TRI-HP Final Event

Heat pumps on natural refrigerants in the context of the **F-Gas Regulation**

07 February 2023

14:00 - 18:00

L42, Rue de la Loi 42, Brussels

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

TRI-HP Final Event:
Heat pumps on natural refrigerants in the context of the F-Gas Regulation Revision

agenda

Session 1 – 14:00 – 15:30: Heat pumps based on natural refrigerants

14:00 – 14:15	**TRI-HP in a nutshell** Dr. Daniel Carbonell – Institute for Solar Technology
14:15 – 14:30	**Natural refrigerants in heat pumps** Raphael Gerber – Heim AG
14:30 – 14:45	**Application of CO2 & propane heat pumps in different sectors** Prof. Dr. Armin Hafner – Norwegian University of Science & Technology
14:45 – 15:00	**Market for heat pumps based on natural refrigerants** Dr. Sabrina Munao - ATMOsphere
15:00 – 15:15	**Social acceptance of heat pumps** Dr. Thomas Friedrich & Dr. Immanuel Stieß – Institute for Social-Ecological Research
15:15 – 15:30	**Q&A**
15:30 – 16:00	**Coffee Break**

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

TRI-HP Final Event:
Heat pumps on natural refrigerants in the context of the F-Gas Regulation Revision

Session 2 – 16:00 – 18:00: F-Gas Regulation: Phasing down HFCs & HFOs in heat pumps	
16:00 – 16:20	**Overview of the F-Gas Regulation Revision** Arno Kaschl – Policy Officer at DG CLIMA, European Commission
16:20 – 16:35	**Opinion of European Economic and Social Committee on the Revision** Kęstutis Kupšys – Rapporteur of the European Economic and Social Committee (EESC) on the Revision
16:35 – 16:50	**Comparing the use of HFCs & HFOs with natural refrigerants in heat pumps** Prof. Dr. Michael Kauffeld – Karlsruhe University of Applied Sciences
16:50 – 17:05	**Negotiations in ENVI on the F-Gas Regulation Revision** Stelios Kympouropoulos – Shadow-Rapporteur (EPP) ENVI Committee for European Parliament
17:05 - 17:20	**Risks of rapid deployment of heat pumps based on natural refrigerants** Coen van de Sande - President Association of Refrigeration, Air Conditioning and Heat Pump contractors (AREA)
17:20 – 18:00	**Panel Discussion on the phase-down of F-Gases in heat pumps:** - Hilde Dhont - Refrigeration Task Force Member at EHPA - Veerle Beelaerts – European Heating Industry - Davide Sabbadin – European Environmental Bureau - Prof. Dr. Michael Kauffeld – Karlsruhe University of Applied Sciences

TRI-HP Final Event:
Heat pumps on natural refrigerants in the context of the F-Gas Regulation Revision

SESSION 1: Heat Pumps based on Natural Refrigerants

07 February 2023: 14:00 - 15:30 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

TRI-HP Final Event:
Heat pumps on natural refrigerants in the context of the F-Gas Regulation Revision

agenda

Session 1 – 14:00 – 15:30: Heat pumps based on natural refrigerants

14:00 – 14:15	**TRI-HP in a nutshell** Dr. Daniel Carbonell – Institute for Solar Technology
14:15 – 14:30	**Natural refrigerants in heat pumps** Raphael Gerber – Heim AG
14:30 – 14:45	**Application of CO2 & propane heat pumps in different sectors** Prof. Dr. Armin Hafner – Norwegian University of Science & Technology
14:45 – 15:00	**Market for heat pumps based on natural refrigerants** Dr. Sabrina Munao - ATMOsphere
15:00 – 15:15	**Social acceptance of heat pumps** Dr. Thomas Friedrich & Dr. Immanuel Stieß – Institute for Social-Ecological Research
15:15 – 15:30	**Q&A**
15:30 – 16:00	**Coffee Break**

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Session 1: Heat pumps based on natural refrigerants

TRI-HP IN A NUTSHELL

Dr. Daniel Carbonell
Project Coordinator
Institute for Solar Technology

07 February 2023: 14:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

OST
Ostschweizer
Fachhochschule

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Dr. Daniel Carbonell

SPF Institute for Solar Technology
Eastern Switzerland University of Applied Sciences (OST)

SPF INSTITUT FÜR SOLARTECHNIK

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

- Horizon H2020 research program
- Research and Innovation Action
- From TRL 3 to TRL 5
- Total EU contribution 5 M€
- Duration 2019 - 2023

TRI-generation systems

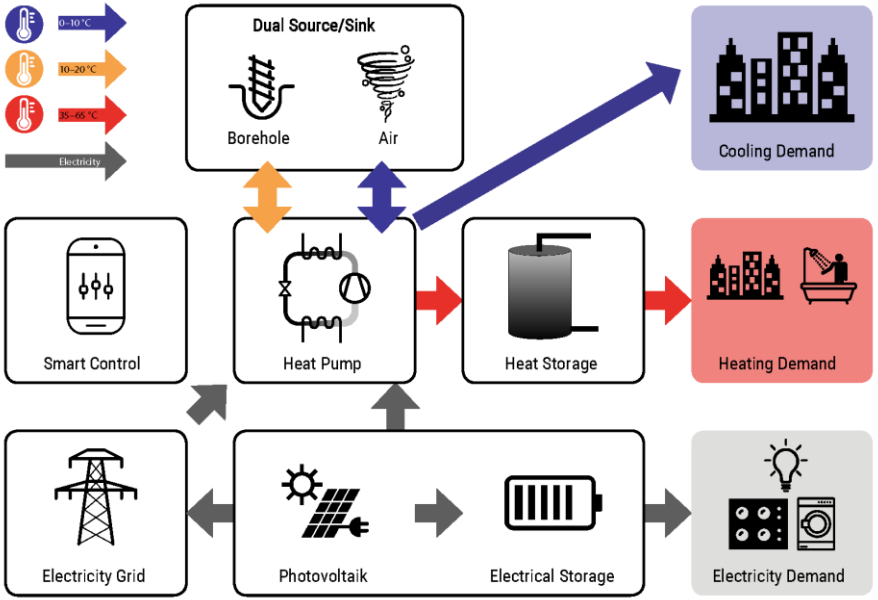
- Based on electrically driven **natural refrigerant heat pumps (HPs)** coupled with PV to provide **heating**, **cooling** and **electricity** to multi-family residential **buildings**

- Targets:
  - **80 % renewable on-site share** with net-zero energy concept (20 % exchanged with the grid)
  - **Cost reduction by 10 – 15 %** compared to current HP technologies with same energetic efficiency
  - **75 % GHG emissions reductions** respect to gas boiler and air chillers with grid purchased electricity.

www.tri-hp.eu

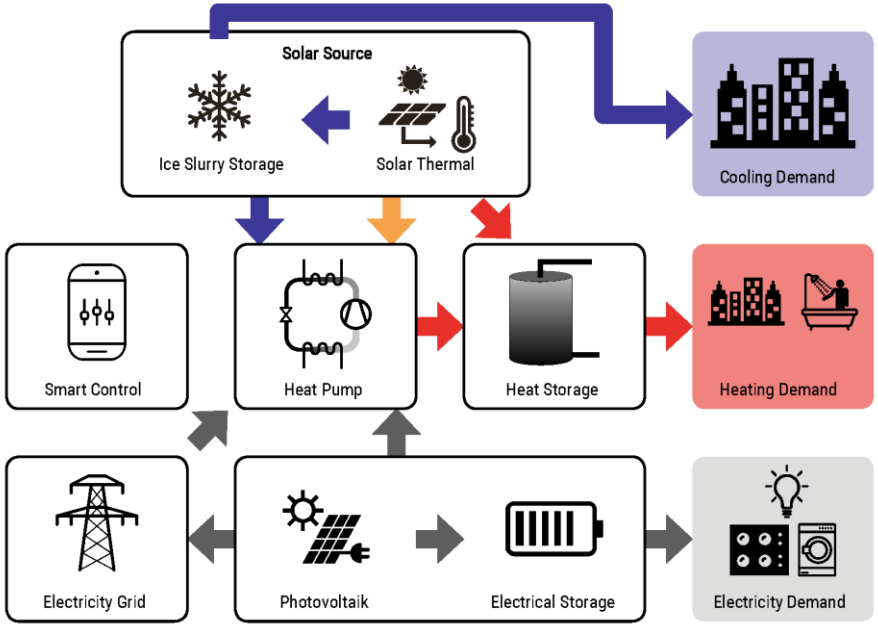
Dual source/sink system

- Source: ground and air
- Heating and cooling with reversible HP

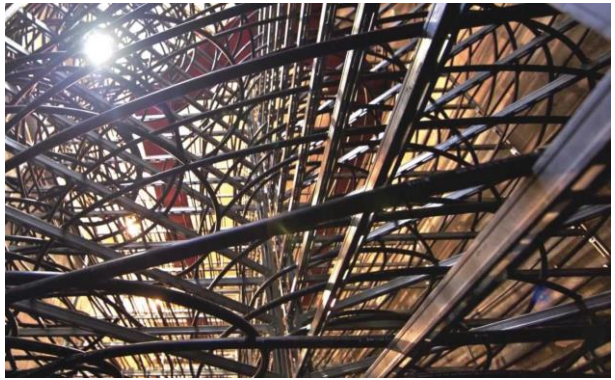


Solar-ice slurry system

- Source: solar with ice slurry as intermediate storage medium
- Heating with cooling as add-on feature



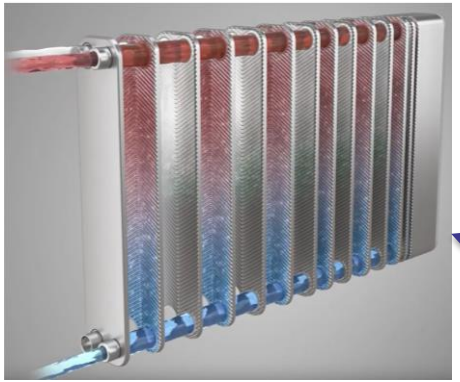
Examples of commercial ice storages

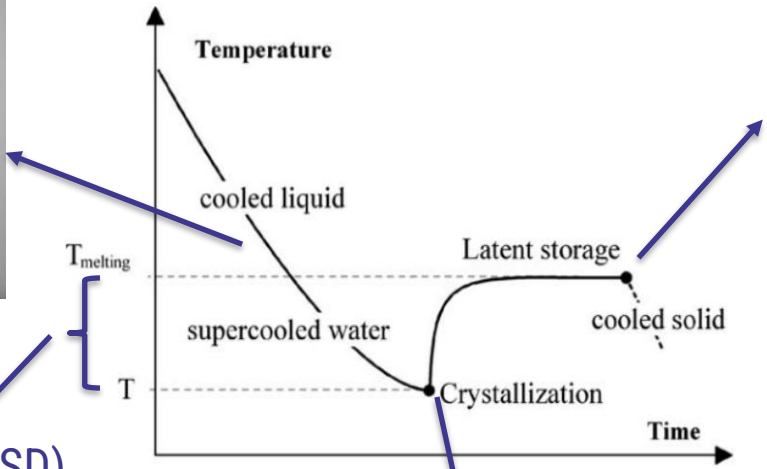


Source : Isocal, Viessmann

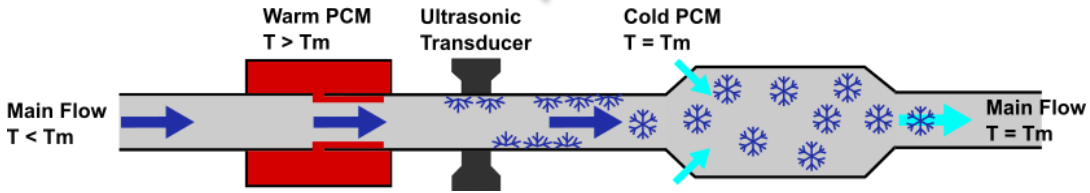
- Most systems have ice-on-coil heat exchangers
- Coils are distributed evenly along the storage volume
  - Coils are costly
  - Cost scales with kWh
- Ice grows on the surface of the coil
- Efficiency is reduced by growing ice layer

Supercooling method with controlled nucleation

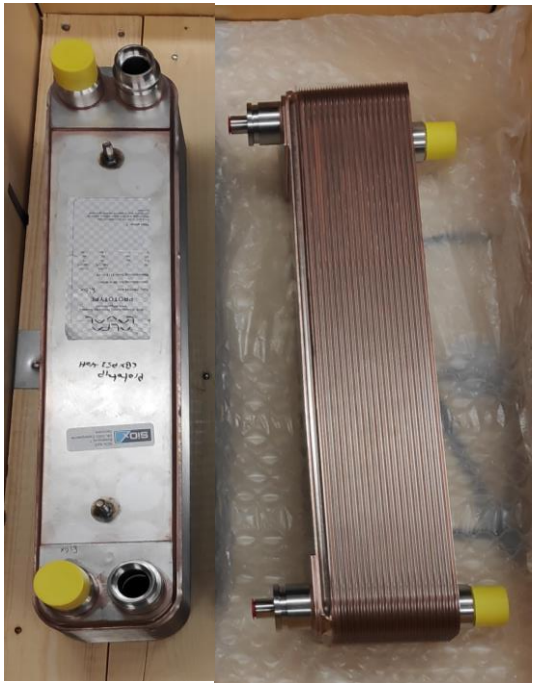




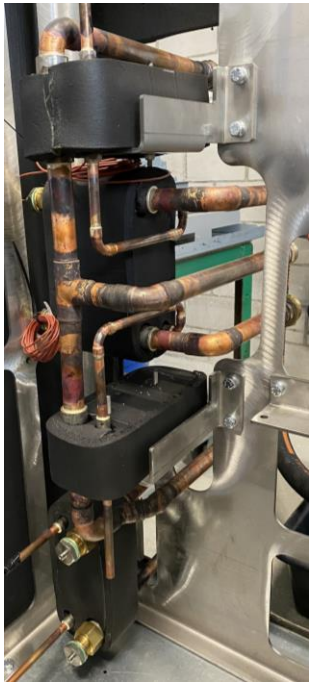
Supercooling degree (SD)



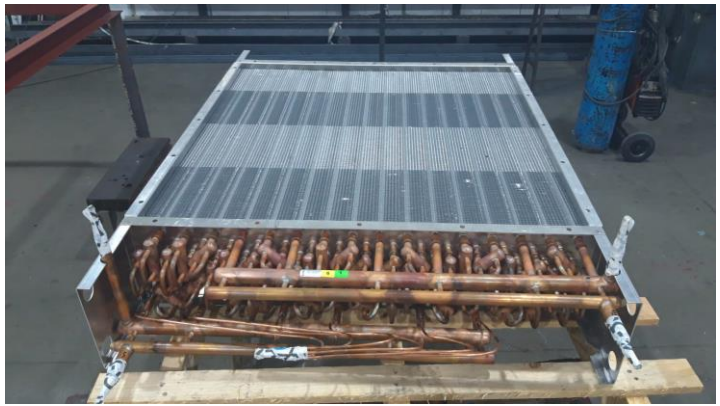
Three Heat Exchangers for Heat Pumps



Supercooler with icephobic coatings



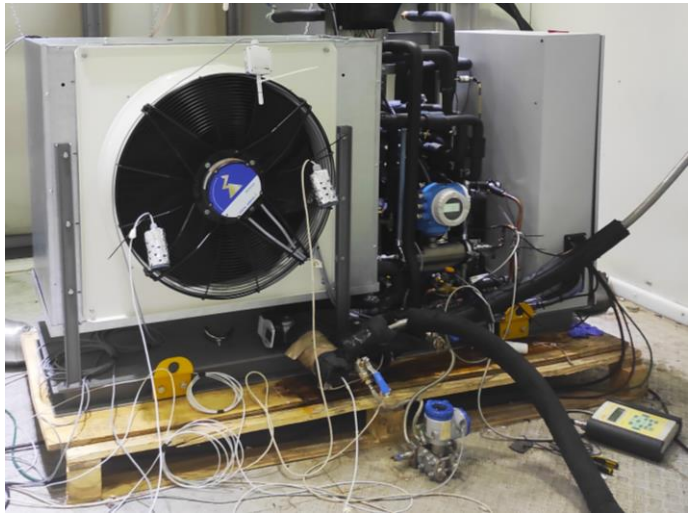
Tri-partite gas cooler for CO_2



Dual source/sink evaporator/condenser

Three Natural Refrigerant Heat Pumps

Refrigerant R-290 (Propane)



