eu

1

Agenda

- Energie- und Umweltziele für die Industrie
- Markt für Hochtemperatur-Wärmepumpen
- Hemmnisse und Chancen
- Anwendungen und ihr Potenzial
- Stand der Technik bei Hochtemperatur-Wärmepumpen
- Laufende Forschungsaktivitäten mit Schwerpunkt auf dem DryFiciency-Projekt

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2

Einleitung AIT

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3

BMK

1.400
employees

Austria's largest
RTO

8 Centers

Applied Research

Infrastructure Systems

System
Competence

Federation of
Austrian Industries
(through VFFI)

Next Generation
Solutions

4 Subsidiary
Enterprises
LKR, NES, SL, Profactor 51%

167
m EUR total revenue

Tomorrow Today

as of YE 2018

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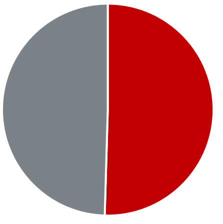
4

AIT Austrian Institute of Technology

OWNERSHIP STRUCTURE



50.46 %

REPUBLIC OF AUSTRIA
Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology

49.54 %

FEDERATION OF AUSTRIAN INDUSTRIES
(through VFFI)

1.400

EMPLOYEES

167 m EUR

TOTAL REVENUES
as of YE 2019

90,4 m EUR	Contract research revenues (incl. grants)
49,8 m EUR	BMK funding
22,8 m EUR	Other operating income, incl. Nuclear Engineering Seibersdorf
4,0 m EUR	Profactor (51% of 7,9 m EUR)

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AIT Austrian Institute of Technology GmbH

AIT Austrian Institute of Technology

Seibersdorf Labor GmbH

Nuclear Engineering Seibersdorf GmbH

Energy	**Health & Bioresourcen**	**Digital Safety & Security**	**Vision, Automation & Control**
Mobility Systems	**Low-Emission Transport**	**Technology Experience**	**Innovation Systems & Policy**

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Focus of the centers

Energy	Health & Bioresourcen	Digital Safety & Security	Vision, Automation & Control
• Electric Energy Systems • Integrated Energy Systems • Photovoltaic Systems • Digital Resilient Cities • Sustainable Thermal Energy Systems	• Biomedical Systems • Bioresourcen • Digital Health Information Systems • Molecular Diagnostics	• Security & Communication Technologies • Sensing & Vision Solutions • Data Science & Artificial Intelligence • Cooperative Digital Technologies	• Assistive & Autonomous Systems • Complex Dynamical Systems • High-Performance Vision Systems

Mobility Systems	Low-Emission Transport	Technology Experience	Innovation Systems & Policy
• Dynamic Transportation Systems • Transportation Infrastructure Technologies	• Electric Drive Technologies • Light Metals Technologies Ranshofen	• Experience Contexts and Tools • Experience Business Transformations	• Digital Innovation • Foresight & Institutional Change • Policies for Change

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Klima und Energie

Trends & Ziele

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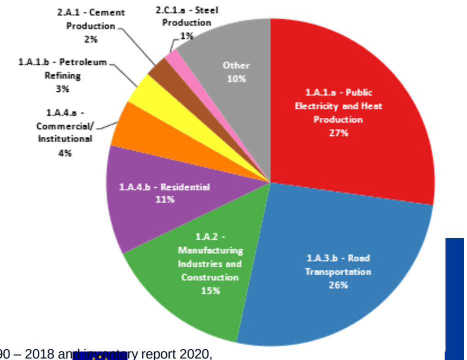
Klima & Energy
Fakten

"Business as usual wird bis zum Jahr 2100 zu einer globalen Erwärmung von etwa 4° C führen" (UN IPCC)

Auf die Industrie in der EU-27 entfallen:

- 25 % auf den Endenergieverbrauch.
- 15% der THG-Emissionen stammen aus dem Verbrauch fossiler Brennstoffe für die Energieerzeugung.

Sektorale THG-Emissionen in den EU-28 nach IPCC-Sektor (2018)



Quellen: IPCC (2020) Annual European Union greenhouse gas inventory 1990 – 2018 and inventory report 2020, EEA https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2020/eea-dashboard-01

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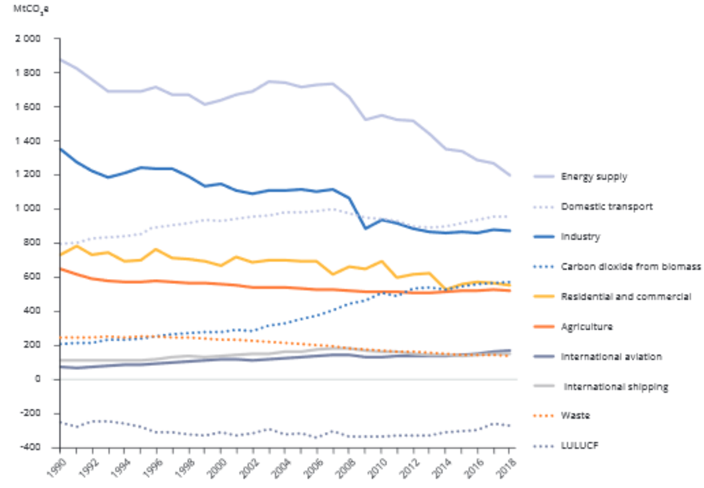
10

Klima & Energie
Entwicklung der Treibhausgasemissionen der EU nach Sektoren (1990-2018)



Quelle: EEA, Trends and drivers of EU greenhouse gas emissions, EEA Report, No. 03/2020

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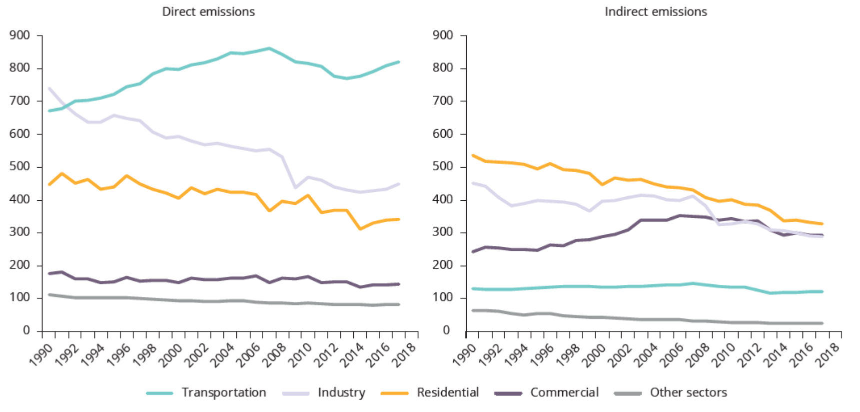
11

Klima & Energie

Energiebedingte THG-Emissionen nach Sektoren (1990-2017)



Quelle: EEA, Trends and drivers of EU greenhouse gas emissions, EEA Report, No. 03/2020

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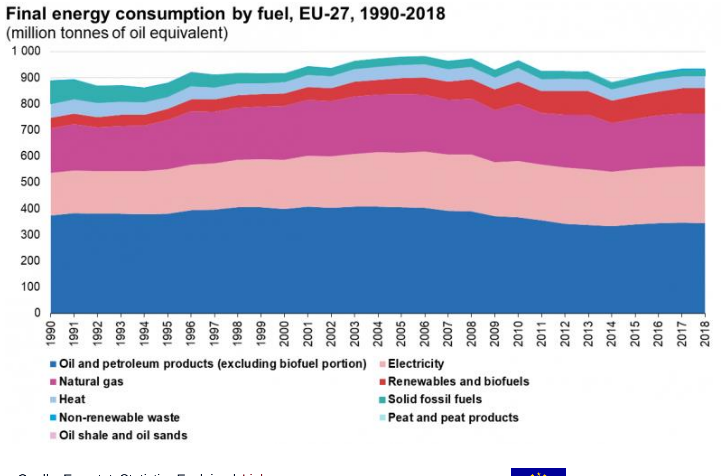
Klima & Energie

Entwicklung des Endenergieverbrauchs der EU-27 nach Brennstoffen (2000-2018)



Quelle: Eurostat, Statistics Explained, Link

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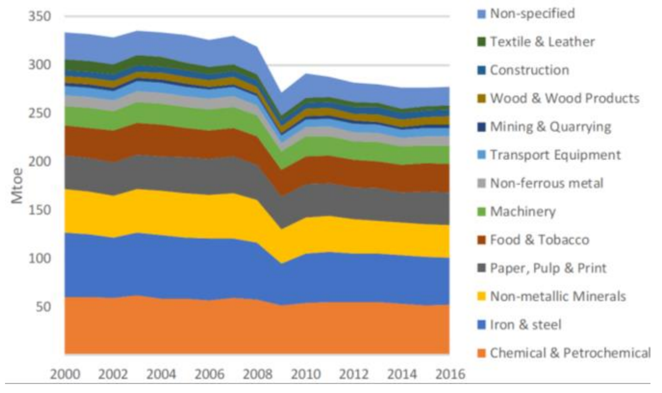
Klima & Energie

Entwicklung des Endenergieverbrauchs der EU nach Industriesektoren (2000-2016)



Seit 2007 verzeichneten 10 von 13 Industriesektoren einen Rückgang des Endenergieverbrauchs

Quelle: Eurostat Energy Balance May 2018, http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb

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Klima & Energie

Ziele

2030 Energy Strategy

- Senkung der THG-Emissionen (im Verhältnis zu 1990) um 40%
- Mindestens 32% Anteil am Verbrauch erneuerbarer Energien (Aufwärtsrevisionsklausel für 2023)
- Verbesserung der Energieeffizienz auf EU-Ebene um mindestens 32,5 %
- Unterstützung der Vollendung des Energiebinnenmarkts durch Erreichen des bestehenden Stromverbundziels von 10 % bis 2020 (Bis 2030 sollen es 15 % sein)

Quelle: IPCC (2018) http://www.ipcc.ch/report/sr15/

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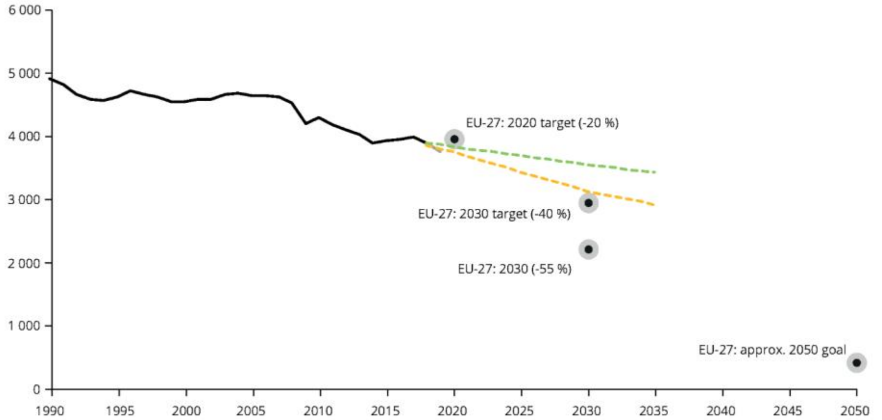
Klima und Energie

THG-Emissionsziele, Trends & Prognosen



Quelle: EEA, Total greenhouse gas emission trends and projections in Europe, https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-7/assessment

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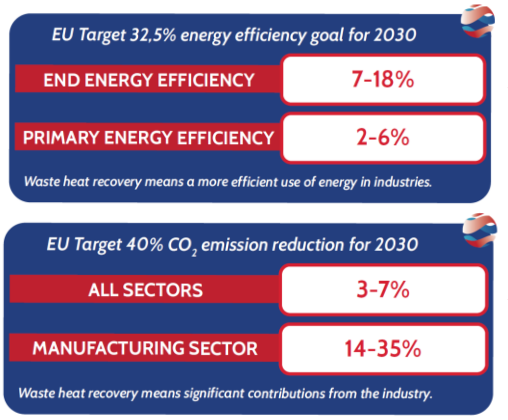
Klima und Energie

Potenzieller Beitrag industrieller Wärmepumpen zu den EU-Zielen



Potenzieller Beitrag des DryFiciency-Projekts

Annahmen: 50% aller Trocknungsprozesse in der EU sind mit DryF WP ausgestattet (durchschnittlicher COP: 3; Wärmequelle: 70, Wärmesenke: 140, Ersatz von Erdgasbrennern mit thermischer Eff. von 95%

Quelle: DryFiciency

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Markt für Hochtemperatur-Wärmepumpen

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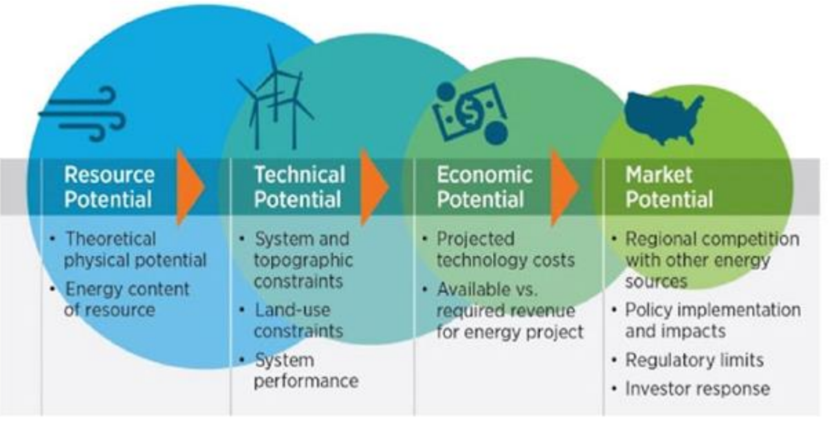
22

Marktpotenzial



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23

Wirtschaftlichkeit von HT-WP

Vorteilhafte Bedingungen für IWP sind:

- Hohes Verhältnis von Gas- zu Strompreis
- Hohe CO2-Preise (abhängig von der Kohlenstoffintensität des Stroms)

Randbedingungen für die Berechnung des wirtschaftlichen Marktpotenzials

	Unit	In 2020 S1: "*Baseline*"	In 2025 S2: "*Future*"
CAPEX Referenztechnologie (Gaskessel)	€/kW	100	100
CAPEX Integration von Referenztechnologie	€/kW	100	100
CAPEX Wärmepumpe	€/kW	500	375*
CAPEX Integration Wärmepumpe	€/kW	500	375*
CO_2-Preis	€/t	25	80
Veränderungen der Energiepreise (Basis: Eurostat, 2019S1)	-	0%	+20%
Max. payback time	a (Jahre)	5	5
Volllaststunden	h/a	5256	5256

- 25% reduction by public subsidies
- and cost reductions of the WP-technology (economies of scale).

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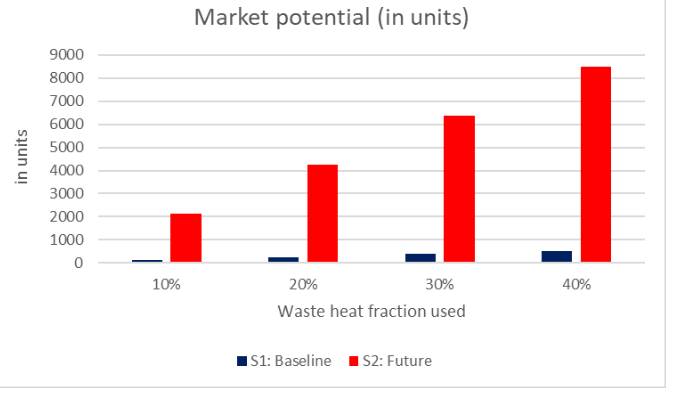
25

Marktpotenzial für Hochtemperatur-Wärmepumpen in Europa

Umsatz in Einheiten (konservative Schätzungen auf Basis der verw. Abwärmeanteil)



Obere Grenze
8481 Stück
Untere Grenze
130 Stück

Quelle: AIT own calculations based on research work of G. Kosmadakis

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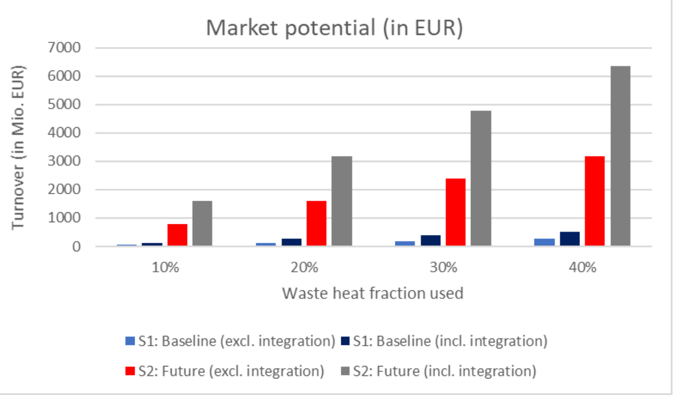
27

Marktpotenzial für Hochtemperatur-Wärmepumpen in Europa

Umsatz in EUR (konservative Schätzungen)



Obere Grenze
6361 (3180) Mio. €

Untere Grenze
130 (65) Mio. €

Quelle: AIT own calculations based on research work of G. Kosmadakis

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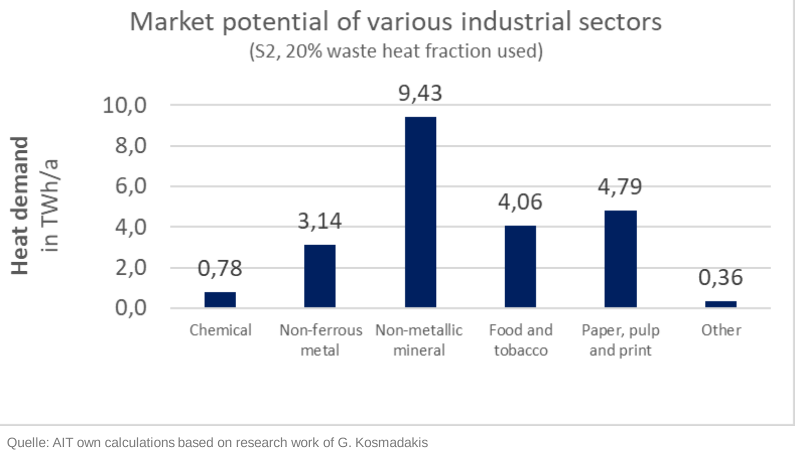
Marktpotenzial für Hochtemperatur-Wärmepumpen in Europa

Industriesektoren



Quelle: AIT own calculations based on research work of G. Kosmadakis

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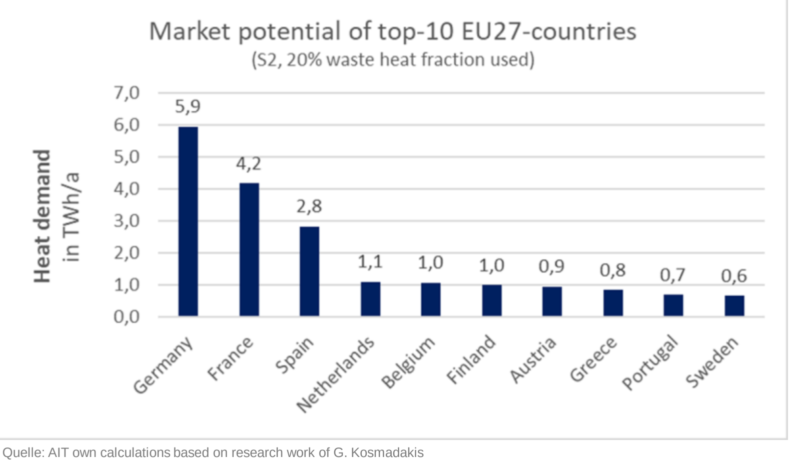
Marktpotenzial für Hochtemperatur-Wärmepumpen in Europa
Top 10 EU-27 Länder



Quelle: AIT own calculations based on research work of G. Kosmadakis

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Industrie-Wärmepumpen
Marktbarrieren

- **Geringes Bewusstsein** für technische Möglichkeiten und wirtschaftlich umsetzbare Anwendungen bei Anwendern, Beratern, Investoren, Anlagenplanern, Produzenten und Installateuren.
- **Mangelndes Prozesswissen und Technologieintegration** = > kostenintensives maßgeschneidertes Design.
- **Fehlende Daten zum Wärmeverbrauch in Unternehmen** = > teure und zeitaufwändige Messungen erforderlich.

Quellen: Laue et al., (2014), IEA Annex 35: Application of Industrie-Wärmepumpen. Final Report, Part 2, p. 2, Arpagaus, C. et al. 2018: Hochtemperatur-Wärmepumpen: Market overview, state of the art, research status, refrigerants and applications. Energy 152, p. 985-1010

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Industrie-Wärmepumpen
Marktbarrieren

- Lange Amortisationszeiten von > 3 Jahren.
- **Konkurrierende Heiztechnologien**, die hohe Temperaturen mit fossilen Brennstoffen zu niedrigen Energiepreisen erzeugen (Strom-Gas-Preis-Verhältnis).
- **Das Fehlen von Pilot- und Demonstrationsanlagen** von HT-WP führt zu mangelndem Vertrauen in Machbarkeit und Leistung; Prozesssicherheit ist wichtiger als Energieeinsparung.
- **Mangel an Schulungen** und Veranstaltungen zur Wissensvermittlung über HT-WP

Quellen: Laue et al., (2014), IEA Annex 35: Application of Industrie-Wärmepumpen. Final Report, Part 2, p. 2, Arpagaus, C. et al. 2018: Hochtemperatur-Wärmepumpen: Market overview, state of the art, research status, refrigerants and applications. Energy 152, p. 985-1010, T. Nowak, (2018), Feedback from Meeting with Industry Associations

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Industrie-Wärmepumpen
SWOT Analyse

Stärken
- Reifende Technologie & Erweiterung der Palette der verfügbaren Produkte
- Dokumentierte Referenzen verfügbar
- Großer Energieeffizienzgewinn und Reduzierung der Treibhausgasemissionen

Schwächen
- Relativ hoher CAPEX
- Relativ komplexe Prozessintegration

SWOT

Chancen
- Großes technisches Potenzial
- Durchsetzung der Klimaschutzpolitik
- Steigende ETS-Kohlenstoffpreise
- Unterstützende Regelungen und Subventionen
- Dekarbonisierung des Strommixes

Bedrohungen
- Hohe Strompreise und niedrige Preise fossile Brennstoffe
- Kurze Amortisationszeiten erwartet
- Mangelndes Wissen bei Planern und Energiemanagern

Quellen: Wolf, S. (2018): Präsentation „Market for High Temperatur Heat Pump Applications“, 2nd EEAB Meeting DryFiciency project

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Hochtemperatur-Wärmepumpen (HT-WP)

State-of-the Art

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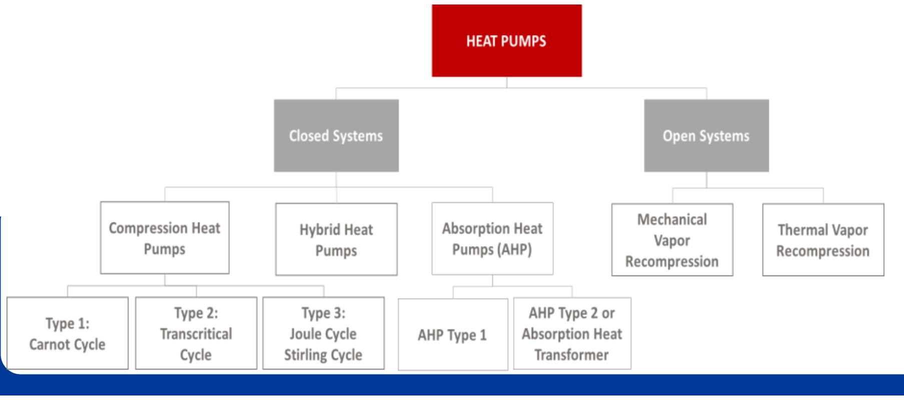
34

Hochtemperatur-Wärmepumpen

Definition & Klassifizierung

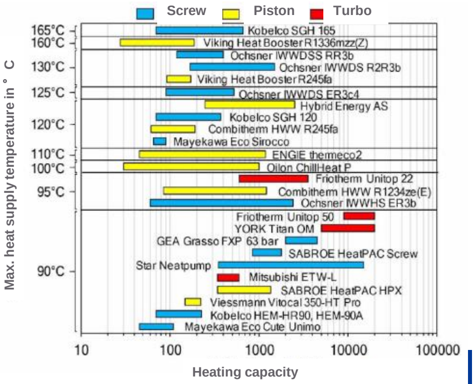
Keine einheitliche Definition. Gemäß IEA HPT Annex 56 sind Hochtemperatur-Wärmepumpen in der Lage, Wärme von 100° C und mehr zu liefern.



35

Industrie-Wärmepumpen
Handelsübliche Systeme

- Kompressionswärmepumpen sind der häufigste Typ.
- 19 WP Hersteller, die kommerziell HT-WP anbieten
- Versorgung bis max. 165 ° C (Kobelco = Kaskadensystem, nur in Japan verfügbar);
- Heizleistung bis 120° C SoA in Europa
- Heizleistung bis 20 MWth
- Kältemittel mit niedrigem GWP teilweise im Einsatz.
- 1- und 2-stufige Closed-Loop-Zyklen sind die gebräuchlichsten Wärmepumpenkonstruktionen.



Quellen: Wolf, S. (2017): Integration von Wärmepumpen in industrielle Produktionssysteme. Dissertation, Universität Stuttgart; Arpagaus, C. et al. 2018: Hochtemperatur-Wärmepumpen: Market overview, state of the art, research status, refrigerants and applications. Energy 152, p. 985-1010 , AIT research

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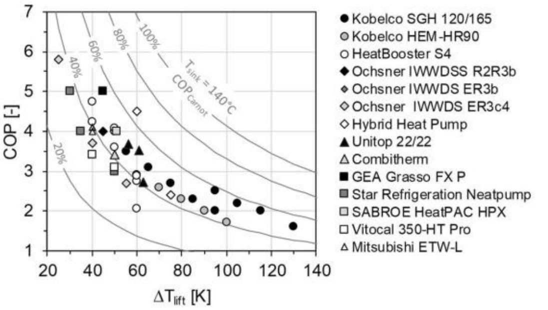
Industrie-Wärmepumpen
Efficienz

- Die Carnot-Wirkungsgrade der verfügbaren IWP liegen zwischen 35% und 60%.
- Der Carnot-Wirkungsgrad steigt mit der Heizleistung und erreicht Spitzen bei der vorgesehenen Temperaturerhöhung.



Anwendungen, die keine Standardanwendung darstellen, erfordern adaptive Wärmepumpen, um maximale Effizienz zu erreichen.

Quellen: Wolf, S. (2017): Integration von Wärmepumpen in industrielle Produktionssysteme. Dissertation, Universität Stuttgart; Arpagaus, C. et al. 2018: Hochtemperatur-Wärmepumpen: Market overview, state of the art, research status, refrigerants and applications. Energy 152, p. 985-1010

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Hochtemperatur-Wärmepumpen

Laufende Forschungsaktivitäten

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HT-WP Forschung & Innovation

Forschungsschwerpunkte

Intensive Forschungsaktivitäten zur Kompressionswärmepumpentechnologie in verschiedenen Ländern

Land	Forschungsinstitute
Austria	AIT Austrian Institute of Technology GmbH Technische Universität Graz
Dänemark	DTI Danish Technological Institute DTU Technical University of Denmark
Frankreich	EDF
Japan	CRIEPI Central Research Institute of Electric Power Industry
Norwegen	NTNU Norwegian University of Science and Technology, SINTEF Energy Research
Schweiz	NTB Technische Hochschule Buchs
Spanien	University Politecnia de Valencia
Niederlande	TNO (formerly ECN)

Quelle: AIT Research

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HT-WP Forschung & Innovation

Forschungsschwerpunkte

KOMPONENTENEBENE

- Neuartige / angepasste Kompressortechnologien
- Neuartige Schmierstoffe, die gut mit neuen HFO- oder natürlichen Kältemitteln arbeiten
- Verbesserte Materialeigenschaften von Bauteilen wie z.B. Dichtungen, Wärmetauscher,...
- Kostengünstigere Komponenten

Quelle: Rotrex A/S

SYSTEMEBENE

- Verschiedene Wärmepumpenkonfigurationen (Kaskadensysteme mit unterschiedlichen Arbeitsflüssigkeiten, mit/ohne Ladeluftkühler, ...)
- Große Demo- und Pilotinstallationen

Quelle: SINTEF

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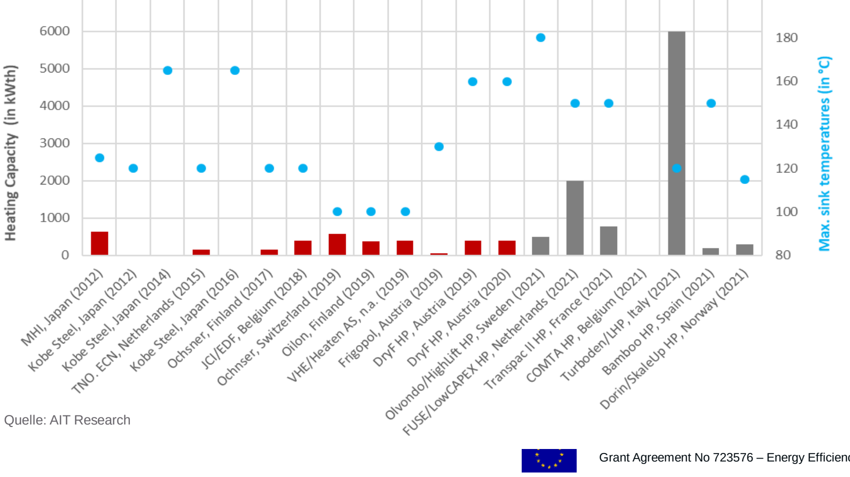
HT-WP Forschung & Innovation

Bekannte Demo- & Pilotinstallationen



Quelle: AIT Research

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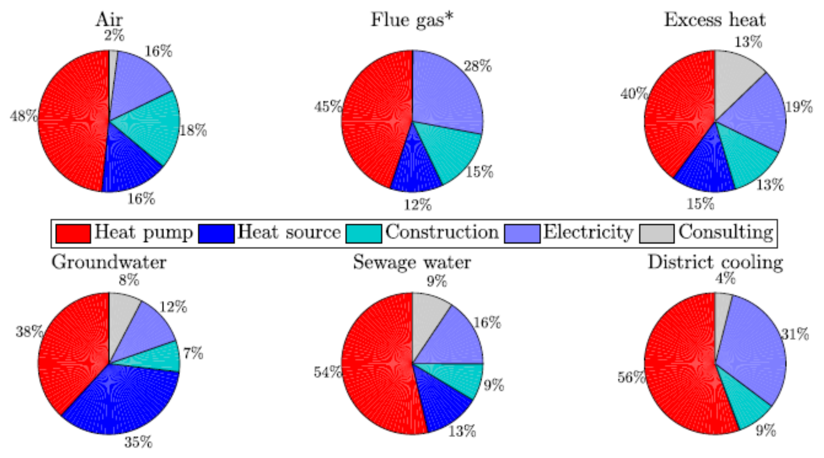
CAPEX von IWP



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42

Verteilung der spezifischen Investitionskosten (SEC)

Distribution of total SEC in €/kW of a HP using excess heat as heat source	Heating capacity		
	≤ 500 kW	≤ 1000 kW	≤ 4000 kW
Heat Pump Unit (40%)	520	388	288
Heat source (15%)	195	145.5	108
Construction (13%)	169	126.1	93.6
Electricity (19%)	247	184.3	136.8
Consulting (13%)	169	126.1	93.6
Specific total investment costs	**1300**	**970**	**720**

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43

SEC verschiedener Arbeitsmitttel

Working principle	SEC in €/kWth
Low Temp. Compression HP (up to 90°C)	800 to 2000
High Temp. Compression HP (up to 140°C)	2000 to 5000
Chemical/Absorption HP	1500 to 3000
Steam compression	100 to 150
MVR based HP	200 to 600

Quelle: Navigant, Verkenning uitbreiding SDE+ met industriële opties, 2019; M. Marsidi, Factsheet Industrial Hochtemperatur-Wärmepumpen, 2018, https://energy.nl/wp-content/uploads/2019/06/Industrial-high-temperature-heat-pump-2.pdf, accessed 2 December 2020.

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44

Operating expenses (OPEX) of IWP

OPEX = Energiekosten + allgemeine Betriebskosten*

***inkl. Kosten für Wartung, Instandhaltung & Überwachung WP-Betrieb**

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45

Rentabilität von IWP

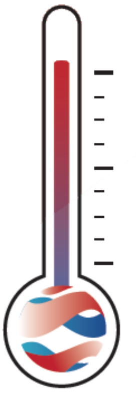
Einfache Amortisationsrechnung

$$PBP = \frac{CAPEX\ bzw.\ Gesamtinvestitionskosten}{Durchschnittlicher\ jährlicher\ Netto - Cashflow}$$

Berechnung der abgezinsten Amortisationszeit

$$DPBP = ln\left(\frac{1}{1-\frac{CAPEX \cdot r}{Jährliche\ Nettoersparnis}}\right) / ln(1+r)$$

DryFiciency – Abwärmerückgewinnung in industriellen Trocknungsprozessen



Research & Innovation Action
Projektlaufzeit: 09/2016 – 08/2021
Budget: € 6,3 Mio.
EU-Beitrag: € 4,98 Mio.

Herausforderung

12 bis 25 %

des industriellen Endenergieverbrauchs wird für **Trocknungsprozesse** verwendet.

Diese erden aktuell überwiegend **fossil** befeuert und erzeugen große Mengen an **minderwertiger Abwärme**, die nicht oder nur minimal genutzt wird.

Industrielle Trocknung bietet ein großes Potenzial für eine verbesserte Energieeffizienz, die Reduktion von CO2-Emissionen und eine erhöhte Wettbewerbsfähigkeit durch die Einführung fortschrittlicher Energieeffizienztechnologien.

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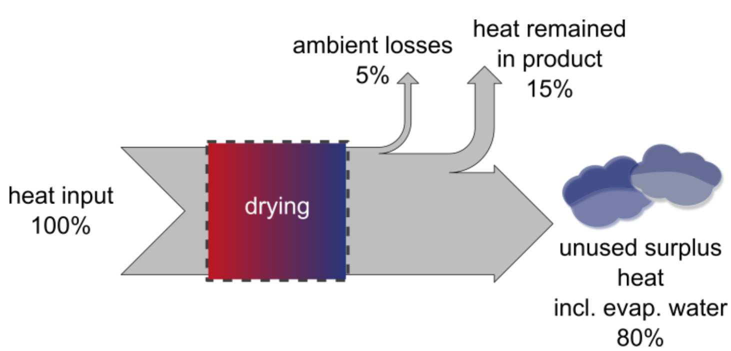
Motivation



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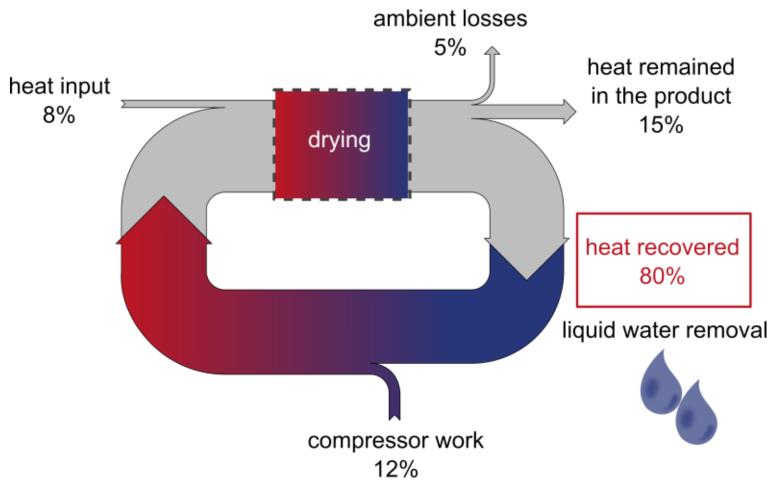
Motivation



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Forschungsansatz

2 Wärmepumpensysteme
- Wärmepumpe mit geschlossenem Kältekreis
- Open-Loop-Wärmepumpe

3 Demonstrationsstandorte
- Wienerberger (Austria)
- Agrana (Austria)
- Scanship (Norwegen)

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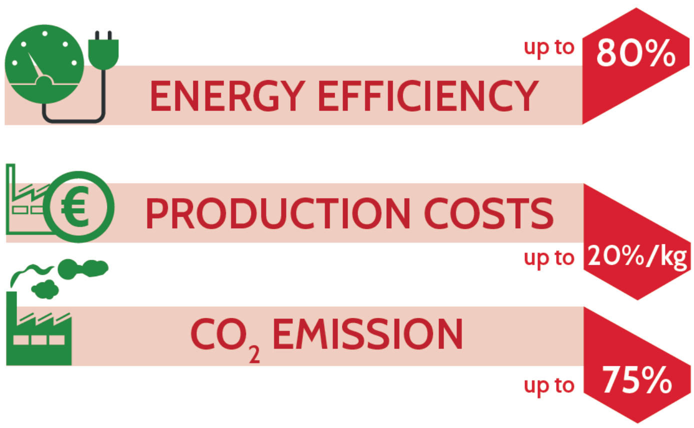
Wichtigste Ziele



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DryFiciency Konsortium

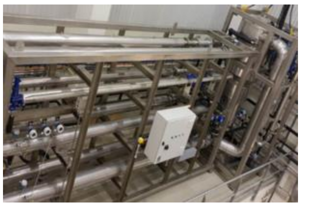
Wärmepumpen mit geschlossenem Kältekreis		Wärmepumpen mit offenem Kältekreis
AIT Austrian Institute of Technology	2 RTOs	SINTEF
Bitzer, HEATEN	3 Hersteller von Kompressoren (2 KMU)	ROTREX
Chemours, FUCHS	1 Kältemittelhersteller 1 Schmierstoffhersteller	
	1 Anlagenbauer/ Systemexperte (1 KMU)	EPCON
Agrana Stärke, Wienerberger	3 Technologieanwender	SCANSHIP

2 experts on dissemination & exploitation (1 SME)

ehpa, RTDS Association

Technische Ziele

- Entwicklung praktikabler Lösungen zur Aufwertung von Abwärmeströmen zur Verarbeitung von Wärmeströmen bei höheren Temperaturen bis zu 160° C
- Schlüsselelemente der Lösungen sind drei fortschrittliche Hochtemperatur-Dampfkompressionswärmepumpen
  - zwei geschlossene Wärmepumpen für Lufttrocknungsprozesse
  - eine Open-Loop-Wärmepumpe für dampfbetriebene Trocknungsprozesse



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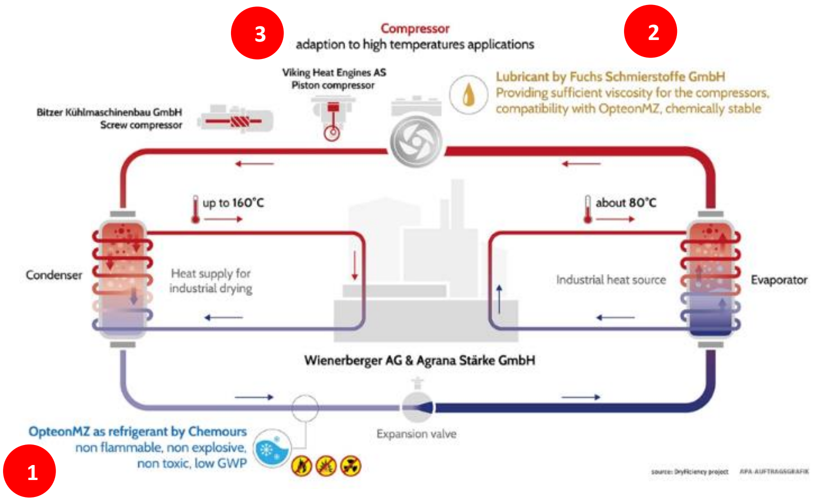
Innovationen: Wärmepumpen mit geschlossenem Kältekreis



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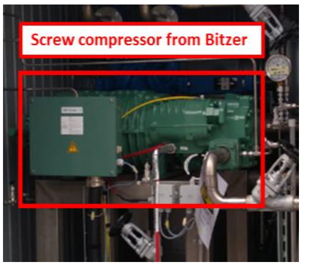
Innovation: Modifizierter Schraubenkompressor

- **modifizierter halbhermetischer Schraubenkompressor** auf Basis der bewährten HS-Serie von Bitzer
- für Sauggastemperaturen bis 100° C und Heißgastempera-turen bis 160° C
- Zweiwellen-Rotationsverdichter-bauweise mit hocheffizienter Geometrie
- 300 m³/h- Fördervolumen bei 60 Hz Betriebsfrequenz
- Optimiert für parallelen Betrieb mit bis zu 6 Kompressoren



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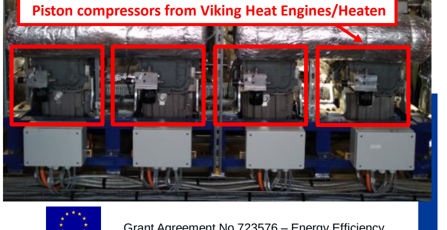
Innovation: Neuartiger Kolbenkompressor

- neuartiger **Kolbenkompressor** von Viking Heat Engines (übernommen von Heaten A/S) und AVL auf Basis eines bewährten, robusten Designs
- entwickelt für den Betrieb bei sehr hohen Innentemperaturen und Drücken (bis zu 215 ° C).
- Ein Kompressor hat ein Verdrängungsvolumen von 55 m³/h bei 60 Hz.