Dual source/sink

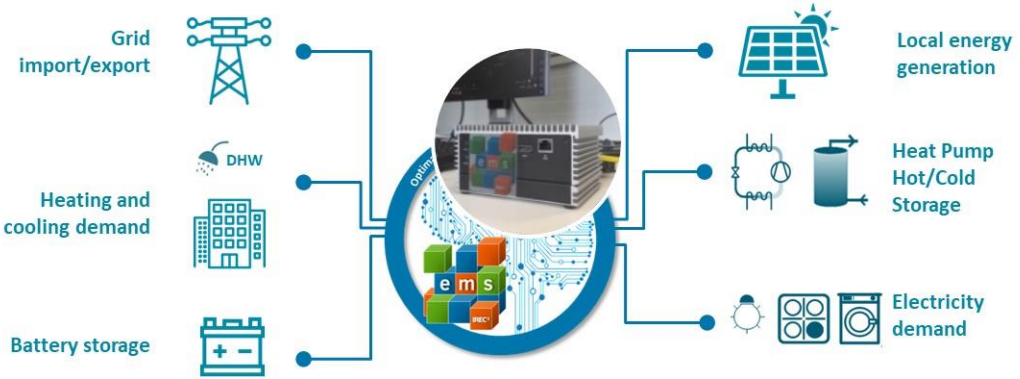
Propane ice slurry

Refrigerant R-744 (CO_2)

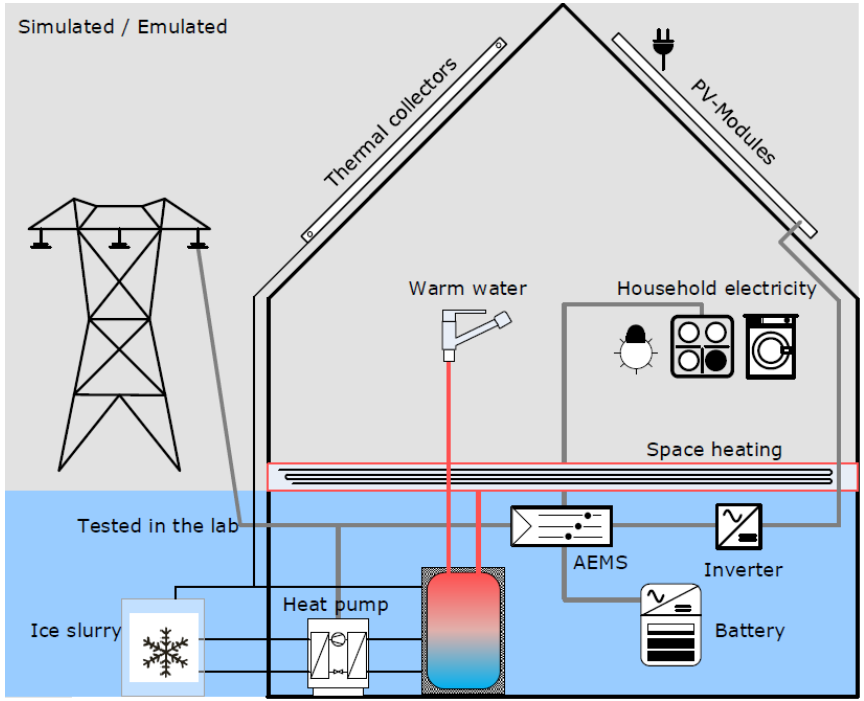
CO_2 ice slurry

Advanced Energy Management System (AEMS)

- Development of an optimal energy management algorithm to minimize the energy cost by up to 15% and increase the share of renewables up to 80%
- The AEMS algorithm relies on models of the heat pumps and HVAC systems to determine their optimal operation over a 24 hours horizon in the future, using weather and occupancy forecasts for this purpose
- Validation of the AEMS by means of simulation and experiments covering different scenarios and conditions.



Concise Cycle Test Concept – Example solar-ice slurry

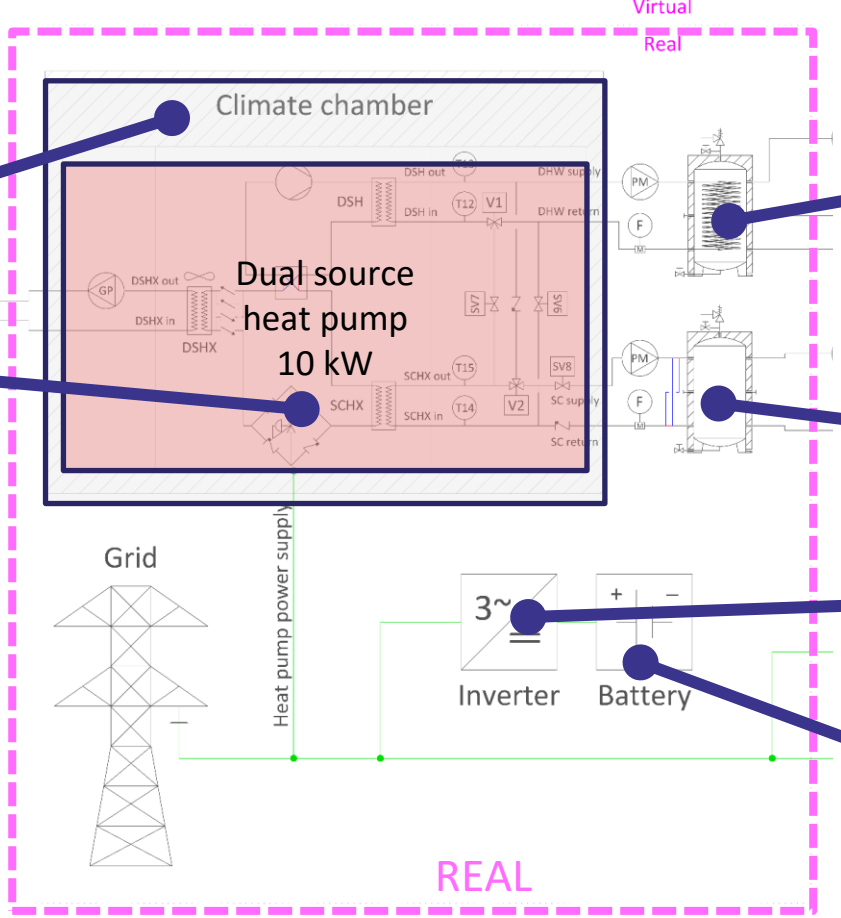


Emulation

- **Sinks**
  - Space heating (& cooling)
  - DHW
  - HH electricity
- **Sources**
  - Solar thermal
  - PV
  - Ice Slurry

Physically Installed

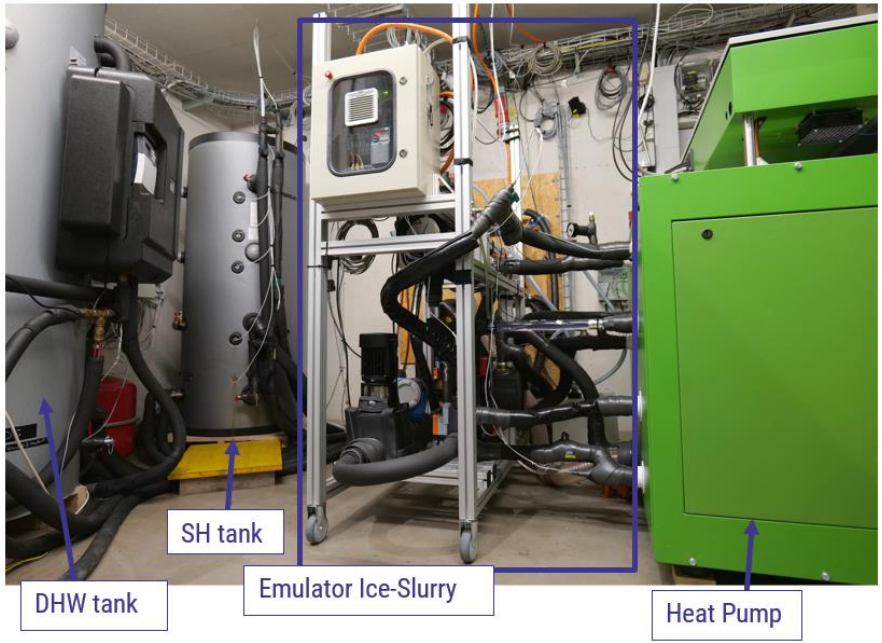
- **Tested system**
  - HP
  - Storage (heat and/or electricity)
  - Controller
  - Hydraulics
- **Measurement**
  - Energy consumption
  - Energy delivered
  - …



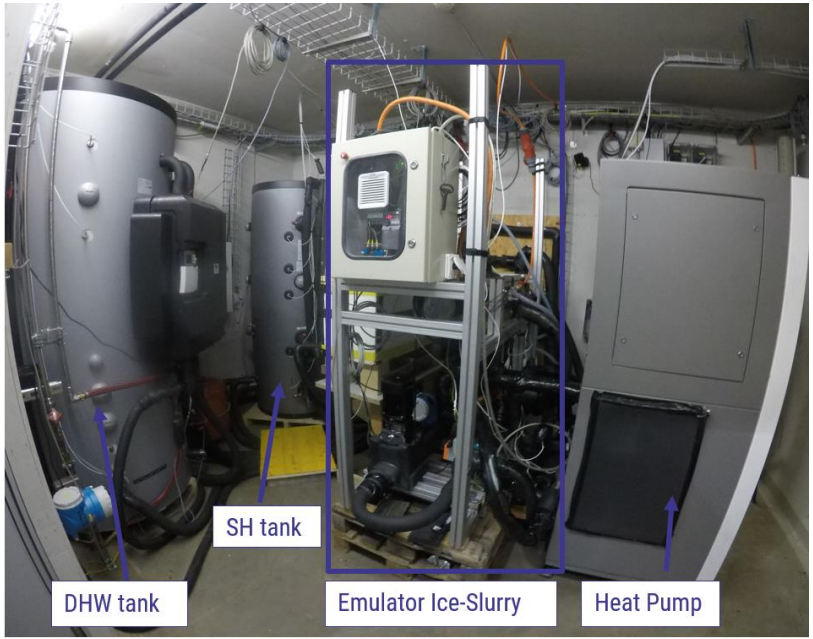
- **Pronane dual source/sink**

Solar-Ice Slurry System CCT

- **Pronane solar-ice slurry**

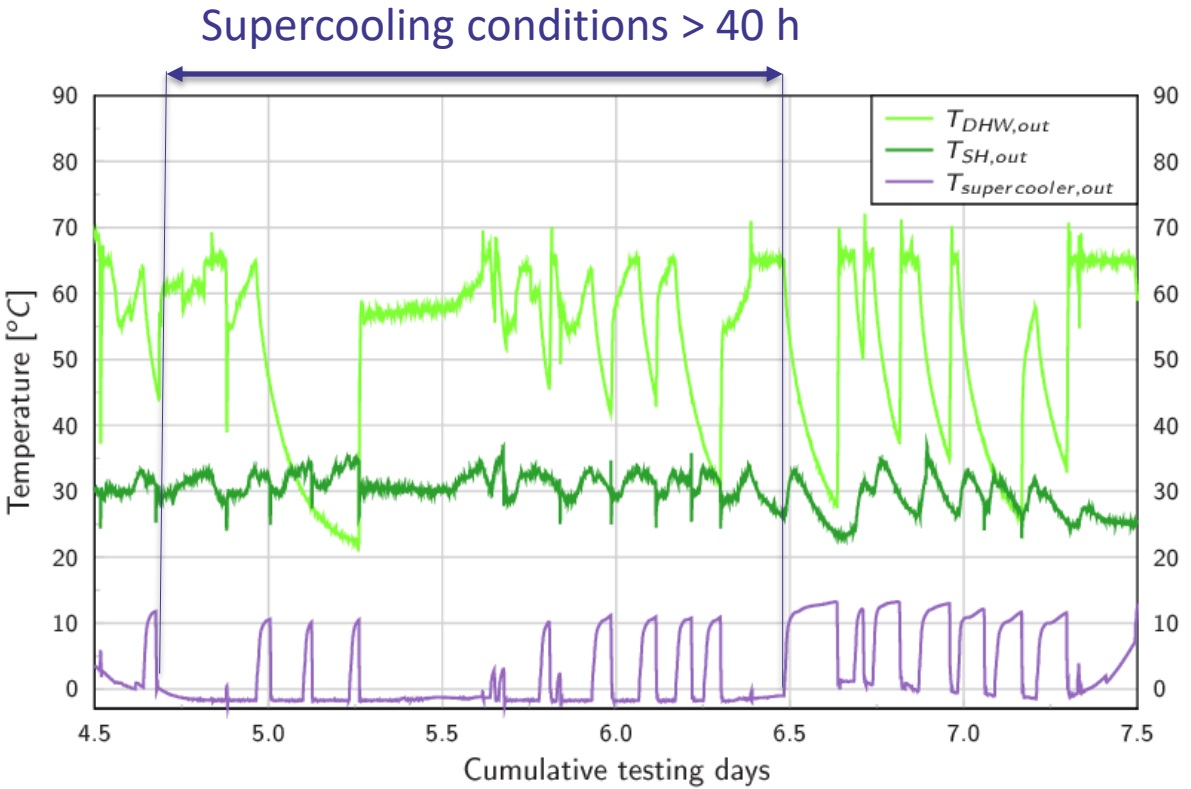


- **CO_2 solar-ice slurry**



CO_2 Solar-Ice Slurry System CCT

- Yearly system performance is around SPF ~ 4.5
- > 40 h operation under supercooling conditions has been demonstrated in dynamic conditions.



Technology Acceptance

- Understanding and improving stakeholder's acceptance
- Analyse and identify the interest and needs of key stakeholders
- Methods
  - Qualitative **interviews** with stakeholders (DE, CH, ES, NO)
  - Regional **stakeholders workshops** (DE, CH, ES, NO)
- Results : Guidelines and recommendations of **stakeholder's acceptance**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this event lies with the organisers. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.