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Innovation: Neuartiger Schmierstoff

- **einzigartiger synthetischer Schmierstoff** für Hochtemperatur-Wärmeanwendungen
- ausgelegt für **hohe Temperaturen (bis 160° C)** und **max. Druck von 18 bar**
- chemisch stabil bei Betrieb mit OpteonMZ (HFO-1336mzz-Z) von Chemours
- wurde mit Additiven angereichert, um den Abbau von Schmier- und Kältemittel zu verhindern
-

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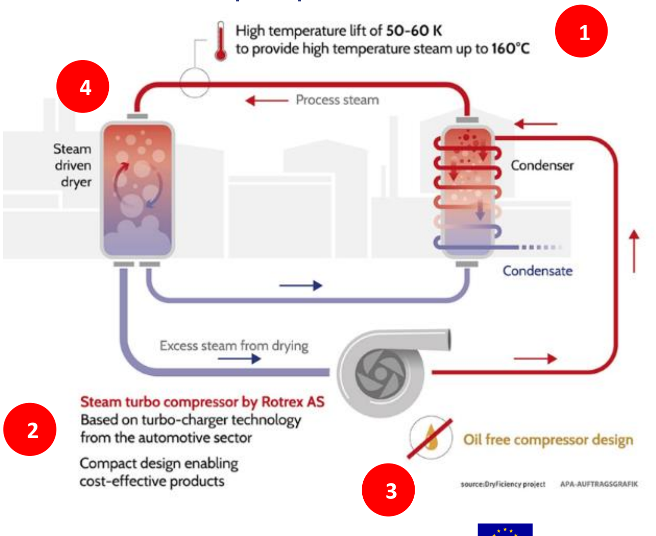
58

Innovation: Wärmepumpe mit offenem Kältekreis



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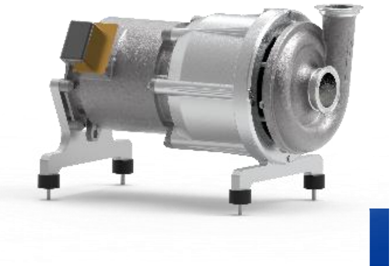
59

Innovation: Dampf-Turbo-Kompressor

- **Neuartiger Dampfturbokompressor**, entwickelt von ROTREX A/S und SINTEF auf Basis eines bewährten Traktionsantriebskonzepts aus der Automobilindustrie
- Ölfrei
- Drehzahl bis 80.000 U/min bei einer Laufradgröße von 15 cm

ROTREX™



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60

Innovation: MVR Trockner Technologie

- Angepasster MVR-Trockner für große Temperaturunterschiede (60K statt 20K) mit verbesserten Eigenschaften
  - Größere Kapazität
  - Verbesserter Motor
  - Verbessertes Design für einfachere Wartung
  - Verbesserte Trocknerpaddel für erhöhte Wärmeübertragung

SCANSHIP for cleaner oceans

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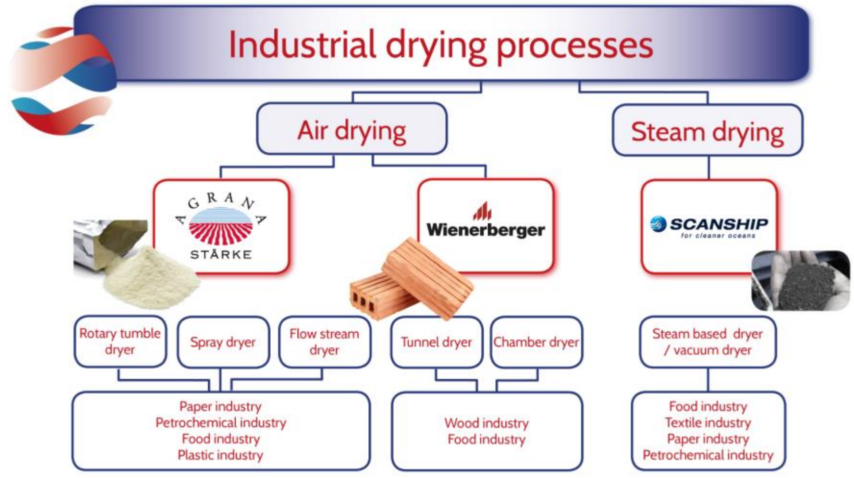
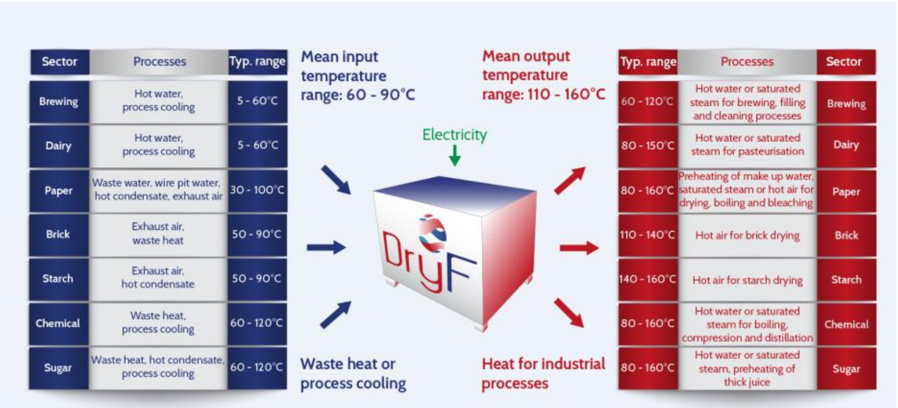
61

Industriesektoren, auf die DryFiciency abzielt

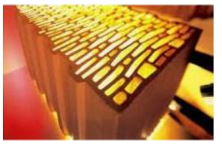


Anwendungsfälle für DryFiciency Wärmepumpen



Trocknungsanwendungen in DryFiciency

Wärmepumpensysteme mit geschlossenem Kältekreis | **Wärmepumpensysteme mit offenem Kältekreis**

STÄRKETROCKNUNG	ZIEGELTROCKNUNG	SCHLAMMTROCKNUNG
		
AGRANA Stärke GmbH Pischelsdorf (Austria)	Wienerberger AG Uttendorf (Austria)	Scanship A/S / Lindum A/S Drammen (Norway)

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64

Stärketrocknung @Agrana Stärke GmbH

FACTS

- **Kompressionswärmepumpe** mit Bitze-Schraubenkompressoren
- **Wärmequelle**: Abwärme (Wasser) bei 70° C
- **Wärmeversorgung**: Heißluft bei 110 bis 160° C

IMPACTS (Plan)

- **Einsparung von CO2-Emissionen:** ca. 500t/a
- **Einsparung von Endenergie**: 2.200 MWh/a
-

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65

DryF | AIT Austrian Institute of Technology TOMORROW TODAY

Ziegeltrocknung @Wienerberger AG

FACTS

- **Kompressionswärmepumpe** mit Kolbenkompressoren von Viking Heat Engines A/S bzw. Heaten A/S
- **Wärmequelle**: Abwärme (Wasser) bei 70° C
- **Wärmeversorgung**: Heißluft bei 110 bis 160° C

IMPACTS (Plan)

- **Einsparung von CO2-Emissionen:** ca. 2.900t/a **Endenergieeinsparung**: 10.500 MWh/a

AIT Austrian Institute of Technology TOMORROW TODAY · Viking Heat Engines · FUCHS · Chemours

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66

DryF | AIT Austrian Institute of Technology TOMORROW TODAY

Schlammtrocknung @Scanship A/S

FACTS

- **MVR-System** mit Turbokompressoren von Rotrex A/S
- **Wärmeversorgung**: Heißdampf bis 155 ° C

IMPACTS (Plan)

- Einsparung von CO2-Emissionen: ca. 450t/a
- Endenergieeinsparung: 1500 MWh/a

SINTEF · ROTREX · SCANSHIP for cleaner oceans · EPCON Evaporation Technology AS

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67

Projekt-Kontakte

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dryficiency@ait.ac.at

Besuchen Sie **www.dryficiency.eu** und melden Sie sich für unseren **Newsletter** an, um auf dem Laufenden zu bleiben.

Folgen Sie uns auf **LinkedIn** und **Twitter**:

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68

Back-up Folien

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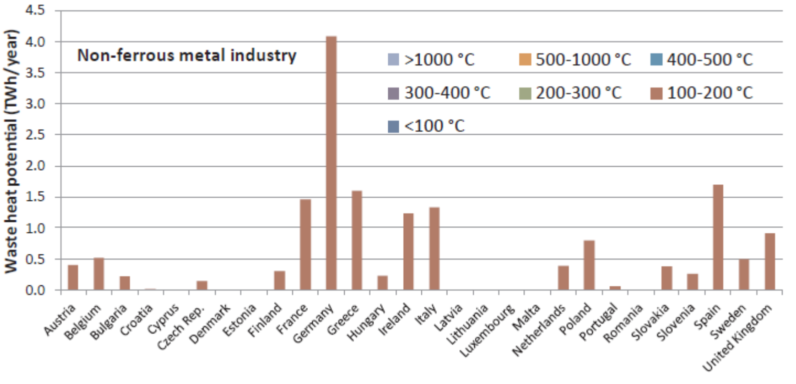
69

Abwärmepotenzial: NE-Metalle (2015)



Quelle: Papapetrou (2018), Industrial waste heat: Estimation of the techncially available resource: in the EU per industrial sector, temperature level and country

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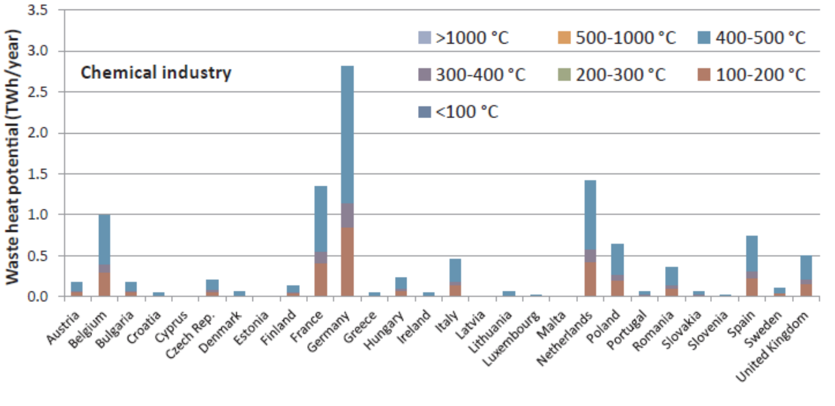
70

Abwärmepotenzial: Chemische Industrie (2015)



Quelle: Papapetrou (2018), Industrial waste heat: Estimation of the techncially available resource: in the EU per industrial sector, temperature level and country

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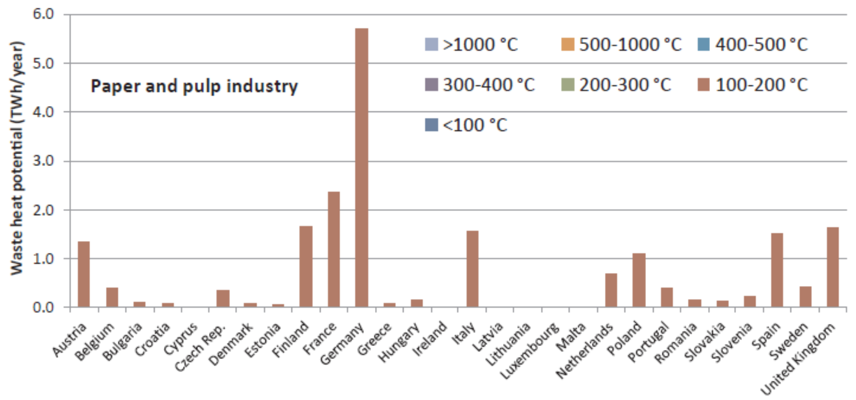
71

Abwärmepotenzial: Zellstoff- & Papierindustrie (2015)



Quelle: Papapetrou (2018), Industrial waste heat: Estimation of the techncially available resource: in the EU per industrial sector, temperature level and country

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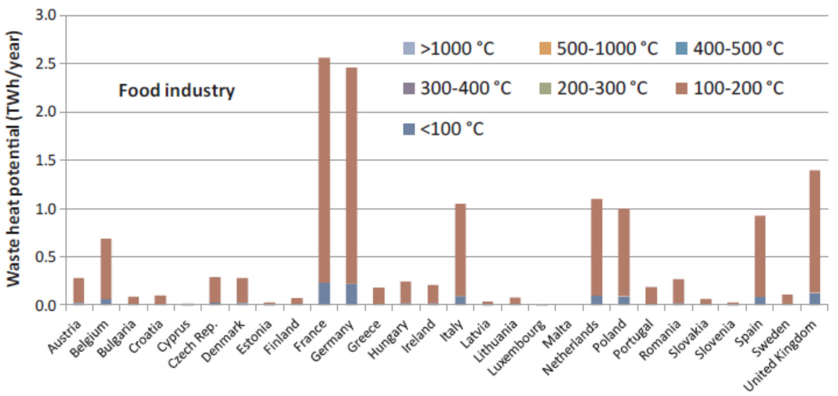
72

Abwärmepotenzial: Lebensmittelindustrie (2015)



Quelle: Papapetrou (2018), Industrial waste heat: Estimation of the techncially available resource: in the EU per industrial sector, temperature level and country

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73

5.3 Presentations from online seminars and final conference

Industrial heat pumps for a greener European industry: February 23rd, 2021

Waste heat solutions for Europe's green recovery: March 19th, 2021

High temperature heat pumps in energy intensive industries: core components: April 7th, 2021

High temperature heat pumps in energy intensive industries: demonstration plants: April 21st, 2021

Final conference: June 6th, 2021

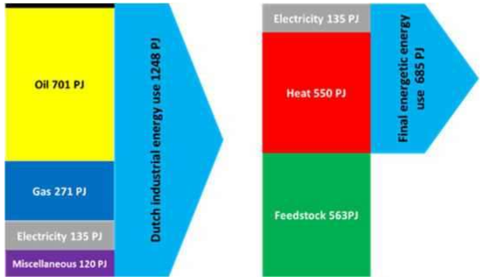
Online seminars for industrial end-users, policy makers, energy managers & consultants

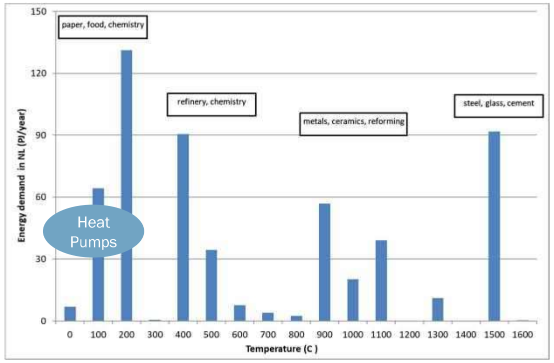
‘INNOVATION FOR LIFE’

TNO CONNECTS PEOPLE AND KNOWLEDGE TO CREATE INNOVATIONS THAT BOOST THE COMPETITIVE STRENGTH OF INDUSTRY AND THE WELL-BEING OF SOCIETY IN A SUSTAINABLE WAY.
THIS IS OUR MISSION AND IT IS WHAT DRIVES US, THE OVER 3,400 PROFESSIONALS AT TNO, IN OUR WORK EVERY DAY!

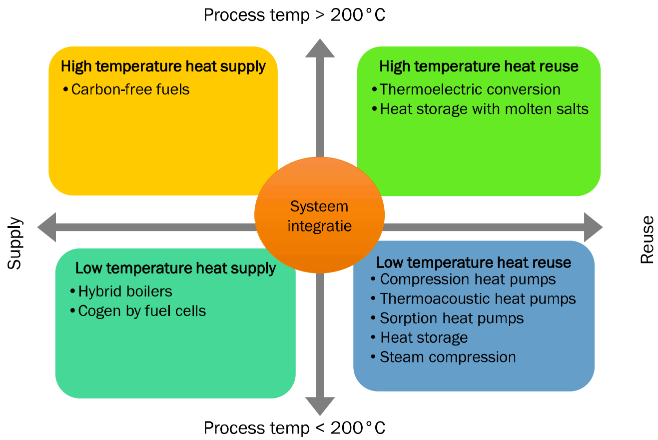
TNO innovation for life

BACKGROUND ON INDUSTRIAL HEAT
ENERGY USE IN THE NETHERLANDS

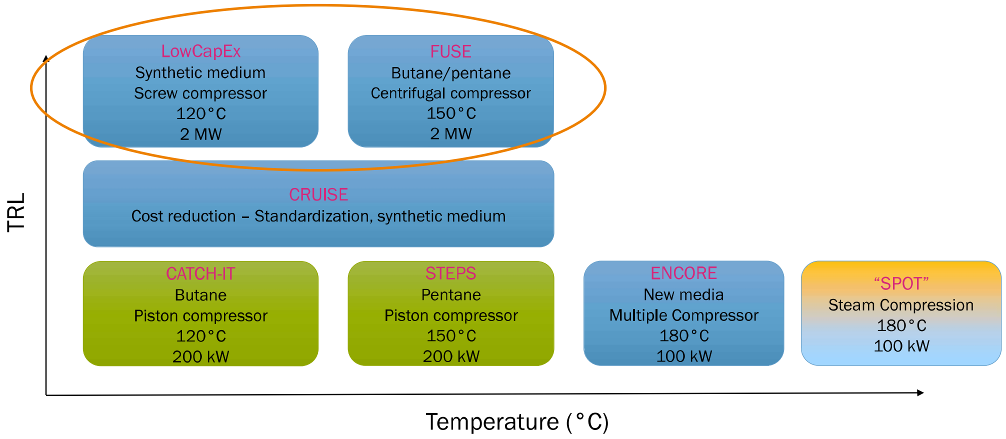




DEVELOPMENT PORTFOLIO TNO



COMPRESSION HEAT PUMP DEVELOPMENT @ TNO



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COMPRESSION HEAT PUMPS
LOW CAPEX PROJECT

TECHNICAL

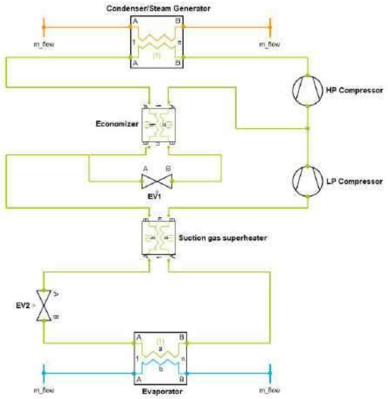
- Steam production @120°C at 2MW scale
- Synthetic working fluid - HFO
- Two compressors
  - Parallel construction of the high pressure side
  - Shared evaporator
- Potential for further lowering capex
- Step towards industrial demonstrations

FOLLOW-UP

- Demonstration in Paper mille (Smurfit Kappa)

TNO innovation for life

COMPRESSION HEAT PUMPS
FUSE PROJECT



TECHNICAL

- Steam production @150°C at 2MW scale
  - Natural working fluid – Pentane
- Using waste heat 60°C-90°C
- Aim for investment cost < 200 €/kWth (excluding integration)

CHALLENGE

- Finding a suitable compressor

FOLLOW-UP

- Demonstration at DOW chemical

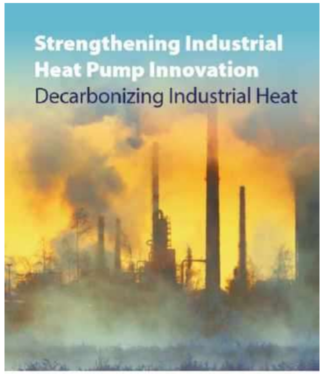
CARNOT LAB
TECHNOLOGY DEVELOPMENT

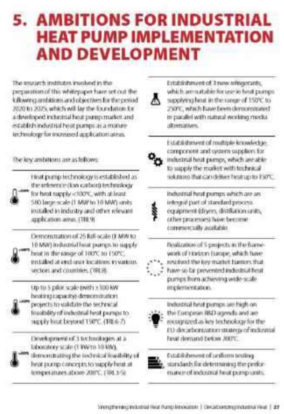
- New lab facilities in the Netherlands; Petten

- Contains general infrastructure for testing small scale to large scale heating equipment; 1 kW to 2 MW
  - HP testing 200 kW, 10 bar steam
  - Full scale HP 2 MW, 10 bar steam)
  - Use of flammable working media
  - 1 MW Electrical connection
  - Humid air (100ºC)
  - Hot air loop (1000ºC)
  - General heating and cooling

WHAT IS NEEDED FOR FURTHER INNOVATION?

WHITE PAPER




5. AMBITIONS FOR INDUSTRIAL HEAT PUMP IMPLEMENTATION AND DEVELOPMENT

Webinar
29th of October
At 15:00

https://www.tno.nl/en/about-tno/events/2020/webinar-heat-pumps-for-decarbonising-the-industry/

http://publications.tno.nl/publication/34636827/LyEUaZ/TNO-2020-heatpump.pdf

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THANK YOU FOR YOUR TIME

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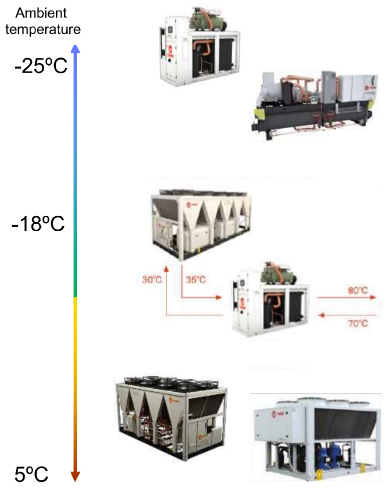
Using heat pumps to re-purpose industrial process waste energy

Case study

Erik Van Oossanen, Applied Portfolio Leader - Trane Europe

30 September 2020

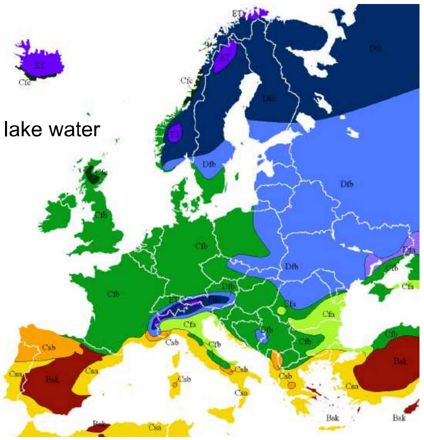
Heating solutions in Europe, sourcing from nature



✓ **Water sourced:**
Sourcing from Geothermal / lake water
high heating temperatures
Up to 85°C

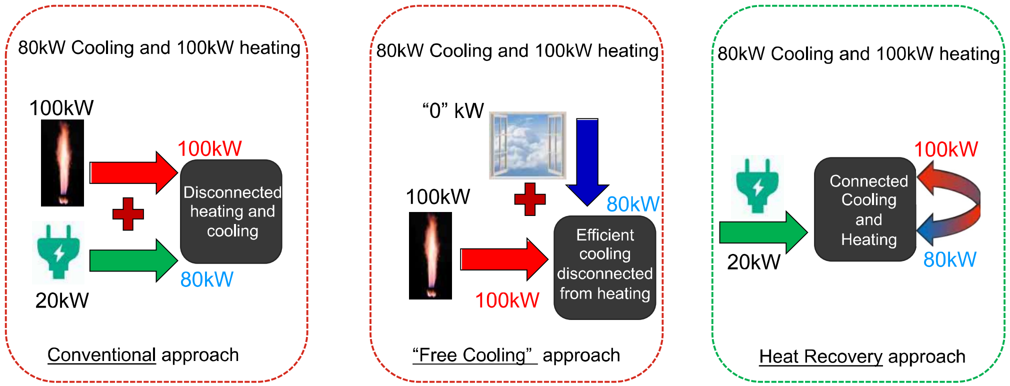
✓ **Cascade**:
Sourcing from ambient air
high heating temperatures
Up to 85°C

✓ **Air sourced:**
Sourcing from ambient air
Medium heating temperatures
Up to 55°C



HEAT Recovery, sourcing from waste

*TER: Total Efficiency Ratio



$TER^* = \frac{100+80}{100+20} = 1.5$

$TER^* = \frac{100+80}{100} = 1.8$

$TER^* = \frac{100+80}{20} = 9$

TRANE

600% efficiency gain by connecting heating and cooling!

A Real Life example
Water-to-water Heat Pumps with Heat Recovery – Industrial application

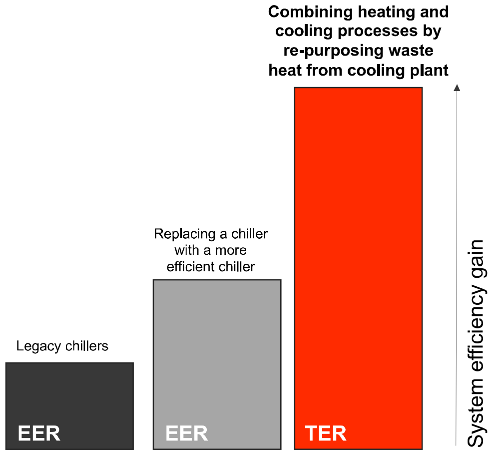
Animal health products factory – France

- A global company focusing on R&D and manufacturing of animal health products
- Annual turnover of almost 1 billion dollars
- Several production sites spread across 10 countries
- Committed to **optimizing the resources they use** with continuous monitoring of energy consumption, water and materials used in their manufacturing processes.

TRANE

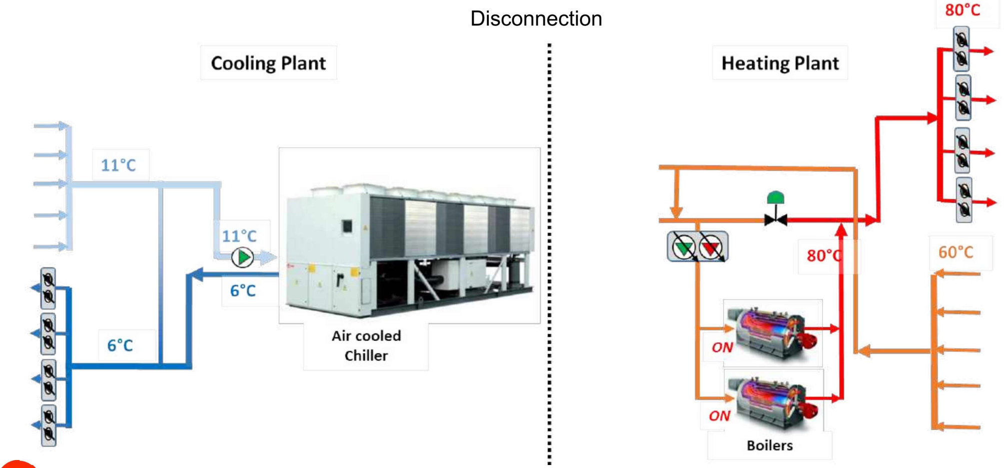
The Challenge and current status

- One of their keys objectives is **to reduce energy (smaller carbon footprint) and gas consumption (lower emissions)**
- Traditionally, replacing old equipment with a more efficient equivalent unit was considered as the best option.
- The company partnered with Trane to identify innovative solutions, starting with a production site located in the south of France
- Proposed solution: connecting the cooling and heating processes to recover the heat from the chiller plant and reuse it for heating in their production process.



TRANE

Solution - Original design



TRANE

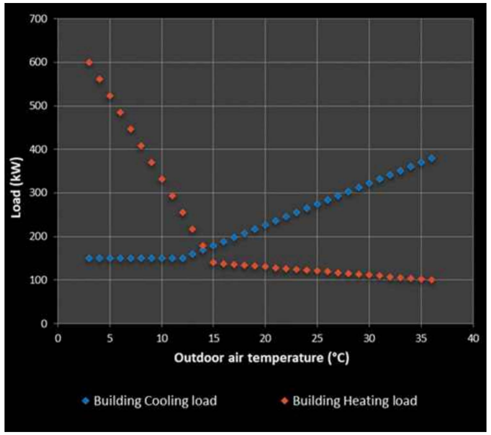
Demand profiles

Cooling requirements:

- Water Temperatures: 6/11°C
- Loads:
  - Manufacturing process
  - Storage (Finished good + raw material)
  - Air conditioning for labs and office

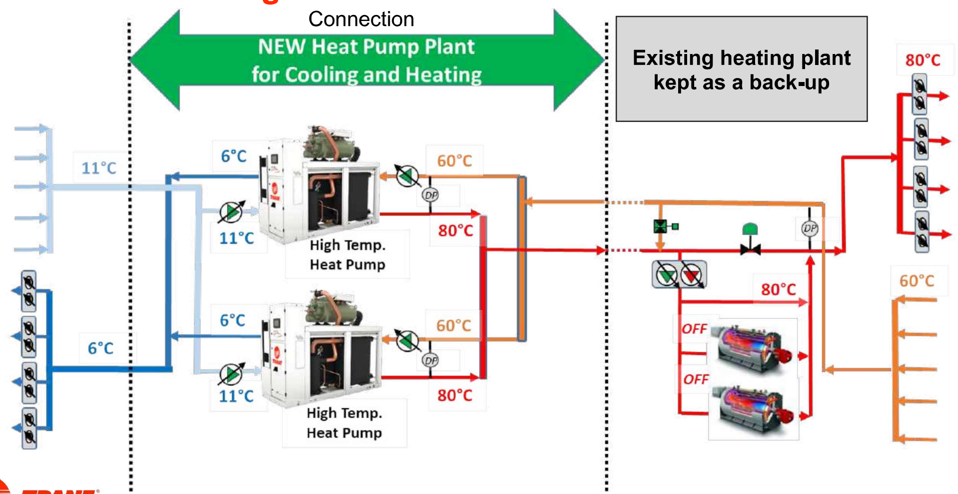
Heating requirements:

- Water Temperature : 80/60°C
- Loads:
  - Manufacturing process
  - Space heating



TRANE

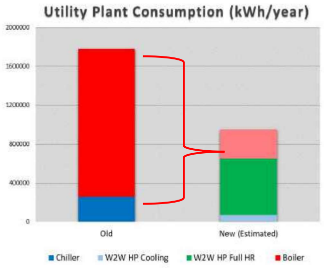
Solution - new design



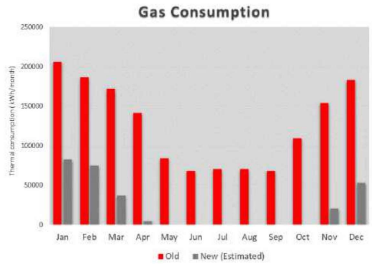
TRANE

Results – Estimated savings

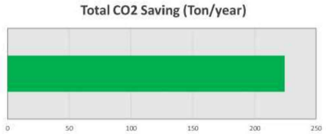
Utility Plant Average
Energy Efficiency Ratio
increased from 1.18 to 2.15



Annual Gas Consumption
decreased by ~ 80%



Avoidance of
225 Tons of CO_2 per year



* Electricity: 0,053 kgCO2/kWh
Gas: 0,2 kgCO2/kWh

REDUCING THE ENERGY INTENSITY OF THE WORLD™

“Some” Heat Pump Applications in Food and Beverage

Decarbonize heating processes and reduce operating costs with heat pump technology

AUTHOR: ROBERT UNSWORTH

EHPA WEBINAR, SEPT. 2020

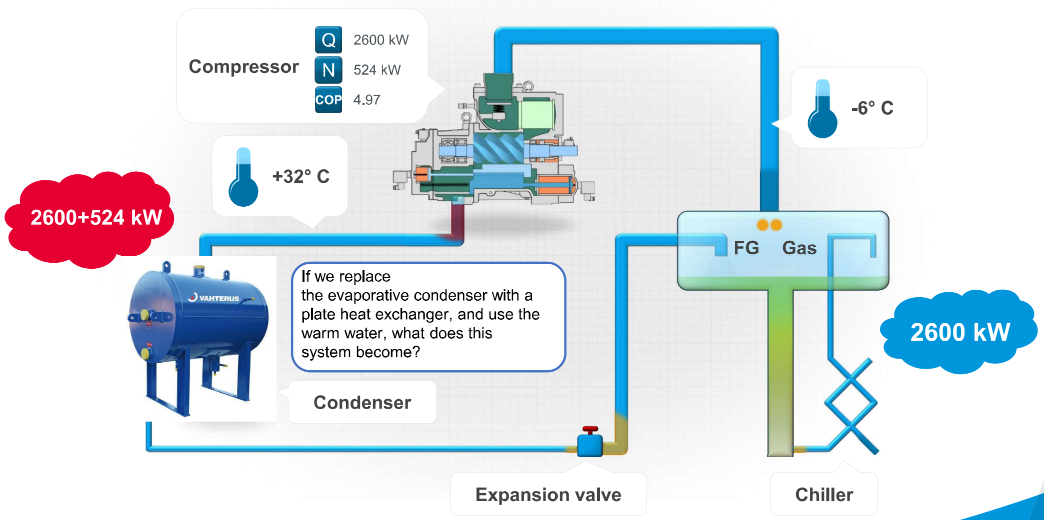
GEA engineering for a better world

Heat pumps – understanding our thermal needs!

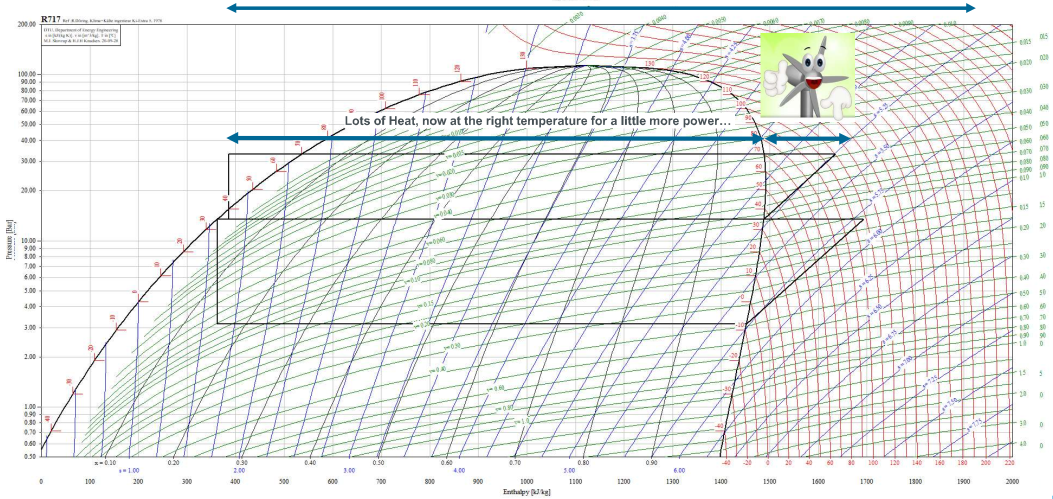
GEA engineering for a better world

Poultry	Product Intake +38 °C	Defeathering +52 °C	Chilling +2 °C	Final Product +2 °C
Dairy Beverage	Product Intake +2 °C	Pasteurisation +74 °C	Chilling +2 °C	Final Product +2 °C
Vegetables	Product Intake +20 °C	Blanching +80 °C	Freezing -18 °C	Final Product -22 °C

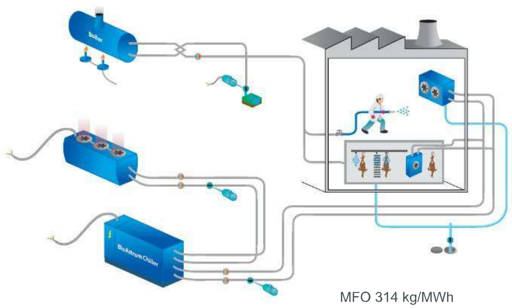
Basic refrigeration chilling system



Enthalpy Diagram



Heating / cooling in traditional poultry plant – 2 million birds per week



MFO 314 kg/MWh
NG 227 kg/MWh
EL 300 kg/MWh

Heating Cost (7 day/week)

1,518 kW x 20 hr x 365 d/year
= 11 million kWh/year energy (fuel) used

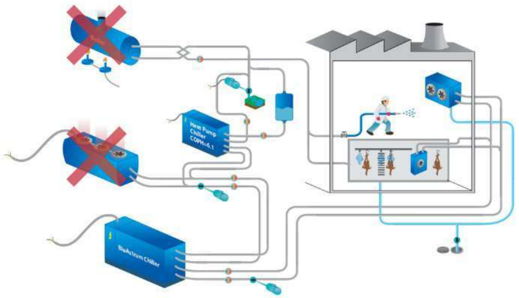
Refrigeration Cost (7 day/week)

(495 + 24 + 82 kW) x 18 hr x 339 d/year
= 3.95 million kWh energy (electricity) used

Total

Energy = 14.95 million kWh/year
CO_2 Emissions = 4,160 tonnes/year

Heating / cooling using Heat Pump – 2 million birds per week



MFO 314 kg/MWh
NG 227 kg/MWh
EL 300 kg/MWh

Heating Cost (7 day/week)

(1,350 kW/11.25) x 20 hr x 365 d/year
= 0.8 million kWh/year electricity used

Refrigeration Cost (7 day/week)

(495 + 24 + 29 kW) x 20 hr x 365 d/year
= 4.0 million kWh electricity used

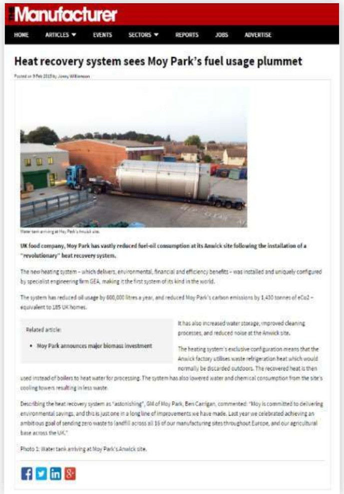
Total

Energy = 4.8 million kWh/year
CO_2 Emissions = 1,440 tonnes/year

Annual Savings:

10.15 million kWh energy
2,720 tonnes CO_2

Realized Moy Park poultry factory savings


The Manufacturer

HOME ARTICLES EVENTS SECTORS REPORTS JOBS ADVERTISE

Heat recovery system sees Moy Park's fuel usage plummet

Water tank arriving at Moy Park's Anwick site.

UK food company, Moy Park has vastly reduced fuel-oil consumption at its Anwick site following the installation of a "revolutionary" heat recovery system.

The new heating system – which delivers, environmental, financial and efficiency benefits – was installed and uniquely configured by specialist engineering firm GEA, making it the first system of its kind in the world.

The system has reduced oil usage by 600,000 litres a year, and reduced Moy Park's carbon emissions by 1,430 tonnes of eCo2 – equivalent to 185 UK homes.

Related article:

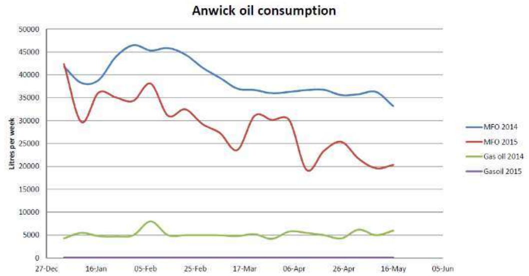
- Moy Park announces major biomass investment

It has also increased water storage, improved cleaning processes, and reduced noise at the Anwick site.

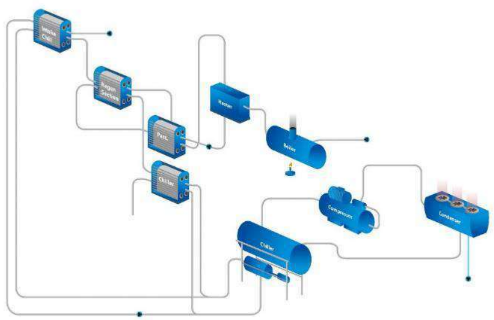
The heating system's exclusive configuration means that the Anwick factory utilises waste refrigeration heat which would normally be discarded outdoors. The recovered heat is then used instead of boilers to heat water for processing. The system has also lowered water and chemical consumption from the site's cooling towers resulting in less waste.

Describing the heat recovery system as "astonishing", GM of Moy Park, Ben Carrigan, commented: "Moy is committed to delivering environmental savings, and this is just one in a long line of improvements we have made. Last year we celebrated achieving an ambitious goal of sending zero waste to landfill across all 16 of our manufacturing sites throughout Europe, and our agricultural base across the UK."

Photo 1: Water tank arriving at Moy Park's Anwick site.