Dani.Carbonell@ost.ch

www.tri-hp.eu

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Session 1: Heat pumps based on natural refrigerants

NATURAL REFRIGERANTS IN HEAT PUMPS

Raphael Gerber
Development Engineer,
Heim AG

07 February 2023: 14:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

HEIM AG
Heizsysteme

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Natural refrigerants in heat pumps

Heat Pumps with Natural Refrigerants in the context of the F-Gas Regulation

Raphael Gerber
7. February 2023, Brussels

properties of popular refrigerants

	toxicity (envir.)	toxicity (human)	flamma-bility	refri-gerant cost	system cost	volumetric refrigeration capacity	theoretic system efficiency
HFCs	high	no	no	medium	low	medium	high
HFOs	high	(no)	low	high	medium	medium	medium - high
hydrocarbons	low	no	yes	low	medium	medium	high
carbon dioxide (CO_2)	low	(no)	no	low	medium	high	medium - high
ammonia (NH_3)	low	yes	low	low	high	medium	high
water	low	no	no	low	medium	low	high

source: Prof. Dr.-Ing. habil. Michael Kauffeld

Reasons for choosing natural refrigerants

in heat pumps

	operational safety	environmental safety	operating cost
properties			
• **no risk** of devastating consequences for environment and beings		👍	👍
• no regular leakage test required (EU 517/2014)			👍
• normally no blends (no temperature glide)	👍		👍
sourcing			
• low refrigerant cost			👍
• high availability	👍		👍
• no risks of restrictions (taxes, recycling fees, bans)	👍		👍
• no variety of refrigerants	👍		👍
• mostly standard technical gas	👍		👍
energy efficiency			
• better performance in many applications		👍	👍
• potential for improvements (innovations, components)		👍	👍

applications of natural refrigerants

in heating, cooling and air conditioning

hydrocarbons (HC), R-290, R-600a, R-1270

- space heating and cooling
- industrial
- high-temperature applications
- plug-in appliances (washer, dryer, domestic hot water heat pump)

carbon dioxide (CO_2), R-744

- domestic hot water
- e-mobility (heating and cooling)
- food (supermarkets, dairy production, drying)
- industry
- space heating and cooling

ammonia (NH_3), R-717

- medium and high capacities
- large temperature range
- space heating and cooling, industry, recreation

water (H_2O), R-718: medium capacity, low temperature difference

air, R-729: vehicle air conditioning, ultra low temperature cooling

TRI-HP Heat pump prototypes

dual-source (ground/air)

ice-slurry source

ice-slurry source
tri-partite gas cooler
ejector technology

1st prototype: industrial design
2nd prototype: compact design

1st prototype: glycol-water evaporator
2nd prototype: ice-slurry evaporator (**supercooler**)

heat pumps with **R-290** (propane) for space heating dominated buildings

heat pumps with **R-744** (CO_2) for domestic hot water dominated buildings

applications of hydrocarbons

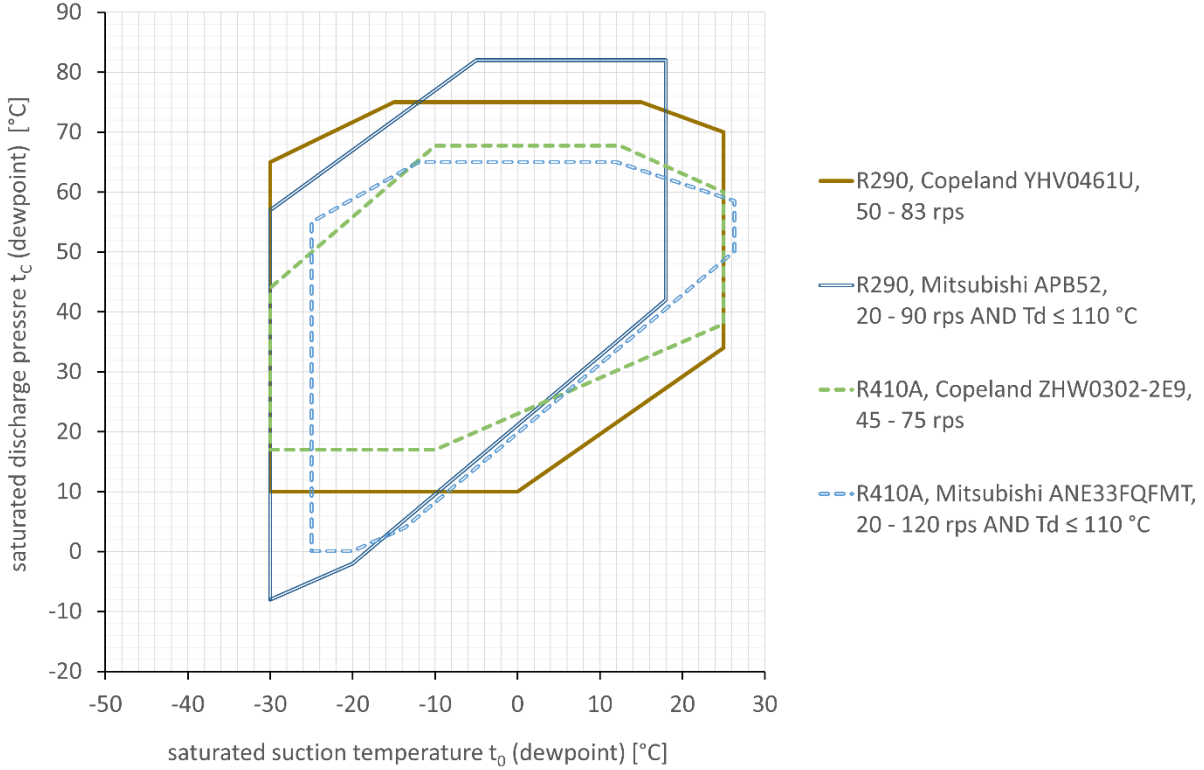
products available on the market

- indoor- and outdoor-installations
- space heating and domestic hot water (70 °C)
- integrated safety concepts
- air-to-water, brine-to-water, water-to-water, air-to-air, split

sources: nibe.eu, enerblue.it, hautec.eu, alpha-innotec.de, teko.de, vaillant.de, heliotherm.com, hoval.de

Propane striking HFCs in domestic applications

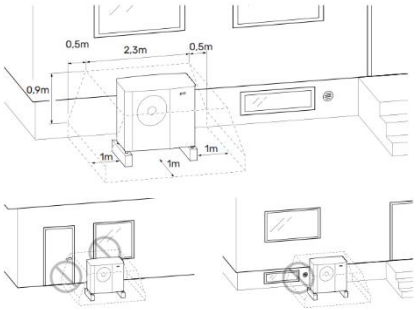
- wide application envelope
- high supply temperatures
- high energy efficiency
- future proof
- negligible GWP (0.02, IPCC2021)



Safe use of hydrocarbons

outdoor installation example

- **safety zone of 1.0 m around the heat pump**
  - no drains/ windows/ doors/ depressions/ wells/ ducts etc.
  - no sparking elements
- **charge limit according to EN378 at least 5 kg**

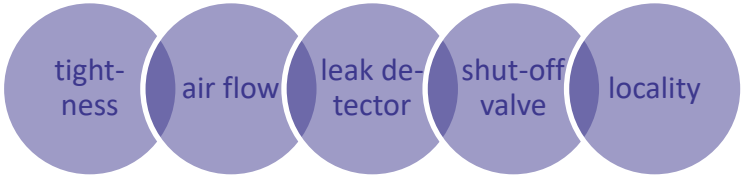


source: NIBE.eu

indoor installations

charge limits (IEC 60335-2-40 ED7):

150 g: no additional requirements



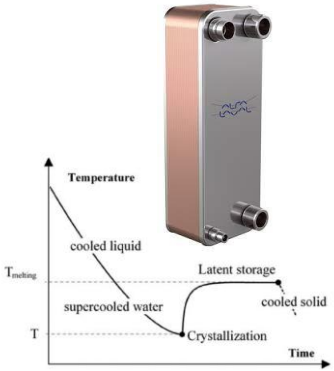
5'000 g: ventilated enclosure

new brine-to-water residential HP released

Q_H (B0W35):	2 - 28 kW
$SCOP_{low}$:	5.3
t_{supply}:	+73 °C
W x H x D:	70 x 100 x 62 cm

TRI-HP example 1

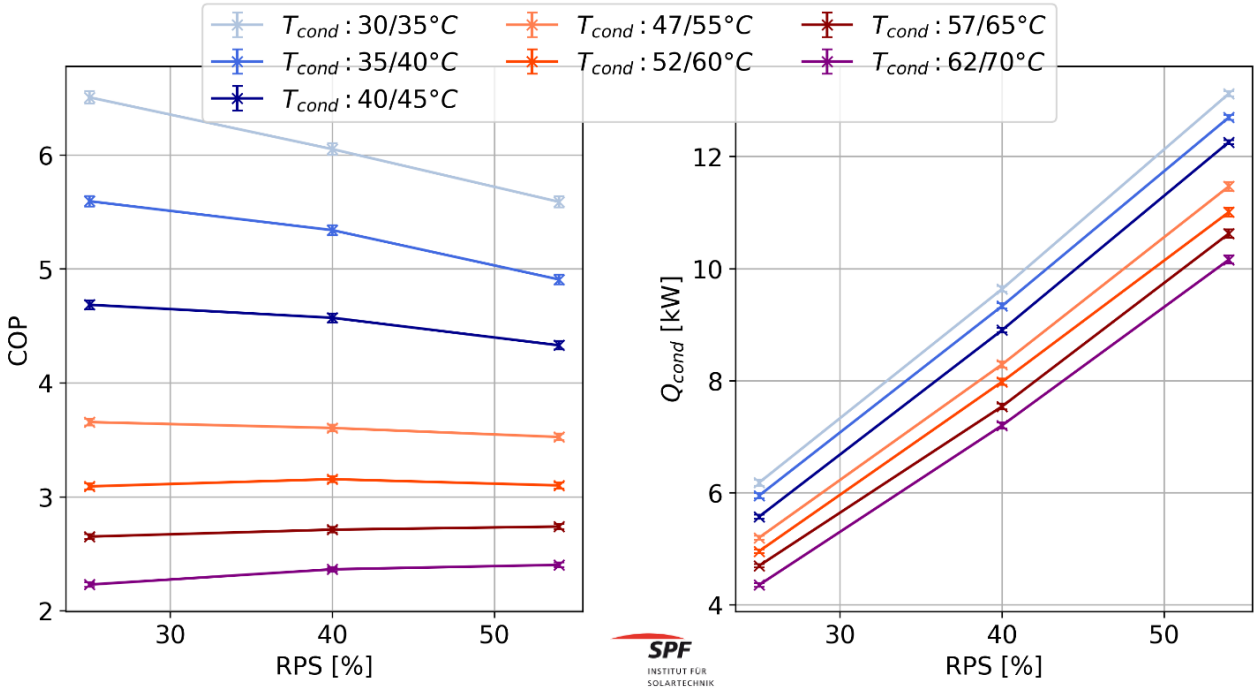
- tight and ventilated enclosure
- calibrated propane detector inside the enclosure
- tightness and leakage simulation test performed
- ATEX-approved radial fan, duct to safe area outside
- air supply to location
- components inside enclosure: ATEX approved or non-sparking
- electrical components that can spark, hot surfaces: outside enclosure
- supercooler for slurry-ice heat source



Test results

Performance of TRI-HP Propane-Ice unit

- at different compressor speeds
- for source temperatures of +10 / +7 °C
- including coated supercooler (evaporator)

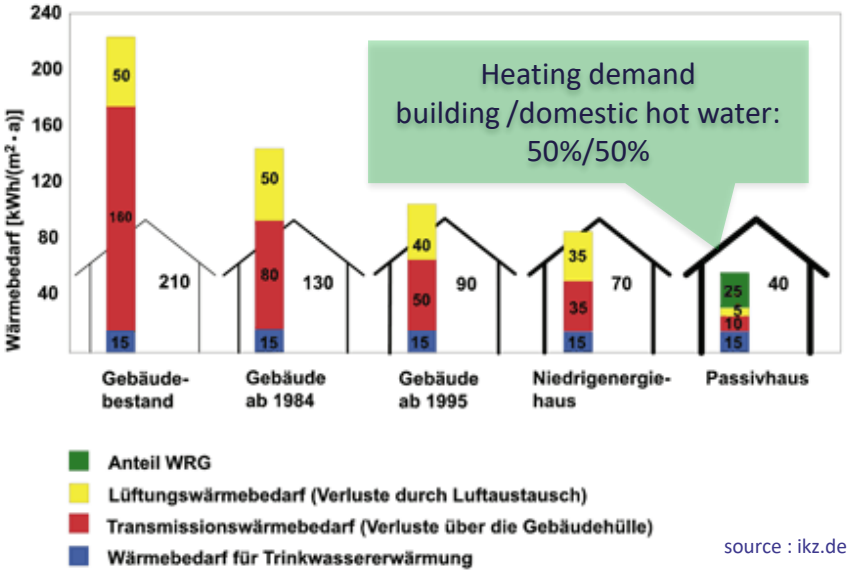


applications of CO_2

examples of small to medium capacity units (indoor and outdoor)

source: enex.it, gea.de, enerblue.it, engie-refrigeration.de, greenandcool.com, efficient-energy.de

in new buildings, the heat demand shifts from space heating to domestic hot water:



source : ikz.de

CO_2 for domestic heating applications

success story 1: domestic hot water (EcoCute)

- domestic hot water production
- millions of units sold
- EUR 3’000 – 4’000 per unit
- cylindrical/ scroll/ rotary compressors
- adiabatic expansion (ejector or expansion valves)
- 66% less electric power consumption

source: Denso

success story 2: district heating

- startup 2020
- 2021-2022: 18 installations, total heating capacity of 20 MW
- 2023: 40 MW planned

source: Fenagy

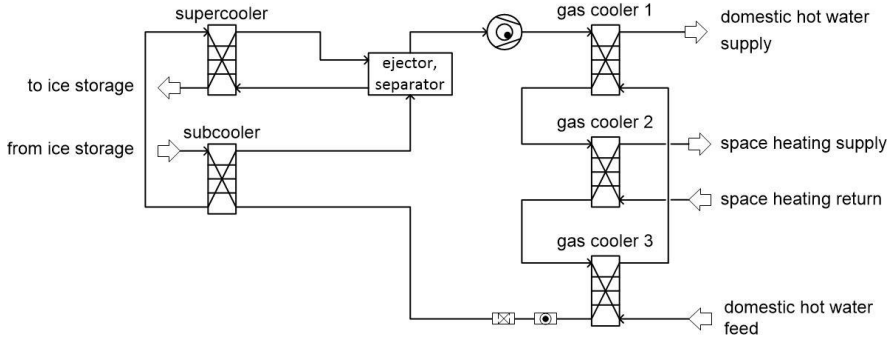
TRI-HP example 2

variable speed compressor

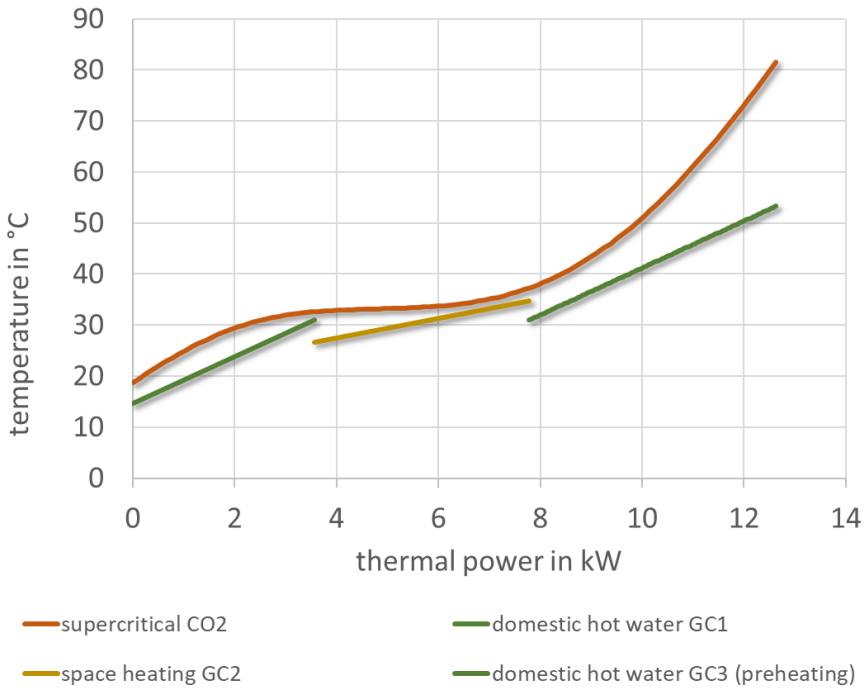
innovative tri-partite heat exchanger for optimized heat extraction

supercooler for slurry-ice heat source

high-class prosses optimization (flooded evaporation, ejector-technology)



simultaneous use of medium and high temperature heat



example of measured performance at SPF system test:

maximum compressor speed

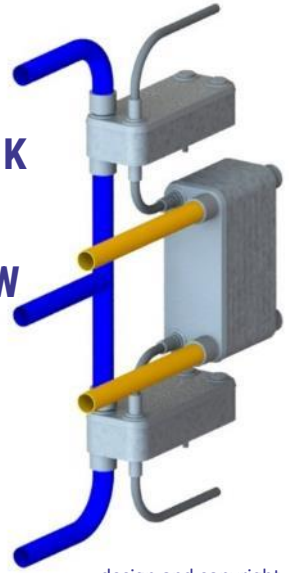
p_{dis} = 76 bar, Δt refrigerant >60 K

domestic hot water
15 °C / 53 °C (Δt = 38 K), 8.4 kW

space heating
27 °C / 35 °C (Δt = 8 K), 4.2 kW

source: water 5 °C / 2 °C

COP: approx. 5.2



design and copyright
by NTNU
more info: tri-hp.eu

applications of natural refrigerants

in **heating**, cooling and air conditioning

hydrocarbons (HC), R-290, R-600a, R-1270

- space heating and cooling
- industrial
- high-temperature applications
- plug-in appliances (washer, dryer, domestic hot water heat pump)

safe

carbon dioxide (CO_2), R-744

- domestic hot water
- e-mobility (heating and cooling)
- food (supermarkets, dairy production, drying)
- industry
- space heating and cooling

efficient

ammonia (NH_3), R-717

- medium and high capacities
- large temperature range
- space heating and cooling, industry, recreation

understood

(H_2O), R-718: medium capacity, low temperature difference

air, R-729: vehicle air conditioning, ultra low temperature cooling

trusted

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this event lies with the organisers. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.

raphael.gerber@heim-ag.ch

www.tri-hp.eu

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

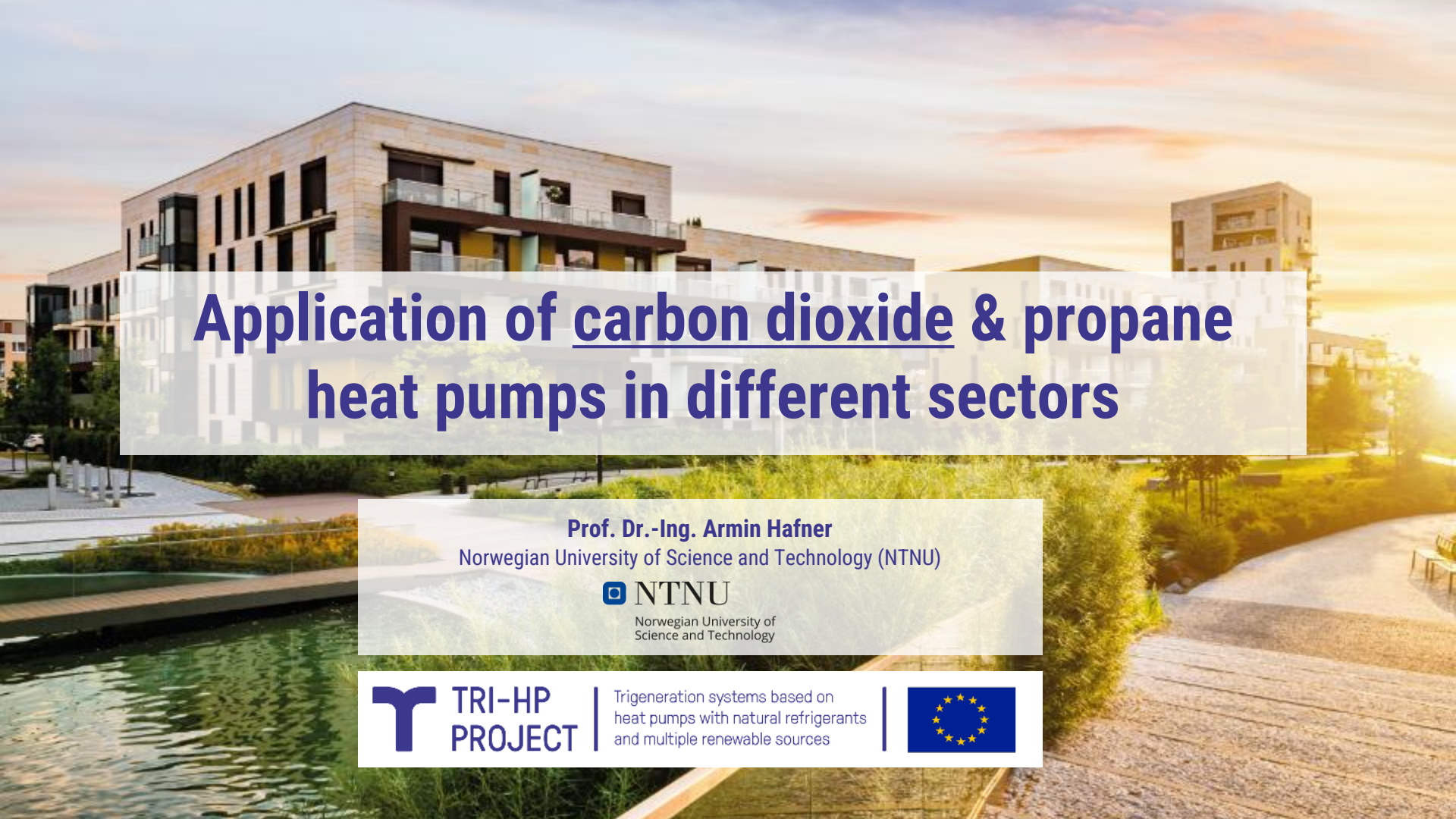
Session 1: Heat pumps based on natural refrigerants

APPLICATION OF CO2 & PROPANE HEAT PUMPS IN DIFFERENT SECTORS

Armin Hafner,
Professor in Refrigeration Technology,
Norwegian University of Science & Technology

07 February 2023: 14:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources



Application of carbon dioxide & propane heat pumps in different sectors

Prof. Dr.-Ing. Armin Hafner
Norwegian University of Science and Technology (NTNU)
NTNU
Norwegian University of Science and Technology

TRI-HP PROJECT
Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Content

- Introduction
  - Why natural working fluid units are **real solutions for end-users**
- Application example (selection):
  - Propane-Butane cascade high temperature heat pump
  - simple CO_2 commercial refrigeration unit
  - CO_2 heat pump chiller
  - integrated CO_2 heat pump for an energy central
- Summary
- Conclusion / Way forward

Introduction

State of the ‘art’:

The use of F-gasses in the past decades has a sever impact on humans and the environment:

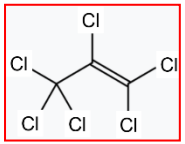
- Depletion of the ozone layer (CFCs)
- Global warming due to CFCs, HCFCs, HFCs
- Acidification of our water by TFA (unsaturated HFCs)
- Poisonous decomposition products (PFAS*)

*PFAS (Per- and polyfluorinated alkyl substances), also known as the **Forever Chemicals.** Large chemical family of over 9,000 highly persistent chemicals that don't occur in nature.

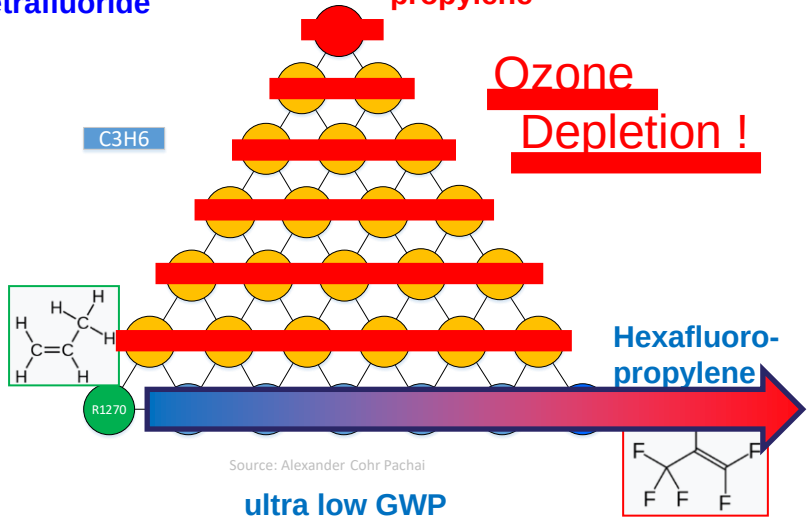
What are sustainable working fluids?

Sustainable working fluids?

Carbon tetrachloride



Hexachloro-propylene



Ozone Depletion !

Source: Alexander Cohr Pachai

ultra low GWP

Propene (propylene)

Summary of Latest scientific results*,:**

- **R-1234yf → transforms mainly to HF and TFA**
- **R-1234ze → ?**
  - **Hansen et al.*** discovered lately that in a unimolecular photolysis channel R-23 (→10%) is formed from CF_3CHO** (<- interm. breakdown product)
  - More scientific experiments are underway
- **Definition of GWP values**
  - **LCA based GWP values are need**
    - **including manufacturing &**
    - **decomposition**

* https://ecostandard.org/wp-content/uploads/2021/05/ECOS-briefing-on-HFO-production-and-degradation_final.pdf
** https://www.umweltbundesamt.de/publikationen/persistent-degradation-products-of-halogenated
*** https://www.green-cooling-initiative.org/news-media/news/news-detail/2021/05/11/green-cooling-summit-2021-germany-opts-for-a-rapid-hfc-phase-down

TRI-HP PROJECT

NTNU

F-gas regulation + PFAS restriction

TODAY!

GWP values does not care about the real environmental impact of refrigerants

- ✓ **F-gas reg. supports fluids with low GWP**
  - **However, definition of GWP and boundary conditions are questionable**

→ Universal PFAS restriction by EU will regulate and initiate the final phase out of F-gasses

Regjeringen.no

Søk

Tema · Dokument · Aktuelt · Departement · Re

Du er her: Forsiden • Aktuelt • Nyheter •
Fremleggelse av forslag om å forby miljøgifter i blant annet sports- og kjøkkenartikler

Fremleggelse av forslag om å forby miljøgifter i blant annet sports- og kjøkkenartikler

Nyhet | Dato: 02.02.2023

Tirsdag 7. februar legger Norge, Sverige, Danmark, Tyskland og Nederland fram et omfattende forslag om å forby PFAS i EU.

Tirsdag 7. februar legger Norge, Sverige, Danmark, Tyskland og Nederland fram et omfattende forslag om å forby PFAS i EU. Forslaget blir offentliggjort i Brussel på en pressekonferanse klokka 11-12.30.

Klima- og miljødepartementet inviterer senere samme dag til en fremleggelse av forslaget i Norge. **Forslaget vil presenteres av Klima- og miljøminister Espen Barth Eide og direktør i Miljødirektoratet, Ellen Hambro. Det blir også innlegg fra Dorte Herzke ved NILU og fra Cathrine Pia Lund ved Miljømerking Norge.**

https://www.youtube.com/watch?v=jDb9uX6DUzw

TRI-HP PROJECT

NTNU

ECHA - PFAS

ECHA receives PFASs restriction proposal from five national authorities

ECHA/NR/23/01

The national authorities of Denmark, Germany, the Netherlands, Norway and Sweden have submitted a proposal to ECHA to restrict per- and polyfluoroalkyl substances (PFASs) under REACH, the European Union's (EU) chemicals regulation. ECHA will publish the detailed proposal, one of the broadest in the EU's history, on 7 February 2023.

https://echa.europa.eu/de/-/echa-receives-pfass-restriction-proposal-from-five-national-authorities

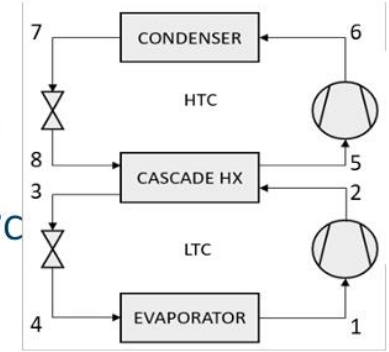
Examples of clean cooling and heat pumping solutions

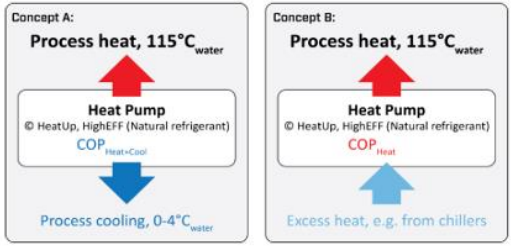
- Propane-Butane cascade high temperature heat pump (industrial)
- Simple CO_2 commercial refrigeration unit (supermarket)
- CO_2 heat pump chiller (hotels, kitchens, gyms, etc.)
- Integrated CO_2 heat pump for an energy central (larger buildings)
- Mobile vehicles (EV, trucks, train, …)
- Freezing plants at -50°C (food processing)
- CTES cold thermal energy storage with CO_2 at low temperatues
- +++

Example: Propane-Butane cascade HTHP (high temperature heat pump)

- HT circuit with R600 (Butane)
  LT circuit with R290 (Propane),
- Sink temperatures up to 115 °C achievable with moderate pressures about 20 bar
- Source temperatures (-15°C) 0 to 30°C
- High temperature lift (70…120 K)
- HTHP is mounted in 10 feet shipping container build after EN-NS-378

➢ **Pilot installed available and flexible system (high TRL-level)**



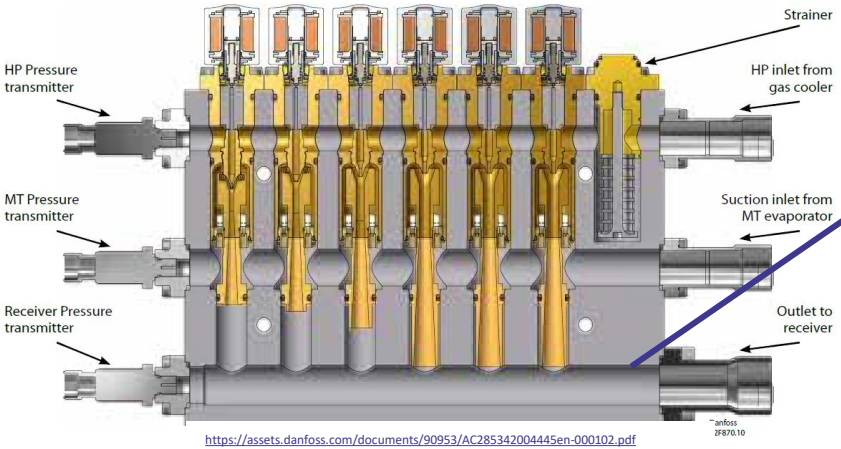


Energy demand

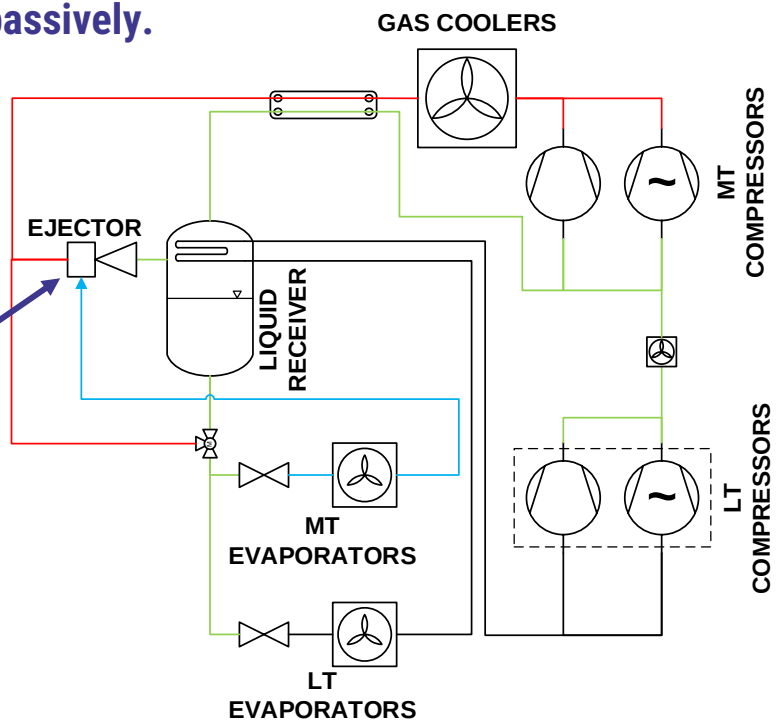
- Process heat 117 MWh
- Hot water 10,7 MWh
- Process cold 77 MWh
- Primary energy (electricity) 126 MWh
- HTHP-Cascade 80 kW to 282 kW @ 90°C to 107°C

Ejector for the World – Simple and Efficient (supermarket refrigeration)

- Medium (MT)- and Low temperature (LT) compressors only.
- Ejector part of the cycle at all conditions, actively or passively.