Heating/Cooling in traditional dairy plant



9.5 million ltr/wk Fresh Milk

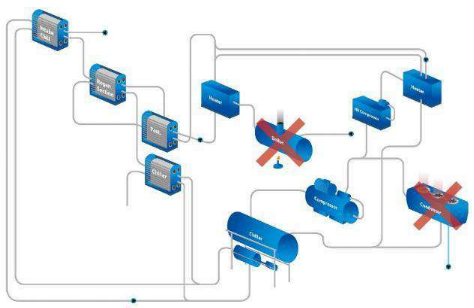
Heating Cost
72,000 kWh/wk Natural Gas (7 day/week) x 52
= 3.74 million kWh/year energy (fuel) used

Refrigeration Cost
14,280 kWh/wk (7 day/week) x 52
= 0.74 million kWh energy (electricity) used

Water used
407 m^3/wk (7 day/wk) x 52
= 21k m^3/year

Total
Energy = 4.48 million kWh/year
CO_2 Emissions = 970 tonnes/year

Heating/Cooling in dairy plant with Heat Pump



9.5 million ltr/wk Fresh Milk

Heating Cost
6,440 kWh/wk (7 day/week) x 52
= 0.33 million kWh/year energy (electricity) used

Refrigeration Cost
14,280 kWh/wk (7 day/week) x 52
= 0.74 million kWh energy (electricity) used

Water used
242 m^3/wk (7 day/wk) x 52
= 12.5k m^3/year

Total
Energy = 1.07 million kWh/year
CO_2 Emissions = 321 tonnes/year

Annual Savings:
3.41 million kWh energy
649 tonnes CO_2

Carbon-neutral smoothie manufacturing site

The innocent way

- 400 million bottles per year
- Zero carbon emission production
- Unique GEA process and utility configuration
- 2.5 MW Heat pump @ 90˚C
- 5 MW heat pump @ 65˚C

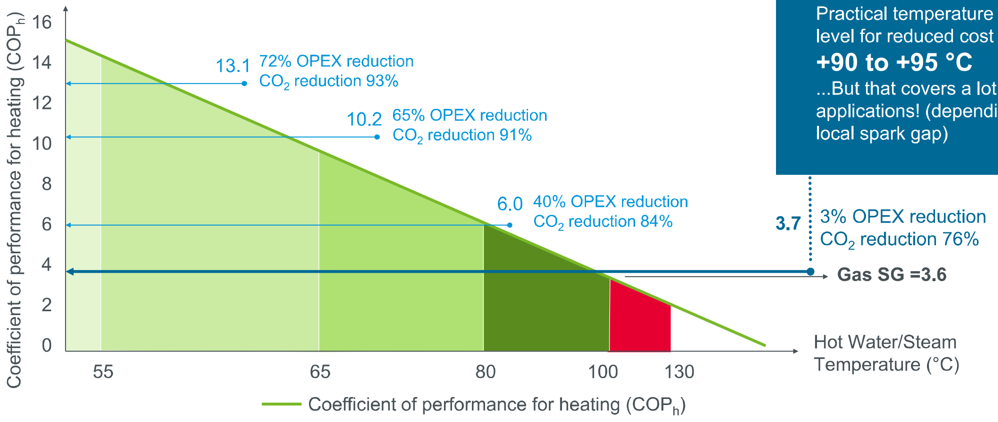
Comparison of OPEX and CO_2 for heating via Ammonia heat pumps vs Steam boiler

engineering for
a better world

Practical temperature level for reduced cost

+90 to +95 °C

...But that covers a lot of applications! (depending on local spark gap)



Note: Figures based on Gas = 2p/kWh, Electricity = 9p/kWh, Boiler efficiency = 80%, Spark Gap = 3.6

engineering for
a better world

Technology for a better society

EHPA

Heat pumps: No-way or Norway?

Michael Bantle
Senior Researcher
SINTEF Energy Research

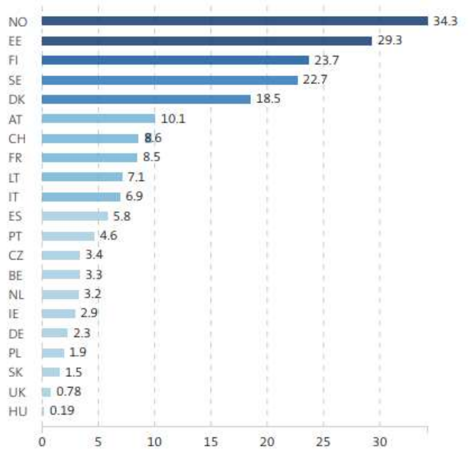
Michael Bantle (PhD)

POSITION	Senior Research Scientist
KEY QUALIFICATIONS	Heat Pumps, High Temperature Heat pumps, Natural Refrigerant , Thermal process engineering, Drying Technology, Food Technology, Food properties and quality,
CONTACT	Michael.Bantle@sintef.no; +47 41014024

since 2012	SINTEF Energy Research, Department Thermal Energy
2011 – 2012	Post-Doc at NTNU, *Energy efficiency in drying processes*
2007 – 2011	PhD at NTNU, *Study of high intensity, airborne ultrasound in atmospheric freeze drying.*
2002 – 2007	University of applied science, Konstanz Germany, Process and Environmental engineering, Diploma thesis: *Dimensioning of drying and conditioning unit for soybeans.*

Heat pump sales per 1000 inhabitants (2017)

- High market acceptance of heat pumps in Scandinavia
- Several Start-Up companies for HTHP
- Heat pumps "standard" solution for building heating (and cooling)

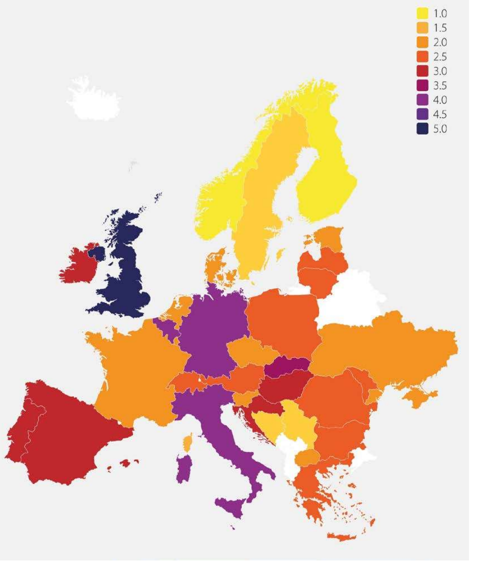


Heat pump sales 2017 per 1000 inhabitants (Figure 4-9 from EHPA's European Heat Pump Markets and Statistics Report 2018)

Energy price ratio

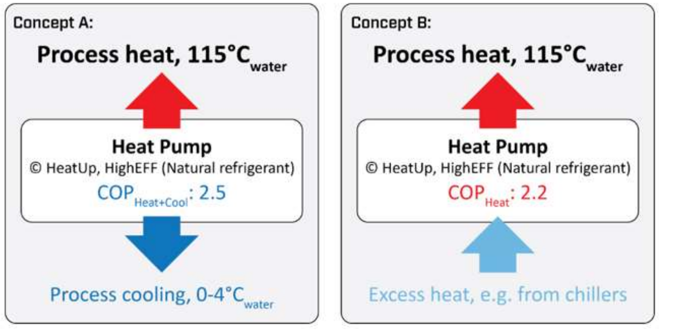
→ Price difference per kWh electricity vs. fossil fuel

- De-carbonized future requires increased used of (renewable) electricity
- Electricity is in many European countries more expensive than fossil fuel



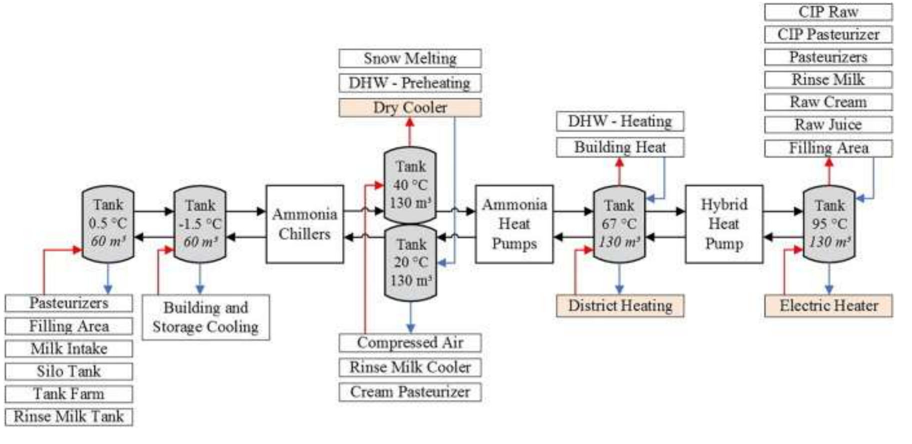
Industrial Heat Pump Examples (Dairy)

- Combined heating and cooling
- Tested on TRL 6
- Integrated on TRL8 in dairy production (5 GWh / year)
- Need for thermal storage to match time-depending heat sink and source demand



Technology for a better society

Industrial Heat Pump Examples (Dairy)

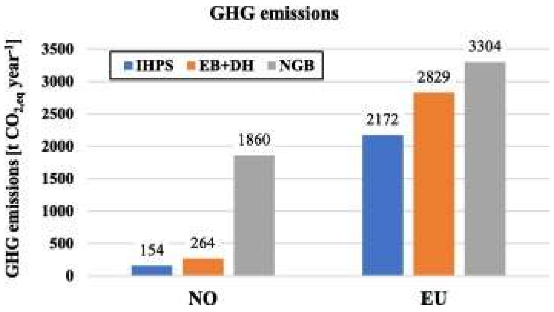


Technology for a better society

Industrial Heat Pump Examples (Dairy)

- NO = 2050 scenario
- EU = 2020 scenario

- IHPS = Fully integrated het pump with thermal storage
- EB + DH = Electric boiler and District Heating
- NGB = Natural Gas Burner



https://www.sciencedirect.com/science/article/pii/S1359431121001861

Industrial High Temperature Heat Pumps

- 1.5 – 5 MW heat pump
- Supply of process heat 150 °C - 180°C
- R718 (water) as refrigerant
- Two-phase compressor technology (patent ToCircle Industries)

Support by the European Union

This project has received funding from the European Union's Horizon 2020 research and innovation – SME Instrument programme under grant agreement No 805689

Technology for a
better society

We are on the edge of an **ELECTRIFICATION ERA**

Is **INDUSTRY** prepared?

Dr Silvia Madeddu

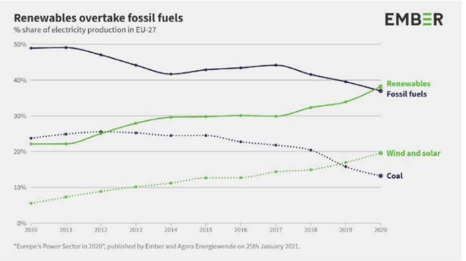
23.02.2021

PIK – Potsdam Institute for Climate Impact Research

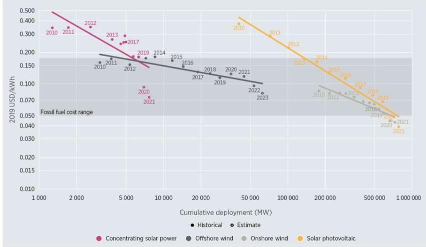
madeddu@pik-potsdam.de

https://twitter.com/MadedduSilvia

The ongoing **RENEWABLES TRANSITION** shows that **ELECTRICITY** is easier and faster to decarbonise than non-electric fuels



In 2020, for the fist time, renewables overtook fossil fuels in the generation of electricity in Europe (38%)



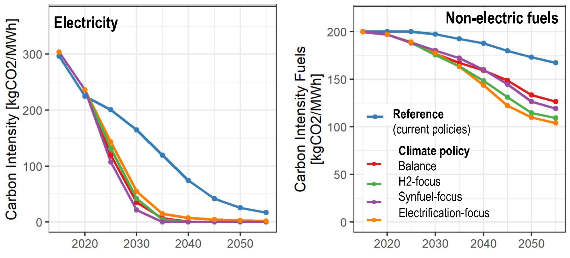
Source: IRENA.
Note: The LCOE and auction price data are for utility-scale projects.

Renewables are becoming increasingly cost competitive with fossil fuels (in some countries they are already cheaper!)

Sources: Agora Energiewende and Ember (2021): *The European Power Sector in 2020: Up-to-Date Analysis on the Electricity Transition (left image)*
IRENA (2020), Renewable Power Generation Costs in 2019, International Renewable Energy Agency, Abu Dhabi. (right image)

The ongoing **RENEWABLES TRANSITION** shows that **ELECTRICITY** is easier and faster to decarbonise than non-electric fuels

REMIND, EU level, 1.5 °C scenario - Carbon Intensity of energy carries



Source: Preliminary data from IAM REMIND (Luderer et al, Accelerated electrification based on cheap renewables facilitates reaching Paris Climate targets, under revision)

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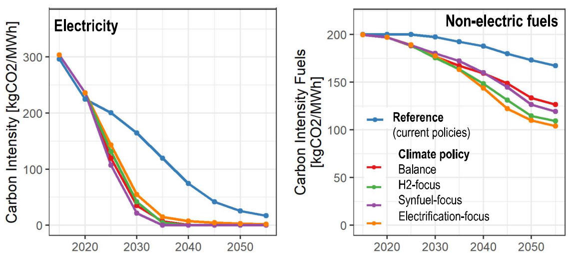
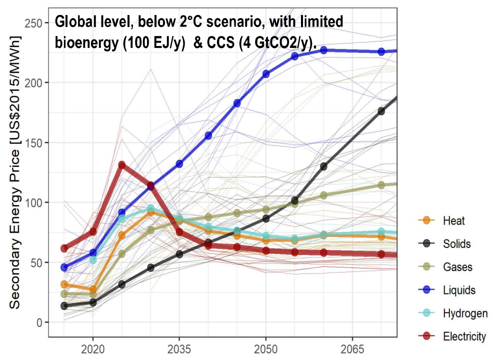
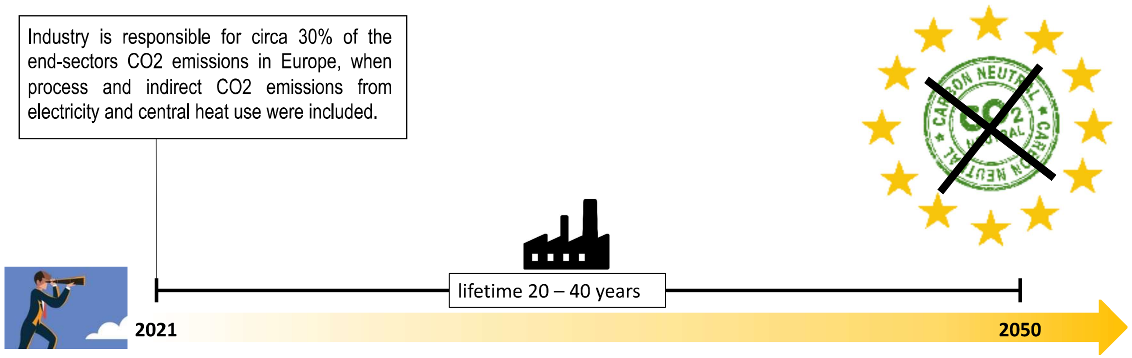




Source: Preliminary data from IAM REMIND (Luderer et al, Accelerated electrification based on cheap renewables facilitates reaching Paris Climate targets, under revision)

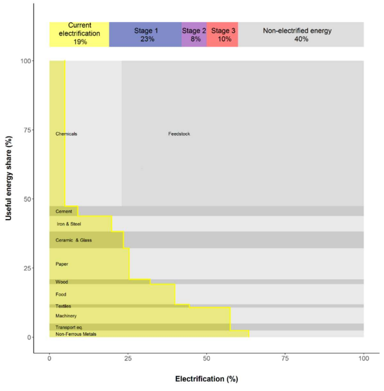
Investments in **CARBON-INTENSIVE** technologies for **INDUSTRY** will **JEOPARDISE THE EU GREEN DEAL**

Investments in CARBON-INTENSIVE technologies for INDUSTRY will JEOPARDISE THE EU GREEN DEAL



The **RENEWABLES TRANSITION** requires an adequate **TECHNOLOGICAL TRANSITION** in **INDUSTRY**

The **RENEWABLES TRANSITION** requires an adequate **TECHNOLOGICAL TRANSITION** in **INDUSTRY**



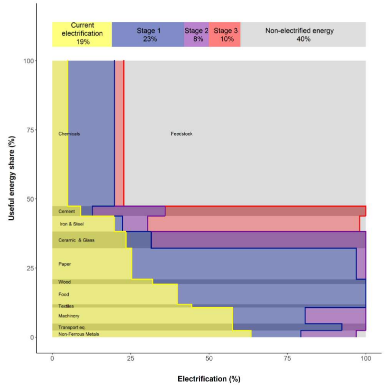
As of today, only 19% circa of the energy used in the European industry is supplied by electricity (circa 25% at final energy level)

<100°C	100 – 400°C	400 – 1000°C	>1000°C	TECHNOLOGICAL MATURITY	APPLICATIONS	EFFICIENCY /COP
Compression heat pumps and chillers				Established in industry (only <100 °C)	Space heating Hot water Low pressure steam Drying Cooling and refrigeration	COP 2 – 5
Mechanical vapour recompression (M VR)				Established in industry	Energy recovery (e.g. in distillation, evaporation) to provide steam and process heat	COP 3 – 10
Electric boilers				Established in industry	Space heating Hot water Thermal oil Steam	0.95 – 0.99
Infrared heaters				Established in industry	Drying Paint curing Plastic treatments Food processing	0.60 – 0.90
Microwave & radio frequency heaters				Established in industry except cement and ceramic firing/sintering	Drying Ceramics firing and sintering Cement treatment Food processing	0.50 – 0.85
Induction furnace				Established in industry	Metals melting, re-heating, annealing, welding	0.50 – 0.90
Resistance furnace				Established in industry	Metals melting, smelting Heaters for the chemical industry Ceramic firing Glass melting Calcination	0.50 – 0.95
Electric arc furnaces				Established in industry	Metals melting and partial refining	0.60 – 0.90
Plasma technology				Established in industry only for metals and waste treatment	Waste treatment Metals treatments (e.g. welding) Sintering Cement production	0.50 – 0.90

Mature and efficient technologies already exist that could be readily implemented to electrify industry

From Madeddu et al., The CO2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat), Env. Res. Letters, 15, 2020, https://doi.org/10.1088/1748-9326/abbd02

The **RENEWABLES TRANSITION** requires an adequate **TECHNOLOGICAL TRANSITION** in **INDUSTRY**

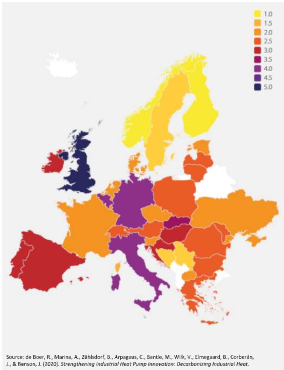


- 78% of the energy demand (excluding feedstocks) is electrifiable with technologies that are already established.
- 99% electrification can be achieved with the addition of technologies currently under development.
- Such a deep electrification could reduce the industry energy consumption by 20%
- Such a deep electrification reduces CO2 emissions already based on the carbon intensity of today's electricity (~300 gCO2 kWhel−1).
- With an increasing decarbonisation of the power sector (12 gCO2 kWhel−1 in 2050), electrification could cut CO2 emissions by 78%, and almost entirely abate the energy-related CO2 emissions, reducing the industry bottleneck to only residual process emissions.

From Madeddu et al., The CO2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat), Env. Res. Letters, 15, 2020, https://doi.org/10.1088/1748-9326/abbd02

INDUSTRY ELECTRIFICATION can be fostered by creating a level plain field in the energy market and a **COMPETITIVE ELECTRICITY PRICE**

INDUSTRY ELECTRIFICATION can be fostered by creating a level plain field in the energy market and a **COMPETITIVE ELECTRICITY PRICE**



Electricity/gas price ratio in Europe

- Industry investments in electrification, not only monetary but also for the acquisition of technical expertise will stall until a clear scenario is presented where electricity is going to be cost-competitive.

- Economic incentives and appropriate policies are needed to support industry transformation:
    - Reduction of electricity taxation and levies to create a level playing field across energy carriers and a competitive electricity price.
    - Carbon pricing system.
    - Stop subsidies for fossil-based technologies

THANK YOU!

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

PROCESS DECARBONIZATION: DRYFICIENCY AND BEYOND…

V. Wilk, F. Helminger, M. Lauermann, B. Windholz, A. Sporr,
A. Beck, G. Drexler-Schmid, T. Fleckl

AUSTRIAN INSTITUTE OF TECHNOLOGY

DRYFICIENCY: INDUSTRIAL DEMONSTRATION

DryF

- Upgrading idle waste heat streams to process heat streams up to 160°C
- Key elements of the solution are three advanced high temperature vapour compression heat pumps
  - » two **closed loop heat pumps** for air drying processes
  - » one **open loop heat pump** for steam driven drying processes

The project has received funding from the European Union's Horizon 2020 programme for energy efficiency and innovation action under grant agreement No. 723576.

DRYFICIENCY: INDUSTRIAL DEMONSTRATION

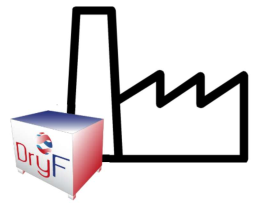
Challenges and research questions

- component design
  - compressors
  - lubricant and refrigerant
- prototype design
  - integration in industrial process
  - design of refrigerant cycle
  - process control and monitoring
- commissioning and demonstration

TECHNO-ECONOMIC ASSESSMENT

Comparison of the heat pump to a natural gas burner

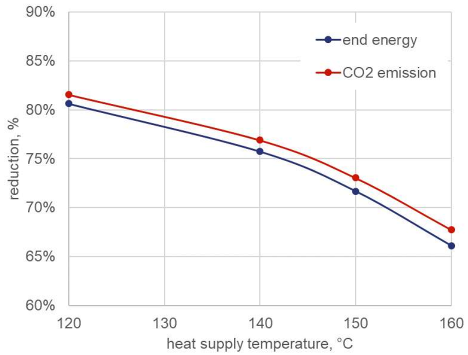
CO_2 emissions: 271 g/kWh
Gas price: 33 €/kWh
…with current CO_2 price: 39.5 €/kWh
…with increased CO_2 price: 46.6 €/kWh

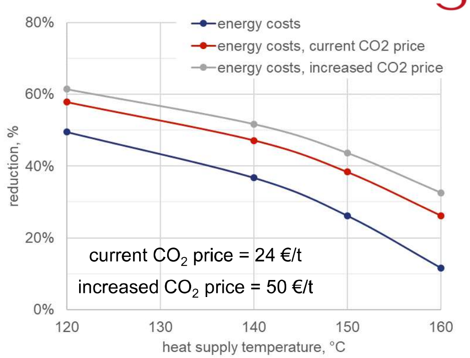


CO_2 emissions: 258 g/kWh
Electricity price: 86 €/kWh
… with current CO_2 price: 86 €/kWh
… with increased CO_2 price: 92.7 €/kWh

V. Wilk et al. High temperature heat pumps for industrial processes – application and potential; ECEEE Industrial Summer Study Proceedings, 4-132-20, 2020, p.329-334.

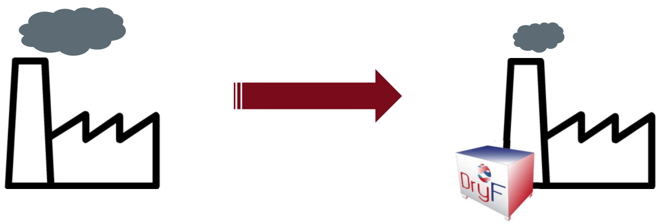
IMPACT ON PROCESS LEVEL





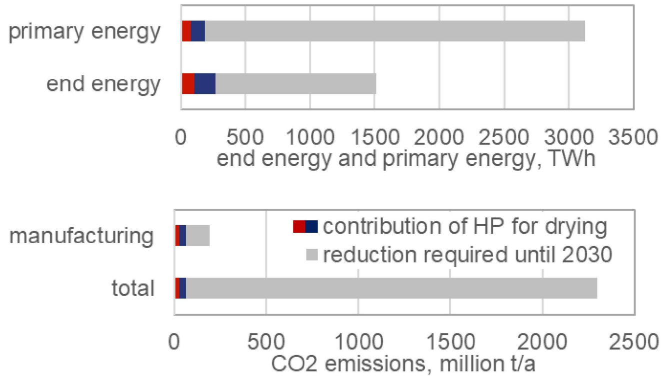
V. Wilk et al. High temperature heat pumps for industrial processes – application and potential; ECEEE Industrial Summer Study Proceedings, 4-132-20, 2020, p.329-334.

IMPACT ON EU LEVEL



- assume that 50% of all drying processes are equipped with a heat pump
- replacement of natural gas burners
- drying accounts for 10-25% of the total industrial energy use in most developed countries: 321 – 803 TWh energy consumption

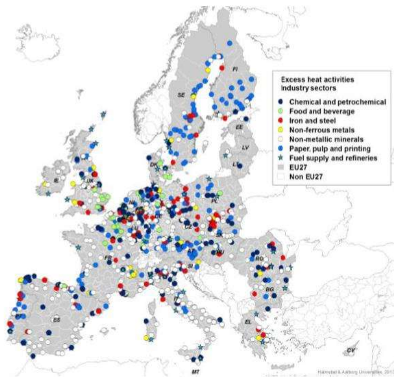
IMPACT ON EU LEVEL



Wilk et al. (2019) Decarbonization of industrial processes with heat pumps, ICR Conference 2019, DOI: 10.18462/iir.icr.2019.832

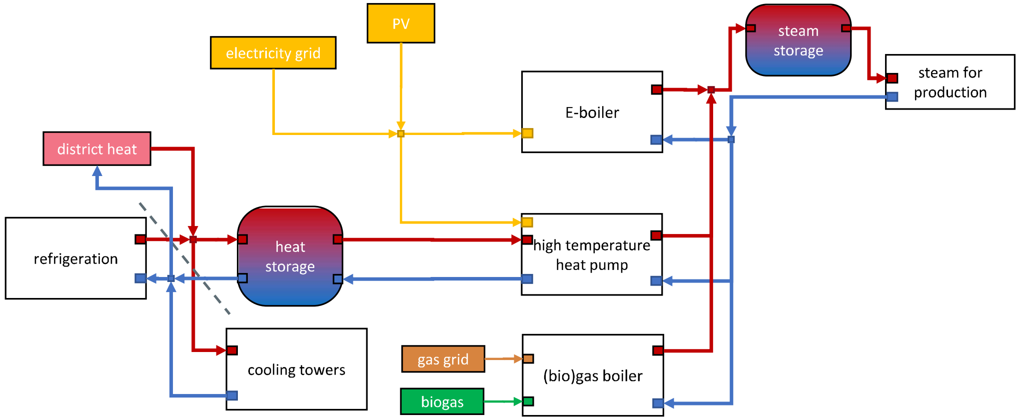
PROCESS INTEGRATION

- electrification of processes for decarbonization
- efficiency increase
- evaluation of sources and sinks
- determination of actual energy demand
- interconnection of streams



Energy intensive industries producing considerable excess heat
From: Connolly et al. (2013). Heat Roadmap Europe 2: Second Pre-Study for the EU27. Department of Development and Planning, Aalborg University.

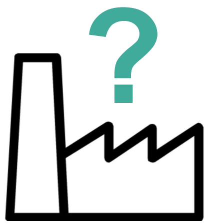
HOW TO INTEGRATE A HEAT PUMP?



HOW TO DECARBONIZE INDUSTRIAL PROCESSES?

Optimization of industrial sites:

- interaction of multiple heat suppliers, storages and consumers
- different options for decarbonization: avoid lock-in effects
- design and operation optimization



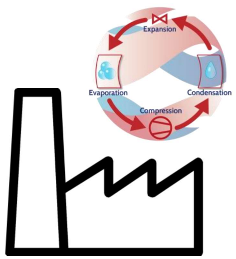
Method development:

- analysis of decarbonisation pathways
- mathematical programming: complex and dynamic systems, discontinuous processes
- dynamic simulations: interaction of heat pump and process

INDUSTRIAL HEAT PUMPS

Expectations of industrial end users

- high availability and reliability, short payback periods
- drivers: increase in efficiency and reduction of CO_2 emissions
- complex industrial processes require intelligent solutions for waste heat recovery



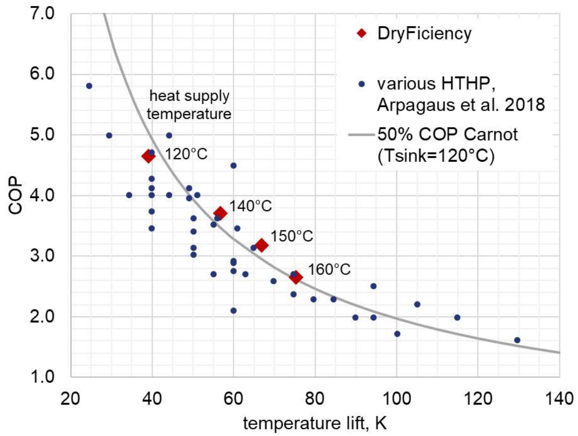
Demonstration projects for new developments

- establish trust in new technologies
- relevant industrial environment

THANK YOU!

Dr. Veronika Wilk
Sustainable Thermal Energy Systems
AIT Austrian Institute of Technology GmbH
Giefinggasse 2 | 1210 Vienna | Austria
veronika.wilk@ait.ac.at

TRIAL OPERATION



C. Arpagaus et al., High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials, Energy (152), p.985-1010, 2018.

R-ACES

Energy Cooperation Platform

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Project Manager
Energy Cluster Denmark
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energy CLUSTER DENMARK

Project

Institute for Sustainable Process Technology

5
EU Countries

LE2C LOMBARDY ENERGY CLEANTECH CLUSTER

7
Partners

energy CLUSTER DENMARK

pom

H2020
Coordination and Support Action

Condugo

Start:
June 2020

End:
November 2022

Spinergy

ESCI
European Science Communication Institute

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **N° 892429**

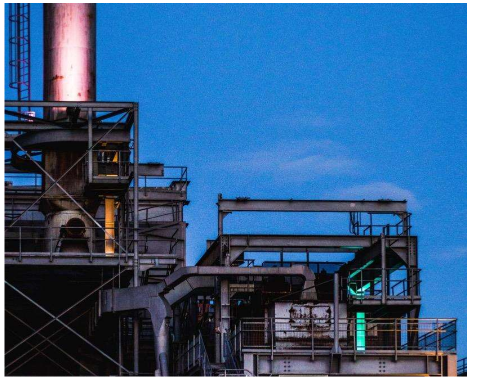
Why?

European Industry energy demand 25%

Only 16% comes from renewables

We need to save energy!

Energy Cooperation as a Solution



Industrial sites & business parks play a key role in the energy transition.

They have the potential to become hubs of energy flows for the entire region around them.

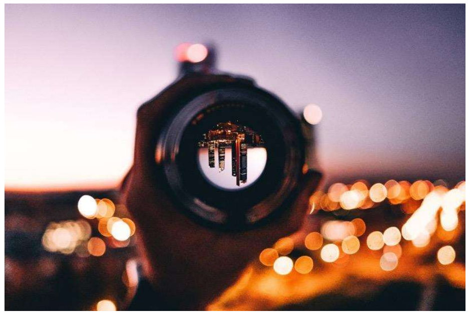
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **N° 892429**

Vision of R-ACES

R-ACES supports industrial sites & business parks in becoming ecoregions that reduce their CO_2 emissions by at least 10%.

R-ACES…

…creates ecoregions where multiple stakeholders engage in energy cooperation by (1) exchanging heat/cold streams, (2) investing in renewable energy solutions, or (3) managing energy streams with the use of the R-ACES toolbox that is aimed at reducing CO2 emissions by at least 10%.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **N° 892429**

R-ACES Approach

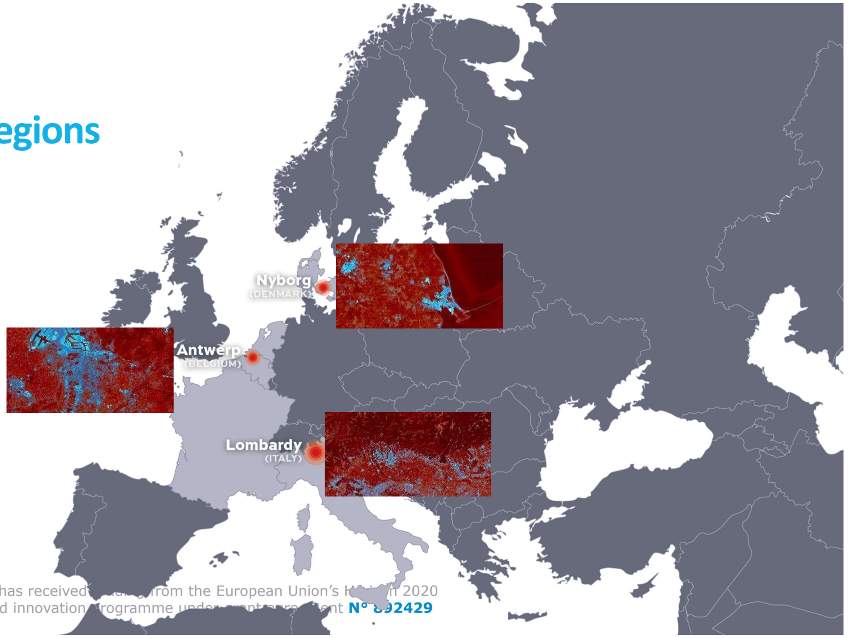
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **N° 892429**

Ecoregion

Multiple organisations cooperate in an ecoregion to establish energy cooperation. Regions consist of an industrial park or business park linked to its surroundings by energy cooperation activities.

An ecoregion relies on an anchor organisation responsible for managing the area. The proximity of stakeholders ensure the interconnected energy flows.

Pilot Ecoregions



This project has received ... rom the European Union's ... n 2020
research and innovation rogramme ... nt N° ...2429

R-ACES Tools

… to support the entire process of organising an ecoregion & the collaboration inside of it.

3 Practical Tools

… are the structuring element of the project. The tools are action oriented & **support ecoregions** to **implement** their **energy cooperation** projects.

The **self-assessment tool** helps to identify potential energy projects in a region. It provides best practices & check lists to users to help them to kick-off the process.

The **legal decision support tool** to help drawing up contracts that need to be signed between participants.

The **energy management platform** is the key to running, settling, and optimising the energy exchanges between companies.

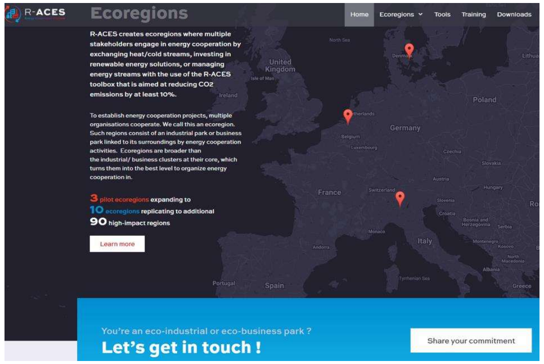
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **N° 892429**

How to become an Ecoregion?

Join us by sharing your commitment to the R-ACES energy cooperation principles

Share Your Commitment!

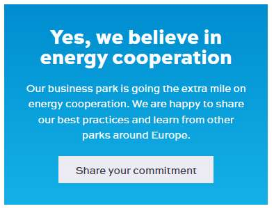
- www.r-aces.eu
- Go to “Ecoregions”
- Click on “Share your commitment”
- Fill in the form & submit
- Additional ecoregions shown in the map



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement **N° 892429**

R-ACES creates maximum impact

- Work on a better deal for Europe’s **clean energy** future
- Energy cooperation **reduces CO2**-emissions
- **Regional energy cooperation** creates maximum impact



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement **N° 892429**

R-ACES Training

R-ACES creates an online education environment with links to available training materials to support capacity building of stakeholders.

Other Materials

TRAINING MATERIALS

SERIOUS BOARD GAME

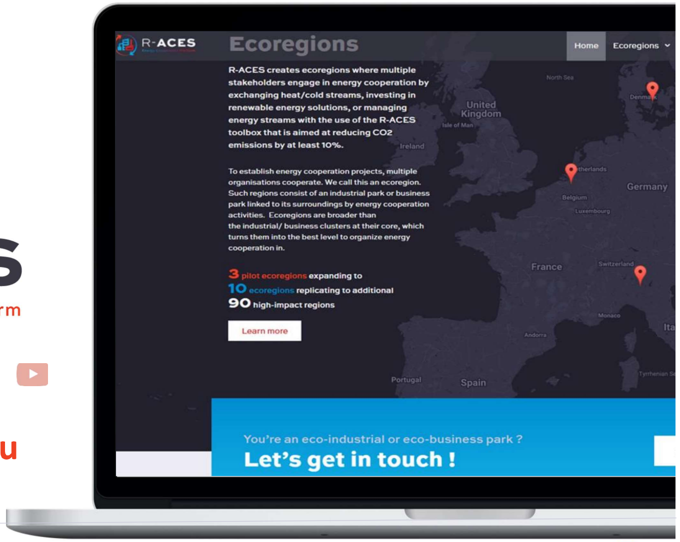
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 892429

R-ACES

Energy Cooperation Platform

Follow us on :

www.r-aces.eu



Institute for Sustainable Process Technology · Condugo · Spinergy · energy CLUSTER DENMARK · LE2C LOMBARDY ENERGY CLEANTECH CLUSTER · pom · ESCI European Science Communication Institute

Waste heat solutions for Europe's green recovery

Experiences from the ReUseHeat project

Kristina Lygnerud (Coordinator)

March 19, 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant ageement No 767429

#ReUseHeat #excessheat #wasteheat #districtheating #districtenergy #energyefficiency #H2020Energy #ResearchImpactEU

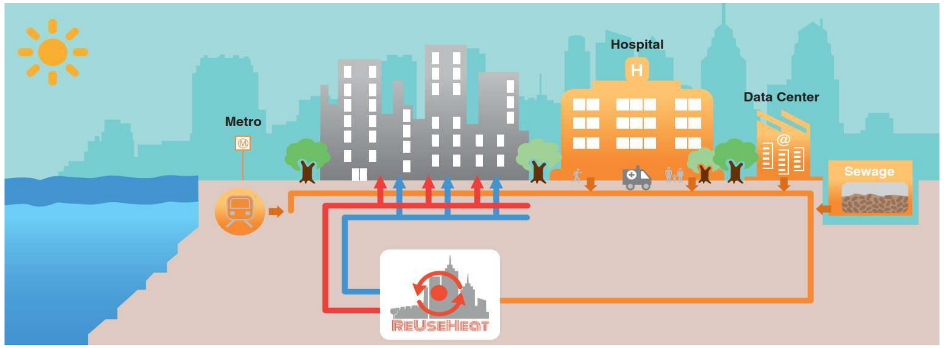
ReUseHeat project

Agenda

- ReUseHeat overview
- Urban waste heat potential
- Learnings to date

#ReUseHeat #excessheat #wasteheat #districtheating #districtenergy #energyefficiency #H2020Energy #ResearchImpactEU

The ReUseHeat -overview



Objective: Demonstrate first-of-their-kind, advanced, modular and replicable systems enabling the recovery and reuse of urban excess heat

ReUseHeat project- overview

Short facts

- Partners from 9 countries
- Academia, Industry and Associations
- H2020 (Innovation action- focusing on system innovations)
- Estimated project cost €4,883,672
- 60 months
- 4 system innovations

#ReUseHeat #excessheat #wasteheat #districtheating #districtenergy #energyefficiency #H2020Energy #ResearchImpactEU

ReUseHeat project- overview

Expected results Useful insight for future investors through:

- Urban waste heat **potential** identification EU28
- Efficient **technologies** and solutions (4 demosites)
- Suitable **business models and contractual arrangements**
- Estimation of investment **risk** and **bankability** and impact of urban waste heat recovery investments

Urban waste heat potential

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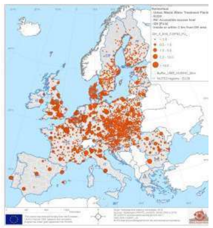
ReUseHeat project- urban waste heat potential

Approximately **1.2 EJ** (or 340 TWh) per year are possible to recover from data centres, metro stations, service sector buildings, and waste water treatment plants.