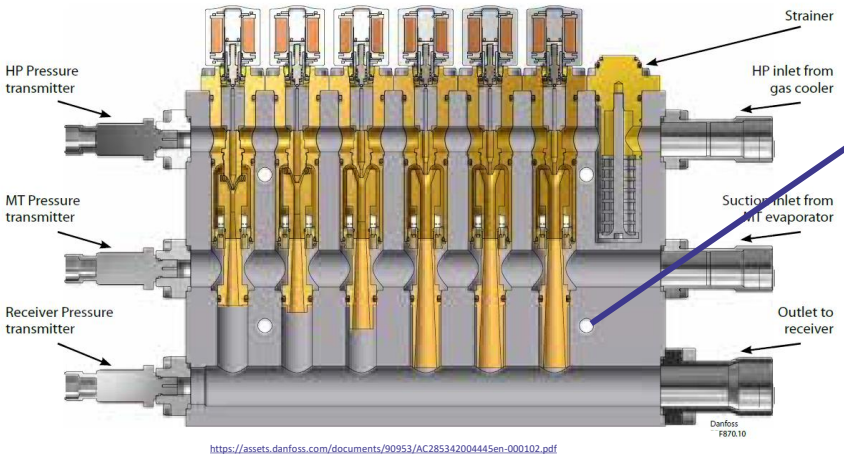
https://assets.danfoss.com/documents/90953/AC285342004445en-000102.pdf



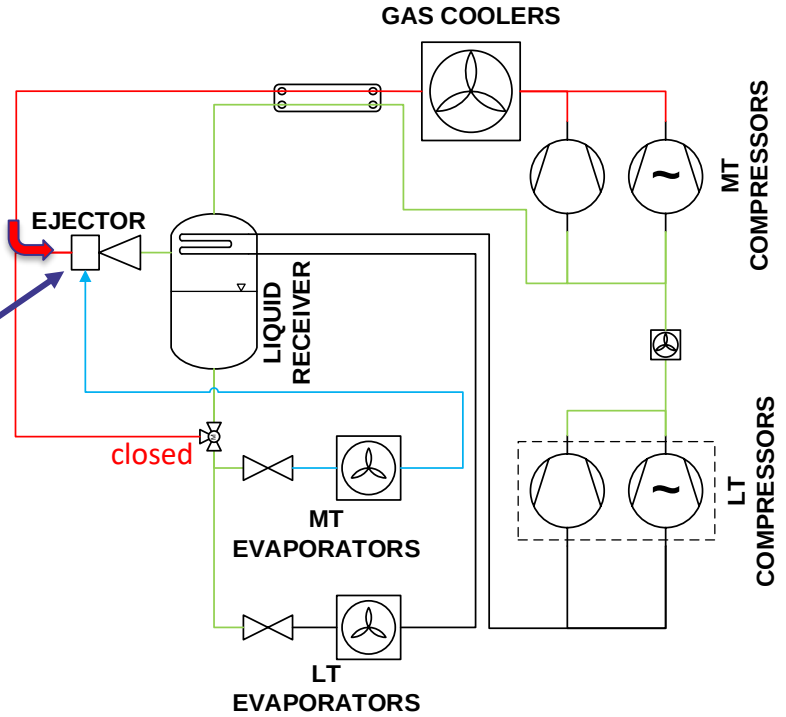
Ejector for the World – Active ejector (summer)

Transcritical conditions:

- **Conventional use of ejector (low-pressure-lift).**
  - High pressure control with ejector.
  - Suction pressure of MT compressors ⇈.



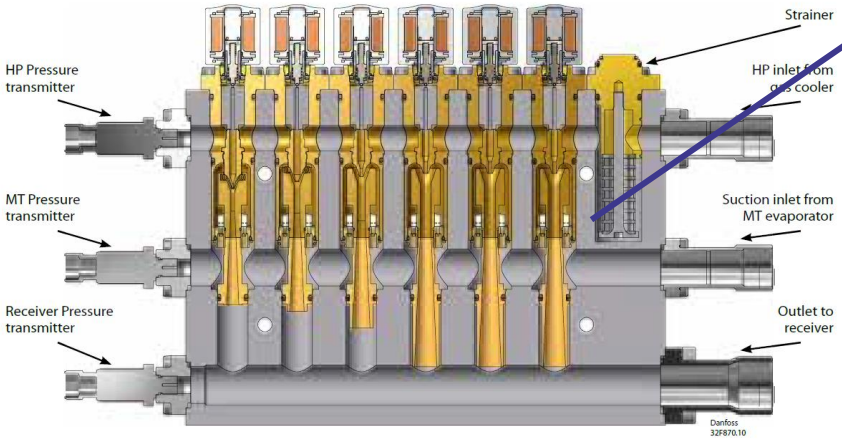
https://assets.danfoss.com/documents/90953/AC285342004445en-000102.pdf

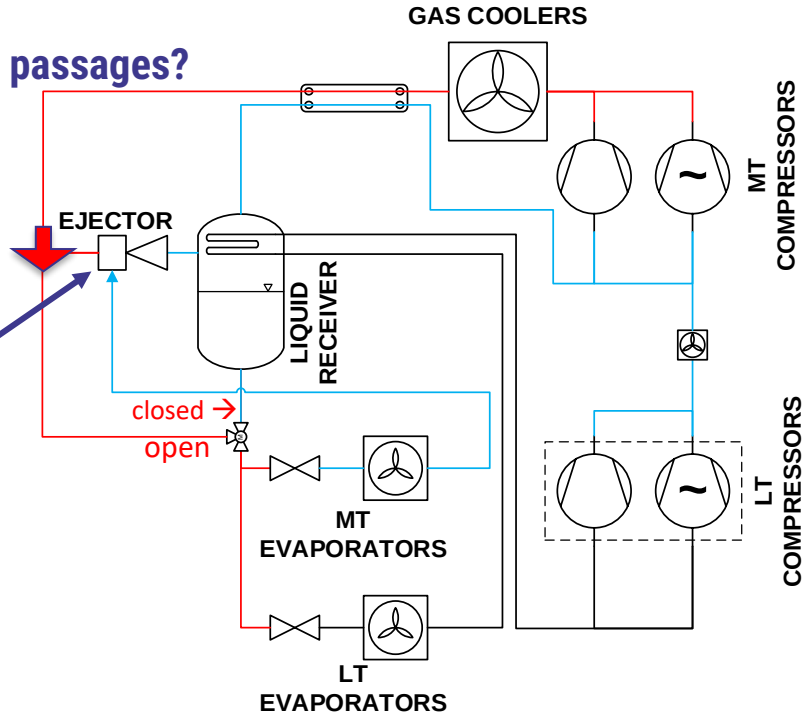


Ejector for the World – Passive ejector (winter)

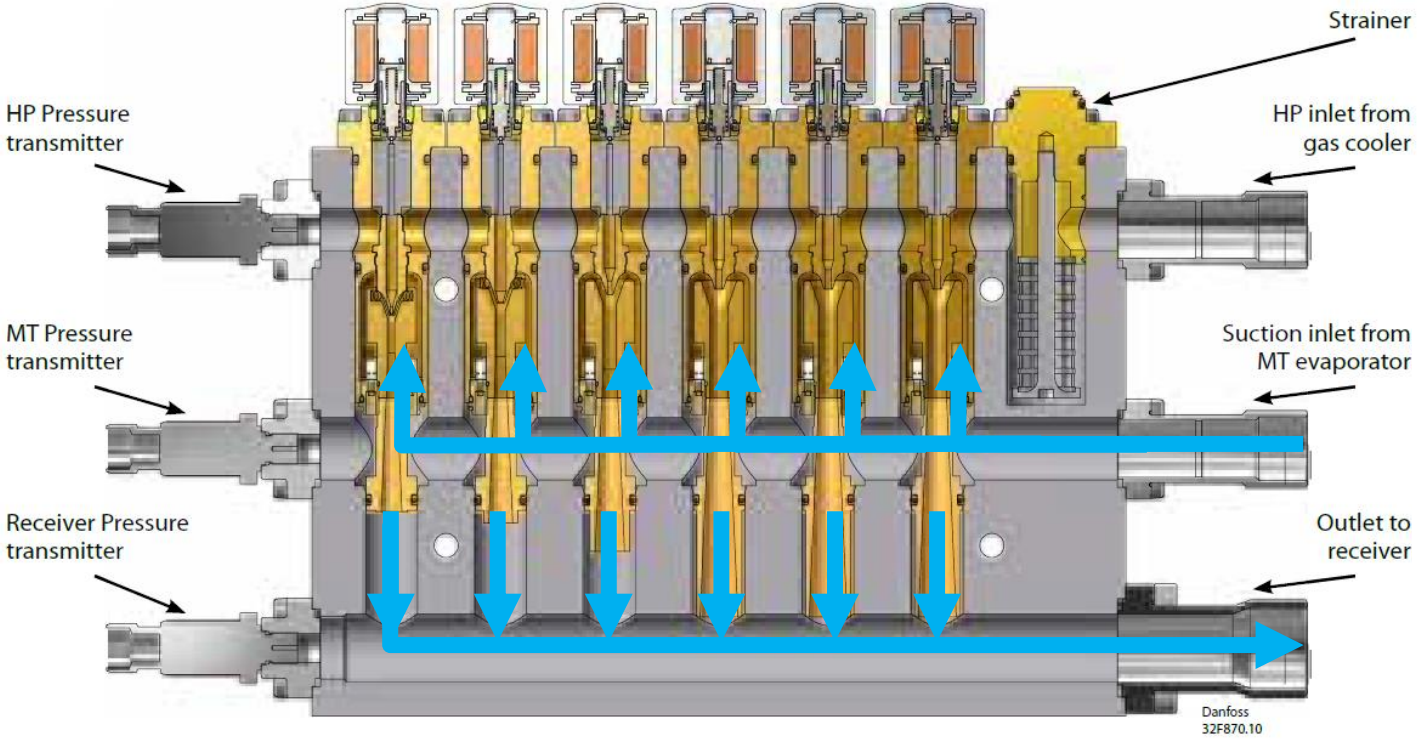
Subcritical conditions:

- Ejector is a check valve. Pressure drop in ejector passages?
- High pressure control?
- Oil management?



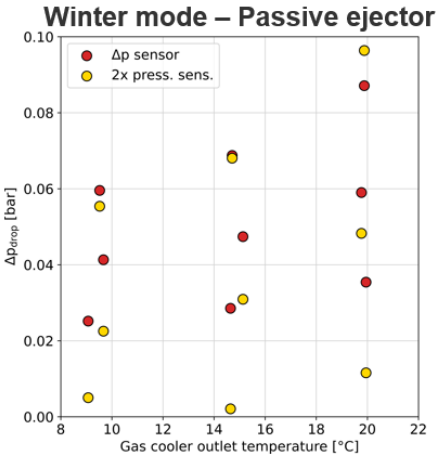


Ejector for the World – Passive ejector (winter)



https://assets.danfoss.com/documents/90953/AC285342004445en-000102.pdf

Pressure drop: <u>below</u> 0.1 bar



Results – Comparison

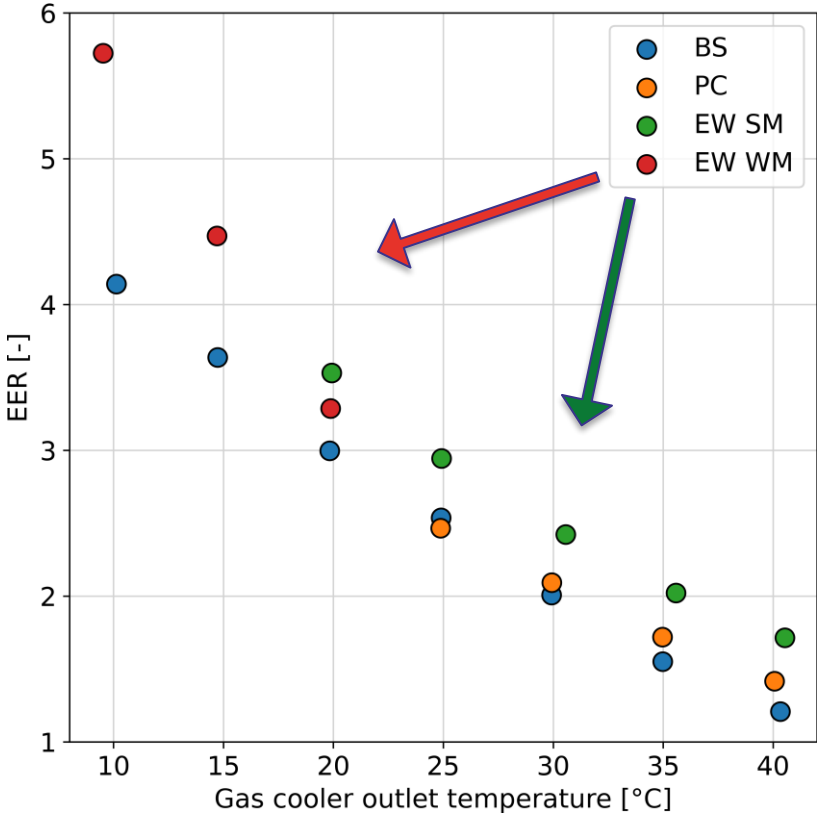
For comparison,

tests with **same system** and **components** (HXs, compressors, etc.), considering:

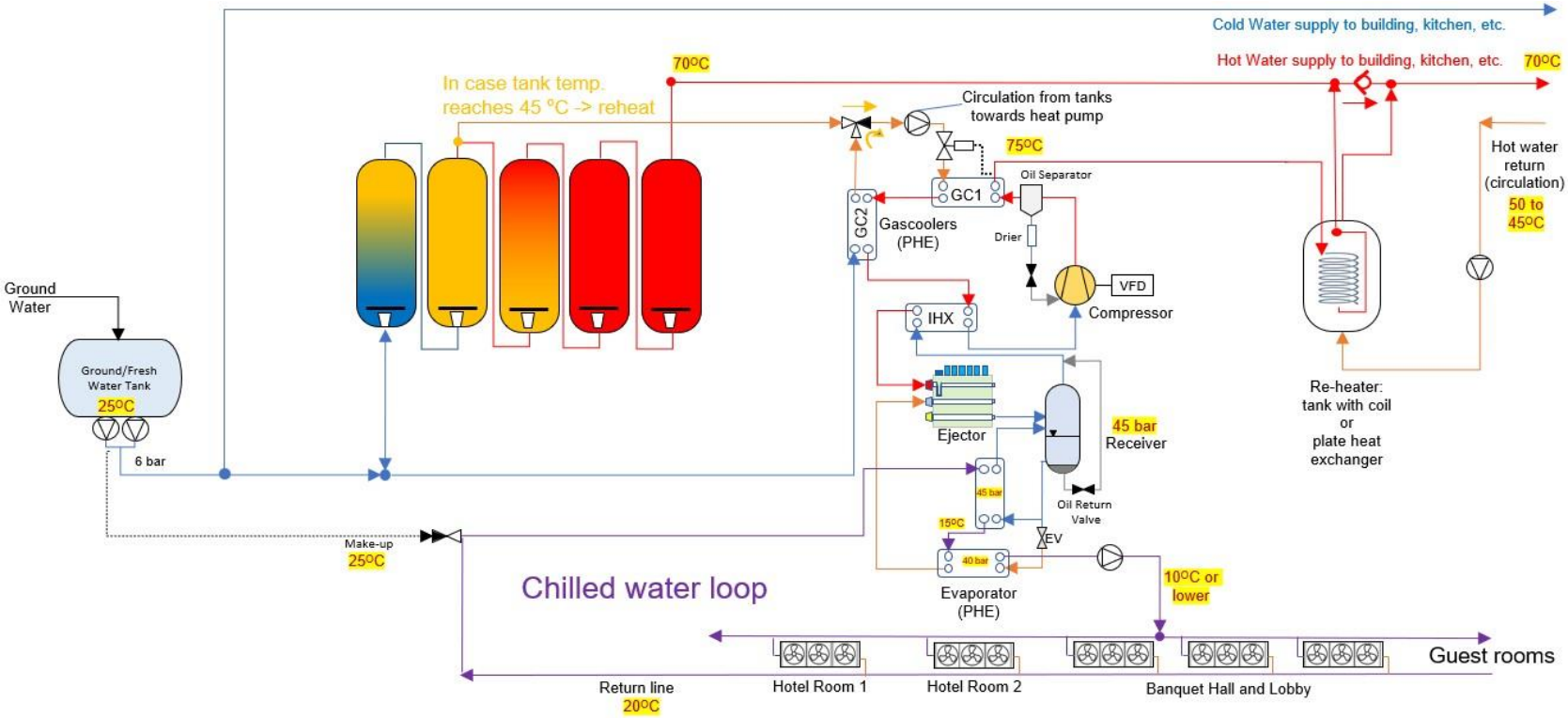
- Booster system (BS).
- Parallel compressor (PC).

$EVAP_{MT}$, DX → -8 °C (SH = 10 K).

First system at EUROSHOP 2023



CO_2 heat pump / chiller unit (made & installed in India)



Example: CO_2 Heat pump / Chiller

Off the shelf in Europe….

enex
INNOVATION AS ENERGY

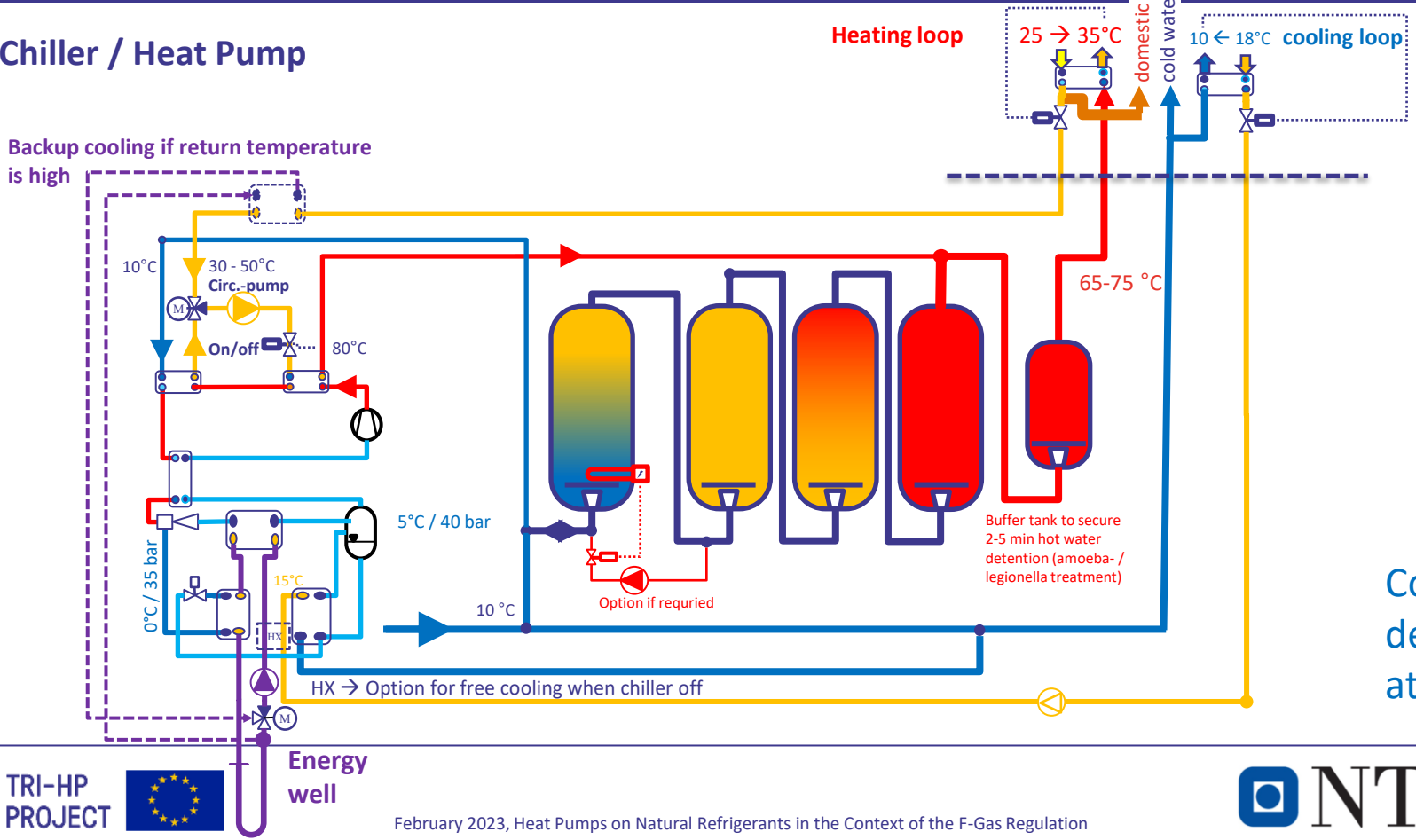
CO_2 CHILLER, 4-PIPES & HEAT PUMP WITH REMOTE GAS COOLER

YUKON Series

Cooling capacities from 35 to 940kW
Heating capacities from 35 to 560kW

4 tube supply system: heating, cooling, hot and cold water

CO_2 Chiller / Heat Pump



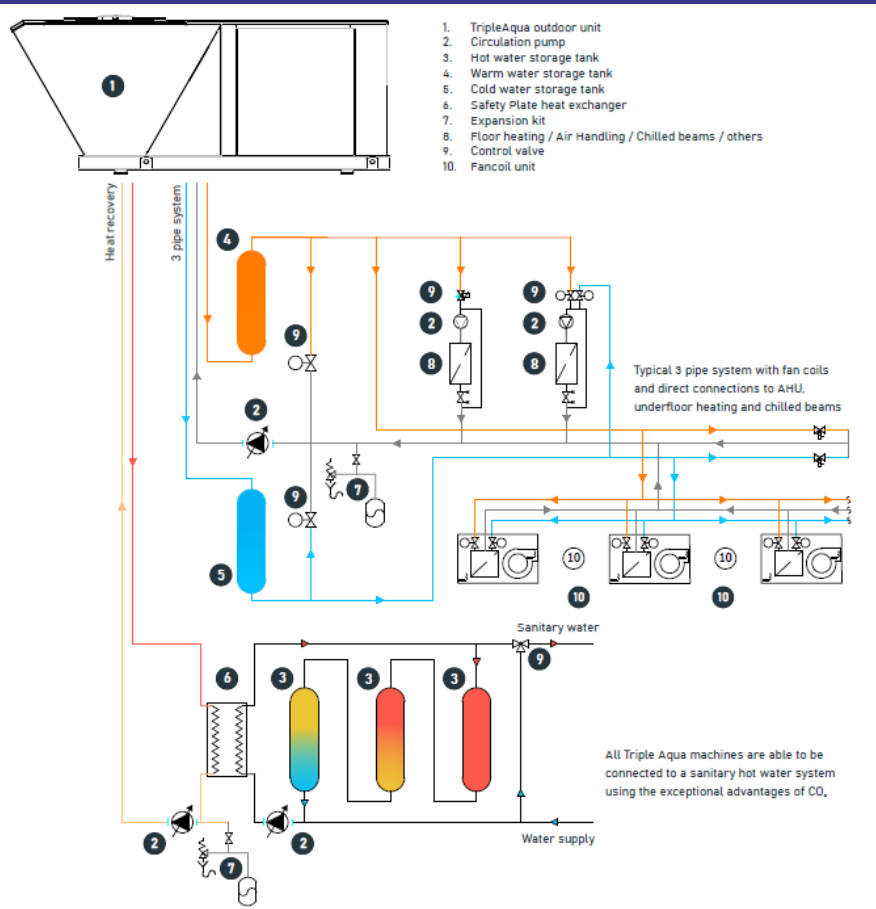
Concept developed at NTNU

Example: CO_2 heating/cooling/hot water

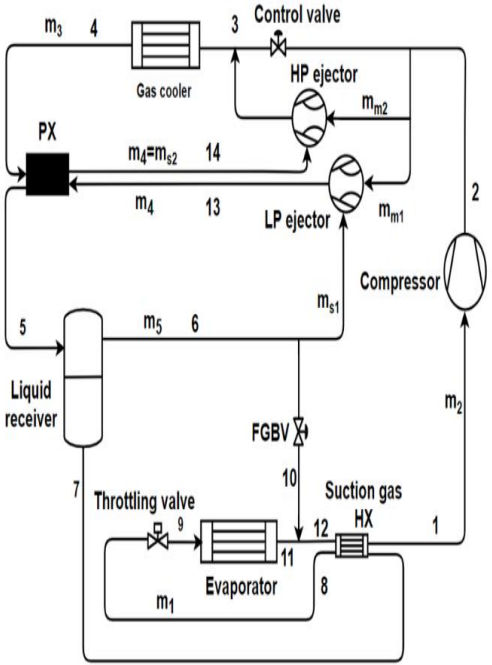
- Commercial product
- Plug-and-play concept
- Water is applied as secondary fluid across the building
- Natural working fluid: R744

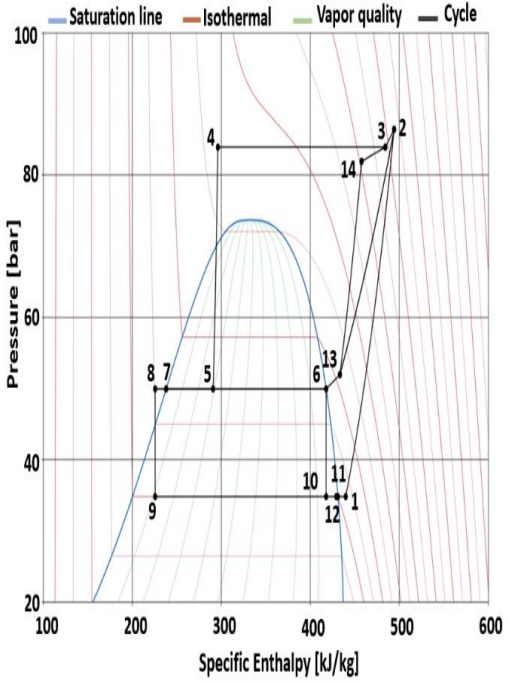
TRIPLE AQUA
Natural Heat Pump Innovation

WE MAKE ANY BUILDING
CO_2 NEUTRAL WITH CO_2
ALL IN ONE: HEATING & COOLING & HOT WATER



Latest news: PX successfully tested (CO_2 chiller mode) in NTNU laboratory





Summary

During the last decade, significant development progress has been made with respect to:

- **Energy efficient heat pumps and chillers** with natural working fluids
- **Market acceptance** is there, and **end-users** are becoming **aware**
- Robustness and serviceability are key (+ training)

Conclusion I of II

All temperature levels and all applications can be cooled by applying natural refrigerants = clean cooling.

There is no technical barrier to replace currently used synthetical fluorine containing refrigerants with natural working fluids.

It is more about seeing the possibilities than the ghosts when selecting the optimal refrigerant for the project or a product.

No single refrigerant can cover all applications; however, the group of natural refrigerants can cover all the applications which can be covered by fluorinated hydrocarbons (= dirty cooling) and even more.

Conclusion II of II

None of the fluorinated hydrocarbons can go as low in temperature or as high as the natural refrigerants, they only cover the most profitable markets in the middle temperature range.

With respect to PFAS pollution on earth, the refrigeration sector does have all possibilities to spearhead a complete phase out of HFCs (= dirty cooling) contributing to the PFAS accumulation in our biosphere, without compromising safety, food supply and human comfort.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this event lies with the organisers. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.

armin.hafner@ntnu.no

www.tri-hp.eu

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Session 1: Heat pumps based on natural refrigerants

Market for heat pumps based on natural refrigerants – current status and projections

Dr. Sabrina Munao
Market Researcher, ATMOsphere

07 February 2023: 14:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Scaling the Clean Cooling Economy

www.atmosphere.cool

Sabrina Munaò, *Ph.D.*
Market Researcher @ ATMOsphere

Brussels, 07 February 2023

ATMO sphere

www.atmosphere.cool

Market for heat pumps based on natural refrigerants – current status and projections

Sabrina Munaò, *Ph.D.*
Market Researcher @ ATMOsphere

Brussels, 07 February 2023

About ATMOsphere

ATMOsphere is a global, independent market accelerator with a mission to clean up cooling and heating.

The company boasts more than 20 years of industry experience amongst its global team located in the USA, Europe and Japan and working with leading companies that have new solutions using natural refrigerants.

Accelerating the EU's shift towards natural refrigerant domestic heat pumps

Objective: Highlight the potential **impact** of the proposed HFC phase down and bans on the domestic heat pump sector in Europe.

Scope: Heat pumps for space heating and domestic- and sanitary- water heating applications. **Capacity below 12 kW** (in line with Ecodesign).

Some results: First-mover OEMs that have set up production lines based on natural refrigerants are experiencing **up to triple-digit growth** in their market segment and **high demand**. Manufacturers reported **confidence** in their ability to **quickly scale up production** and **reconvert** old technology production lines pushed by the right **policy framework**.