This corresponds to more than 10 percent of the EU's total energy demand for heat and hot water, which is approximately 10.7 EJ (or 2,980 TWh)*



**ReUseHeat D1.4, Halmstad University, Urban Persson*

www.reuseheat.eu @ReUseHeat

LEARNINGS TO DATE

ReUseHeat project- Learnings to date: Contracts/ Business Model

- Existing incentives for RES and CHP
- Absence of legal framework for urban waste heat recovery
- Low technical maturity of building system solutions of HP and low temp source
- Long payback periods
- Absence of standardized contracts
- Diverging views on the value of waste heat

ReUseHeat project- Learnings to date

- Computer center heat recovery (Germany)

- Close customer dialogue needed for understanding each others' processes
- Datacenters ramp up gradually (heat is provided with increasing volumes over time)
- For future cases, it might be considered to offer cooling services to data cente rather than to purchase the waste heat

#ReUseHeat #excessheat #wasteheat #districtheating #districtenergy #energyefficiency #H2020Energy #ResearchImpactEU

ReUseHeat project- Learnings to date

- Metro system heat recovery (Germany)

- It is difficult to match the heat source with heat demand
- There is strict safety regulation in the metro tunnel constraining the installation that can be made (maintenance free)
- The access to the site is restricted to a limited number of hours each night (when the trains standstill)
- The air in the tunnels is charged with metal dust which impacts the heat pump design

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ReUseHeat project- Learnings to date

- Hospital heat recovery (Spain)

- Long term energy service contract facilitates the operations
- The hospital has its own, local network over which it has control
- The hospital sector was challenged during the pandemic: making access difficult

#ReUseHeat #excessheat #wasteheat #districtheating #districtenergy #energyefficiency #H2020Energy #ResearchImpactEU

ReUseHeat project- Learnings to date

- End-user engagement through visualization of sea and sewage water heat recovery (France)

- the data available from substations in a DHN are not suited for visualization purposes (need to clean up data, install new substations and other)
- the end-user demand is not yet in place: it is uncertain that visualized energy performance data is in demand
- dashboard can be placed on any DHN

#ReUseHeat #excessheat #wasteheat #districtheating #districtenergy #energyefficiency #H2020Energy #ResearchImpactEU

ReUseHeat

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REWARDHeat

Low-Temperature Waste Heat Recovery in District Heating and Cooling Networks

Waste Heat solutions for Europe's green recovery, 19.03.2021

Roberto Fedrizzi, EURAC Research

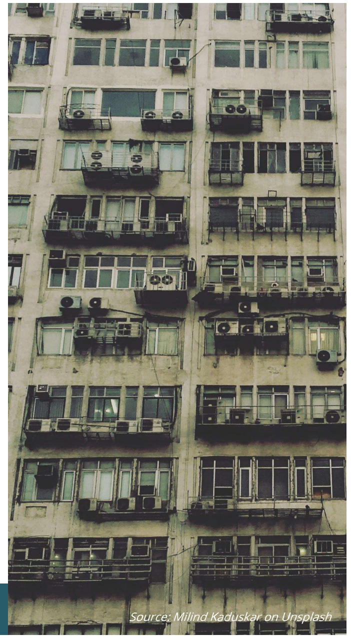
Background

- 72% of the European population (EU28) lives in cities and towns
- A huge amount of low-grade waste heat is diffused within the urban texture, the largest amount being rejected by air-conditioners, cooling systems in industrial processes and tertiary buildings, chillers of refrigeration systems and service facilities, e.g. sewer pipes
- For historic reasons, cities and towns have born along rivers, lakes and seashores. All these sources make low-temperature renewable energy available, which utilisation is highly replicable because it is accessible right where it is needed

Source: Ricardo Gomez Angel on Unsplash

The Vision

- The overall objective of REWARDHeat is to demonstrate district heating and cooling (DHC) networks, which are able to recover renewable and waste heat available at low temperature, i.e. lower than 40°C
- Focus is on the exploitation of the energy sources available within the urban context, allowing to maximize the upscale potential of the decentralized solutions developed
- To do this, we need to lower the supply temperature compared to conventional networks. Focus on supply temperature lower than 60 °C and down to 10-20°C.



Source: Milind Kaduskar on Unsplash

Specific Objectives

REWARDHeat

TO INTEGRATE MULTIPLE URBAN RENEWABLE AND WASTE ENERGY SOURCES

REWARDHeat explores configurations of a DHC network, providing tools and recommendations for the integration of multiple renewable and waste heat sources

- Planning schemes database
- Pre-design tool
- Informational material for publication in wiki-tools
- Guidebook for planners
- Serious gaming

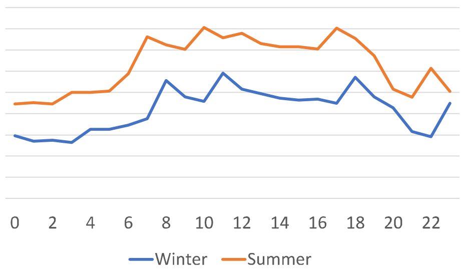
Source: Kelly Sikkema on Unsplash

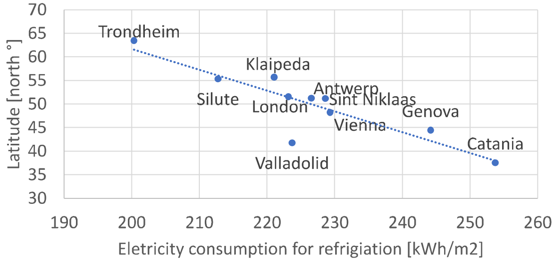
To integrate multiple waste energy sources

REWARDHeat

Starting from publicly available data

- Hourly **electricity** consumption for refrigeration (for reference days)



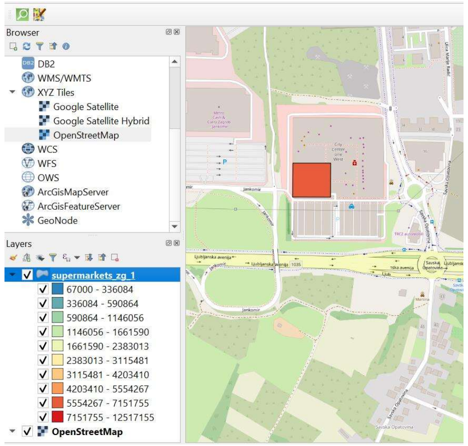


To integrate multiple waste energy sources

REWARDHeat

To total yearly potential “educated guess”

- According to the **specific yearly electricity consumption** + equivalent **COP** of the system → specific yearly **waste heat**
- Combined with Open Street Maps → location and area of waste heat generation



Specific Objectives

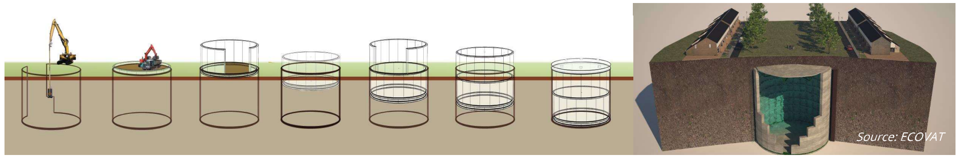
REWARDHeat

TO DEVELOP INNOVATIVE TECHNOLOGIES FOR FLEXIBLE USE OF HEAT IN DHC NETWORKS

Substations - Two approaches are pursued: prefabrication for building solutions and standardisation for large-scale district heating plants

Thermal storages

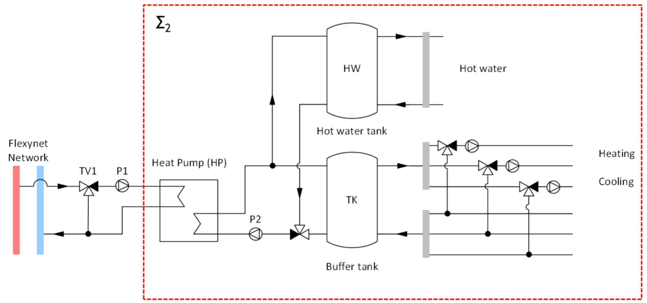
- Local, intra-day storages at customer substations
- Central, intra-day storages to balance the network and store energy during off-peak periods



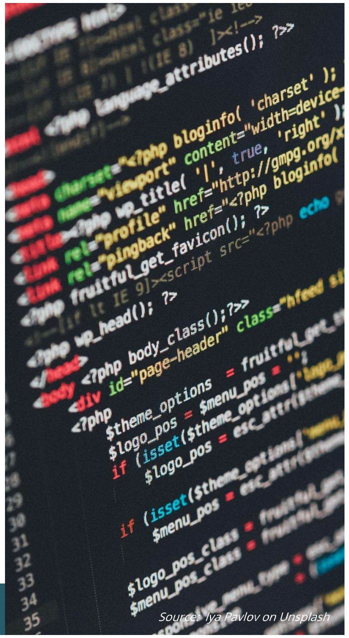
To develop innovative technologies

REWARDHeat

Prefabricated bi-directional substations with heat pump and storages for installation in single buildings



Specific Objectives

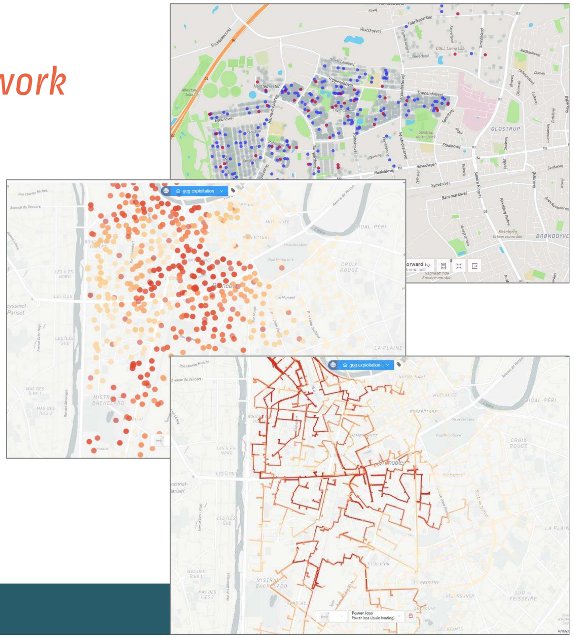

Source: Ilya Pavlov on Unsplash

TO DEMONSTRATE DIGITALISATION SOLUTIONS ALLOWING TO OPTIMISE THE MANAGEMENT OF THE DHC NETWORK

In REWARDHeat, storage capacity and control will be used synergically to manage the system.

- Smart metering communicating real-time
- Data-mining platform will permit to manage communication with smart meters and to handle controls
- Fault detection and expert control strategies elaboration for optimisation and electricity grid coupling

Digitalisation of the DHC network



- Data mining and user interfaces for assets' real-time monitoring
- Real-time performance analysis and KPIs calculation for wise management of the network
- Smart controls based on model-prediction of loads for next hours and days under elaboration

Specific Objectives

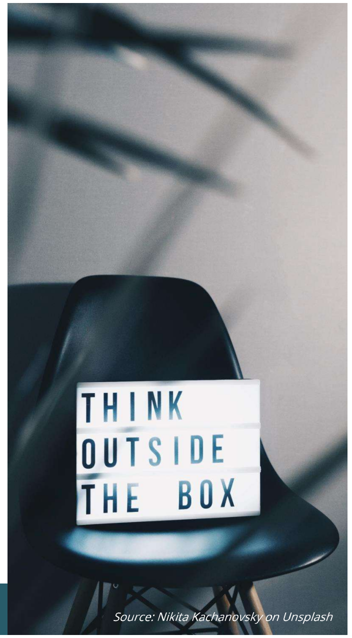
TO DEVELOP BUSINESS MODELS AND FINANCIAL SCHEMES ATTRACTING LARG

Private customers:

- Heat sold as a service

Waste Heat recovery - Barriers to overcome:

- Split between property owner and Waste Heat owner, hence split of interest
- Hard to calculate economic benefit for utility company due to risk of Waste Heat owner leaving and different financial cycles compared to industries and services
- RED and EED do not price Waste Heat as renewable energy and do not provide clear definitions and methods



Source: Nikita Kachanovsky on Unsplash

REWARDHeat demonstration networks

1 **MILAN -** Newly built neutral-temperature networks

2 **HAMBURG -** Newly built low-temperature network

3 **HELSINGBORG -** Newly built low-temperature networks

4 **MöLNDAL -** Newly built low-temperature networks

5 **TOPUSKO –** Heat cascading in low-temperature network

6 **TOULON -** Upscaled neutral-temperature network

7 **HEERLEN –** Intra-day storage in neutral-temperature network

8 **SZCZECIN -** Newly built neutral to low-temperature network

REWARDHeat

Roberto Fedrizzi, EURAC Research
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Thank you

www.rewardheat.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857811.
The document reflects the author's view. The European Commission has no liability for any use that may be made of the information it contains.

DryFiciency:
high temperature heat pumps for drying

V. Wilk
AIT Austrian Institute of Technology GmbH

Waste heat recovery

106 EJ
industrial energy
consumption
worldwide (2012)

52 EJ = 49% utilization

54 EJ = 51% losses
waste heat in waste water and off-gases
radiation, friction, resistance, etc.

Forman et al. Estimating the global waste heat potential, Renewable and Sustainable Energy Reviews 57 (2016) 1568-1579

Grant Agreement No 723576 – Energy Efficiency

DryFiciency: Industrial demonstration

High temperature heat pumps up to 160°C

Closed loop heat pump		Open loop heat pump
Brick drying	Starch drying	Bio sludge drying

Wienerberger AG
Uttendorf (AT)

AGRANA Stärke GmbH
Pischelsdorf (AT)

Scanship A/S
Drammen (NO)

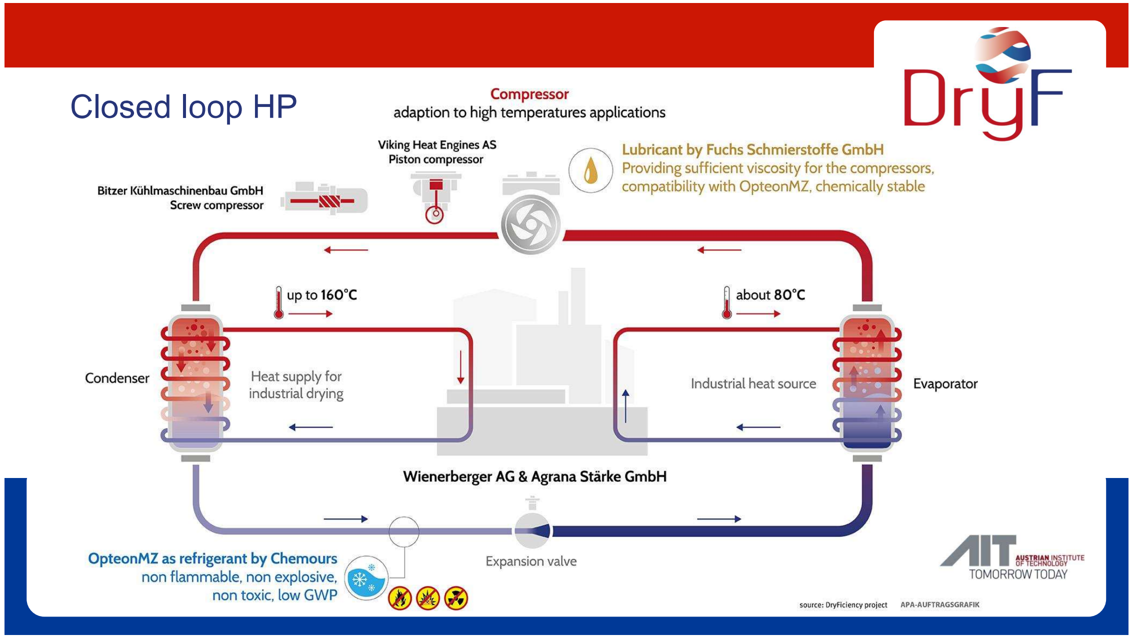
Grant Agreement No 723576 – Energy Efficiency

DryFiciency Consortium

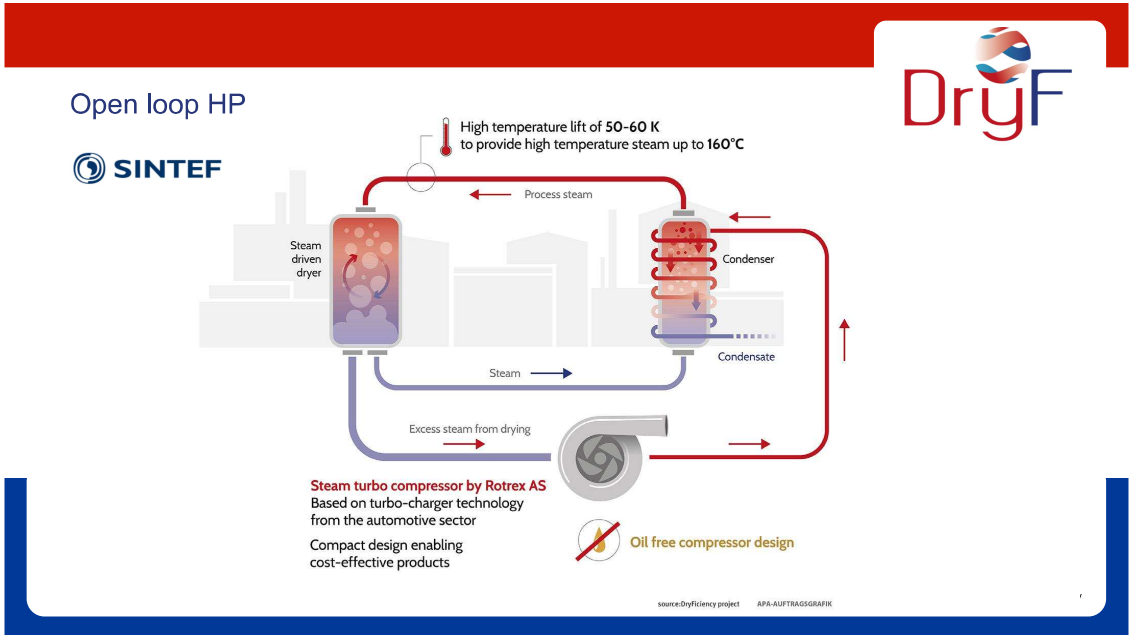
Closed Loop Heat Pumps		Open Loop Heat Pump
AIT Austrian Institute of Technology – Tomorrow Today	2 RTOs	SINTEF
Bitzer, HEATEN	3 compressor manufacturers (2 SME)	ROTREX
Chemours, FUCHS	1 refrigerant manufacturer 1 lubricant manufacturer	
	1 plant engineer/ system expert (1 SME)	EPCON Evaporation Technology AS
Agrana Stärke, Wienerberger Building Material Solutions	3 end-users	SCANSHIP for cleaner oceans

2 experts on dissemination & exploitation (1 SME)

ehpa, RTDS Association

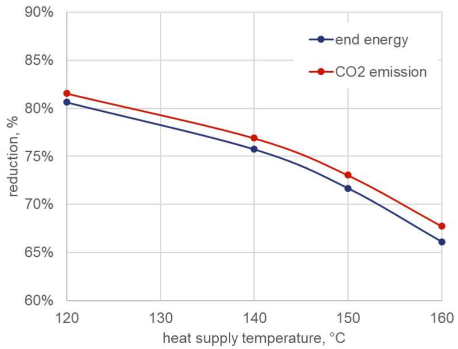


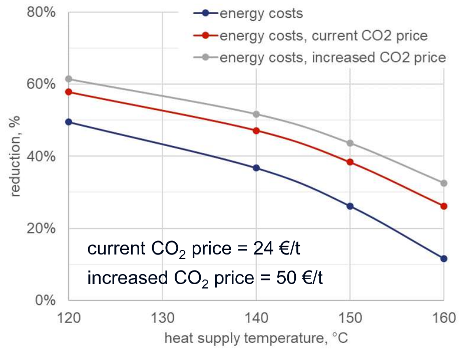
Closed loop HP
DryF
Compressor
adaption to high temperatures applications
Viking Heat Engines AS
Piston compressor
Bitzer Kühlmaschinenbau GmbH
Screw compressor
Lubricant by Fuchs Schmierstoffe GmbH
Providing sufficient viscosity for the compressors,
compatibility with OpteonMZ, chemically stable
up to 160°C
about 80°C
Condenser
Heat supply for
industrial drying
Industrial heat source
Evaporator
Wienerberger AG & Agrana Stärke GmbH
Expansion valve
OpteonMZ as refrigerant by Chemours
non flammable, non explosive,
non toxic, low GWP
AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY
source: DryFiciency project APA-AUFTRAGSGRAFIK



Open loop HP
DryF
SINTEF
High temperature lift of 50-60 K
to provide high temperature steam up to 160°C
Process steam
Steam
driven
dryer
Condenser
Condensate
Steam
Excess steam from drying
Steam turbo compressor by Rotrex AS
Based on turbo-charger technology
from the automotive sector
Compact design enabling
cost-effective products
Oil free compressor design
source:DryFiciency project APA-AUFTRAGSGRAFIK

Closed loop heat pump vs. natural gas burner

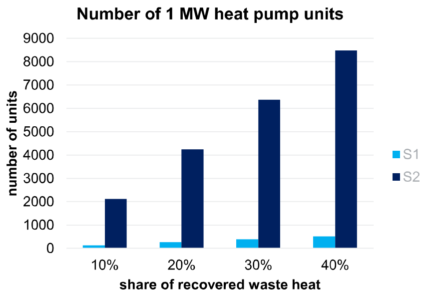


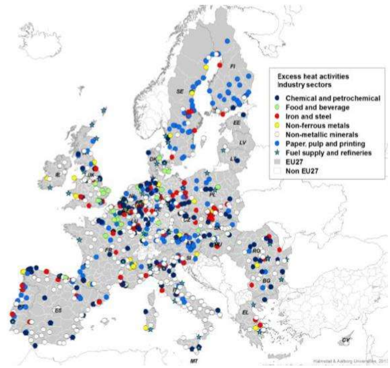


CO_2 emissions natural gas 271 g/kWh, natural gas price 33 €/MWh
CO_2 emissions electricity 258 g/kWh, electricity price 86 €/MWh

V. Wilk et al. High temperature heat pumps for industrial processes – application and potential; ECEEE Industrial Summer Study Proceedings, 4-132-20, 2020, p.329-334.

DryFiciency – vast market potential



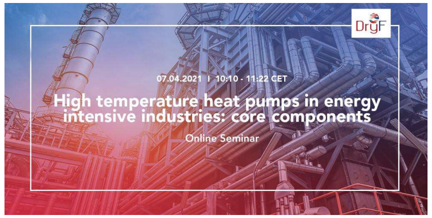


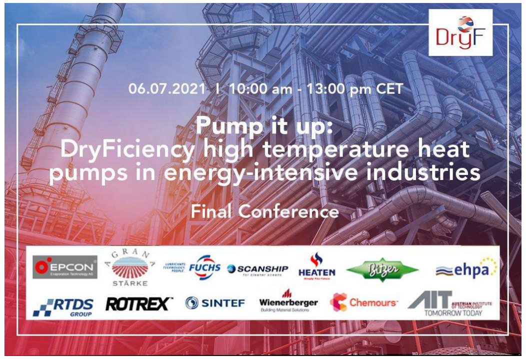
DryFiciency market study: M. Koller et al (2020). Marktpotenzial für Hochtemperatur-Wärmepumpen in Europa, Symposium Energieinnovation, Graz.

Connolly et al. (2013). Heat Roadmap Europe 2050: Second Pre-Study for the EU27. Department of Development and Planning, Aalborg University

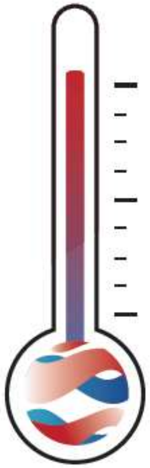
Grant Agreement No 723576 – Energy Efficiency

Invitation





Grant Agreement No 723576 – Energy Efficiency



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Grant Agreement No 723576 – Energy Efficiency

Online seminars for heat pump manufacturers and plant engineers

DryFiciency

Core Component: Lubricants for DR-2

7th April 2021

Christian Puhl | Dennis Ebert

LUBRICANTS. TECHNOLOGY. PEOPLE. FUCHS

Lubricants for DR-2 – PAG

LUBRICANTS. TECHNOLOGY. PEOPLE. FUCHS

Task in the project:

Development of lubricants for high temperature heat pumps with DR-2 (= R1336mzz-Z) screw and reciprocating compressor

Condition:

- High temperature and high pressure in the system

→ Strong dilution by the working fluid + high temperature decreases the lubricant viscosity

PAG lubricant:

- Good miscibility with DR-2 at high viscosities
- Higher viscosity index compared to Ester, higher film strength at elevated temperature
- Good thermal stability with DR-2 with an optimized additive system

Miscibility PAG VG 600 with DR-2

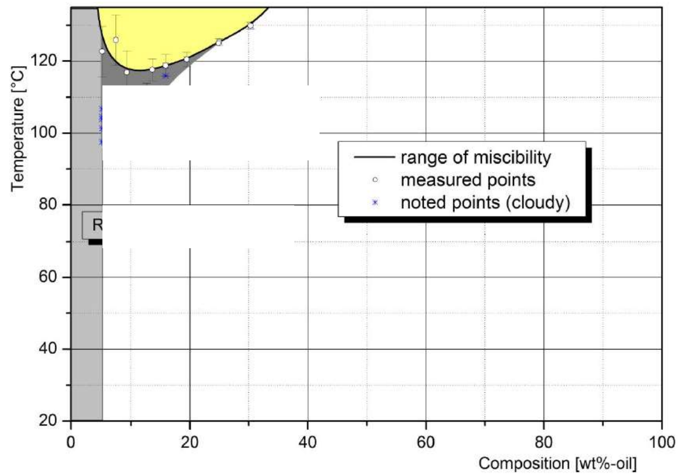
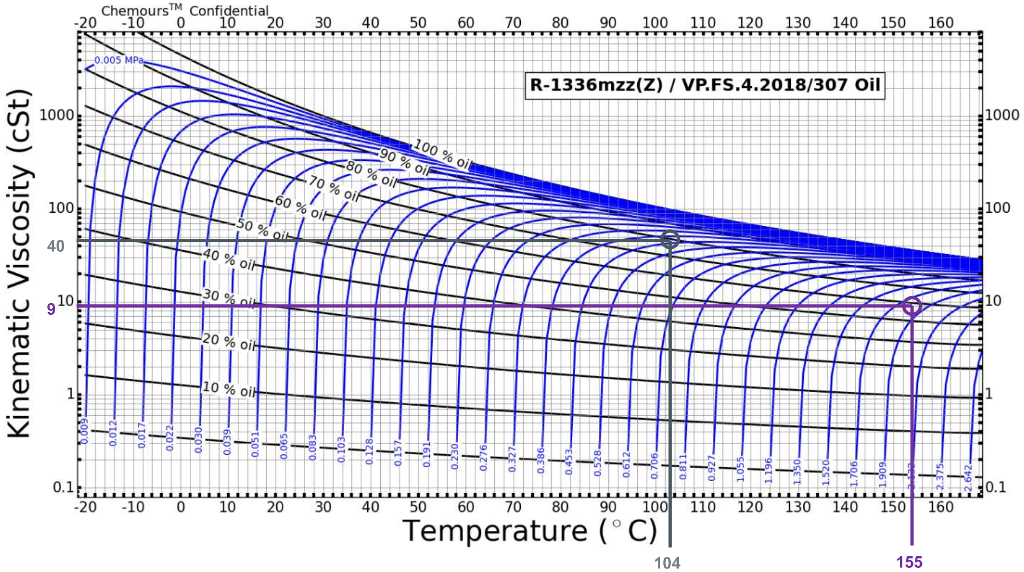


Figure 2: Miscibility gap of DR 2 – VP.FS.4.2018/485

Small miscibility gap of VP.FS.4.2018/485 DR-2 > +117°C

→ no problem as < 6 w% and > 33 w% lubricant with working fluid are miscible

pVT Measurement of PAG VG 680 / DR-2



→ Bitzer Screw compressor: 155°C / 18 bar → 9 mm²/s (minimum 6 mm²/s)

→ Viking Reciprocating compressor: 104°C / 4,1 bar → 40 mm²/s (minimum 15 mm²/s)

→ One Oil can be used for both applications

Sealed Tube Test / Ageing Stability Test
Different PAG Lubricants / DR-2: Parameter

Optimizing and testing the thermal / chemical stability of DR-2 / refrigerant with different lubricants at Spauschus. Spauschus can measure the TAN of the oil and ion chromatography to determine refrigerant and lubricants decomposition.

Sealed Tube Test:

Heat pump lubricant: PAG Type

Refrigerant: DR-2

Time: 336h

Temperature: 175°C

Metals: Fe + Cu + Al separated

Lubricant amount: 2 ml

Refrigerant amount: 2 ml

Water content: < 350 ppm

TAN before test: < 0,1 mg KOH/g

Analysis after test:

-TAN after test

-Ion Chromatography

Sealed Tube Test / Ageing Stability Test
Different PAG Lubricants / DR-2: Results

Table 1: Visual Observations of Sealed Tubes

Lubricant	Visual Observations	
	Liquid	Metal coupons
VP.FS.4.2018/53	Clear (same as unaged); color slightly darker (color=3.0 versus 2.0 for unaged); no deposit	All metals unchanged
VP.FS.4.2018/55	Clear (same as unaged); color slightly darker (color=2.25 versus 2.0 for unaged); no deposit	All metals unchanged
VP.FS.4.2018/195	Clear (same as unaged); color same as unaged (color=2.0); no deposit	All metals unchanged
VP.FS.4.2018/196	Clear (same as unaged); color same as unaged (color=2.0); no deposit	All metals unchanged
VP.FS.4.2018/197	Clear (same as unaged); color slightly darker (color=2.5 versus 2.0 for unaged); no deposit	All metals unchanged
VP.FS.4.2018/198	Clear (same as unaged); color slightly darker (color=2.75 versus 2.0 for unaged); no deposit	All metals unchanged

Table 2: TAN and IC Results of Sealed Tubes

Lubricant	Total Acid Number mg KOH/g	Ion Chromatography Results, ppm						
		Fluoride	Propanoate	Pentanoate	Hexanoate	2-Ethyl-Hexanoate	Heptanoate	Total Organic Acid (TOA) ppm
53 before aging	0.02	0	4	0	6	21	0	31
53 after aging	1.07	364	57	0	9	0	0	66
55 before aging	0.05	0	2	0	34	1	0	37
55 after aging	0.53	155	12	0	224	30	0	266
195 before aging	0.03	1	11	0	55	1	0	67
195 after aging	0.79	140	9	0	201	0	77	287
196 before aging	0.05	1	10	0	66	1	0	77
196 after aging	0.39	106	7	0	358	0	0	365
197 before aging	0.07	0	3	0	44	1	0	48
197 after aging	0.38	142	4	0	19	10	12	45
198 before aging	0.08	0	6	1	33	0	0	40
198 after aging	0.56	195	10	0	10	5	2	27

Results:

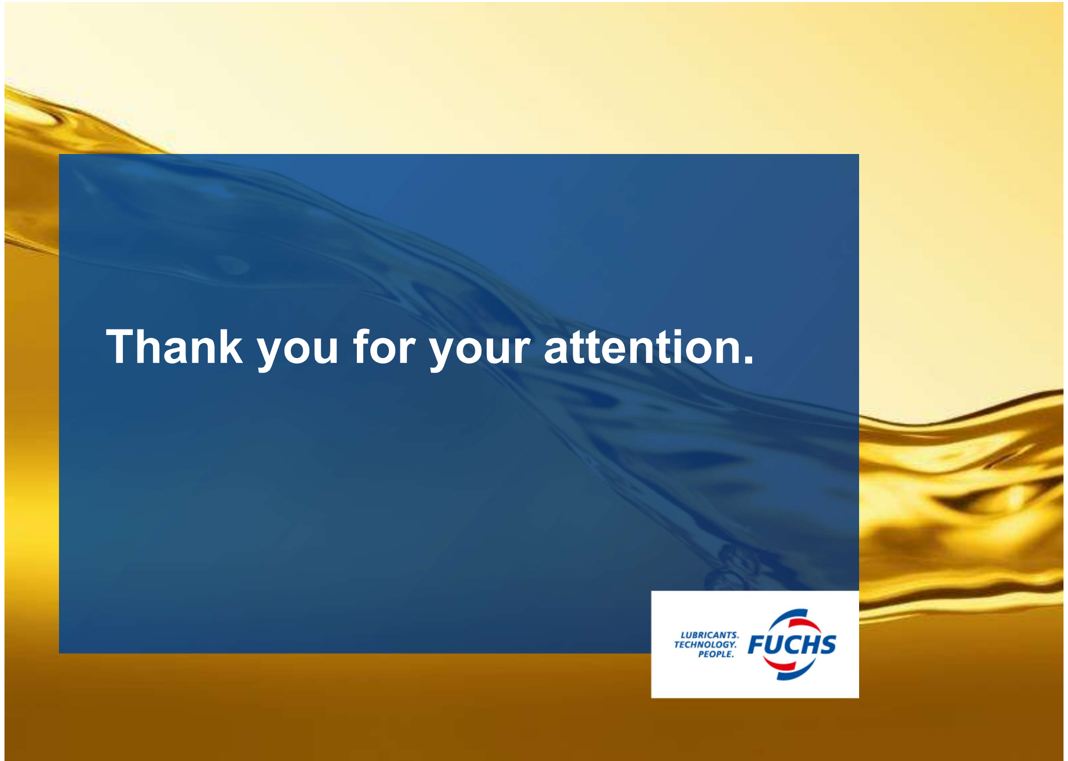
VP.FS.4.2018/197 best results in TAN and in creation of ions

Final Product VP.FS.4.2018/485

Product		VP.FS.4.2018/485
Type		PAG 600/2
Additiv System		197/2
Measurement	Method	Value
V40 [mm²/s]	DIN EN ISO 3104	598,0
V100 [mm²/s]	DIN EN ISO 3104	94,5
VI [-]	DIN ISO 2909	250
TAN [mg KOH/g]	DIN 51558-1	0,01
Pourpoint [°C]	DIN ISO 3016	-36
Density 15°C [g/ml]	DIN 51757	0,997
Flashpoint CoC [°C]	DIN ISO 2592	220
Color [-]	DIN ISO 2049	0,5

Performance lubricant with DR-2:

- Good miscibility → safe oil transport and reliable heat transfer
- Good lubrication performance → excellent wear protection for all compressor parts
- Good thermal / chemical stability → longterm stability of oil / refrigerant system



HFO-1336mzz(Z) – Opteon™ MZ

Low GWP refrigerant for High Temperature Heat Pump

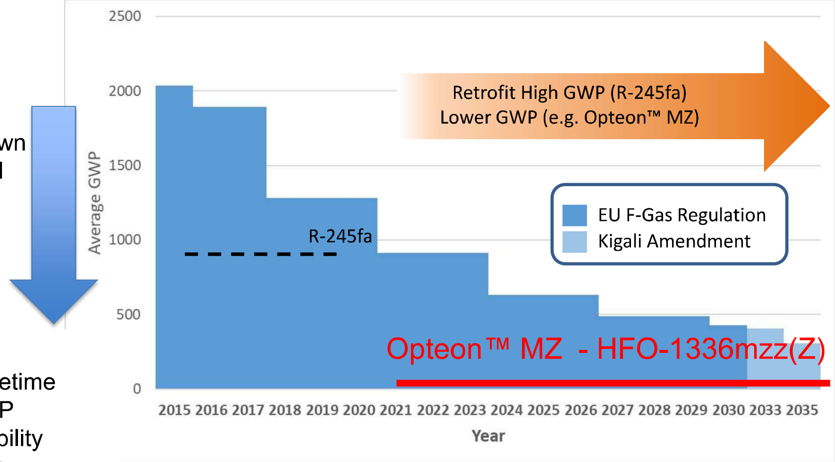
April 1, 2021

Outline

- **INTRODUCTION**
  - Regulatory drivers
  - Refrigerant Properties:
    - Thermo-Physical Properties and Thermodynamic Cycle Performance, COP_H and CAP_H comparison (30°C and 50°C uplift)
- **COMPATIBILITY AND VISCOSITY STUDIES**
  - Elastomers and lubricants selection
  - Conclusions

F-Gas Regulation and Kigali amendment Transition to Low GWP

GWP phase-down to reduce global warming GHG



Criteria:

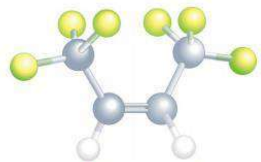
- Low GWP lifetime
- zero/low ODP
- Low flammability
- high efficiency
- high Tcrit

Product Characteristics

BASIC PROPERTIES

Chemical Name	HFO-1336mzz(Z)
Chemical Formula	$CF_3CH=CHCF_3$(Z)
OEL [ppm]	500
Flammabilty	Non-Flam
ODP	None
GWP_{100}	2
T_{cr} [°C]	171.3
P_{cr} [MPa]	2.90
T_b [°C]	33.4

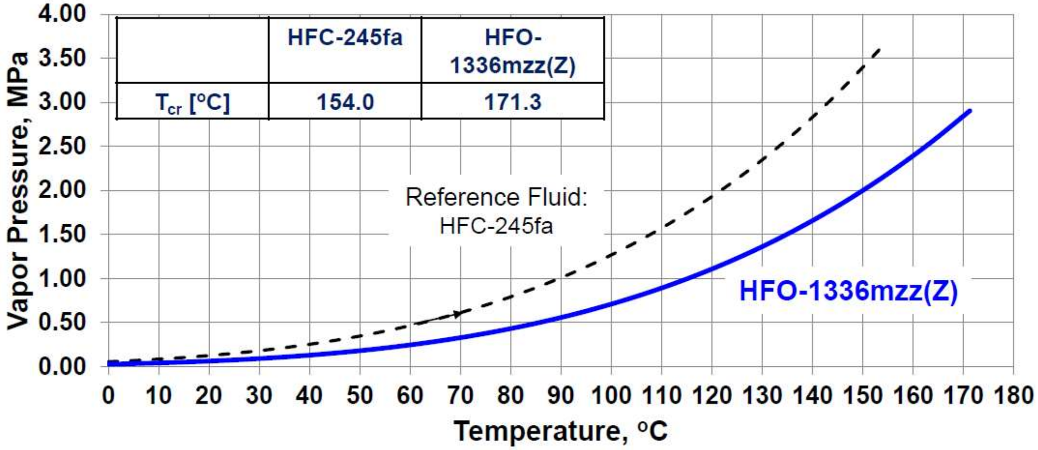
HFO-1336mzz(Z)
Opteon™ MZ



- R-1336mzz(Z) **classified as A1** (low toxicity, No flammability)
- Very low GWP

HFO-1336mzz(Z) Vapor Pressure compared with HFC-245fa

Opteon™



Set of properties now set in latest version of NIST Database (REFPROP)

HFO-1336mzz(Z) High Temperature stability

Opteon™

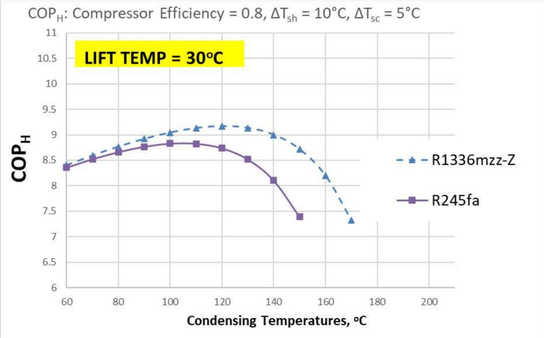
High Chemical Stability up to at 250 C in the presence of air, moisture, carbon steel, copper and aluminum.
Visual inspections of the tubes and coupons after aging showed no liquid or metal discoloration, insoluble residues or other signs of degradation

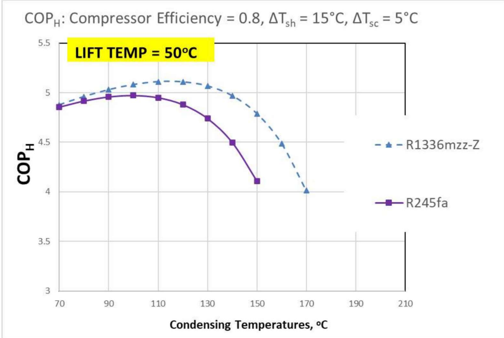
HFO-1336mzz(Z) (Opteon™ MZ) as stable as HFC-245fa

Test method ASHRAE-97 was applied (Sealed Glass Tube Method to Test the Chemical Stability of Materials for Use within Refrigerant Systems). Sealed glass tubes are prepared and charged with refrigerant, lubricant, other materials to be tested, or combinations of these. Tubes are exposed to elevated temperatures for two weeks to simulate aging

Theoretical Coefficient of Performance (COP)

Opteon



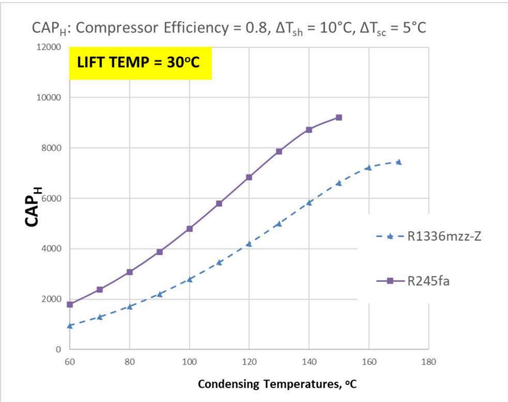


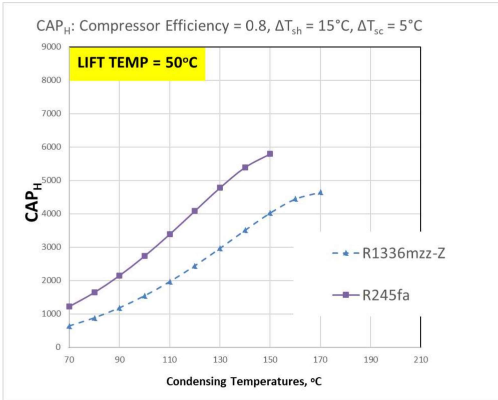
- COP of the heat pump for an application envelope of 90 °C evaporation temperature and 160 °C condensation temperature could result in a good COP >3.5 but with some operating limits (Temp. lift)
- R1336mzz-Z exceeds other material alternative in application temperatures above 140oC

Chemours™

Theoretical Heating Capacity (CAP_H)

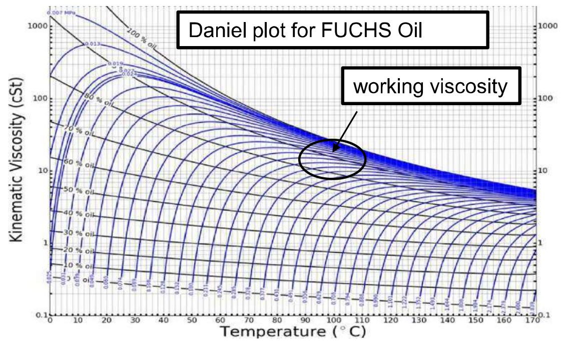
Opteon



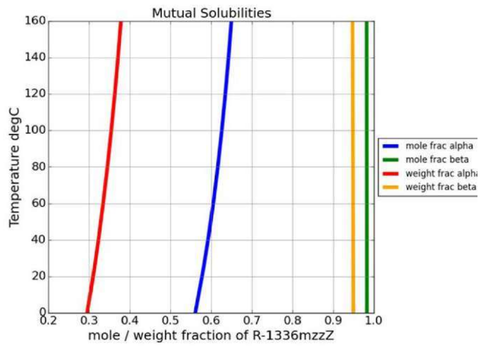


- R1336mzz-Z also has a very good CAPH which is approximately the same as R245fa, and still exceeds incumbent alternatives in application temperatures above 140oC

Lubricant Selection: Lubricity



Daniel plot generated to map the viscosity as a function of temperature, pressure and mixing ratio



Viscosity of various lubricants (POE and PAG) evaluated compatibility with the refrigerant to determine whether they have enough viscosity at high temperature to lubricate the compressors

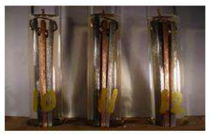
Miscibility of various lubricants (POE and PAG) evaluated thru vapour-liquid-equilibrium (VLE) and liquid-liquid-equilibrium (LLE) predictions and mutual solubility curves were calculated

Figure 9: Mutual solubility curve for refrigerant and POE VG 520

Stability tests with refrigerant and lubricants

HFO-1336mzz-Z / POE oil, dry air (after)

HFO-1336mzz-Z / PAG oil, dry air (after)



HFO-1336mzz-Z / POE oil, wet air (after)

HFO-1336mzz-Z / PAG oil, wet air (after)

- Visual observations: Before and after the ageing the test of the refrigerant and the lubricant
- Help to determine the lubricant compatibility

Elastomers and other Compatibility

Weight and Hardness Changes tested with Various Elastomers and Plastics with HFO-1336mzz(Z) at 120°C with FUCHS POE Oil

EPDM E7131 + Elastomers after 0 hrs	0 hr Rating	0 hr % Weight Change	0 hr % Linear Swell	0 hr Hardness Change, Delta
POE 211 + DR2	1	11	3	-7
POE 211 + DR2	1	11	3	-6
POE 212 + DR2	1	12	4	-6
POE 212 + DR2	1	13	4	-7
EPDM E7131 + Elastomers after 24 hrs	**24 hr Rating**	**24 hr % Weight Change**	**24 hr % Linear Swell**	**24 hr Hardness Change, Delta**
POE 211 + DR2	0	8	2	-5
POE 211 + DR2	0	8	2	-5
POE 212 + DR2	0	10	3	-5
POE 212 + DR2	0	10	2	-7

- EPDM exhibits good resistance with HF)-1336mzz(Z)

Before/ After EPDM

*Conducted in Sealed Tube Tests - ASHRAE Standard 97-2007

Conclusions

The HFO-1336mzz(Z) have all of the characteristics (Low GWP, Class A1 refrigerant, Excellent Chemical & Material Compatibility, High Critical Temperature, Exhibiting favorable toxicity profile) to be a viable working fluid in Waste Heat Recovery applications which include both high temperature heat pumps (and low temperature ORC applications).

The HFO-1336mzz(Z) allow higher condensing temperatures than R134a and have a lower GWP than R245fa. It could enable development of industrial high temperature heat pump for

- Drying / dehydration
- Process heating
- Food manufacturing industry

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THAN YOU
Questions?

for additional questions, contact:
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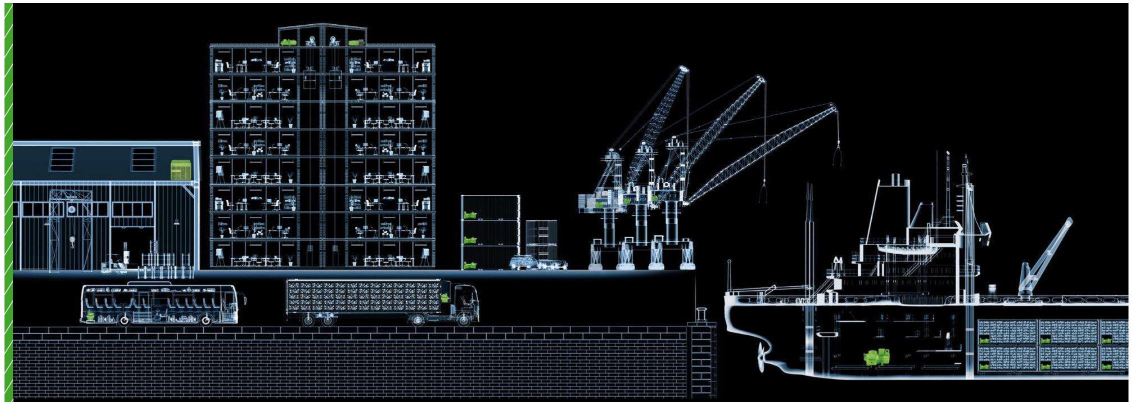
+41 22 719 1535



SCREW COMPRESSORS FOR HT APPLICATIONS

Rottenburg, April 2021
Julian Pfaffl

DAS HERZ DER FRISCHE

SCREW COMPRESSOR FOR HT APPLICATIONS
SELECTION OF PARTS THAT NEED TO BE CONSIDERED IN DRY-F

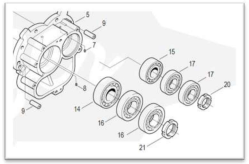
// O-rings / gaskets / plastics
- Pressure relief valve
- Check valve
- Shut-off valves, etc.

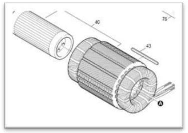
// Mechanical parts
- Bearings (HT version)
- Schrader valves
- Sight glass, etc.

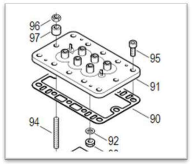
// Oil
- POE / PAO / PAG / Other ?
- Daniel plots > +100°C?

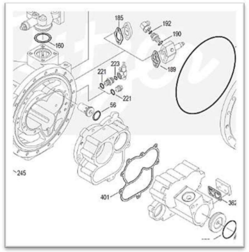
// Electrical parts
- Solenoid valves
- Motor (HT version)
- Terminal plate
- Internal cables
- Motor protection device
- Oil level control OLC, etc.

// Painting „BITZER green"
- 2K-painting





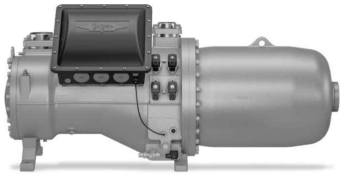




CSH2T NEW COMPRESSOR GENERATION FOR HT APPLICATIONS

// General features

- SST max up to +75°C
- → max SGT up to +100°C (compressor inlet)
- → max DGT up to +140°C (compressor outlet)
- Operates with HFO HT Refrigerants



BITZER has started first field tests to gain more experience.

CSH2T NEW COMPRESSOR GENERATION FOR HT APPLICATIONS

// Field tests started with EEAB member Geelen Counterflow

- Hybrid dryers (gas + HP) for petfood and aquafeed
- Locations in South Korea (1200kWth), China (2400kWth) and Norway (3350kWth)
- Operating point to/tc = 35°C/122°C

DAS HERZ DER FRISCHE

ROTREX™
SUPERCHARGERS

DryF Webinar

April 7th 2021

Speaker: Søren Schmidt

OUR STORY

Key points

- *ROTREX* is an automotive company founded in year 2000
- Company core technology is ultra high-speed planetary drives, with units mechanically exceeding shaft speed of 340.000 rpm
- Develops, produces and markets superchargers and air pumps for a wide range of industries based on patented traction technology for OEM, OES, and aftermarket companies worldwide

ROTREX PRODUCTS

AUTOMOTIVE SUPERCHARGERS

1996 → TODAY

FUEL CELL COMPRESSORS

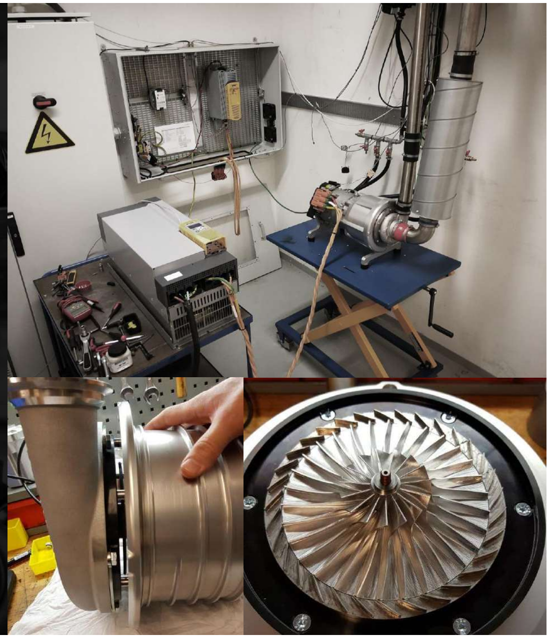
2010 → TODAY

CUSTOM SUPERCHARGERS

ROTREX

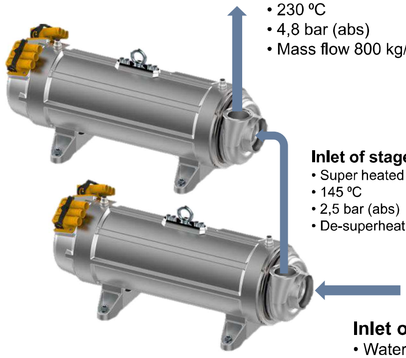
DryF – Why Rotrex?

- Prior the DryF project, there were existing compressors mainly screw and piston type
- DryF Open loop is re-compression of high temperature steam – not possible with existing compressors
- Additionally, MVR requires high volumetric capacity, because of the lower density of steam
- A pioneer in the DryF project, Sintef, identified Centrifugal turbo compressors to be the solution as they offer high volumetric capacity and are “oil-free” heat pump solutions

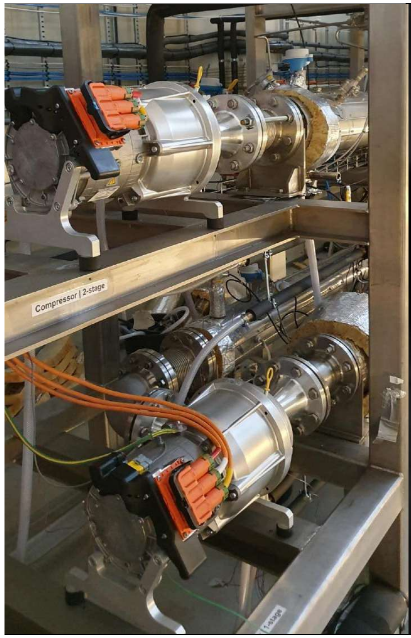


DryF requirements

- Specifications defined in the first Work package based on demo plant requirements
- Steam producing heat pumps, and supply steam from 1 to 2-6 bar. (Commonly expanded from 10 to 2/5 bar).
- Target thermal capacity: 300kW – 1MW
  - Specific mass flow: 800kg/h
  - Inlet temperature: 110 °C @ Ambient temperature
- To achieve the relatively high pressure ratio, a two stage compression is required
- Each compression stage demanded a specific compressor design



ROTREX



The journey from Automotive to industrial demands

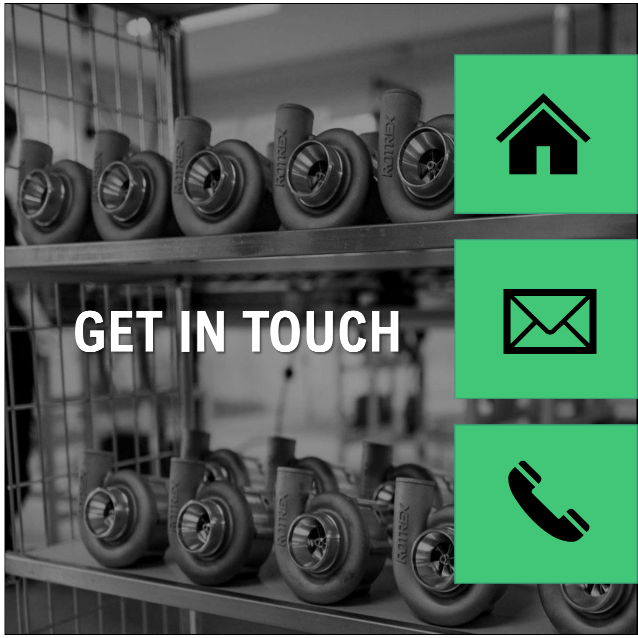
- Normal automotive applications deals with temperatures up to 50°C and ambient pressure
- DryF demands nearly 300% higher temperatures along with steam and over-pressure at inlet
- Several designs made and tested under these extreme conditions
- New design includes:
  - Simulated impeller design, CNC 5-Axis billet machined in Titanium
  - Highly specialized hydrodynamic sealing solutions
  - Special compression chamber separation design
  - Integrated lubrication circuits
- Stable operation speeds up to 80.000 rpm
- Two-stage MVR compression tested successfully in TRL6 (Lab)

ROTREX

The foundation for industrial compressors achieved

- DryF have introduced Rotrex to a completely “new world”
- Challenges going from automotive to industrial processes are identified
- “Supercharging” the industry towards a carbon free future

ROTREX



GET IN TOUCH

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Industrigrenen 13
DK-2635 Ishøj
Denmark

EMAIL ADDRESS

sls@rotrex.com

PHONE NUMBER

Telephone: +45 7080 7005
VAT Number: DK 25381238

ROTREX

HEATEN

Experience from VHE-200 kWth HTHP and participation in Dry-F contributed to the Heaten MW-family heat pumps

SPRING 2021

HEATEN TODAY

Who?

Heaten is continuing where Viking left off, then add a seasoned CEO and strong collaboration partners, and you have the Heaten team today!

Whom?

Heaten has experienced a vast pull in Europe and have already backing from well known, large international customers and industry.

How?

Heaten is currently scaling VHTHP technology platform up to MW HP family in collaboration with the world's largest engine development company, AVL.

SOLUTION

Heaten has **8 years of R&D**, design and engineering experience in developing piston-based ORCs (heat-to-power) and heat pumps (power-to-heat).

Heaten has **successfully sold its smaller engines** to an industrial customer in a key market.

Heaten has a significant head start, and is confident to deliver on an R&D and IP **roadmap towards mid-temperature processes** of 150-400°C.

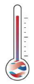
Heaten's **digitalisation strategy** will build a new culture of customer-centric innovation in an agile organisation.

STATUS & TECH ROAD MAP

1 Piston-based heavy-duty core technology
Owns both core technology and heat pump design

2 MW thermal product family launch 2022

3 Pilot phase already sold out!



TECH ROAD MAP OVERVIEW

IMMEDIATE
VHTHP 165 °C

SHORT TERM
VHTHP 200 °C

LONG TERM
UHTHP →400°C

MEDIUM/LONG TERM
Variants


Heaten AS
Follow us on LinkedIn
INFO@HEATEN.NO
https://www.linkedin.com/company/heaten-as

DRYficiency

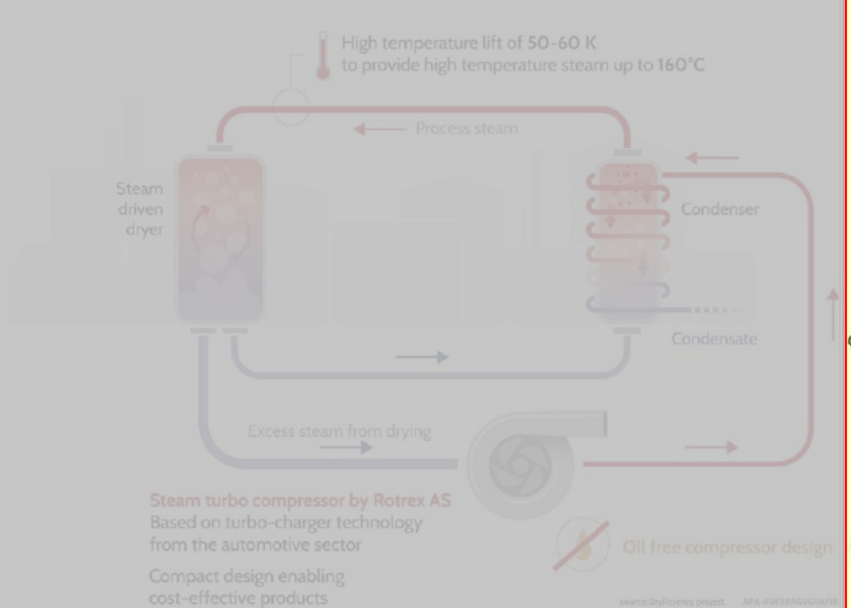
Stefan Puskas
21.04.2021

Wienerberger

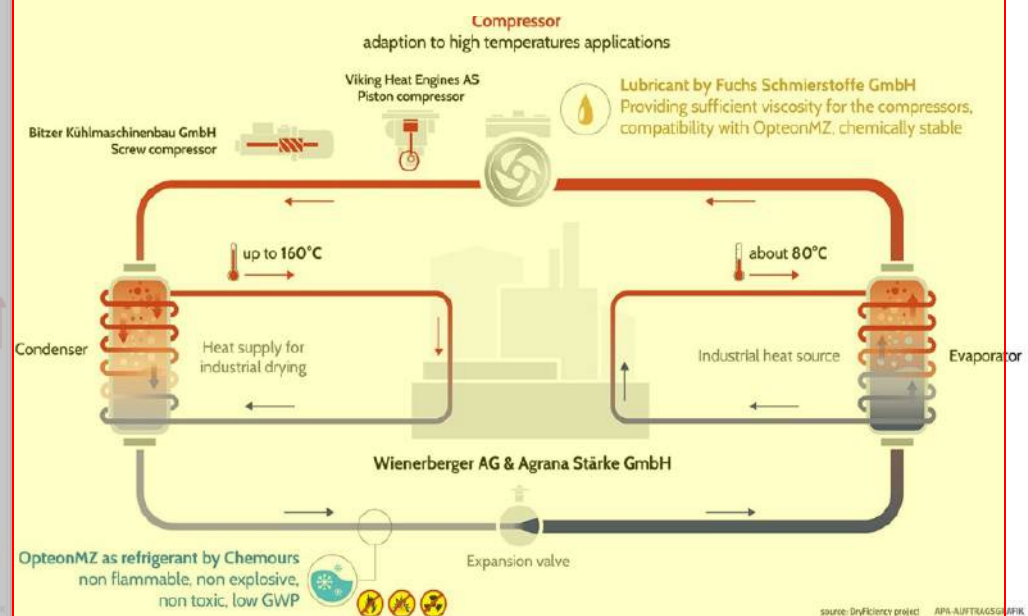
2- Approaches

Estimates show that 12-25% of the national industrial energy consumption in developed countries is attributable to industrial drying.

Open Loop HP-System
Mechanical Vapour Recompression systems

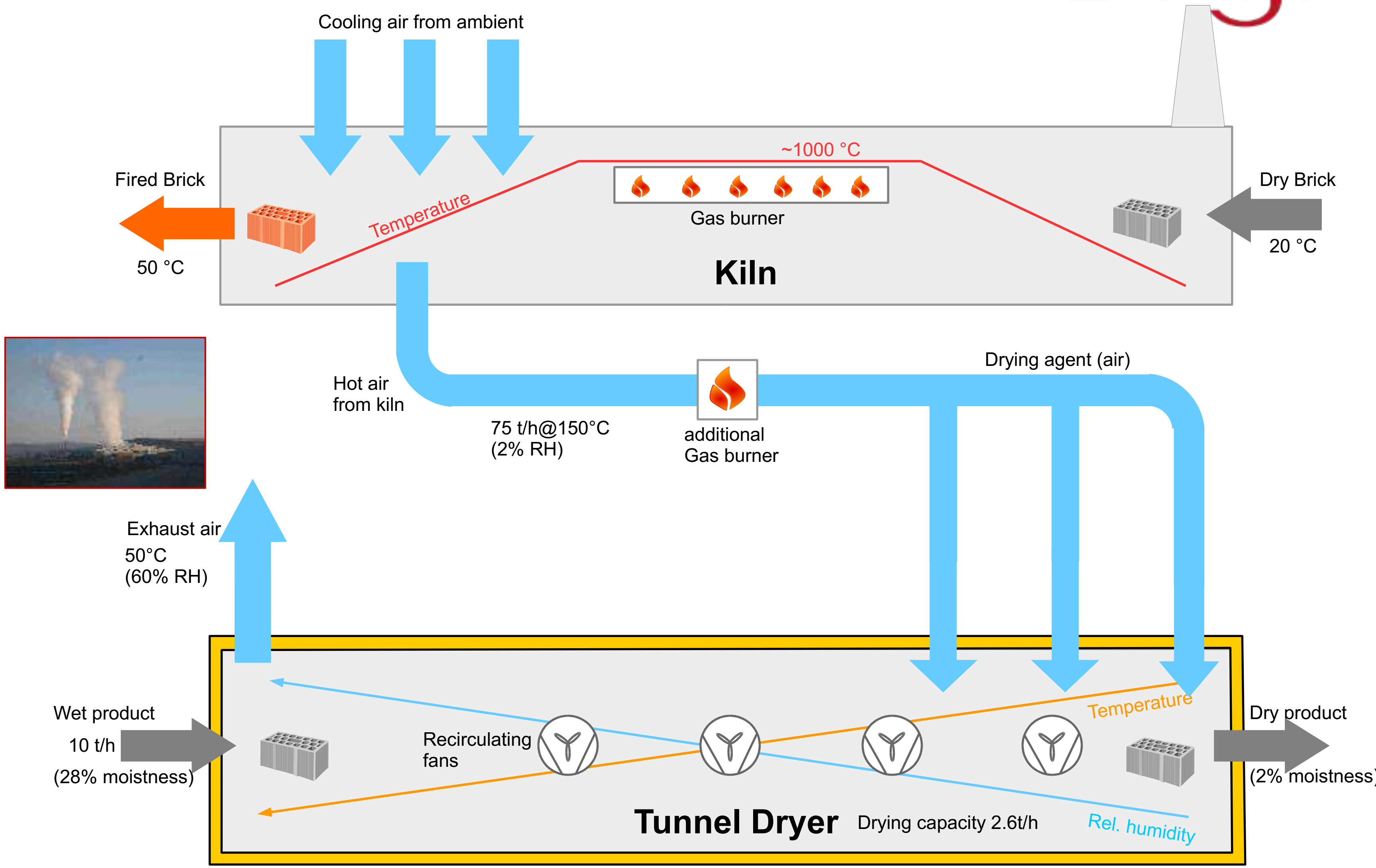


Closed Loop HP-System
Compression heat pump



DemoPlant Uttendorf (Austria)

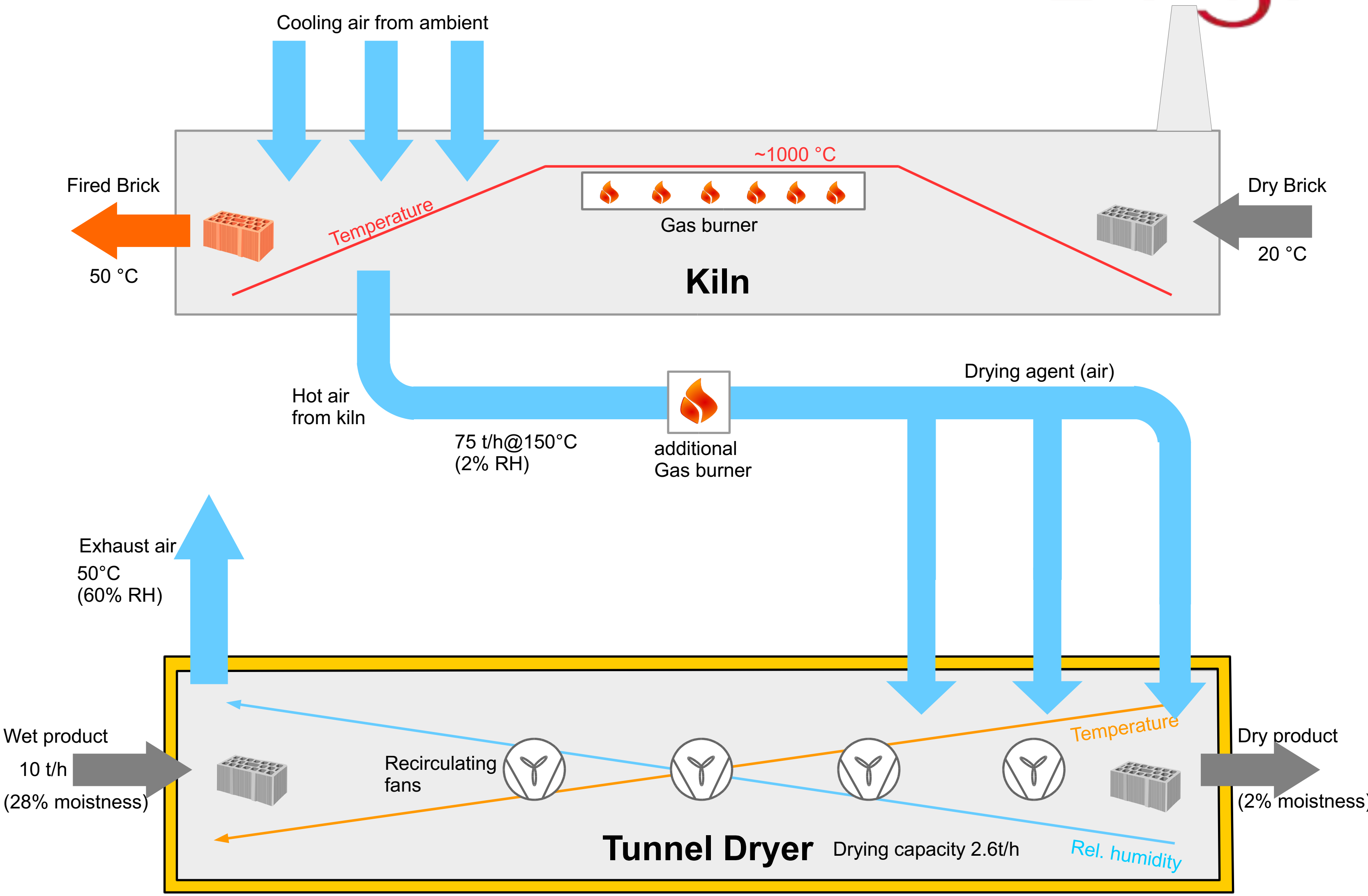
Conventional process



stefan.puskas@wienerberger.com

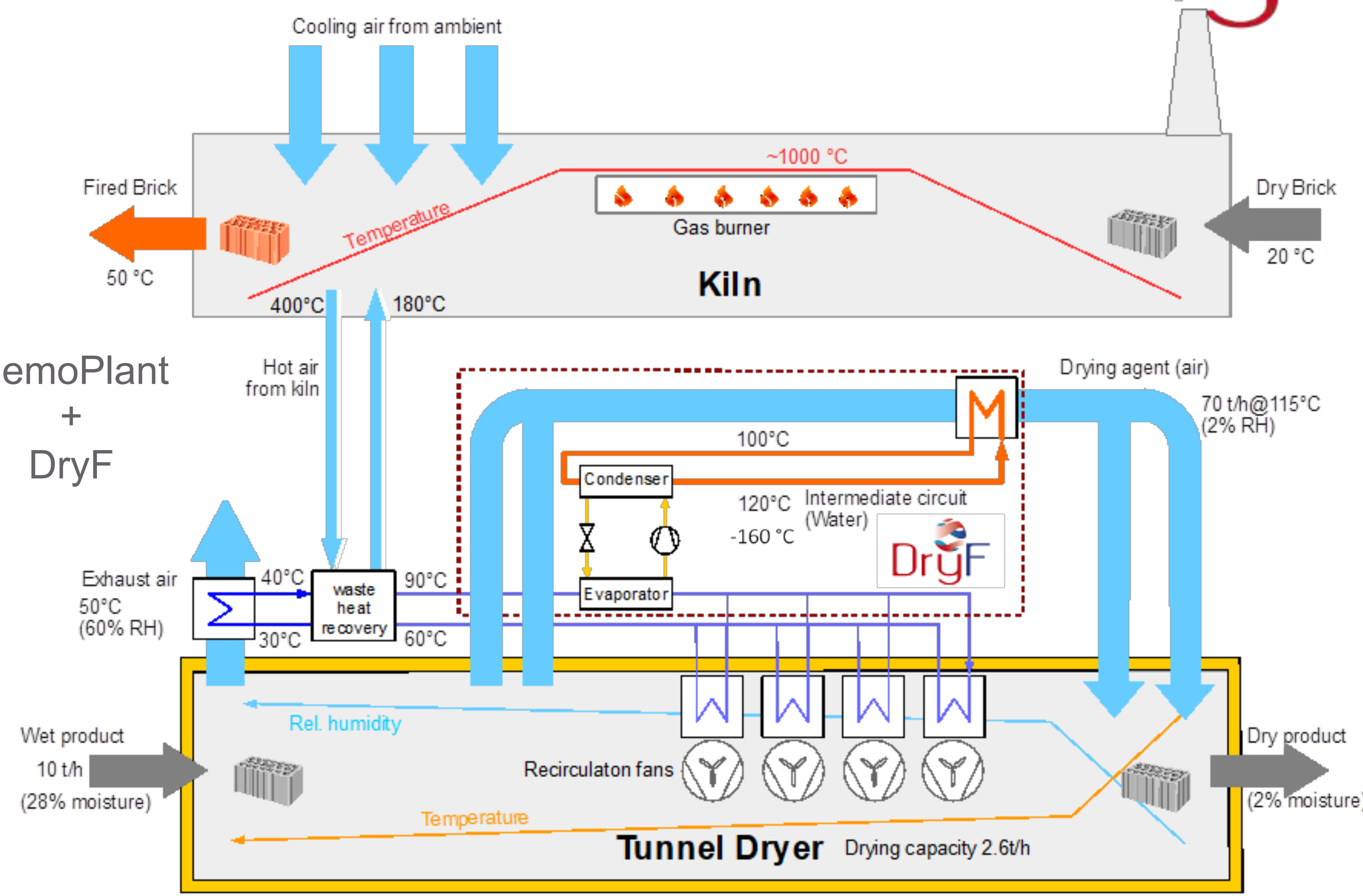
Grant Agreement No 723576 – Energy Efficiency

Conventional process

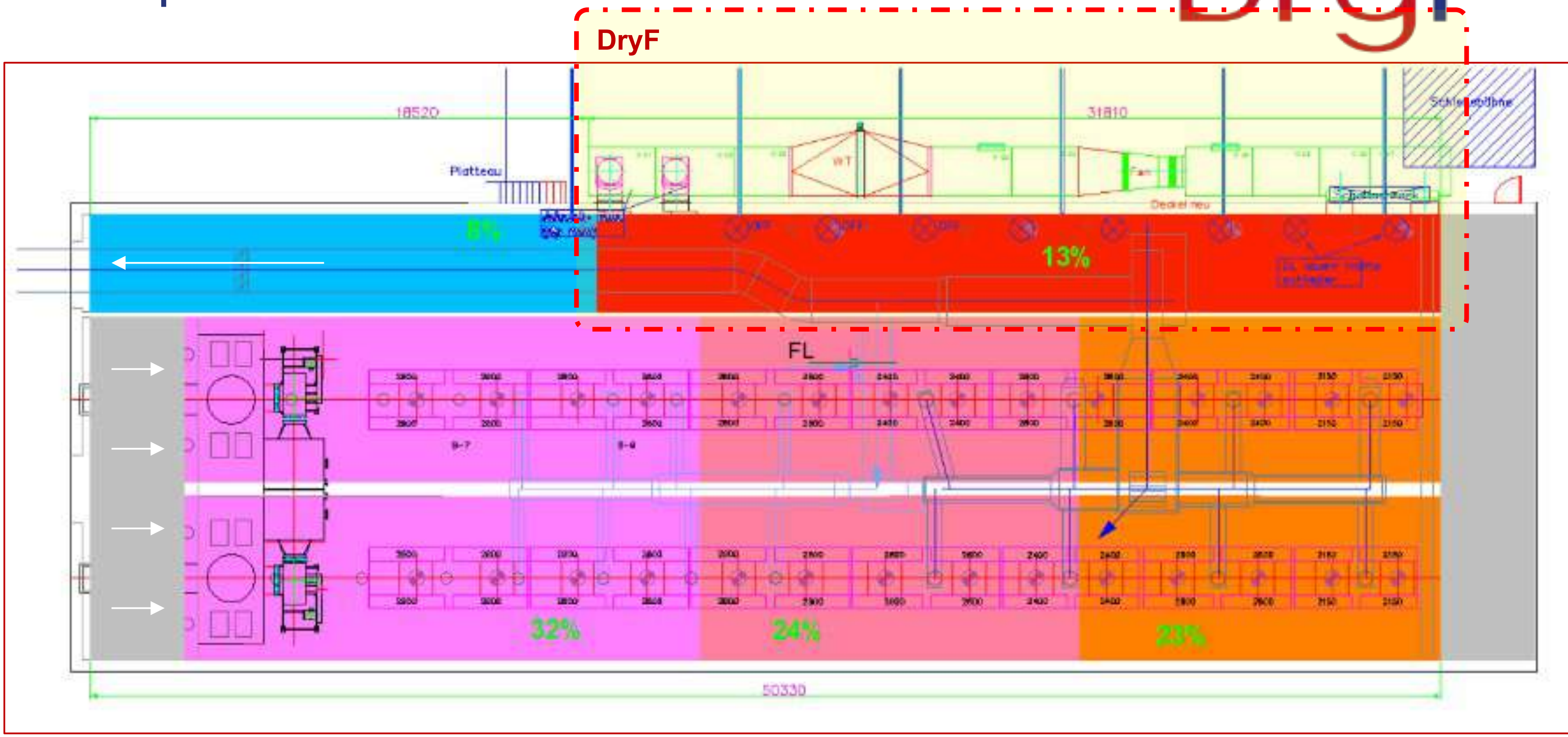


DemoPlant + DryF

DemoPlant
+
DryF



Temperature zones



DryF heats the return track; the products spends approx. 13% of the overall drying time in that part of the dryer.

1st stage: Absorption Heat Pump

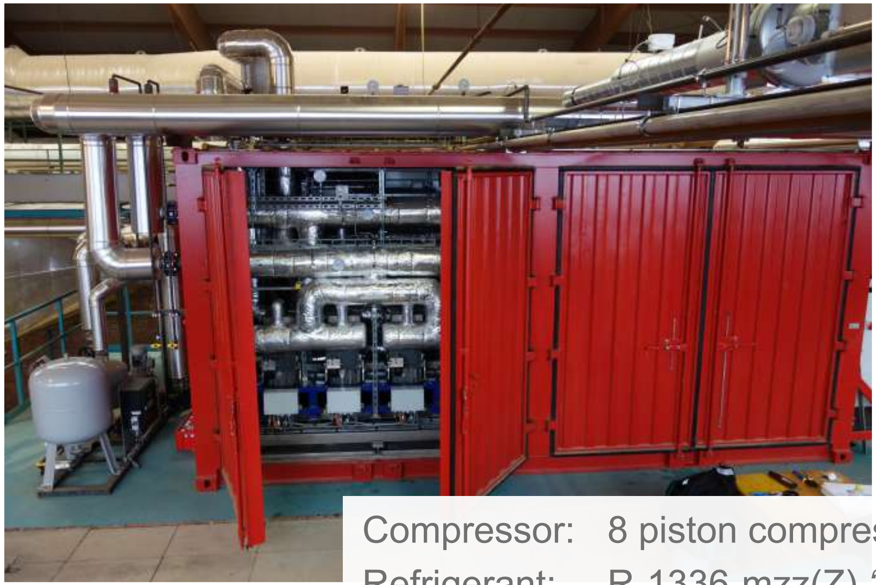
powerd by

EFRE

Europäische Union

MINISTERIUM
FÜR EIN
LEBENSWERTES
ÖSTERREICH

2nd stage: DryF Heat Pump



Compressor: 8 piston compressors

Refrigerant: R-1336-mzz(Z) *"OpteonMZ"*

Lubricant: Fuchs Schmierstoffe GmbH

Findings / impact

Goal of DryF is to demonstrate the functionality and reliability of high-temp. HPs!

HPs in a brick factory: HPs are the best available instruments to recover latent heat from the moist-air flows (e.g. out of the dryers).