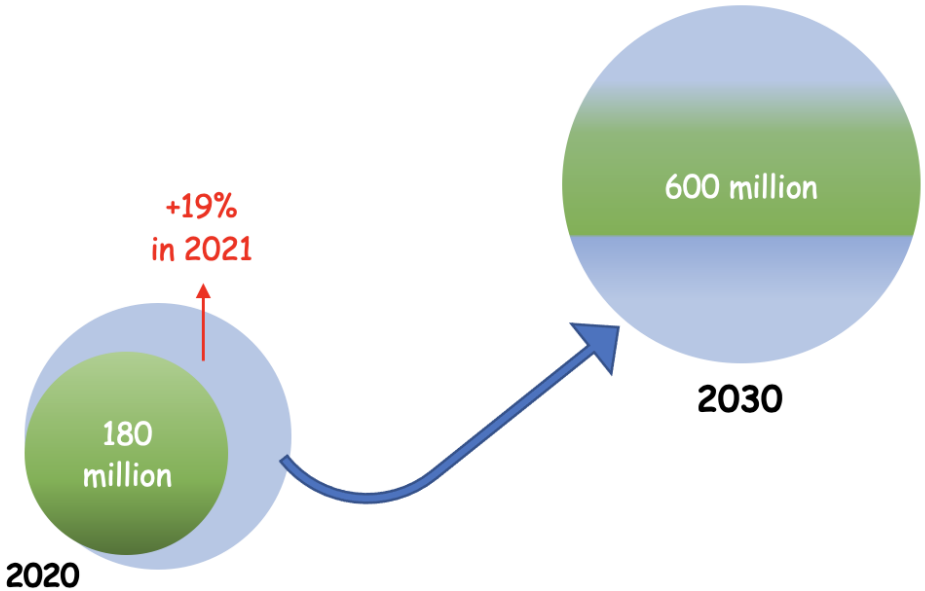
An even **stricter phase down -** in line with EU climate neutrality objectives - can accelerate the **shift from fossil-fuel-based heating systems to clean heat pumps**.

In collaboration with ECOS (Environmental Coalition on Standards), EEB (European Environmental Bureau) and ECF (European Climate Foundation).

For more insights please go to [**https://atmosphere.cool/heat-pumps-report-2022/**] and download our report.

GLOBAL MARKET

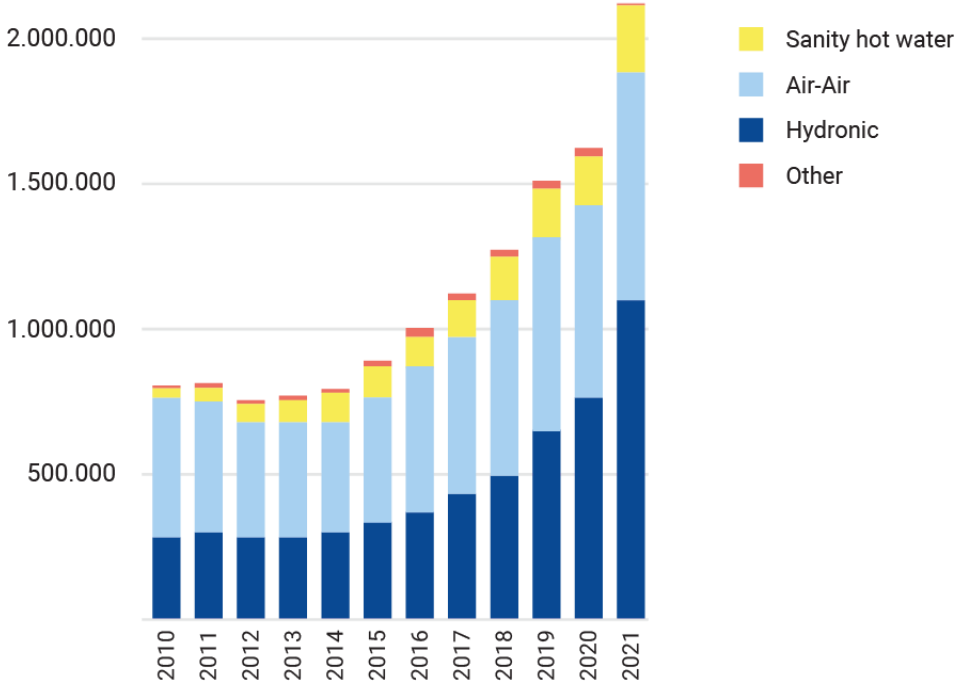
Heat Pumps used mainly for HEATING



- In 2020 there were **180 million** units worldwide.
- In 2021 the market **increased by 19.3%**.
- The number of heat pumps needs to rise to **600 million by 2030** to be on track to meet a goal of net-zero emissions by 2050.

Source: Own elaboration based on European Commission (2022). Heat Pumps in the European Union. Status Report on Technology Development, Trends, Value Chains and Markets.

Heat pump **sales** in the European markets



Heat pump sales - hydronic, air-to-air and sanitary hot water - growth of **34%** in Europe in 2021:

- **2.18 million** heat pump units were sold in 2021 compared with **1.62 million** units sold in 2020.
- Analysing the data per type of ambient heat source, the **hydronic sector** shows the highest growth.
- JARN estimated that the ATW heat pump market **increased by 46%** year on year in 2021

The total number of installed heat pumps in the EU results to be **16.98 million** at the end of 2021, covering **21.5% of the heating market**.

The **REPowerEU** measure is aimed to have **30 million heat pumps by 2030**.

If the average annual sales growth in Europe between 2019 and 2021 of all types of heat pump used for heating (20% per year) will be maintained, **it would be possible to achieve that target**. *

Source: based on EHPA 2022 Market Report; European Commission (2022), Heat Pumps in the European Union. Status Report on Technology Development; JARN, World ATW Heat Pump Market – 2022 Update

Natural refrigerants alternatives

	CO_2 / R744	NH_3 / R717	HC	H_2O / R718	Air / R729
Domestic applications	✓			✓	
Commercial refrigeration	✓	✓	✓	✓	
Industrial refrigeration and heat pump systems	✓	✓	✓	✓	
Water and space heating heat pumps	✓	✓	✓		
Chillers	✓	✓	✓	✓	
Vehicle air conditioning	✓		✓		✓

Natural refrigerants are a market **reality** today, a credible **alternative** to HFCs and HFOs and are **available** for many applications: domestic, commercial, industrial, transport, but also for cooling systems.

In addition, there are **different natural refrigerant options available that compete with each other for each of the applications.**

The market is now predicted to **ramp up** further in Europe and beyond.

Sources of the table: Hafner, A., Ciconkov, R. (2021). Current state and market trends in technologies with natural refrigerants. 9th IIR Conference: Ammonia and CO2 Refrigeration Technologies, Ohrid, 2021; European Commission (2022) EU F-gas Technical Annexes to the Revision; Norwegian Chemical Agency (2022) Report Summary F-gas Uses.

Natural refrigerants alternatives

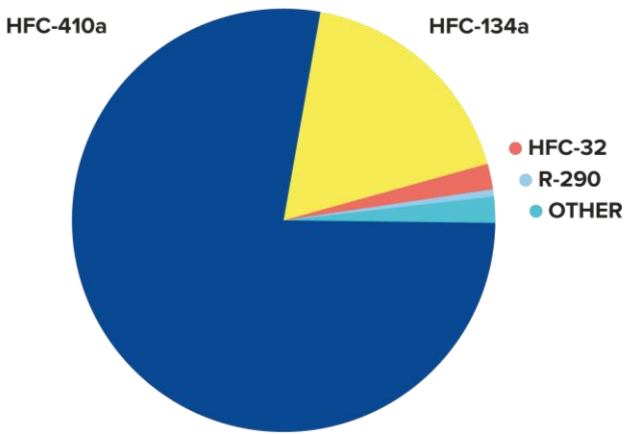
	CO_2 / R744	NH_3 / R717	HC	H_2O / R718	Air / R729
Domestic applications	✓			✓	
Commercial refrigeration	✓	✓	✓	✓	
Industrial refrigeration and heat pump systems	✓	✓	✓	✓	
Water and space heating heat pumps	✓	✓	✓		
Chillers	✓	✓	✓	✓	
Vehicle air conditioning	✓		✓		✓

At least **4 different natural refrigerants** can cover heat pumps and chillers' applications.

Sources of the table: Hafner, A., Ciconkov, R. (2021). Current state and market trends in technologies with natural refrigerants. 9th IIR Conference: Ammonia and CO2 Refrigeration Technologies, Ohrid, 2021; European Commission (2022) EU F-gas Technical Annexes to the Revision; Norwegian Chemical Agency (2022) Report Summary F-gas Uses.

The state of natural refrigerants market penetration rates in 2019

Refrigerants Used in Heat Pumps
(2019)



- **80%** of hydronic heat pumps **sold in 2019 contained HFC-410a.**
- **HFC-134a** is the second most common.
- The other two refrigerants in use are **HFC-32 and R-290** and, **by 2023**, their use is expected to increase - representing **a move away from HFC-410a.**

Source: BSRIA (2020)

Market penetration rates related to refrigerants for new domestic heat pump installations in Germany with projection until 2030

Refrigerant in heat pumps	Market penetration rates for new installations [%]				
	2015	2018	2020	2025	2030
HFC-410A	40	45	35	0	0
HFC-407C	54	40	20	0	0
HFC-134A	6	6	0	0	0
HFC-466A	0	0	0	2	2
HFC-32	0	<1	20	30	12
HFC-513A	0	0	2	5	3
HFC-454C/ HFC-455A/ HFC-454B	0	0	12	35	50
R-290	0	7	10	25	30
R-744	0	<1	<1	3	3

Data are related to Ground HP - refrigerant charge = 2.5 kg – and ATW HP - refrigerant charge = 4 kg.

By 2030:
30% of new domestic heat pumps in Germany will be charged with **R-290;** 3% is expected to use **R-744**.
HFC-32 will rapidly decline with a share of 12% in 2030.

Even if a relevant share of HFC refrigerants is still estimated for new installations beyond 2020, **HFC-410A** (GWP_2100) **and HFC-407C** (GWP_1700) **are going to disappear** from the market by 2025.

Other conclusions based on OEMs interviews following the release of 2020 study:

- **The market share of the refrigerant mixtures HFC-454B, HFC-454C and HFC-455A seems overestimated**. The manufacturers interviewed stated that they do not currently use the HFO mixtures; it seems more realistic to assume that these mixtures will increase less and only represent a **transitional solution**.
- The market share of **R-290** will increase quicker.

Source: Öko- Recherche GmbH (2020)

Natural refrigerants alternatives and their market penetration rates from European Commission

Market penetration rates for small heat pumps* - new installations - Different scenarios

Refrigerant in heat pumps	Baseline Scenario		Montreal Protocol Scenario		Proportionate Action Scenario		Maximum Feasibility Scenario	
	2024-2036 average	2050	2024-2036 average	2050	2024-2036 average	2050	2024-2036 average	2050
HFC-410A	3.4%	-	8.2%	-	0.7%	-	0.7%	-
HFC-407C	-	-	-	-	-	-	-	-
HFC-134A	0.1%	-	0.6%	-	0.1%	-	0.1%	-
HFC-32	38.9%	30%	51.1%	20%	2.0%	-	2.0%	-
HFC-513A	1.5%	-	4.2%	-	0.2%	-	0.2%	-
HCs	56.1%	70%	35.9%	80%	97%	100%	97%	100%

* Small heat pumps <12 kW, excluding small reversable air/air heat pumps

Source: Öko- Recherche GmbH and European Commission (2022)

- In **2024–2036 hydrocarbons** penetration grows to **56%** in the Baseline Scenario, **36%** in the MP Scenario and to **97%** in the Proportionate Action and Maximum Feasibility Scenarios for new installations of small heat pumps.
- **HFC-410a** can still count on a modest **3.4%** market share in the Baseline Scenario and **8%** in the MP Scenario for the 2024-2036 decade, but will in any case **disappear** from new installations in the following years.
- For **2050**, the percentages vary **from 70% to 80% up to 100%** between the most conservative and most progressive scenarios.
- This research doesn't provide penetration rates for blends used in Germany as HFC-454B, HFC-454C and HFC-455A.

Market overview:
HP running on R290 in Germany (2020)

This was two years ago…

in the last few months, we can registered a growth of natural refrigerant-based heat pumps in number of **companies** that switch at least one line of production, number of **models** and **capacity**.

Hersteller	Modell	Kältemittel
Luft-Wasser Wärmepumpen		
AIT/alpha innotec	alira LWD 50	R290
AIT/alpha innotec	alira LWD 70	R290
AIT/alpha innotec	alira LWD 90	R290
AIT/alpha innotec	alira LWD 90A-HTD	R290
AIT/alpha innotec	alira LWD 5050	R290
AIT/alpha innotec	alira LWD 7050	R290
AIT/alpha innotec	alira LWD 7070	R290
AIT/alpha innotec	alira LWD 9050	R290
AIT/alpha innotec	alira LWD 9070	R290
AIT/alpha innotec	alira LWD 9090	R290
AIT/alpha innotec	alira LWD 50A/RX-HMD	R290
AIT/alpha innotec	alira LWD 70A/RX-HMD	R290
AIT/alpha innotec	alira LWD 5050 RX	R290
AIT/alpha innotec	alira LWD 7050 RX	R290
AIT/alpha innotec	alira LWD 7070 RX	R290
AIT/alpha innotec	alira LWDV 91-1/3 HDV9-1/3	R290
AIT/alpha innotec	alira LWDV 91-1/3 HDV 12-3	R290
AIT/NOVELAN	LADV 9-HDV 9	R290
AIT/NOVELAN	LADV 9-HDV 12	R290
AIT/NOVELAN	LADV 9-HSDV 9	R290
AIT/NOVELAN	LADV 9-HSDV 12 1	R290
AIT/NOVELAN	LAD 5-CSD	R290
AIT/NOVELAN	LAD 7-CSD	R290
AIT/NOVELAN	LAD 9-CSD	R290
AIT/NOVELAN	LAD 5-HID	R290
AIT/NOVELAN	LAD 7-HID	R290
AIT/NOVELAN	LAD 9-HID	R290
AIT/NOVELAN	LAD 5/RX-HID	R290
AIT/NOVELAN	LAD 7/RX-HID	R290
AIT/Roth	ThermoAura 5 kW	R290
AIT/Roth	ThermoAura 7 kW	R290
AIT/Roth	ThermoAura 9 kW	R290
AIT/Roth	ThermoAura F 9 kW	R290
Auer	HTi706 kW	R290
Auer	HTi708 kW	R290
Auer	HTi7011 kW	R290
Auer	HTi7014 kW	R290
Auer	HCR70 11 kW	R290
Auer	HCR70 17 kW	R290
Auer	HCR70 20 kW	R290