High temp HPs (like DryF): Make sense when an energy source "not very much colder" then the needed one is available (e.g. 1-stage = absorption HP)

Other benefits to be considered

- Water recovery due to condensation in the heat-recovery (~ 1.2 kgH2O/kWh)
- Reduction of air-mass flows through the dryer

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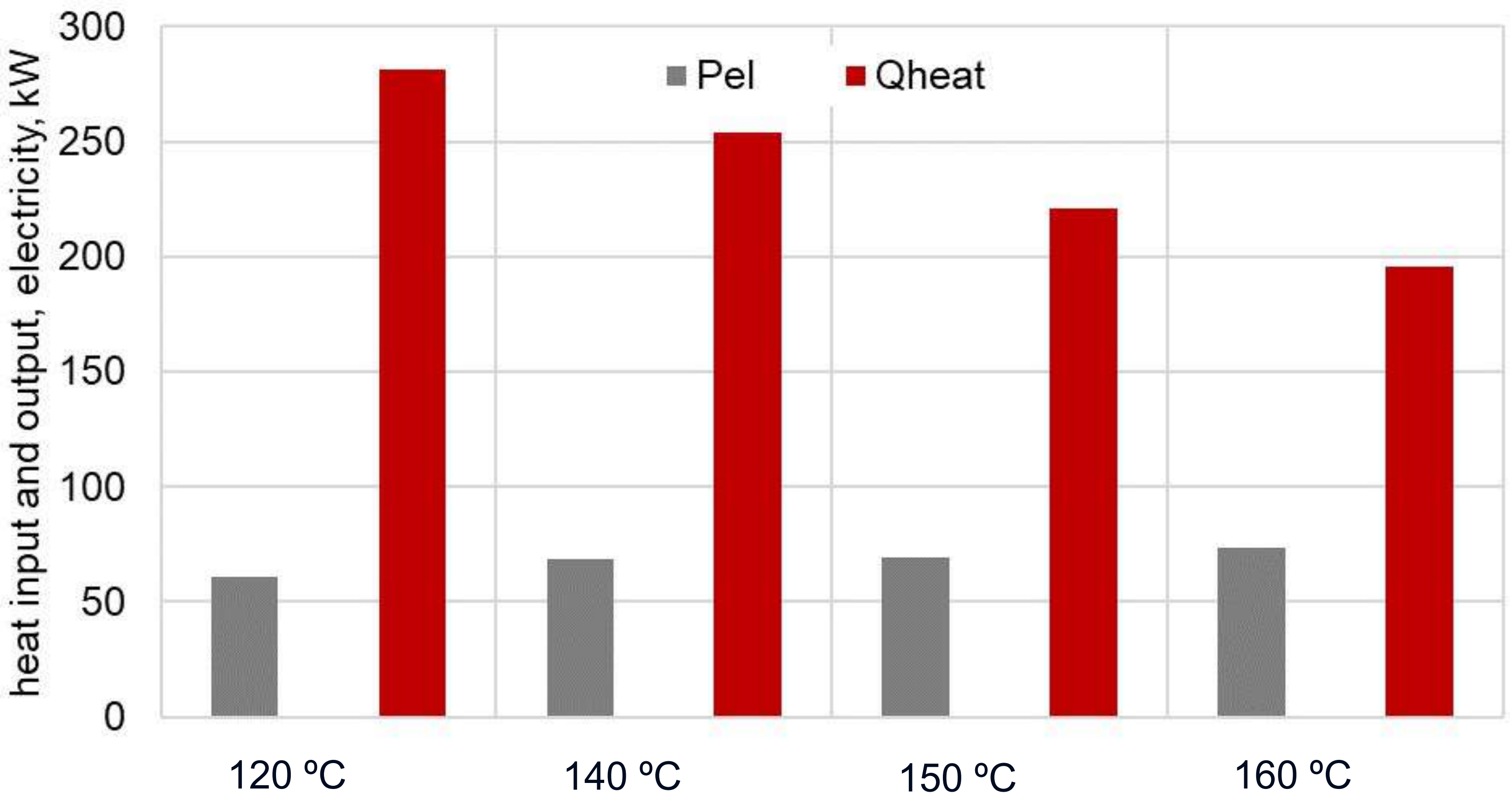
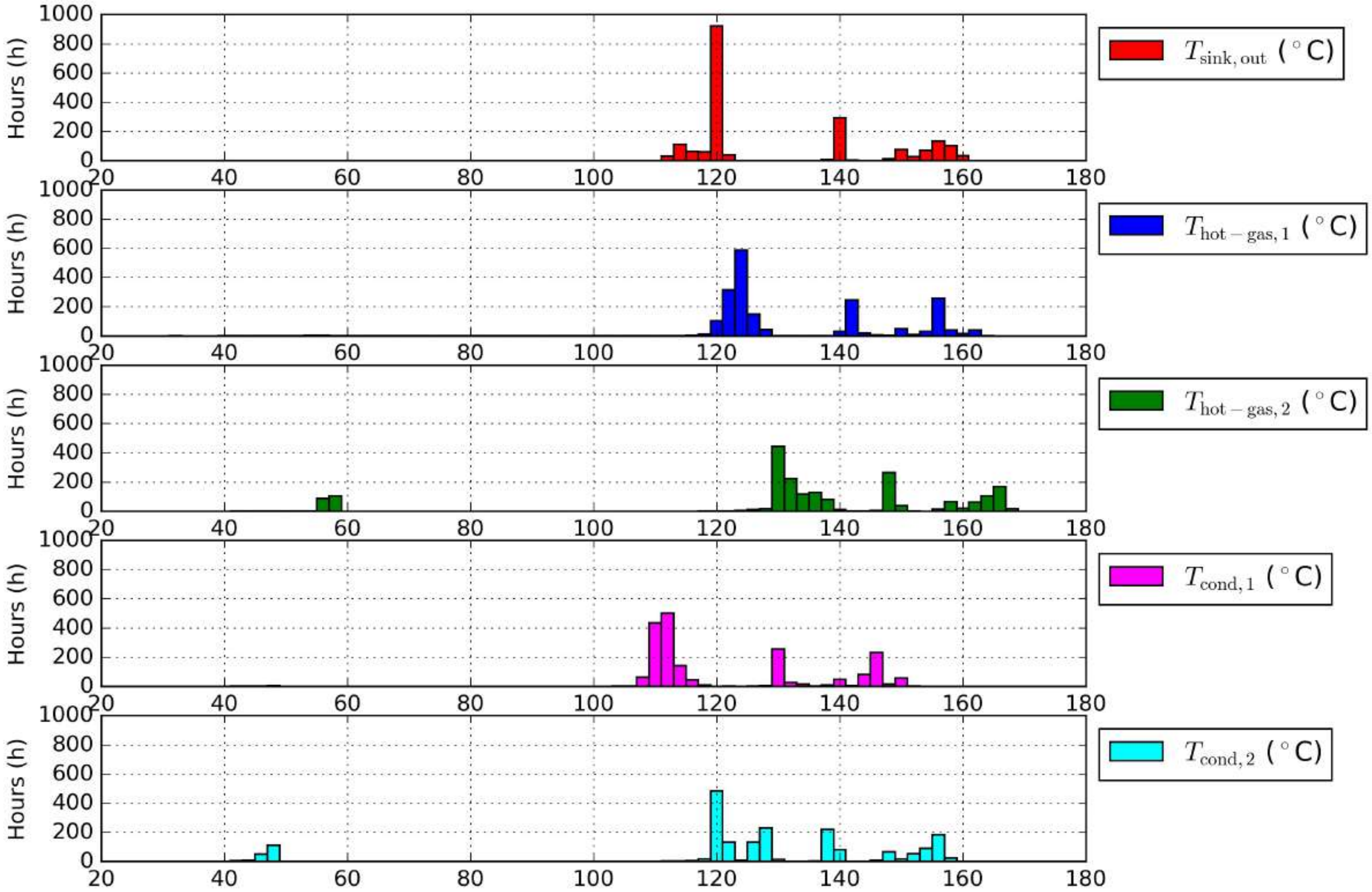
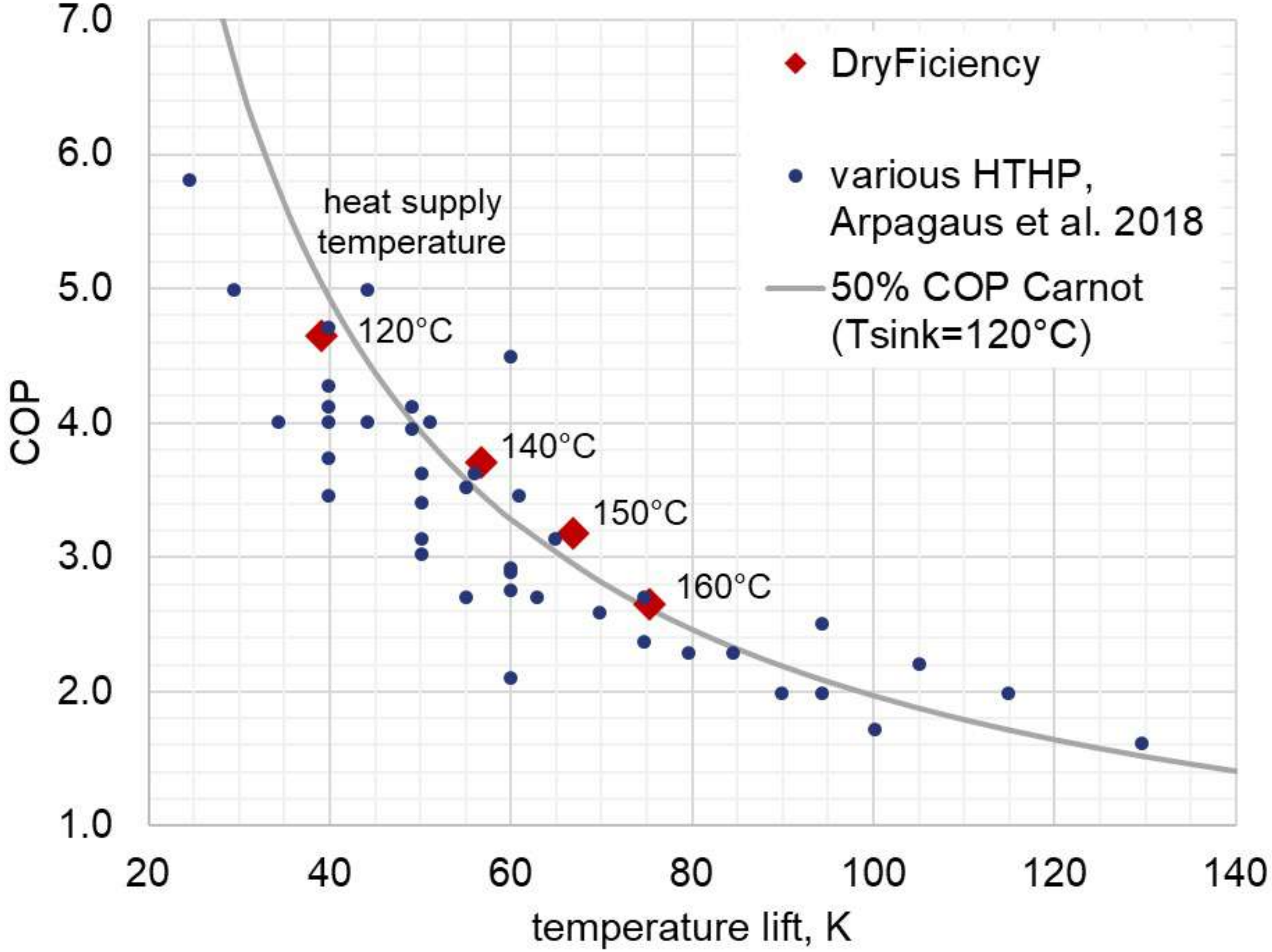
Energy balance



Status of operating hours: 2.034 h



Trial operation



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

Calculated impact of HP assisted drying

CO_2-emission factor natural gas

Austria: 271 g/kWh

EU: 290 g/kWh

Primary energy factor for gas

Austria: 1.18 kWh/kWh

EU: 1.36 kWh/kWh

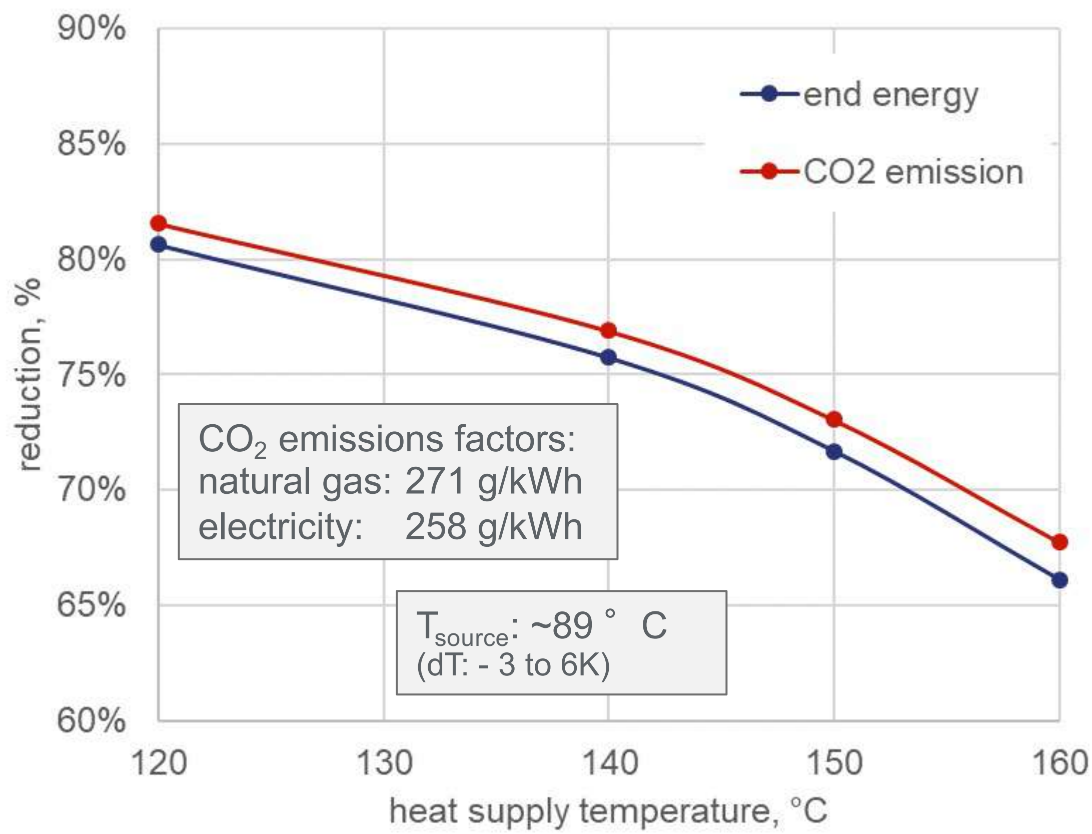
Primary energy factor for electricity

Austria: 1.91 kWh/kWh

EU: 2.10 kWh/kWh

Compare:

Gas-driven drying vs. HP-assisted drying (el)



Grant Agreement No 723576 – Energy Efficiency

Thank you for your attention!

stefan.puskas@wienerberger.com

Grant Agreement No 723576 – Energy Efficiency

Heat pump demonstrator at AGRANA wheat starch dryer in Pischelsdorf, Austria

High temperature heat pumps in energy intensive industries: demonstration plants
21st April 2021

AGRANA Stärke GmbH
Thomas Laminger

Grant Agreement No 723576 – Energy Efficiency-Innovation Action H2020-EE-2016-2017

AGRANA Biorefinery, Pischelsdorf

- 250.000 m³ bioethanol
- 80.000 t biogenic CO_2
- 260.000 t wheat starch
- 50.000 t wheat protein
- 170.000 t ActiProt®
- 100.000 t ActiGrano®
- 10.000 t bran

Grant Agreement No 723576 – Energy Efficiency

Heat pump demonstrator – Starch dryer WSA1

- Container outside the starch dryer WSA1
  - Start of installation September 2019
  - Start of commissioning May 2020
  - Trial test until August 2020
  - Ongoing performance optimization

- Design parameters
  - Heating capacity of appr. 400 kW (appr. 10% of the starch dryer's heat demand)
  - The heat supply temperatures are in the range of 110 - 160 ^{0}C.
  - COP up to 4

- Integration
  - Heat source: heat recovery circle (water)
  - Heat sink: drying air

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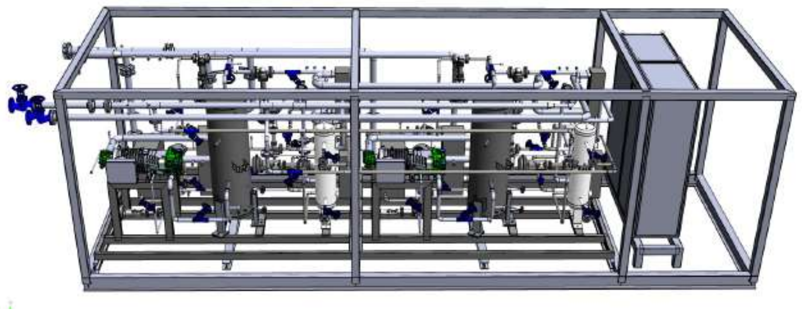
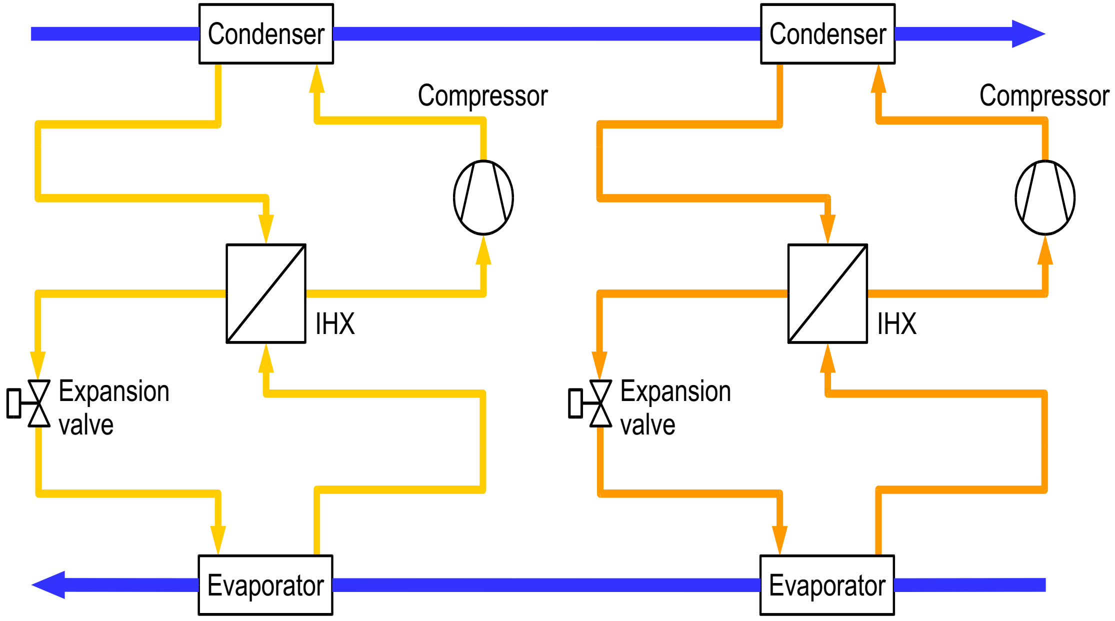
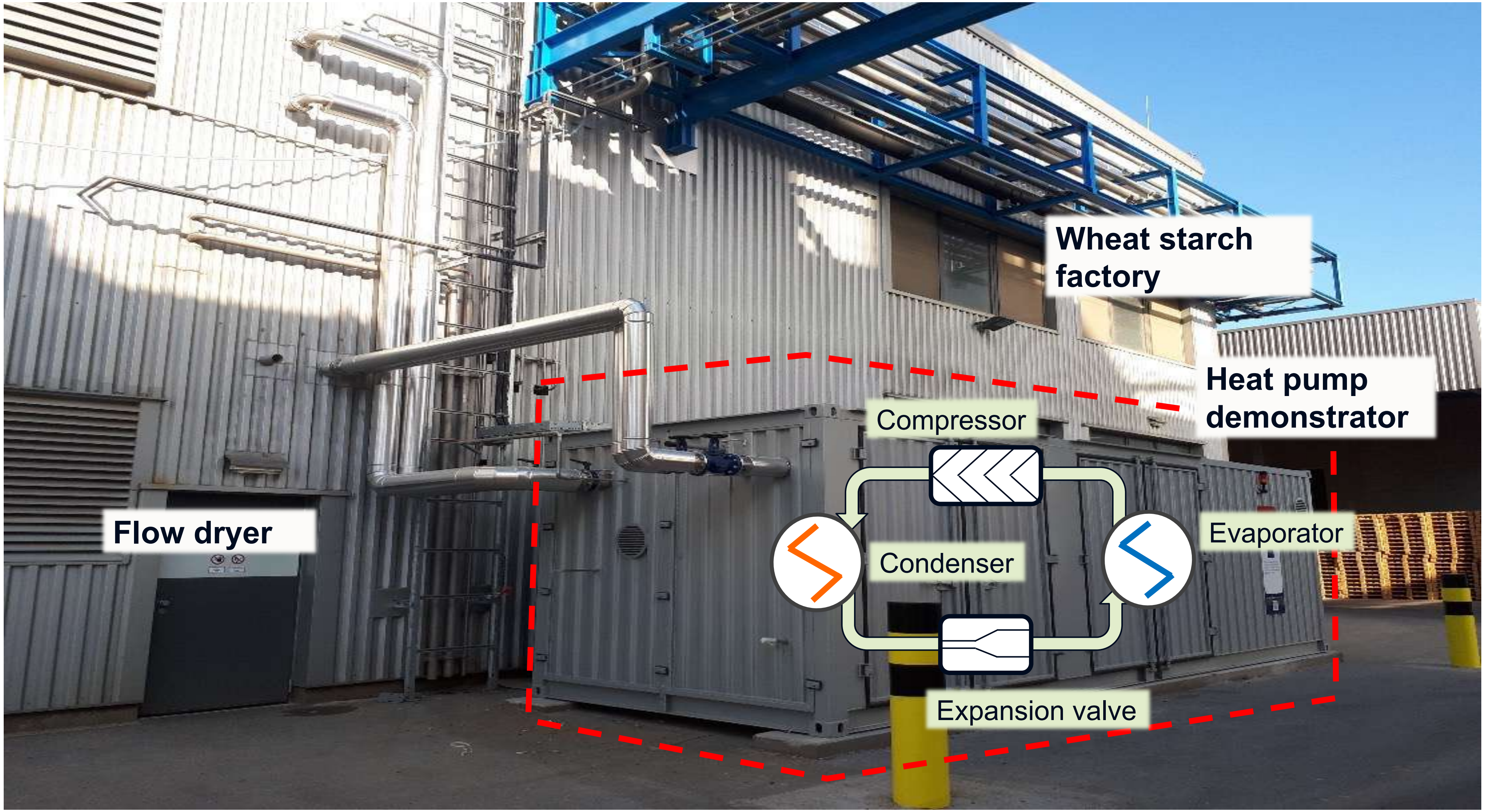
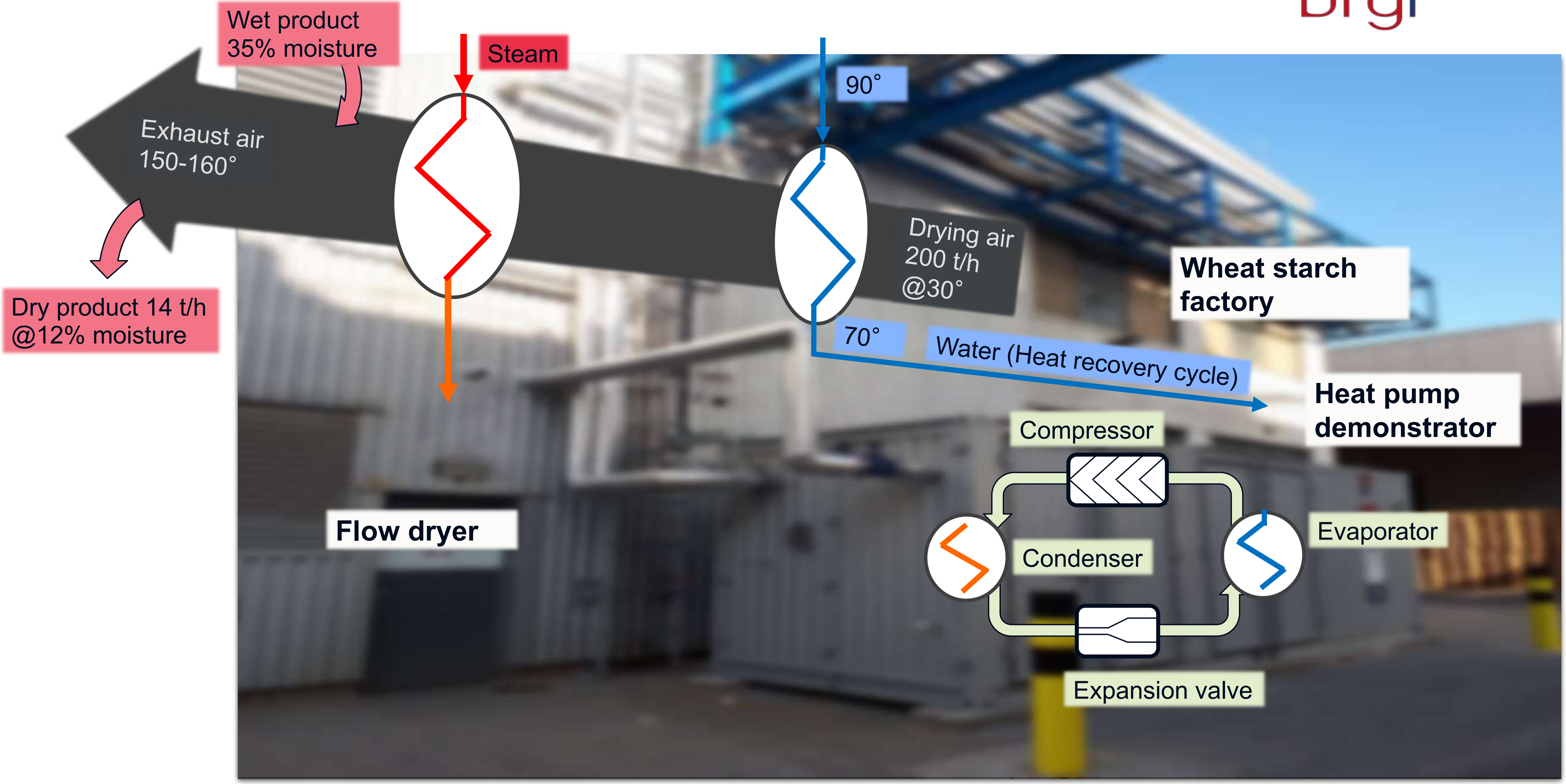
Closed loop heat pump cycle

- Variable configuration (twin-cycle source parallel or serial)
- Refrigerant OpteonMZ^{TM} by Chemours
- 2 screw compressors (Bitzer)

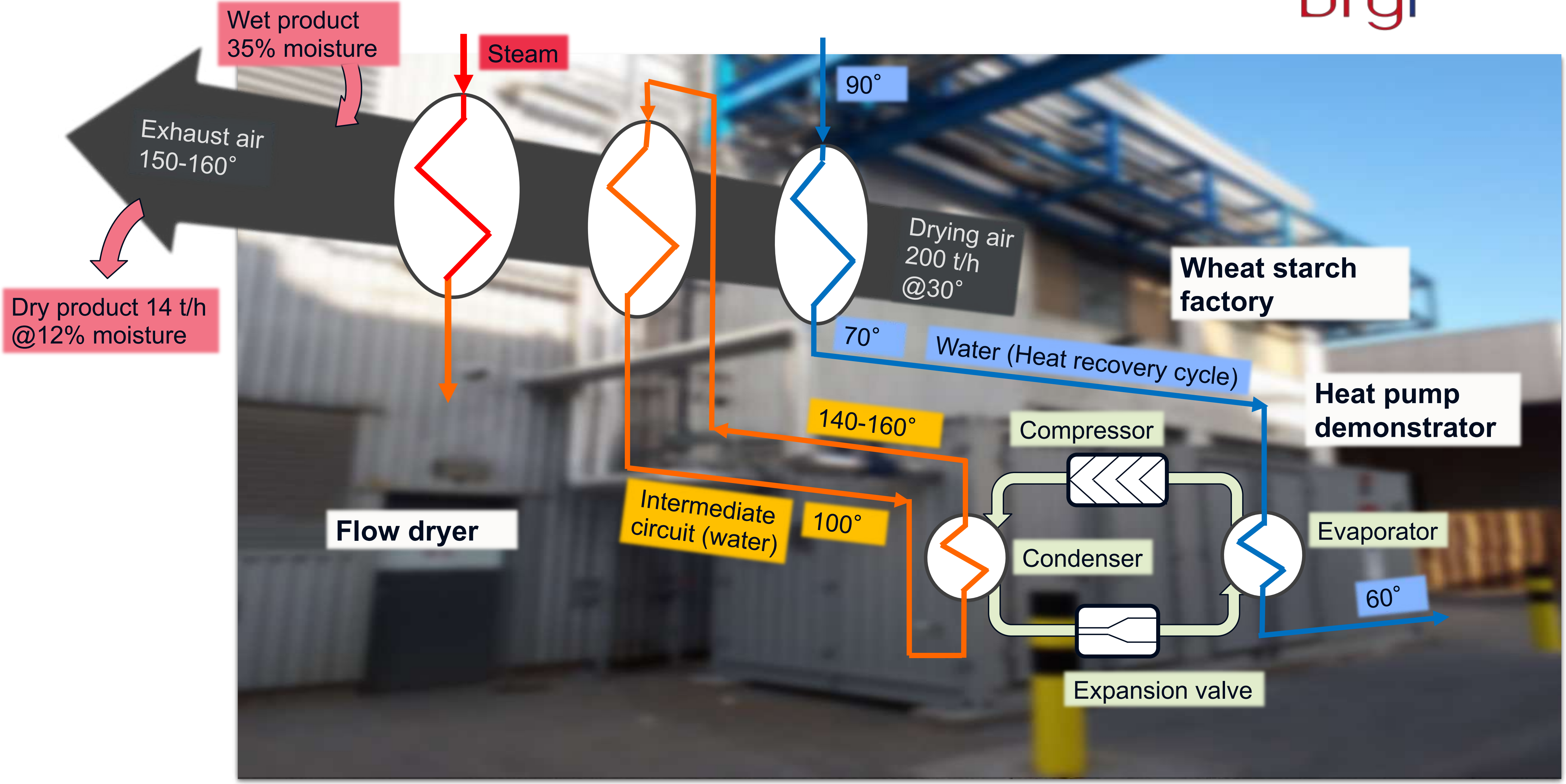





Wheat starch factory
Heat pump demonstrator
Compressor
Flow dryer
Condenser
Evaporator
Expansion valve



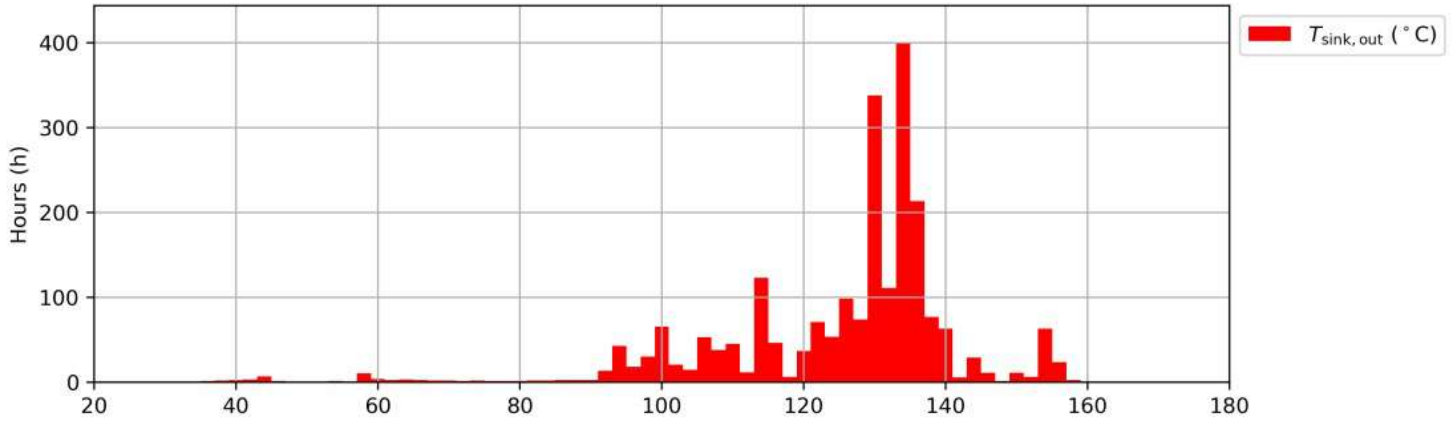
Wet product
35% moisture
Steam
90°
Exhaust air
150-160°
Drying air
200 t/h
@30°
Dry product 14 t/h
@12% moisture
Wheat starch factory
70°
Water (Heat recovery cycle)
Heat pump demonstrator
Compressor
Flow dryer
Evaporator
Condenser
Expansion valve

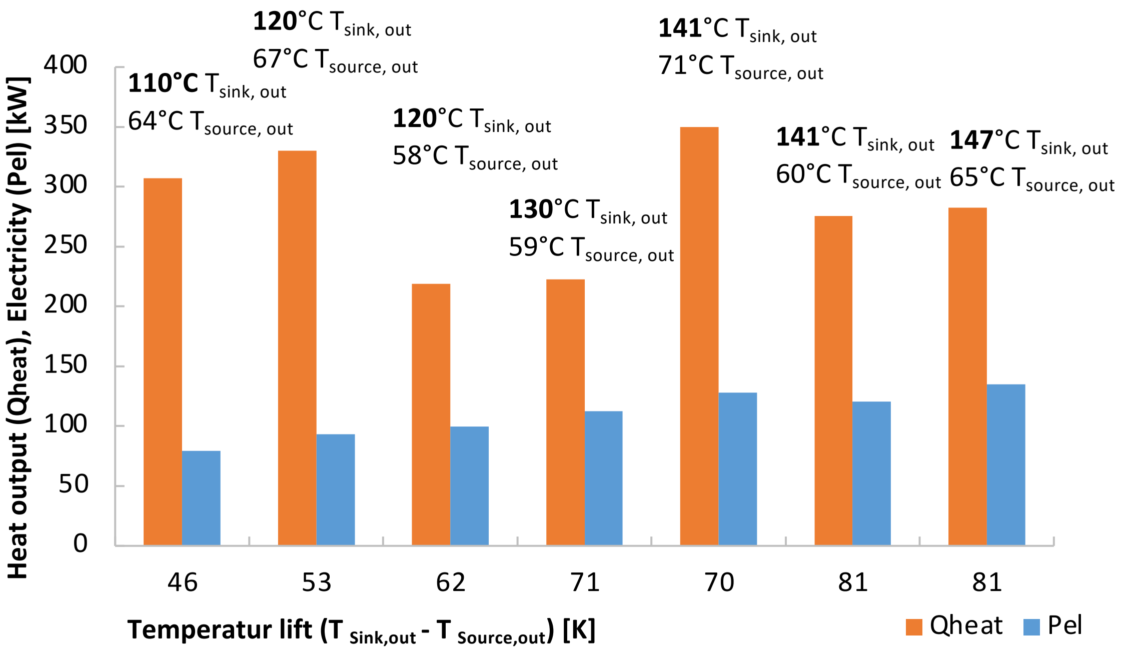


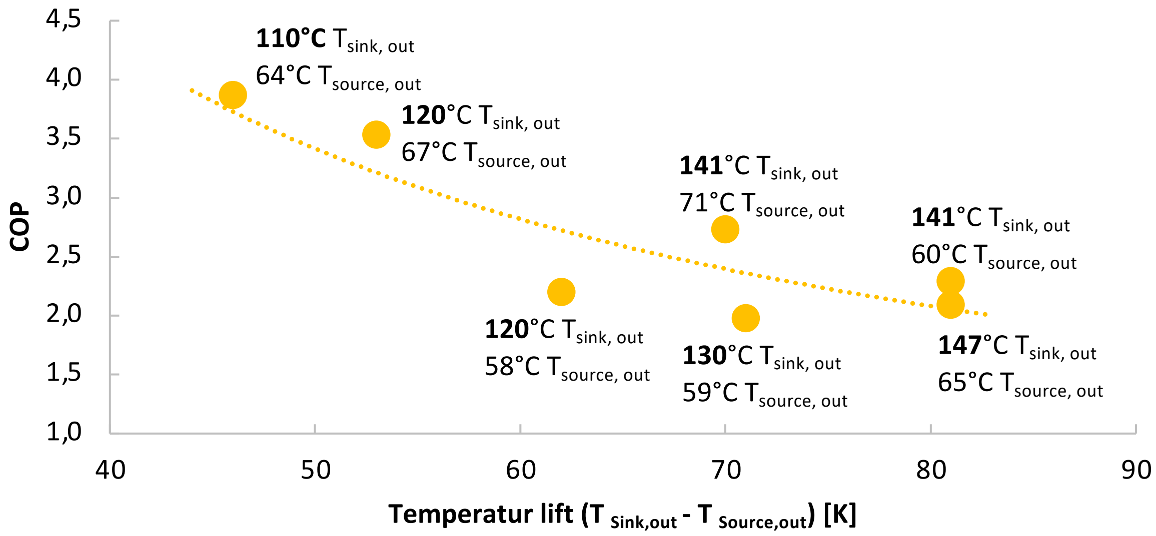
Wet product
35% moisture
Steam
Exhaust air
150-160°
Dry product 14 t/h
@12% moisture
90°
Drying air
200 t/h
@30°
Wheat starch factory
70°
Water (Heat recovery cycle)
Heat pump demonstrator
140-160°
Compressor
Flow dryer
Intermediate circuit (water)
100°
Condenser
Evaporator
60°
Expansion valve

Performance

- ~2300h Operation hours
- max. heat output ~350kW
- COP between 2-4
- Varying source temperature



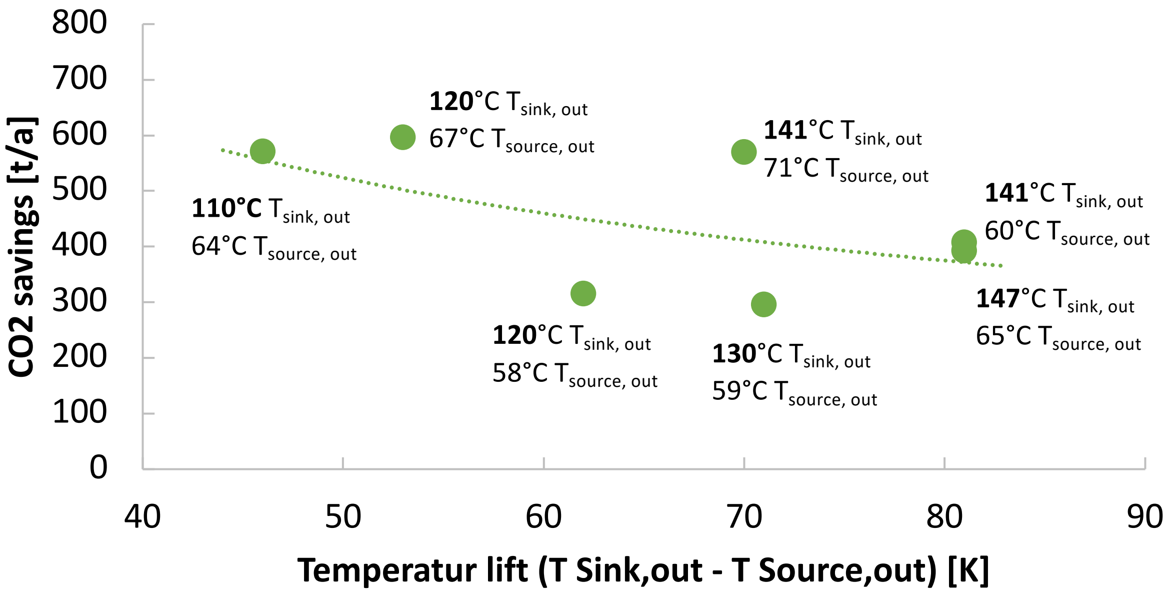




Performance

- Annual CO_2 savings up to 600 t

Operation hours: 8280 h/a
CO_2-Factors: 271kg/MWh Natural gas; 258 kg/MWh Electricity (Austrian Mix) [Umweltbundesamt 2019]



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Time schedule

Ongoing optimization in cooperation with AIT, AMT and ENERTEC.

The demo phase until August 2021 will be split in thirds:

- providing the heat supply temperature of the design point with different operation conditions and
- providing the heat supply temperature close to the design point with different operation conditions.
- more challenging conditions at the operational limits of the heat pump

DryFiciency at a glance

- H2020 project with 13 partners and 6 Mio € funding
- started in September 2016
- development and demonstration of high temperature heat pumps



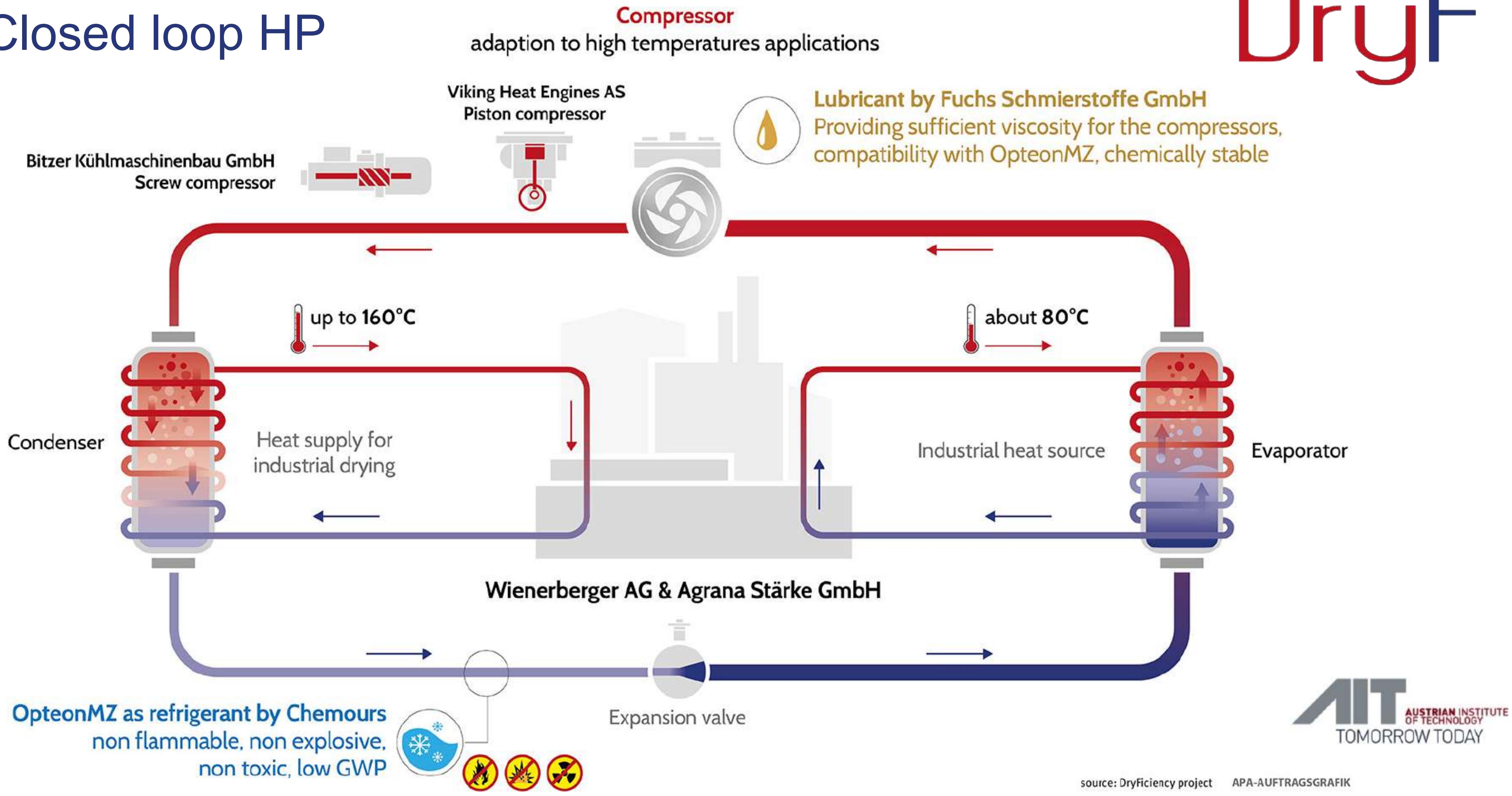
DryFiciency Consortium

Closed Loop Heat Pumps		Open Loop Heat Pump
AIT Austrian Institute of Technology – Tomorrow Today	2 RTOs	SINTEF
Bitzer, Viking Heat Engines	3 compressor manufacturers (2 SME)	ROTREX
Chemours, Fuchs (Lubricants. Technology. People.)	1 refrigerant manufacturer 1 lubricant manufacturer	
	1 plant engineer/ system expert (1 SME)	EPCON Evaporation Technology AS
Agrana Stärke, Wienerberger Building Material Solutions	3 end-users	SCANSHIP for cleaner oceans

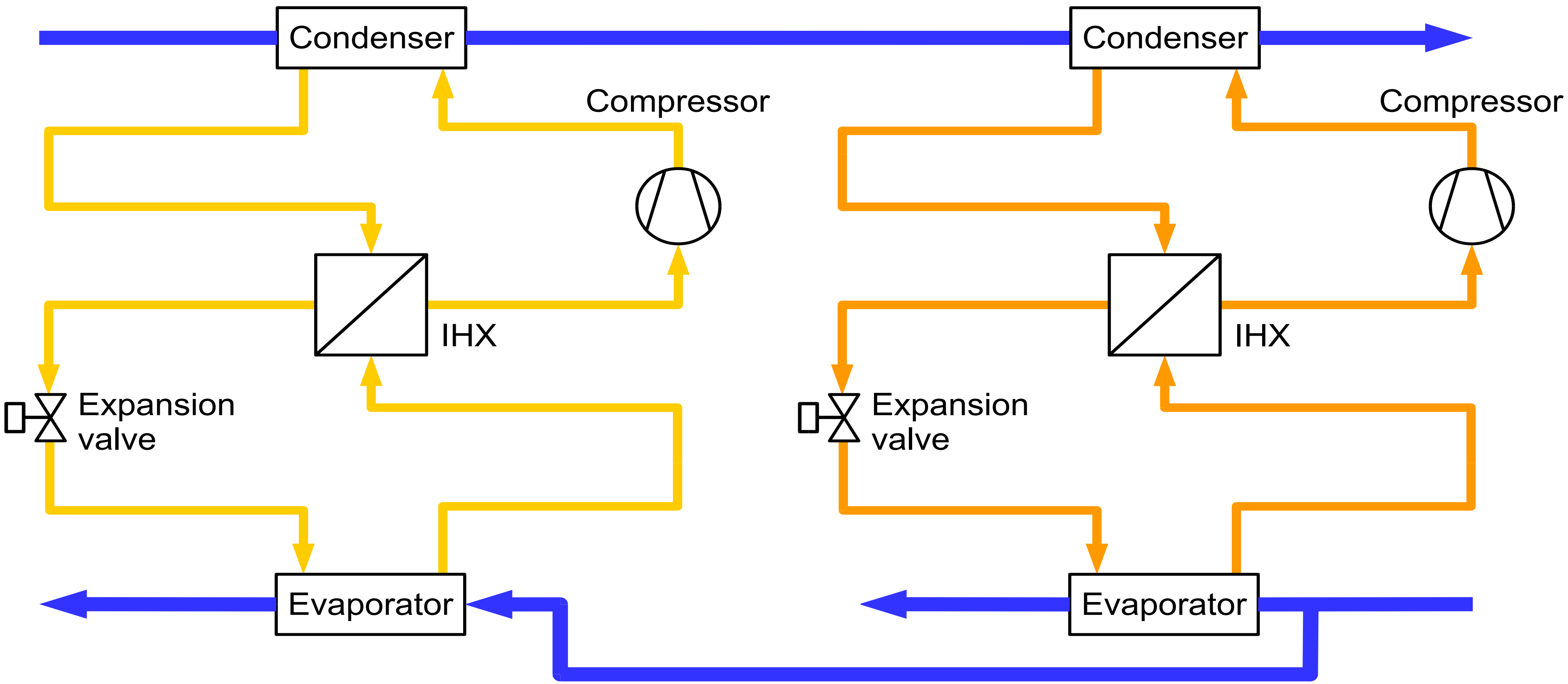
2 experts on dissemination & exploitation (1 SME)

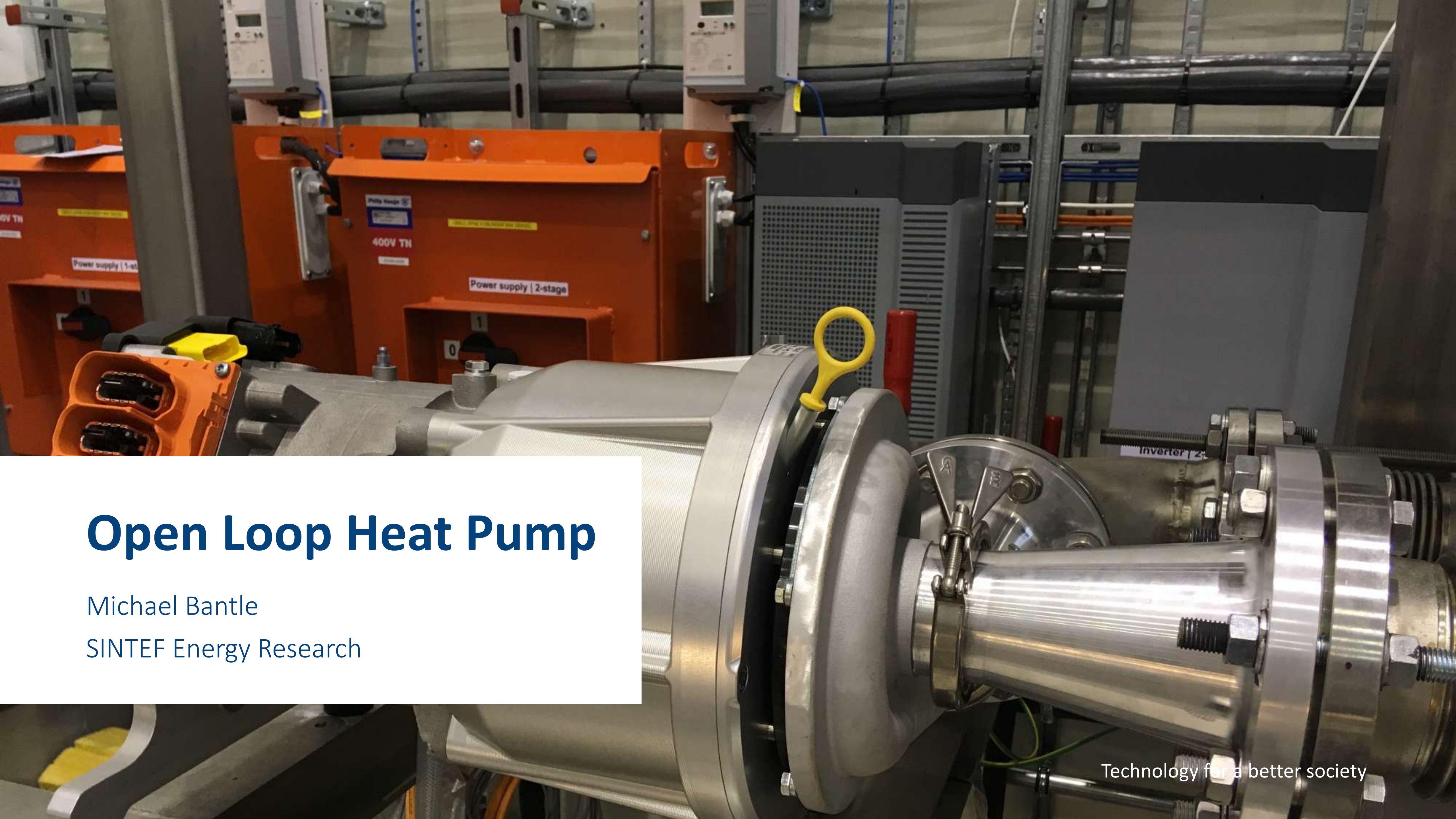
ehpa, RTDS Association

Closed loop HP



Twin cycle heat pump design



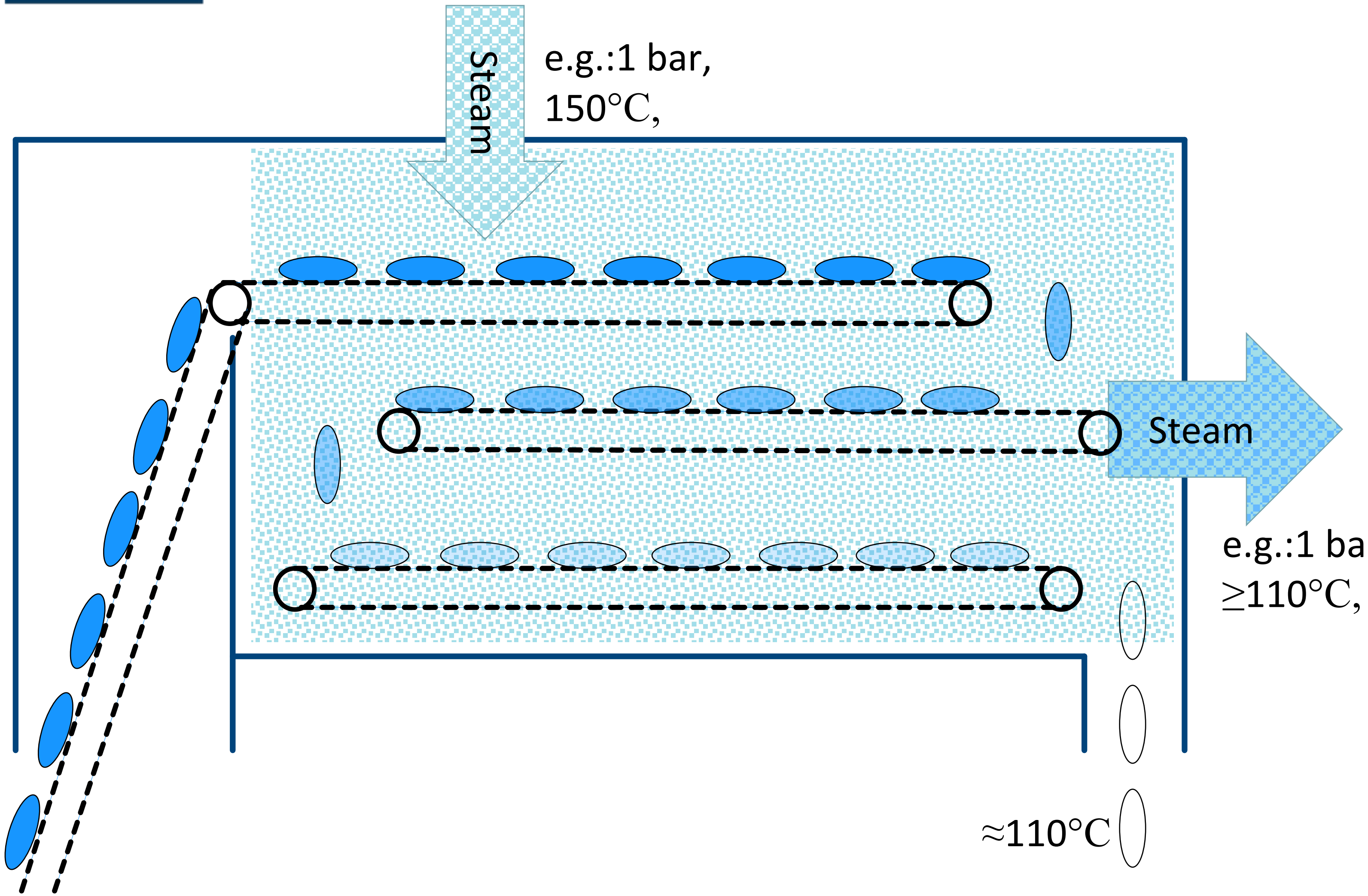


Open Loop Heat Pump

Michael Bantle
SINTEF Energy Research

Technology for a better society

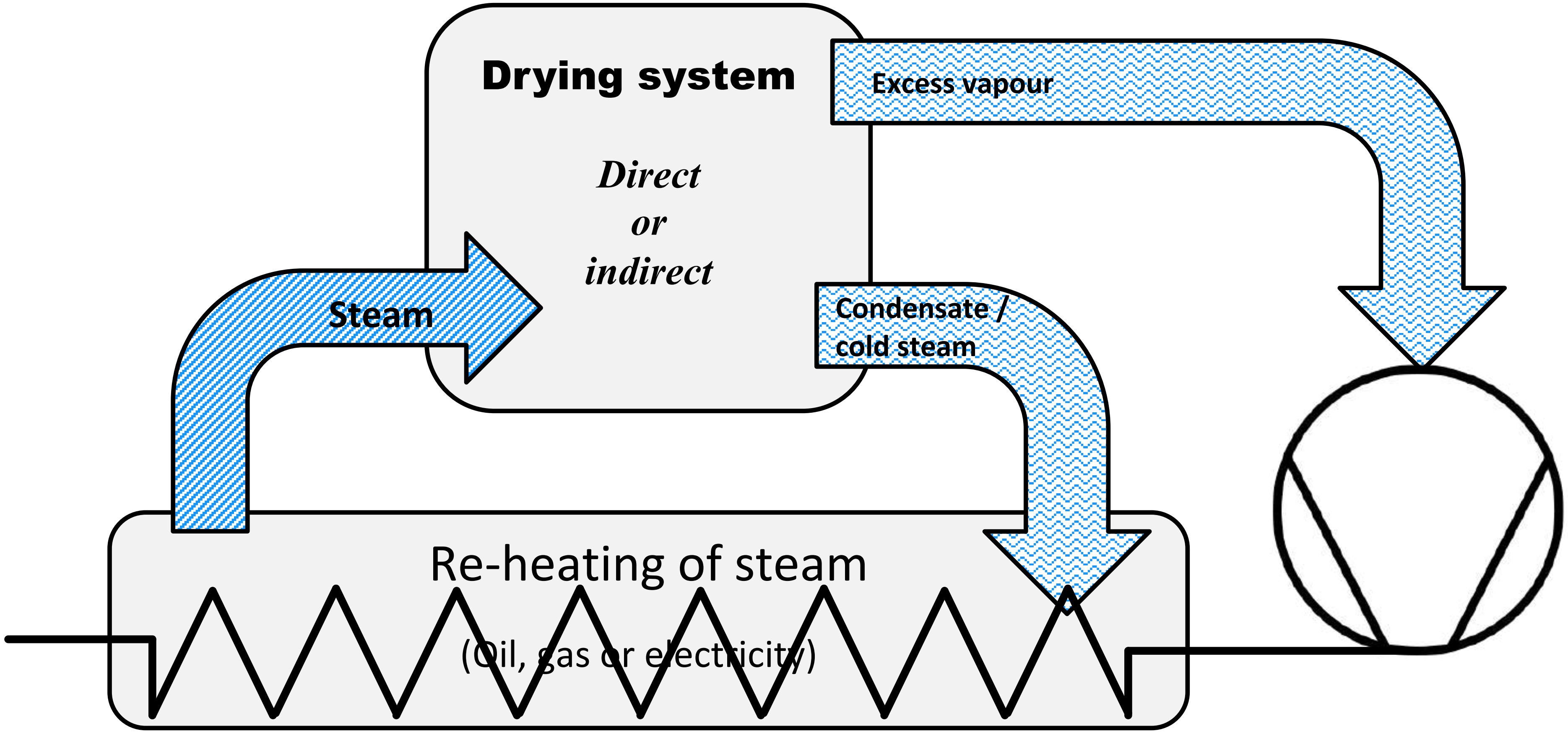
Superheated Steam Drying



Specific Energy Consumption:

- Dryer 0.8 kWh/kg
  - Ideal 0.63 kWh/kg
- Excess steam available
- Aim 0.2 kWh/h

Open Loop Heat Pump (Mechanical Vapor Recompression)



Why using Superheated Steam instead of Air as Drying medium?

$H = m \cdot c \cdot \Delta T$

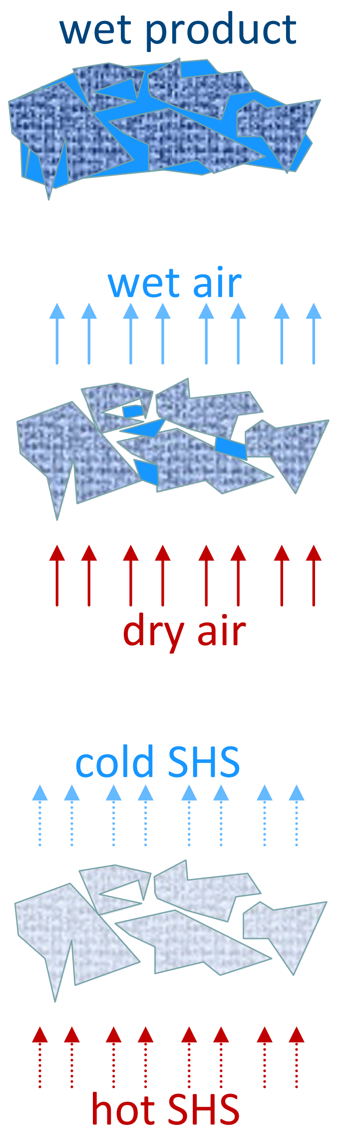
$$RE = \frac{w \cdot d_P \cdot \rho}{\eta (1-\varepsilon)}$$

Overall heat transfer coefficient c and viscosity η

	T [°C]	STEAM	AIR
c [kJ/(kg K)]	100	2.042	1.012
	150	1.980	1.018
η [10-6 kg/ms]	100	12.27	21.94
	150	14.18	24.07

As higher c value as higher drying rate

As lower η value as better pore diffusion



Refrigerant R718 (water)

- Abundance and Safety:
  - Most abundant elements on earth; low cost and nearly unlimited available
  - From environmental point of view: water is ideal refrigerant above 0°C
  - Non-toxicity, non flammable, 0 Ozone Depletion Potential, 0 Global Warming Potential
- Regulatory Relief:
  - Not subject to present or future environmental or safety regulations
- Efficiency:
  - High latent heat of evaporation (2270 kJ/kg); 4-5 times higher than hydrocarbons or CO2
  - Critical temperature: 380-386°C
  - General high COP

Multistage systems

	COP	COP (+Intercool)	$\dot{Q}_{ThermCap}$ $[kW]$	$\dot{Q}_{Intercool}$ $[kW]$	P_{Compr} $[kW]$	p_2 $[bar]$	T_2 [°C]
One Compressor	12.79		247.3		19.3	2.03	187
Two Compressors	6.57		255.4		38.9	3.67	270
Two Compr. + Intercooling	6.12	6.46	240.6	12.8	39.3	4.13	213
Three Compressors	4.50		263.7		58.6	6.12	351
Three Compr. + Intercooling	4.00	4.38	237.3	22.6	59.3	7.84	255

Results of the Performance Analysis for Multi-Stage Compression for Compressor Speeds of n = 82 700 rpm, Inlet Pressure p = 1 bar, Inlet Temperature T = 105 ℃ and Mass Flow of $\dot{m}$ ≈ 0.1 kg sec-1, Pcompr is required compression power, p2 the discharge pressure and T2 the discharge temperature after the last compression stage

SINTEF

Cost for Compressor

MVR-Compressor	screw compressor		steam fans/blowers		Turbocompressor	
stages	1 stage		5 stage		2 stage	
Inlet	110°C/1bar		110°C/1bar		110°C/1bar	
Outlet	150°C/5bar		150°C/5bar		150°C/5bar	
Investment	1 200 000 €		700 000 €		50 000 €	
Capacity	1300 kW		1300 kW		1300 kW	
steam flow	2000 kg/h		2000 kg/h		2000 kg / h	
COP (W/W)	4.25		4.25		4.25	
net savings	8.48 GWh		8.48 GWh		8.48 GWh	
Location	Germany	Norway	Germany	Norway	Germany	Norway
net savings**	52 275 €	482 885 €	52 275 €	482 885 €	52 275 €	482 885 €
ROI	**23 years**	**2.5 years**	**13.4 years**	**1.4 years**	**1 year**	**0.1 year**

**** based on: electricity 0.15€/kWh Germany, 0.07€/kWh Norway; gas 0.04€/kWh Germany 0.06 €/kWh Norway**

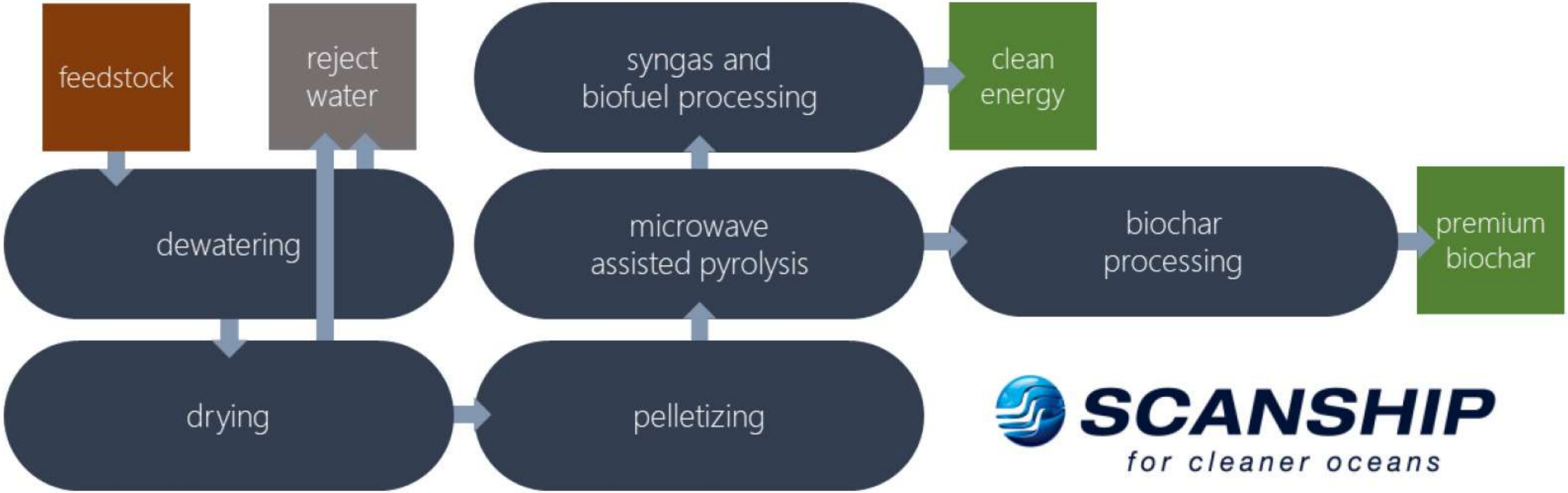
Technology for a better society

Lindum Demo Site

Pål Jahre Nilsen
VP Innovation
Scanship

Grant Agreement No 723576 – Energy Efficiency

Motivation - Lindum Demo Site

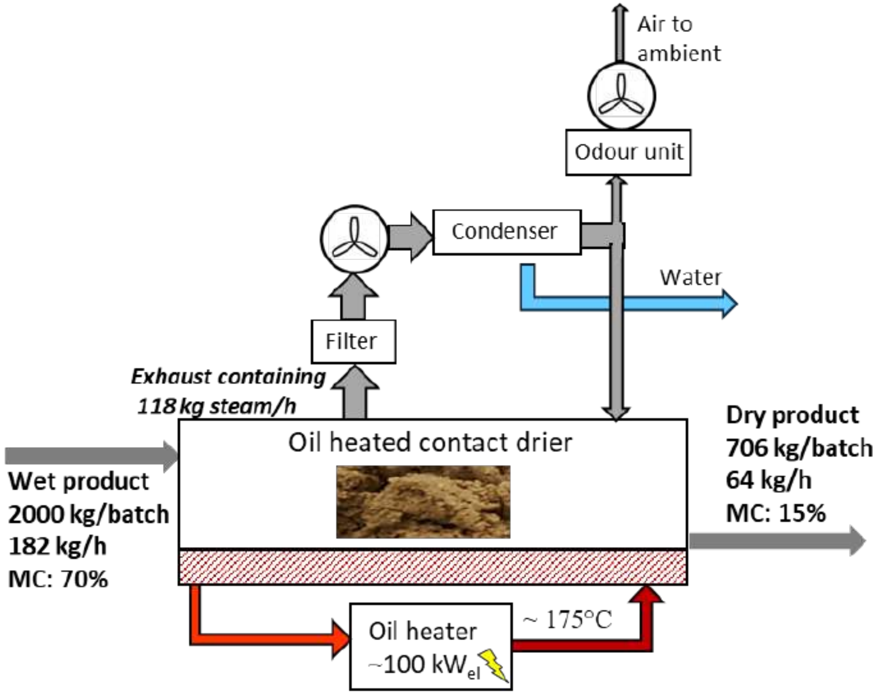


SCANSHIP for cleaner oceans

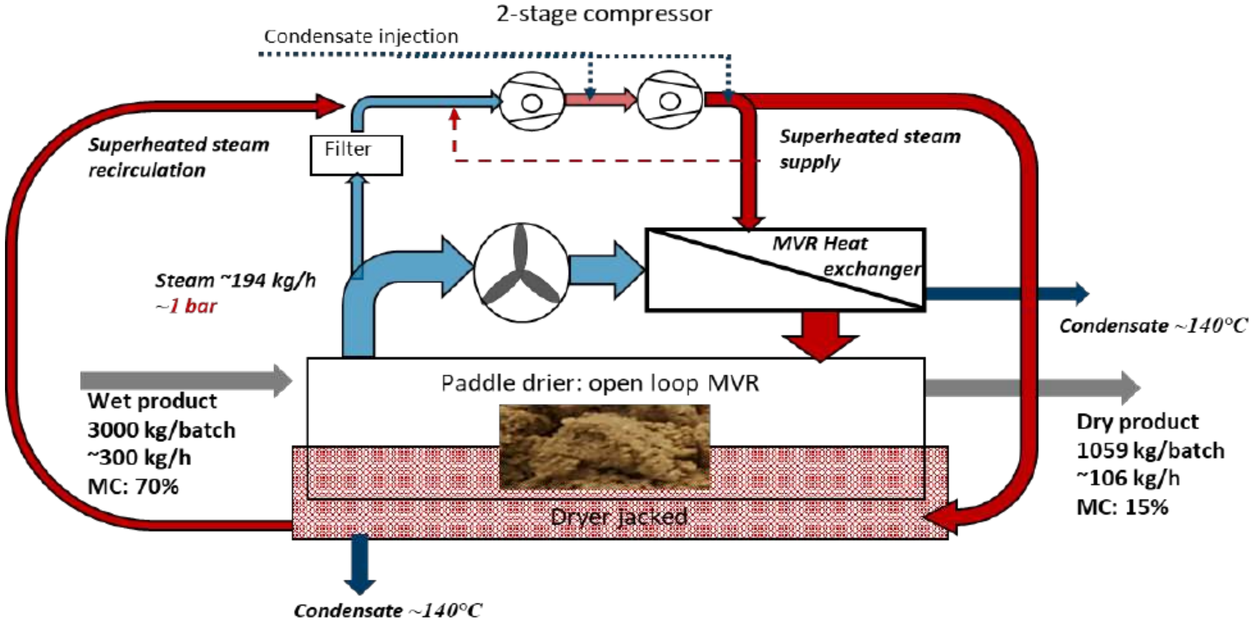
Grant Agreement No 723576 – Energy Efficiency

Boundary conditions Bio-Mass Drying – Modification towards energy efficient SHS drying

Currently

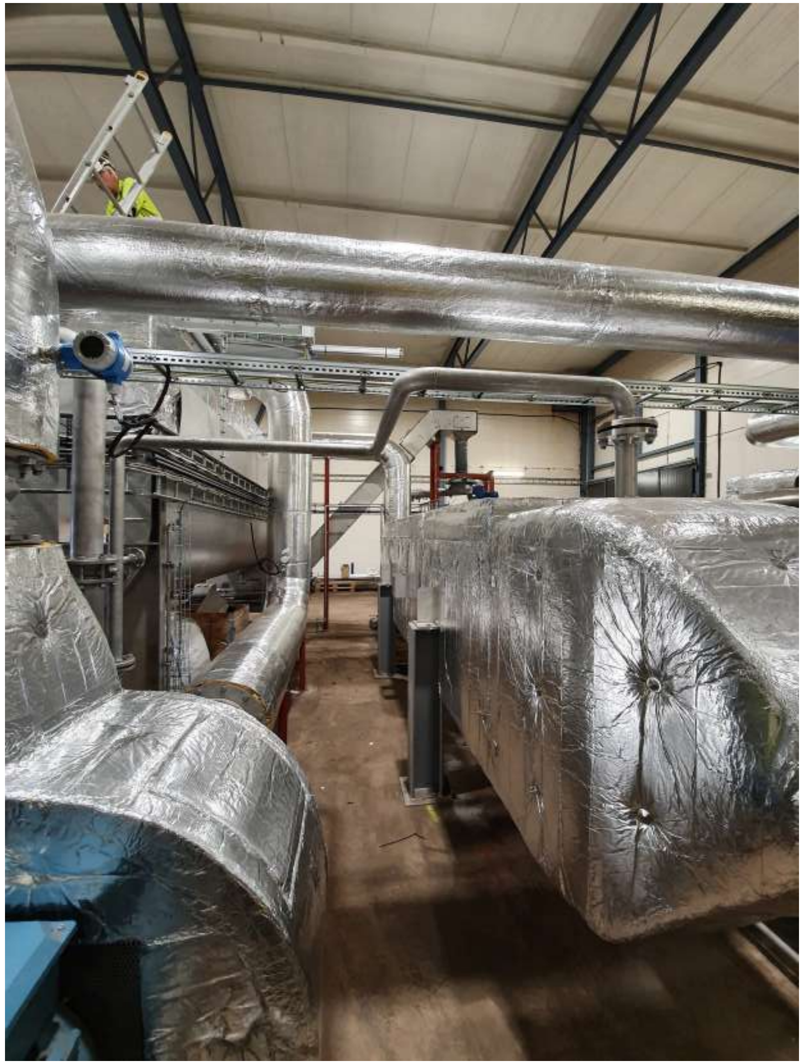


After DryF



SCANSHIP
for cleaner oceans

DryF



Final conference

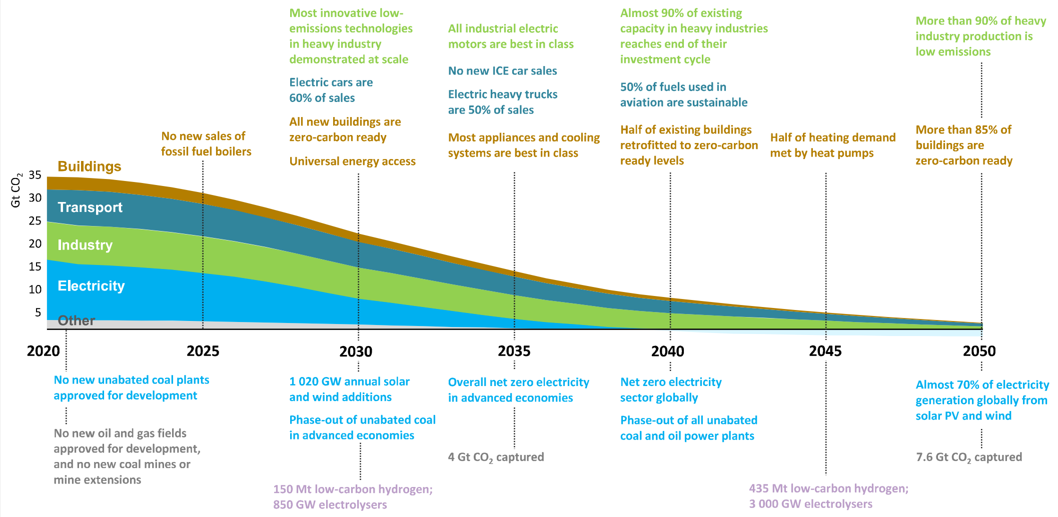
International Energy Agency

Net Zero by 2050: A Roadmap for the Global Energy Sector

Dr Timur Gül, Head of the Energy Technology Policy Division
Dr Peter Levi, Energy Technology Policy Division

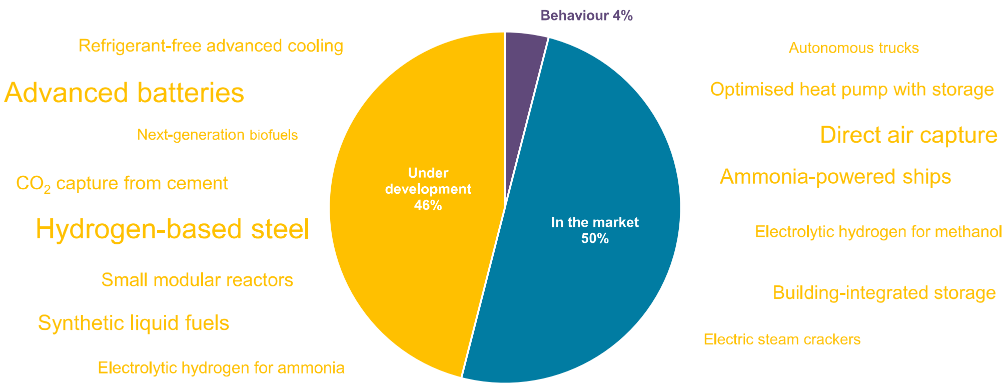
DryFiciency Conference, July 2021

Set near-term milestones to get on track for long-term targets



Prepare for the next phase of the transition by boosting innovation

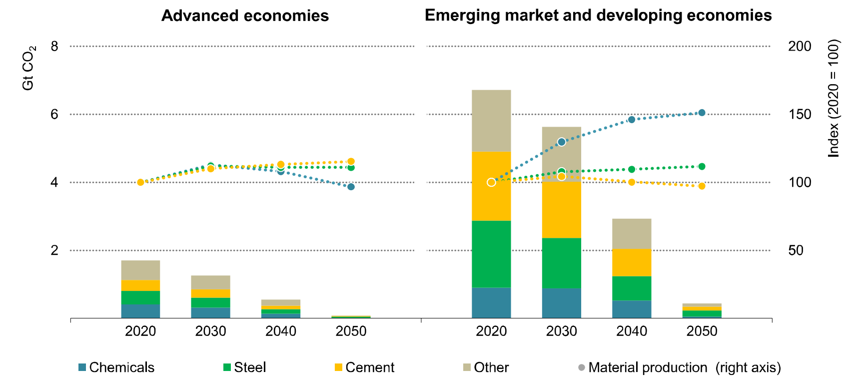
CO_2 savings by technology maturity in 2050, NZE scenario



Unlocking the next generation of low-carbon technologies requires more clean energy R&D and $90 billion in demonstrations by 2030; without greater international co-operation, global CO_2 will not fall to net-zero by 2050.

Dramatic reductions in industrial CO_2 emissions are required

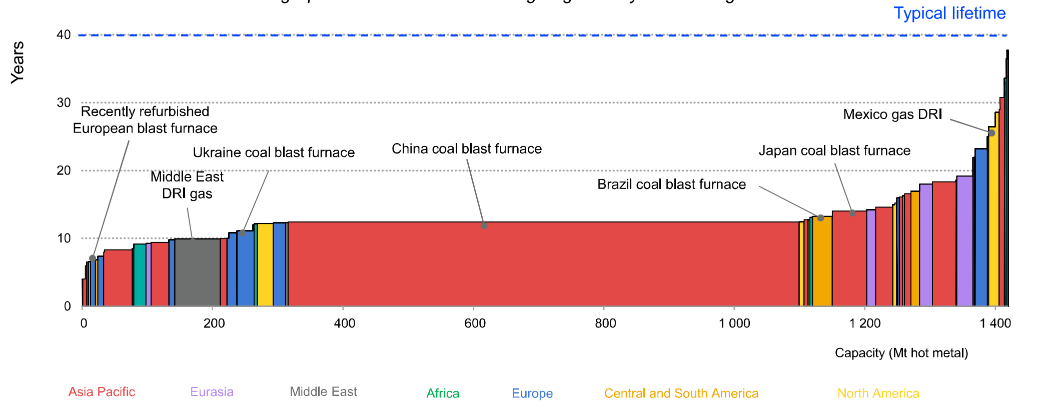
Global CO_2 emissions from industry by sub-sector in the NZE



The majority of residual emissions in industry in 2050 come from heavy industries in emerging market and developing economies

Where do we start in industry? Examining existing assets

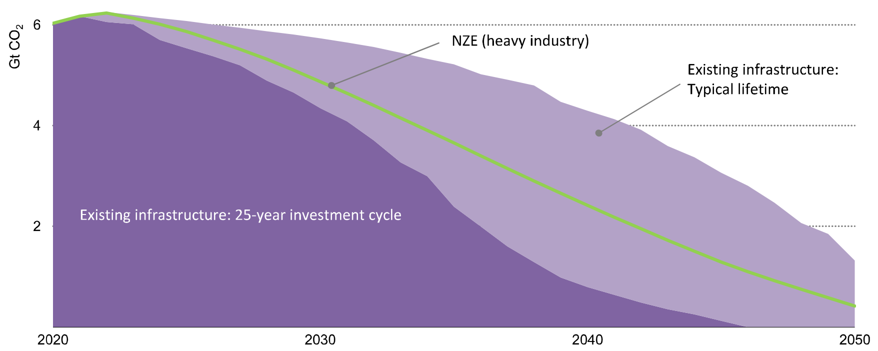
Geographic distribution and average age of key ironmaking assets



Around 60% of the existing stock of ironmaking equipment is based in China.
The current stock is quite young, with a global average age of 13 to 14 years for blast furnaces and DRI furnaces.

Addressing CO_2 emissions from heavy industry

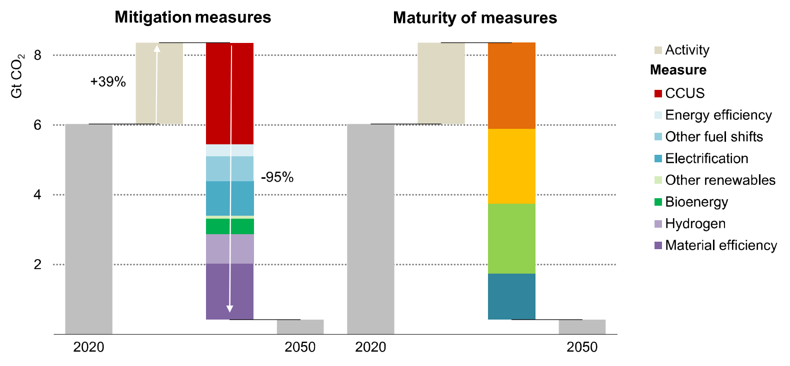
CO_2 emissions from existing heavy industrial assets in the NZE



Intervening at the end of the next 25-year investment cycle could help unlock 60 Gt CO_2, around 40% of projected emissions from existing heavy industry assets

Addressing CO_2 emissions from heavy industry

Global CO_2 emissions reductions in heavy industry by mitigation measure and technology maturity category in the NZE



An array of measures reduces emissions in heavy industry, with innovative technologies like CCUS and hydrogen playing a critical role

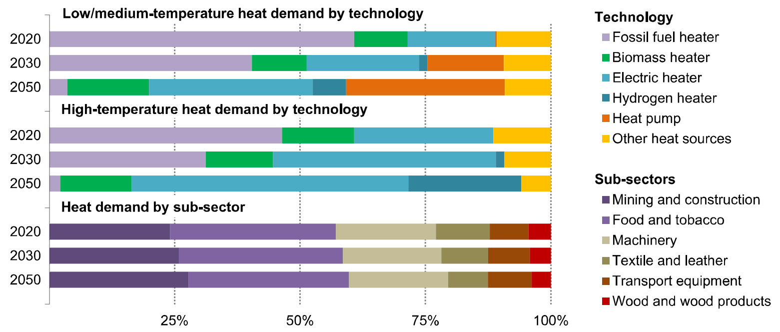
Innovative technology deployment in heavy industry

Share of innovative technology deployment in heavy industries in the NZE

Near-zero emissions routes dominate cement, primary steel and chemicals production by 2050, with key roles for CCUS and hydrogen-based technologies

Heating technologies in light industries

Share of heating technologies in light industries in the NZE



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

DryF

Grant Agreement No 723576 – Energy Efficiency

DryFiciency at a glance

start in September **2016**

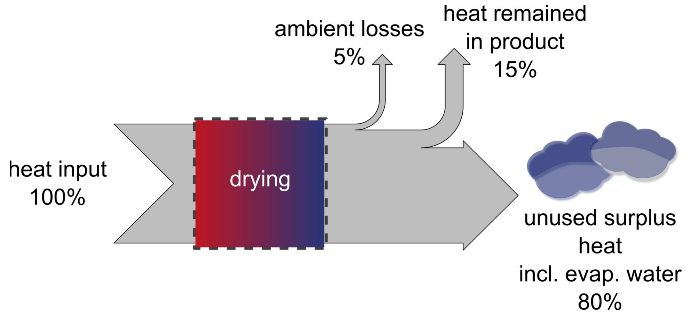
13 partners

DryF

3 demo-sites

6 million € EU funding

Drying: 10 – 25% of industrial energy consumption



Consortium

Closed Loop Heat Pumps		Open Loop Heat Pump
AIT AUSTRIAN INSTITUTE OF TECHNOLOGY TOMORROW TODAY	2 RTOs	SINTEF
Bitzer, HEATEN	3 compressor manufacturers (2 SME)	ROTREX
Chemours, LUBRICANTS. TECHNOLOGY. PEOPLE. FUCHS	1 refrigerant manufacturer 1 lubricant manufacturer	
	1 plant engineer/ system expert (1 SME)	EPCON Evaporation Technology AS
AGRANA STÄRKE, Wienerberger Building Material Solutions	3 end-users	SCANSHIP for cleaner oceans

2 experts on dissemination & exploitation (1 SME)

ehpa RTDS ASSOCIATION

Industrial demonstration

High temperature heat pumps up to 160ºC

Closed loop heat pump | **Open loop heat pump**

Brick drying

Wienerberger AG
Uttendorf (AT)

Starch drying

AGRANA Stärke GmbH
Pischelsdorf (AT)

Bio sludge drying

Scanship A/S
Drammen (NO)

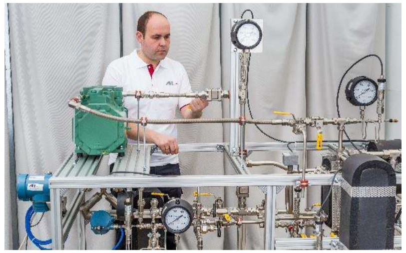
Closed loop heat pumps

Initial situation, expectations and results

V. Wilk, B. Windholz, F. Helminger,
M. Lauermann, S. Kling, J. Riedl,
A. Sporr, A. Schneeberger, T. Fleckl

AIT Austrian Institute of Technology

How it all started…

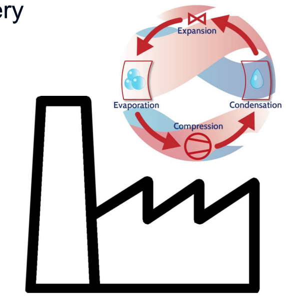


- Drying chamber with heat pump at WBG
- Process analysis for HP integration at AGA

- 12 kW heat pump with R1336mzz(Z)
- Experimental investigation in AIT's lab
- Condensation temperatures up to 160°C

Expectations

- develop a viable solution for industrial waste heat recovery
- increase heat supply temperatures up to 160°C
- solve the challenges for components
  - compressor
  - lubricant
  - refrigerant
- demonstration in industry



Videos

Grant Agreement No 723576 – Energy Efficiency

Technology development

Grant Agreement No 723576 – Energy Efficiency

Screw compressor development

CSH2T NEW COMPRESSOR GENERATION FOR HT APPLICATIONS

// General features

- SST max up to +75°C
- → max SGT up to +100°C (compressor inlet)
- → max DGT up to +140°C (compressor outlet)
- Operates with HFO HT Refrigerants

BITZER has started first field tests to gain more experience.

Piston compressor development

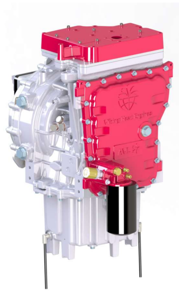
DryF

8 compressors at Wienerberger
- design based on an ORC expander
- operation as compressor due to change in the valve settings
- designed for R-1336mzz(Z)
- swept volume of 54 m³/h at 1800 rpm
- around 50 kWth output

new product family with 1-8 MWth
- 1 MWth to be launched in 2022

Viking Heat Engines

HEATEN

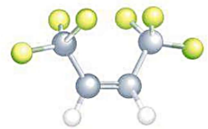


Lubricant and refrigerant development

DryF

R-1336mzz(Z)
- A1 refrigerant (low toxicity, no flammability)
- GWP = 2, OPD = 0
- Critical temperature = 171ºC

PAG lubricant
- Miscible with refrigerant
- Thermally and chemically stable with refrigerant
- High viscosity at high temperature and pressures



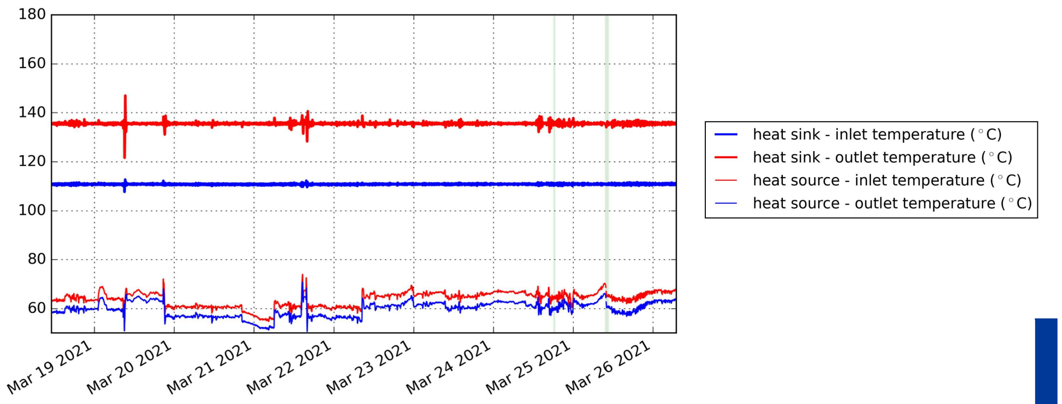
HFO-1336mzz-Z

Chemours

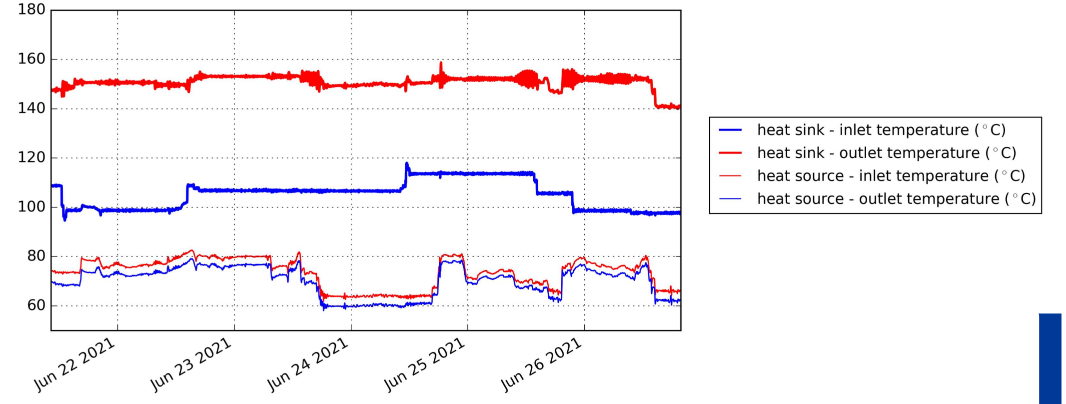
LUBRICANTS. TECHNOLOGY. PEOPLE. FUCHS

Operation of the demonstrators

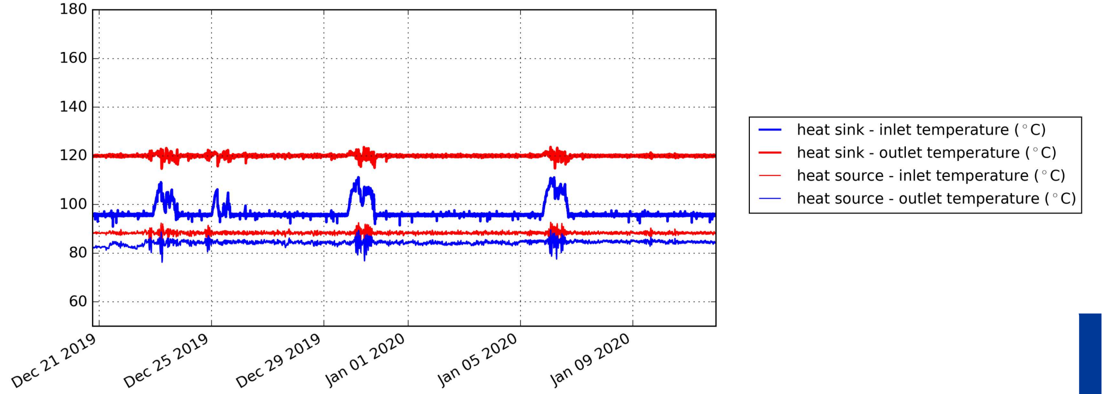
Performance: Agrana demonstrator



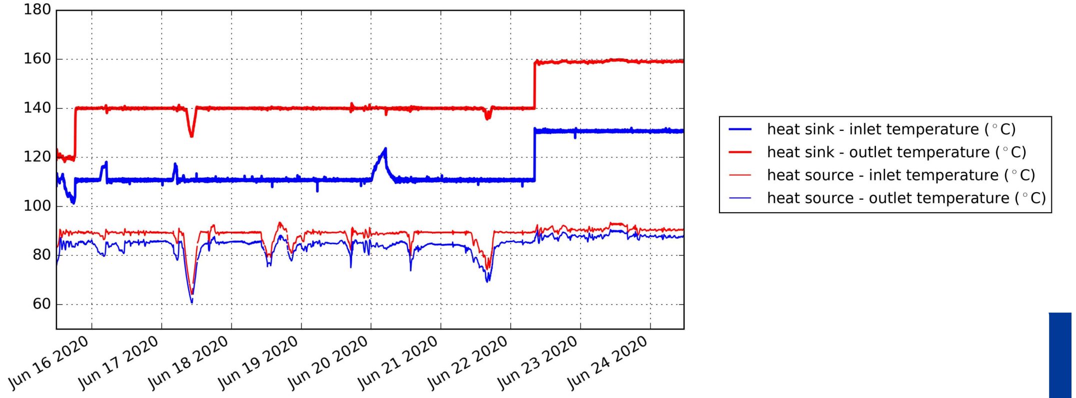
Performance: Agrana demonstrator



Performance: Wienerberger demonstrator

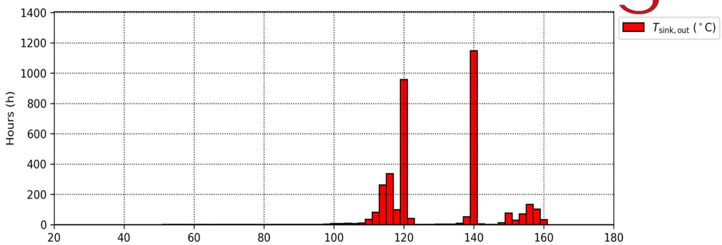


Performance: Wienerberger demonstrator

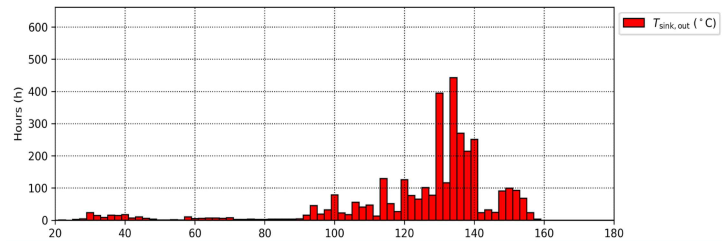


Performance: Operating hours

- WBG:
  3560 h until 30.6.2021



- AGA:
  3392 h until 30.6.2021



Challenges encountered during the development of DryFiciency

Global factors
- Corona pandemic
- lead times for materials

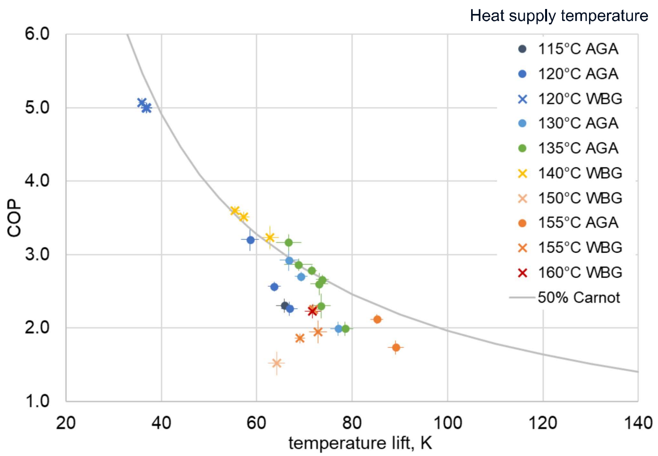
Material compatibility
- sealing materials for safety valves
- sealing materials in components

Mechanical design
- vibrations of piston compressors

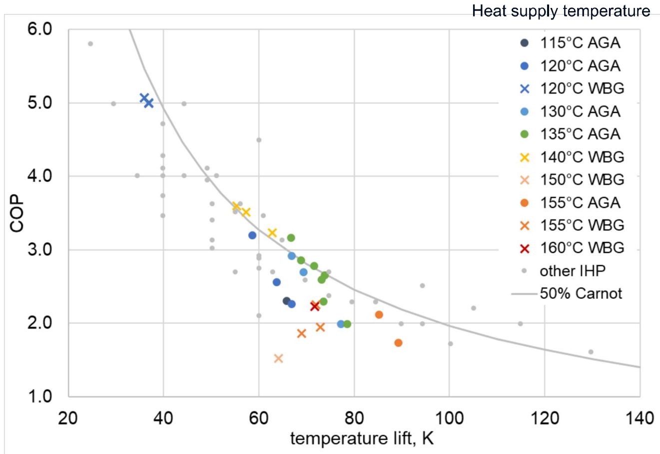
Integration infrastructure:
- pressure maintenance device
- water pump for the oil cooler
- flow measurement for the oil cooler
- pressurized air supply
- availability of the source and the sink

Process control
- start up procedure
- data transfer
- measurement devices

Overview on COP

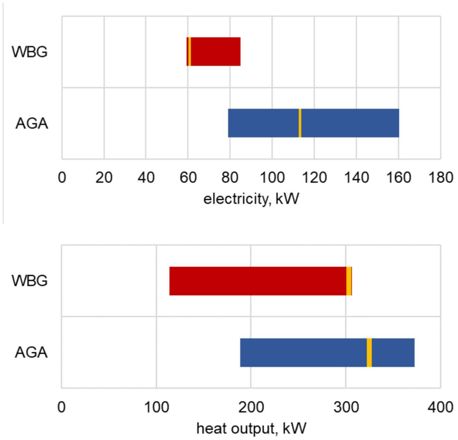


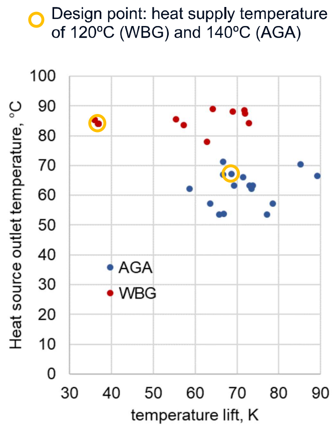
Overview on COP



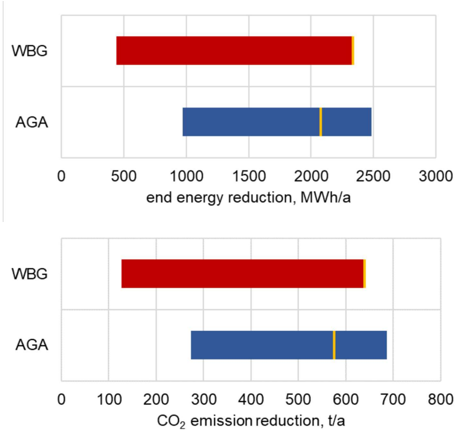
other IHP from Arpagaus et al. High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials, Energy (152), p.985-1010, 2018.

Energy balance: input and output





Environmental impact: End energy and CO_2 emission reduction

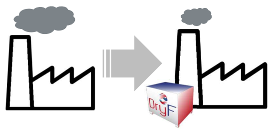


Comparison to a natural gas burner (90% efficiency, 8400 h/a)

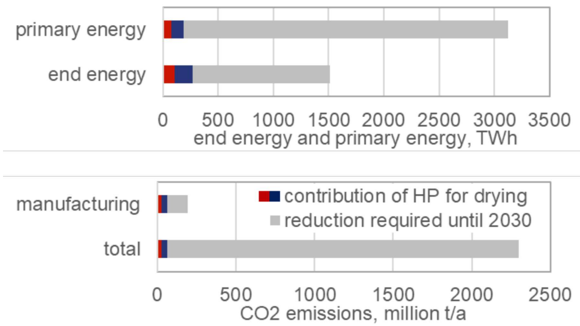
CO_2 emissions natural gas: 271 g/kWh

CO_2 emissions electricity: 258 g/kWh

Outlook



- assume that 50% of all drying processes in Europe are equipped with a DryFiciency heat pump
- replace natural gas burners
- impact on end energy consumption, primary energy and CO2 emissions



Summary

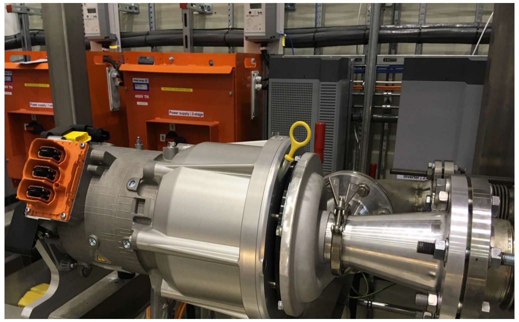
- Successful component development for high temperature applications
  - compressors, lubricant and refrigerant
- Successful demonstration of the closed loop heat pumps
  - stationary operation with satisfying performance
  - process control works well and balances variations in the heat source and sink
  - almost 7000 h operation hours achieved for both demonstrators until end of June
- Heat pumps are a future proof process heat supply technology
  - CO_2 emission reduction
  - waste heat recycling

Initial situation, Expectation and Results of open loop heat pump

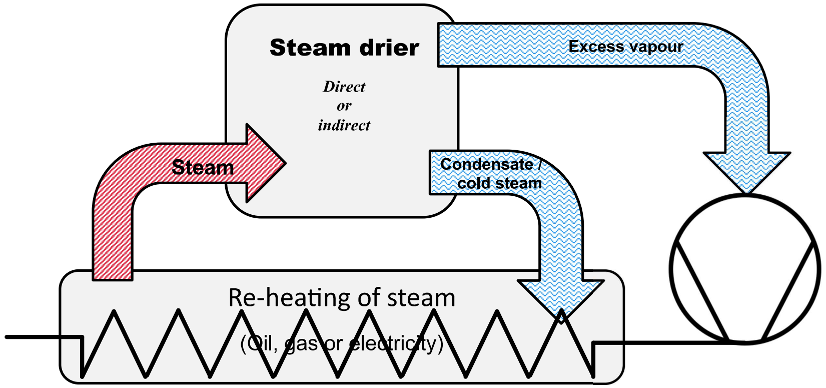
Michael Bantle (PhD)
Senior Researcher
SINTEF Energy

Jan Haraldsen
Chairman
EPCON Evaporation Technology

Trondheim/Norway



Open Loop Heat Pump with Steam Drier



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Refrigerant R718 (water)

- **Abundance and Safety:**
  - Most abundant elements on earth; low cost and nearly unlimited available
  - From environmental point of view: water is ideal refrigerant above 0°C
  - Non-toxicity, non flammable, 0 Ozone Depletion Potential, 0 Global Warming Potential
- **Regulatory Relief:**
  - Not subject to present or future environmental or safety regulations
- **Efficiency:**
  - High latent heat of evaporation (2270 kJ/kg); 4-5 times higher than hydrocarbons or CO_2
  - Critical temperature: 380-386° C
  - General high COP
- **Disadvantages**
  - Requires high volume flow
  - High superheating during compression

Multistage compression for open loop heat pump

	COP	COP (+Intercool)	$\dot{Q}_{ThermCap}$ $[kW]$	$\dot{Q}_{Intercool}$ $[kW]$	P_{Compr} $[kW]$	p_2 $[bar]$	T_2 [°C]
One Compressor	12.79		247.3		19.3	2.03	187
Two Compressors	6.57		255.4		38.9	3.67	270
Two Compr. + Intercooling	6.12	6.46	240.6	12.8	39.3	4.13	213
Three Compressors	4.50		263.7		58.6	6.12	351
Three Compr. + Intercooling	4.00	4.38	237.3	22.6	59.3	7.84	255

Results of the Performance Analysis for Multi-Stage Compression for Compressor Speeds of n = 82 700 rpm, Inlet Pressure p = 1 bar, Inlet Temperature T = 105 °C and Mass Flow of $\dot{m} \approx$ 0.1 kg sec-1, Pcompr is required compression power, p2 the discharge pressure and T2 the discharge temperature after the last compression stage

Open loop demo: Scanship

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Open Loop heat pump: expectations and results

Speed	Speed	$\dot{m}$ (at 1bar)	Pressure ratio	Tsat	Tlift	Heat delivery	COP	COP_{Carnot}	η_{system}
RPM	%	kg/h	-	° C	K	kW	-	-	%
72000/ 81000	90/90	756	4.23	146	45.6	494	**4.54**	9.2	49.4
68000/ 81000	85/90	648	4.05	144	44.0	423	**4.8**	9.5	50.4 %
64000/ 81000	80/90	720	3.59	140	39.7	461	**5.2**	10.4	50.5 %
64000/ 76500	80/85	684	3.44	138	38.2	440	**5.1**	10.8	47.1 %
60000/ 76500	75/85	648	3.21	136	35.9	413	**5.8**	11.4	50.5 %
56000/ 72000	70/80	576	2.83	132	31.5	367	**6.4**	12.8	50.0 %
52000/ 67500	65/75	504	2.49	127	27.3	325	**6.5**	14.7	44.2 %
48000/ 63000	60/70	360	2.32	125	24.9	226	**8.7**	16.0	54.7 %

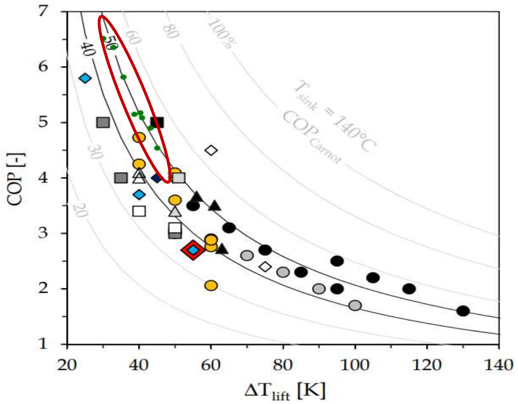

Figure modified from C. Apargaus, Book: "Hochtemperatur Wärmepumpen"

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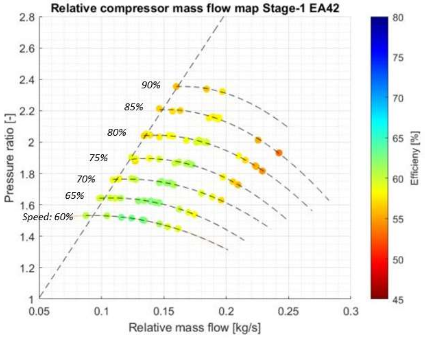
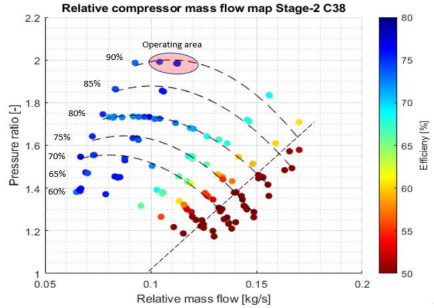
Further Rotrex developments

- Impeller design is maximised (pressure ratios of 2.4 to 2.6)
- Updated design with "purge chamber" is under development





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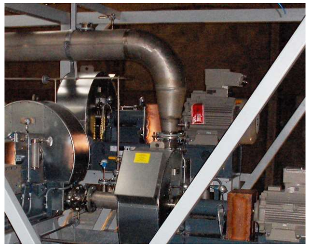
MVR machinery in EPCON MVR-HP

- High pressure centrifugal fan:
  - **Left**: standard MVR fan
  - **Left**: 3-stage MVR-fans
  - **Right**: compact MVR fans
- **Below**:
  - Roots blower / positive displacement compressor



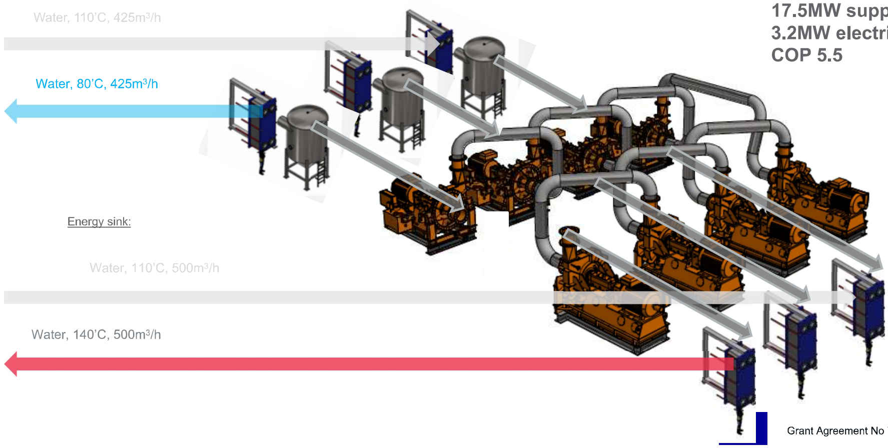
EPCON

Case study - HighEFF

Closed MVR-HP circuit

EPCON

DryF



COP:
17.5MW supplied heat by 3.2MW electrical cons. = COP 5.5

Summary

- Demonstration of 2 stage open loop heat pumps
  - Temperature lifts of 45 degrees
  - COP of >4
  - Capacities of 500 kW
- Further development of MVR-heat pumps for large capacities
  - Capacities >10 MW
  - COP of > 5
  - Temperature lifts of 60 degrees
- "Recycling" of waste heat (80-100%)
- Reduction of primary energy by 50-70 % is achievable
  - no greenhouse gas emissions (depending on origin of electricity)
- Development of steam producing heat pump solutions is ongoing

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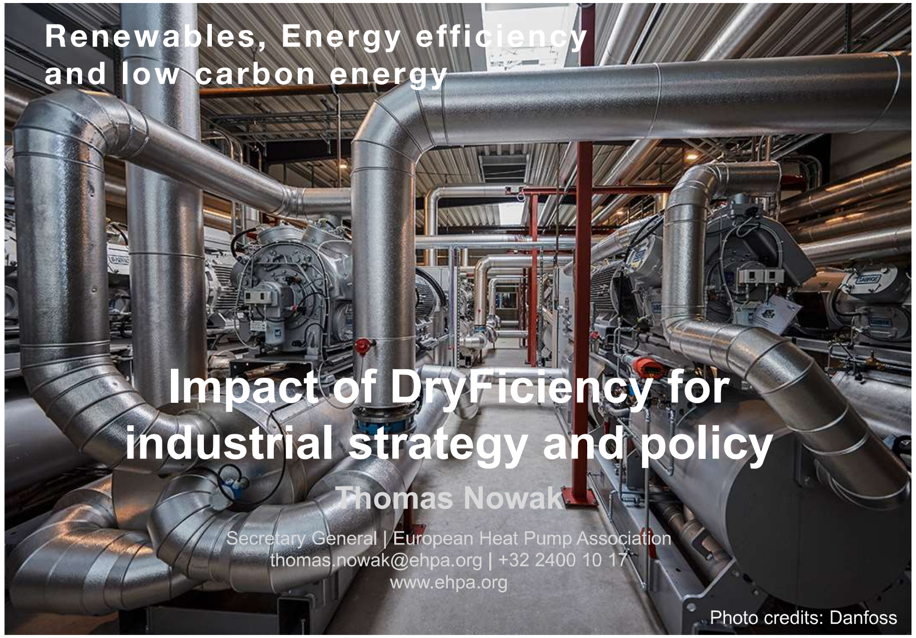

Renewables, Energy efficiency and low carbon energy

Impact of DryFiciency for industrial strategy and policy

Thomas Nowak

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www.ehpa.org

Photo credits: Danfoss

The European Heat Pump Association aisbl / founded 2000

146

Members

Heat pump manufacturers
Component manufacturers
National associations
Consultants
Research & test institutes

22

countries represented

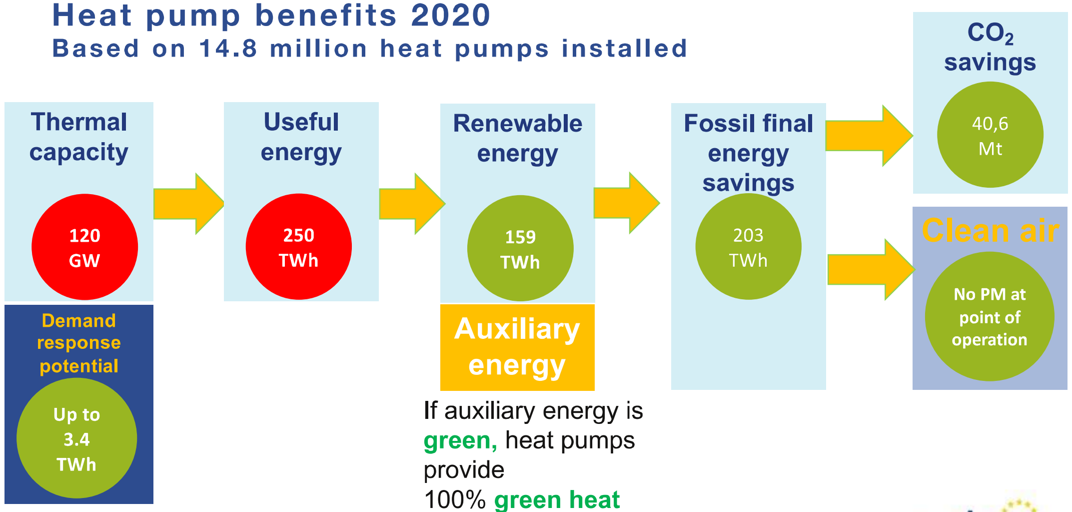
International cooperation

CECA, IEA, IEA HPC, IRENA, HPCJ

Vision

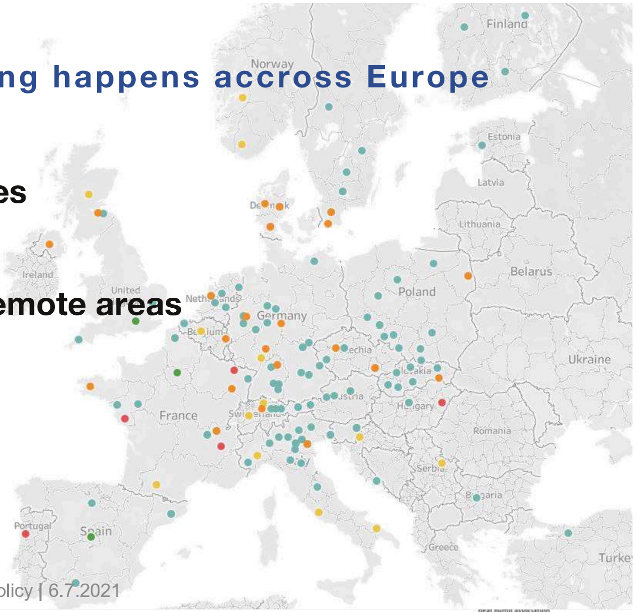
In a fully decarbonised Europe, **heat-pump technologies are the number one heating and cooling solution**, being a core enabler for a renewable, sustainable and smart energy system.

Heat pump benefits 2020
Based on 14.8 million heat pumps installed

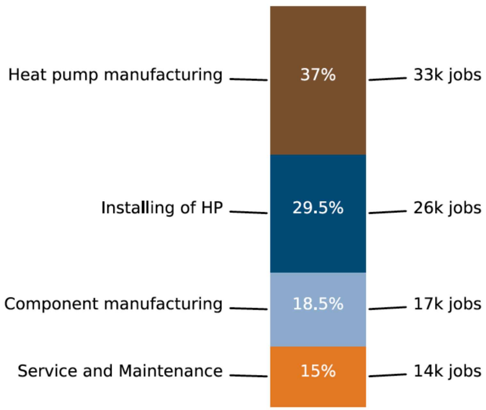


Heat pump manufacturing happens accross Europe

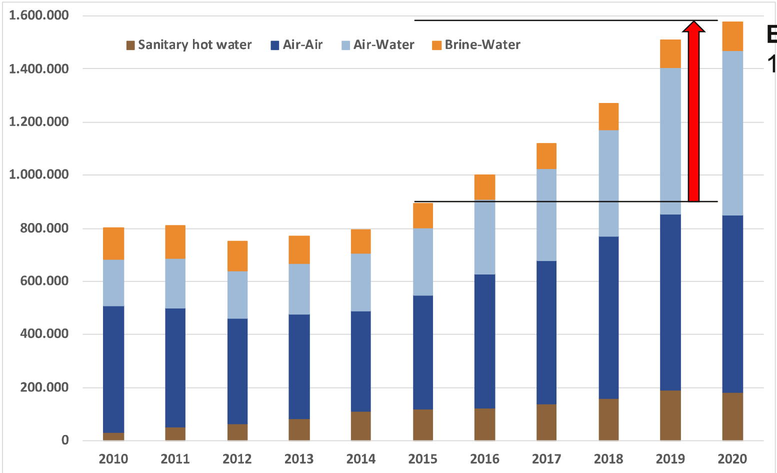
- 165+ manufacturing sites
- SME based
- Often located in rural/remote areas
- Turnover of 8.2 billion €



Employment impact of heat pumps (89 784 FTE)



Market growth ‘10 – ’20 | HP stock^{2020}: 14.8 mill. installed

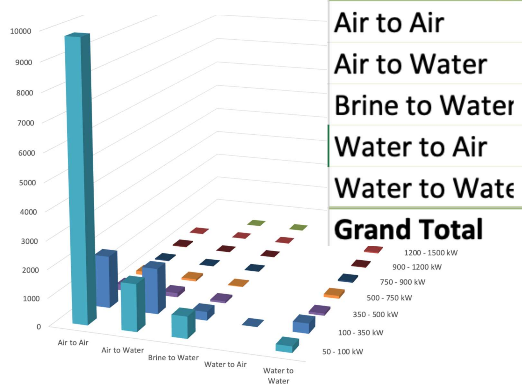


EU-28 building stock:
115 – 120 mill. buildings

YoY	1%	-7%	3%	3%	13%	12%	12%	13%	19%	6%

Industrial HP?

Numbers not integrated with the rest of statistics



Air to Air	12081
Air to Water	3555
Brine to Water	1207
Water to Air	1
Water to Wate	942
Grand Total	**17786**

50 - 100 kW	100 - 350 kW	350 - 500 kW	500 - 750 kW	750 - 900 kW	900 - 1200 kW	1200 - 1500 kW	1500 - 5000 kW
12472	4158	525	334	119	75	66	36

http://stats.ehpa.org | Data for 2019

energy demand for heating residential buildings in Europe

2 625 TWh$_{2015}$

Source: https://www.mdpi.com/1996-1073/13/8/1894/htm

energy demand for industry in Europe

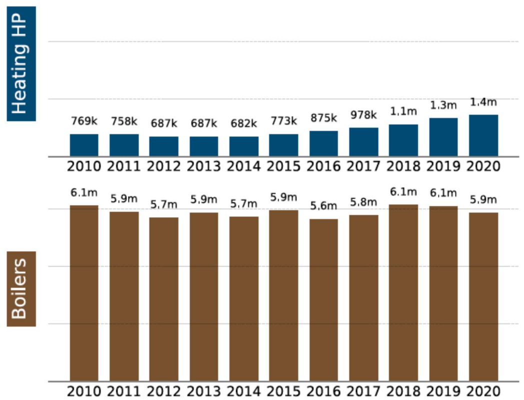
2 950 TWh$_{2015/2019}$

1958 TWh for heat

724 TWh for HP (37%)

R. de Boer, A. Marina, B. Zühlsdorf, C. Arpagaus, M. Bantle, V. Wilk, B. Elmegaard, J. Corberán, J. Benson. Strengthening Industrial Heat Pump Innovation – Decarbonizing Industrial Heat, 2020

Market share development: HP in total heater sales

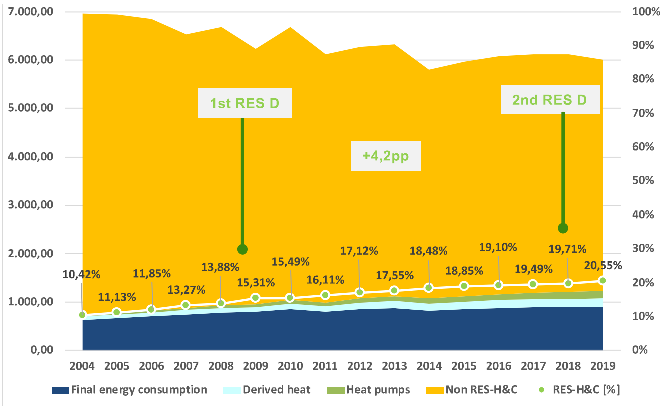


11% 11% 10% 11% 11% 13% 14% 15% 18% 20%

What about industry?

HP share → 50% before 2035?

RES in heating and cooling (Eurostat Shares)



< 1pp

annual increase of renewable share

EU Energy systems integration strategy

10 – 15 mio office & commercial buildings

65 %

7-10 mio heat pumps

90 mio residential single family units

15 mio residential multi family units

40 %

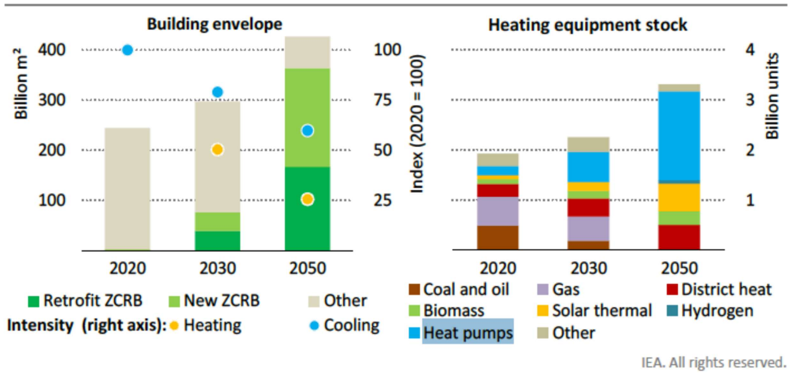
42 mio heat pumps

todays HP stock

x 4

+ industry approx. 200 TWh = 0,1 mio

IEA report: net zero by 2050 (2021)

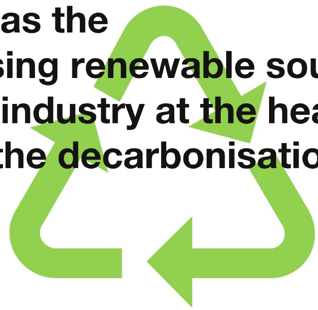


By 2050, over 85% of buildings are zero-carbon-ready, reducing average useful heating intensity by 75%, with heat pumps meeting over half of heating needs

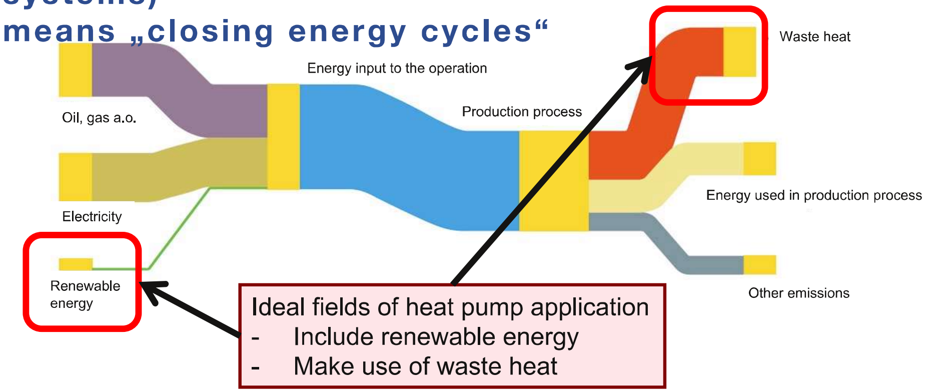
For industrial heat pumps: +500 MW per months until '50

Large Heat Pumps: An industry for an industry, in industry for an industrialised Europe

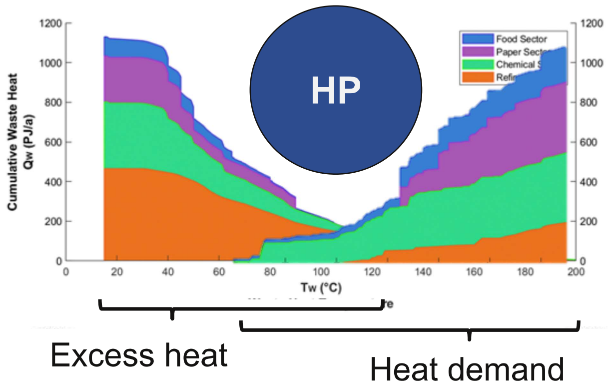
By closing energy cycles, using excess energy of one service as the resource of another and/or using renewable sources, heat pumps help position the industry at the heart of the EU energy transition and the decarbonisation of industrial processes



Heat pumps in industrial applications (and district systems) means „closing energy cycles“



Waste heat and process heat – a comparison ➔ heat pumps do the lifting



A. Marina, S. Spoelstra, H.A. Zondag, A.K. Wemmers, An estimation of the European industrial heat pump market potential, Renewable and Sustainable Energy Reviews, Volume 139, 2021, 110545.

Barriers to wider use of large heat pumps

- Energy price ratio: gas/electricity
- Process industry requests for short ROI ← DryF
- Competition from existing heat sources ← DryF
- Possible feed-in temperature from HP too low ← DryF
- integration of HP in existing process diffcult/expensive ← DryF
- Doubts with regards to security and reliability ← DryF
- Limited knowledge on the match between HP and process demands with key decision makers ← DryF

What do we need?

Industry is ready, but…

- **Do we have enough planners?**
- **Do we have enough engineers?**
- **Is financing a problem?**
- **R&D**
  - **Institutions**
  - **Scientists**
  - **Programs/projects**

    → DryF 2?

Policy has recognized, but …

- **Electricity taxation**
- **CO_2 price signal**
- **Fossil fuel subsidies**
- **Industrial subsidies**

→ An industrialisation opportunity