Hersteller	Modell	Kältemittel
Luft-Wasser Wärmepumpen		
Auer	HCR70 25 kW	R290
Auer	HCR70 32 kW	R290
Auer	HCR70 40 kW	R290
Auer	HCR70 60 kW	R290
Auer	HCR70 80 kW	R290
Ecoforest	ecoAIR 1-7 PRO	R290
Ecoforest	ecoAIR 1-9 PRO	R290
Ecoforest	ecoAIR 3-12 PRO	R290
Ecoforest	ecoAIR 3-18 PRO	R290
Ecoforest	ecoAIR EVI 4-20	R290
Glen Dimple	System C 60 kW	R290
Glen Dimple	System Zero	R290
Hautec	HWL-AS 36	R290
Hautec	HWL-AS 43	R290
Hautec	HWL-AS 52	R290
Hautec	HWL-AS 56	R290
HKS Lazar SP	HT10/12	R290
HKS Lazar SP	HT10/14	R290
HKS Lazar SP	HT10/16	R290
HKS Lazar SP	HT10/20	R290
Hoval	Belaria pro (8) comfort	R290
Hoval	Belaria pro (13) comfort	R290
Hoval	Belaria pro (15) comfort	R290
Hoval	Belaria pro (8 100/300) compact	R290
Hoval	Belaria pro (13 100/300) compact	R290
IDM Energie	AERO ALM 2-8	R290
IDM Energie	AERO ALM 4-12	R290
IDM Energie	AERO ALM 6-15	R290
IDM Energie	AERO ALM 10-24	R290
Lambda	EU08L	R290
Lambda	EU13L	R290
Vaillant	aroTHERM plus VWL 35 / 6 A	R290
Vaillant	aroTHERM plus VWL 55 / 6 A	R290
Vaillant	aroTHERM plus VWL 75 / 6 A	R290
Vaillant	aroTHERM plus VWL 105 / 6 A	R290
Vaillant	aroTHERM plus VWL 125 / 6 A	R290
Viessmann	Vitocal 250-A	R290
Viessmann	Vitocal 252-A	R290
Wolf	CHA-07	R290
Wolf	CHA-10	R290

Hersteller	Modell	Kältemittel
Wasser-Wasser Wärmepumpe		
Hautec	H-HCW-PN 15	R290
Hautec	H-HCW-PN 21	R290
Hautec	H-HCW-PN 26	R290
Hautec	H-HCW-PN 30	R290
Hautec	H-HCW-PN 38	R290
Hautec	H-HCW-PN 45	R290
Warmwasser-Wärmepumpe		
Auer	Edel 80	R290
Auer	Edel 100	R290
Auer	Edel 150	R290
Auer	Edel 200 D/2	R290
Auer	Edel 270 D/2	R290
Auer	Edel 270 DE/2	R290
Auer	Edel WATER 100	R290
Auer	Edel WATER 150	R290
Auer	Edel WATER 200	R290
Auer	Edel WATER 270	R290
ecodesign	ED 100P	R290
ecodesign	ED 180P	R290
ecodesign	ED 100 KWL	R290
ecodesign	ED 180 KWL	R290
ecodesign	ED 100 RF	R290
ecodesign	ED 180 RF	R290
Vaillant	aroSTOR VWL BM 270/5	R290
Vaillant	aroSTOR VWL B 270/5	R290
Vaillant	aroSTOR VWL BM 200/5	R290
Vaillant	aroSTOR VWL B 200/5	R290
Sole-Wasser Wärmepumpe		
Ecoforest	ecoGEO B/C 1-6 PRO	R290
Ecoforest	ecoGEO AU6	
Hautec	H-HCS-PN 15	R290
Hautec	H-HCS-PN 21	R290
Hautec	H-HCS-PN 26	R290
Hautec	H-HCS-PN 30	R290
Hautec	H-HCS-PN 38	R290
Hautec	H-HCS-PN 45	R290
Heliotherm	SNTM 3-10	R290
Heliotherm	SNTM 5-15	R290

Source: Heat GmbH and Deutsche Umwelthilfe (DUH) (2022). Domestic heat pumps with natural refrigerants. Interim Report.

Investments and Subsidies to scale-up production

European manufacturers announced heavy **investment to scale up the production of HP**.
As EU policy tightens around the use of f-gases, the path to **changing to natural refrigerant alternatives** becomes even more obvious for ensuring **future-proof, sustainable** installations.

Panasonic to Launch Home R290 Air-to-Water Heat Pumps in Europe

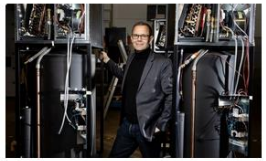
The new Aquarea L Series will launch in 2023, offering an A+++ high-efficiency rating and a SCOP of up to 5.12.

Read More

Viessmann to Accelerate NatRef Heat Pump Production with Site in Poland

Expanding its development of energy-efficient R290 heat pumps is helping Viessmann support the clean energy transition.

Read More



Swedish Manufacturer Qvantum Raises €42 Million for Accelerated R290 Residential Heat Pump Deployment

The funding will also support the completion of the company's production facility in Åstorp, Sweden.

Read More

Daikin To Introduce First Residential Propane Heat Pump

Daikin Europe is set to launch the new Altherma 4 air-to-water heat pump series at ISH 2023, including models running on natural refrigerant propane.

Read More

In Germany, subsidies for heat pumps cover up to **40%** of their cost. Heat pumps using natural refrigerants like propane are favoured.

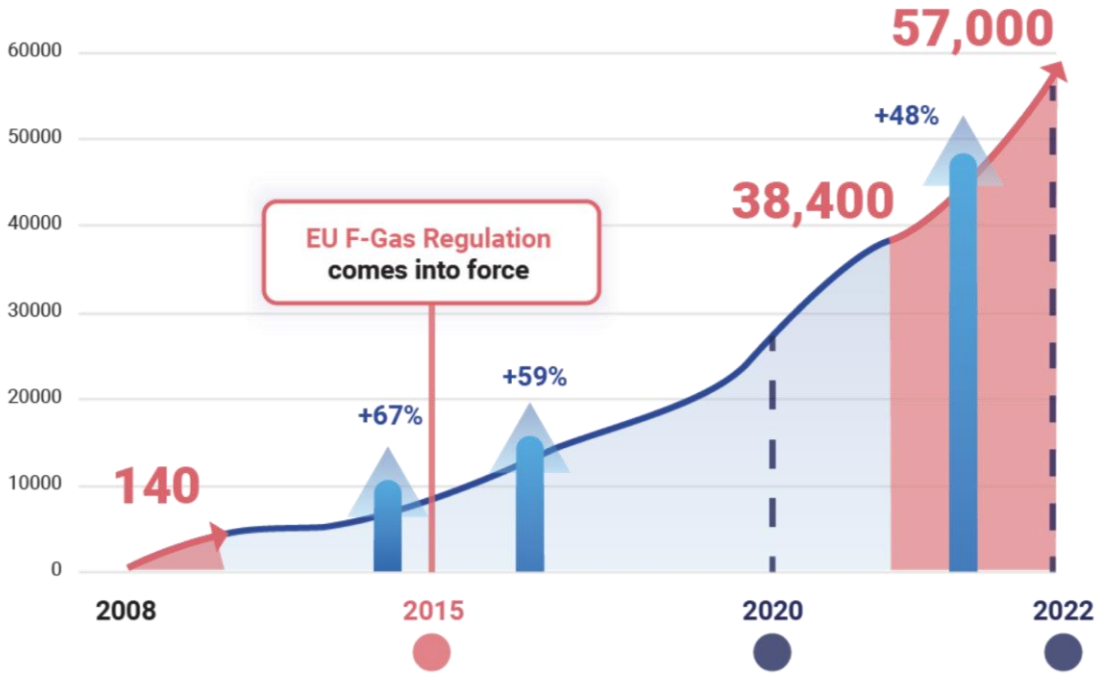
*"An **additional bonus of 5%** is therefore planned in the federal subsidy for efficient buildings for end customers purchasing a heat pump with natural refrigerant **from 1.1.2023**" **

From **2028** only natural refrigerant heat pumps will be subsidised.

Source: hydrocarbons21.com

Natural refrigerants in Commercial Refrigeration: a precedent

Evolution of the number of transcritical CO2 installations in Europe – commercial applications



In the last 10 years, NatRef have taken over commercial refrigeration.

From less than 10k supermarkets in Europe using natural refrigerants in 2015 to almost **60k** now.

An exponential growth:
the strongest growth correspond with the entry into force of the regulation:
+67% between 2014 and 2015 and
+59% between 2015 and 2016.

This relation proves that market players **are attentive to policy regulations and can respond promptly**.

Source: Atmosphere (2022). Natural Refrigerants: State of the Industry.

Next ATMO Heat Pumps Report: Spring 2023

ATMO sphere

Thank you for listening.

Session 1: Heat pumps based on natural refrigerants

Social Acceptance of Heat Pumps

Dr. Immanuel Stieß
Senior Researcher, Institute for Social-Ecological Research

07 February 2023: 14:00 - 18:00 L42, Rue de la Loi 42, Brussels

SOCIAL ACCEPTANCE OF HEAT PUMPS

Results from a stakeholder process in four European countries

Dr. Immanuel Stieß
ISOE – Institute for Social-Ecological Research,
Frankfurt a.M., Germany

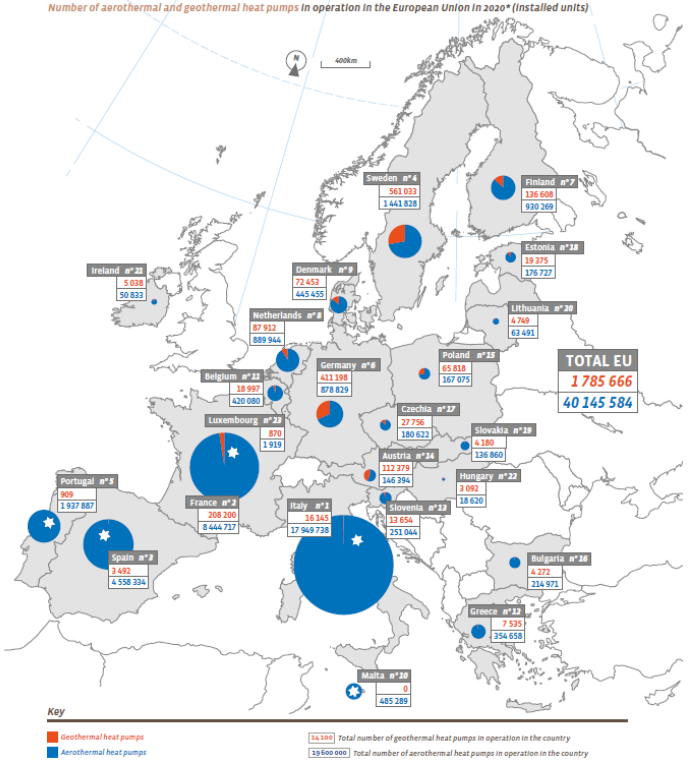
TRI-HP PROJECT
Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Table of content

- Background and objective
- Research Design
- Literature Review on Social Acceptance
- Stakeholder Interviews
- National Stakeholder Workshops
- Conclusions

Heat Pumps and energy transition

- increasing deployment of HP in most European countries.
- market share varies strongly between market segments and countries:
  - high market share in newly constructed SFH: above 90 % in Norway, Sweden and over 50% in Germany (2021).
  - refurbishment of MFB: HPs are used around 10 % in Austria, France and Germany (EurObserv'ER 2018).
- renovation market of MFB as a huge potential and challenge for HP



Quelle: Heat Pumps Barometer (2021)

Objective

- better understanding of barriers, hindrances and incentives to **market adoption** of heat pumps in in multi-family buildings.
  - identification of interests and needs of key stakeholder groups towards the adoption of HP
  - determination of benefits and incentives to overcome barriers
- cross-national perspective
  - identification of geographical, legal and cultural differences
- focus on **innovative** electric heat pumps (tri-generation, natural refrigerants, solar-ice…)

Research Design

Literature study on social acceptance of novel renewable energy powered heating and cooling systems

Expert interviews with key stakeholder in CH, ES, NO, and DE

Expert stakeholder workshops with key stakholder in CH, ES, NO, and DE

European level stakeholder workshop

December 10, 2019 (2.0) Report Open Access

Social issues of novel renewable energy heating/cooling syste

Friedrich, Thomas; Stieß, Immanuel;

This Deliverable 2.1 presents the results of Task 2.1 "Social issues enabling accepta and market barriers" of the TRI-HP project, which aims to develop systems based o heat pumps coupled with PV to pr

Uploaded on April 23, 2020

February 28, 2021 (1.0) Report Open Access

Social acceptance of innovative renewable heating and cooling systems: Barriers, hindrances, drivers and incentives (D2.2)

View

Friedrich, Thomas; Stieß, Immanuel;

Executive Summary Deliverable 2.2 presents the results of Task 2.3, "Social acceptance o and cooling (RE H/C) systems: barriers, hindrances, drivers and incentives". This task is p (WP 2) which has the overall objective t

Uploaded on September 10, 2021

August 31, 2021 (1.0) Report Open Access

Enhancing stakeholders' acceptance of trigeneration heating and cooling systems: Recommendations from the TRI-HP stakeholder process (D2.3)

View

Friedrich, Thomas; Stieß, Immanuel;

Executive Summary Deliverable D2.3 presents results on expert knowledge and stakeholder acceptance of trigeneration heating and cooling systems. This task has the overall objective to explore potential social implications of TRI-HP systems and improve stakeholders' acceptance towards these sy

Uploaded on September 10, 2021

social and market acceptance

- **social acceptance** of RE is widespread among European citizens.
- **market acceptance** of RET varies strongly among different stakeholders groups throughout Europe
- categories that drive market acceptance:
  - (1) economic-financial
  - (2) practical implementation and feasibility
  - (3) psychological, social-cultural and organizational issues
- perspectives of **key stakeholders** need to be taken into account!
  - **investors / building owners** who make investment decisions for a building
  - **planers and other decision makers for installation** of energy systems (architects, engineers, HVAC planners, plumbers, heating installers)
  - **building/facility managers** who are in charge of HP operation.

full report available at:
https://zenodo.org/communities/tri-hp

Stakeholder Interviews

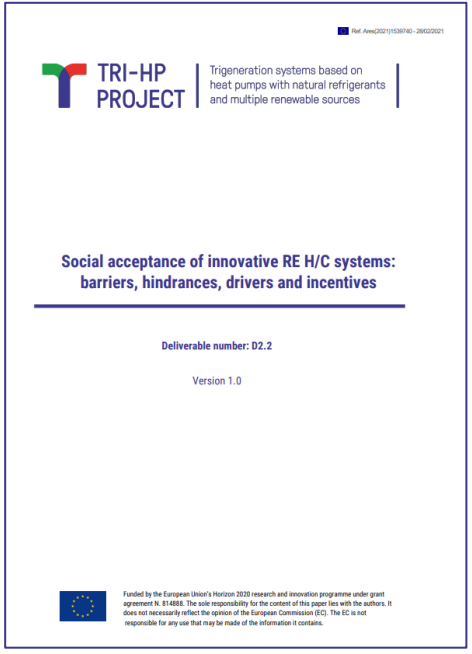
expert interview sample					
respondents: primary stakeholder assignment					
	DE	CH	ES	NO	Total
building owners, housing cooperatives, investors	1	2	2	2	**7**
HVAC consultants, planners	3	2	1	2	**8**
manufacturers, distributor	2	1	1	1	**5**
installers, craftsmen	2	1	2	1	**6**
architects	3	1	1	1	**6**
engineers	1	1	1	1	**4**
Total	**12**	**7**	**8**	**8**	**36**

<u>interview conduction:</u>

- 36 interviews conducted and fully transcribed
- 11% women,
- mean age: 50 years (28-72)
- transcripts fully analysed (qualitative content analysis)

Stakeholder Interviews

- barriers and drivers of market acceptance:
  - investment and upfront costs
  - public funding and support
  - practical feasibility of installation and maintenance
  - competence and skill
- **heating installers** as “middle actors”
  - important advisory function to end users
  - poor knowledge on HP technology
  - expertise and routines linked to fossil heating systems
  - low incentive to acquire additional knowledge through further qualification



full report available at:
https://zenodo.org/communities/tri-hp

Natural Refrigerants

Safety Risks

- safety risks of the use of NR in HP are considered to be rather low
- long tradition of using NRs such in the HC business
- existing standards and regulations
- installation and maintenance rules
- NR require **appropriate skills** and **higher effort** for installation!

Benefits

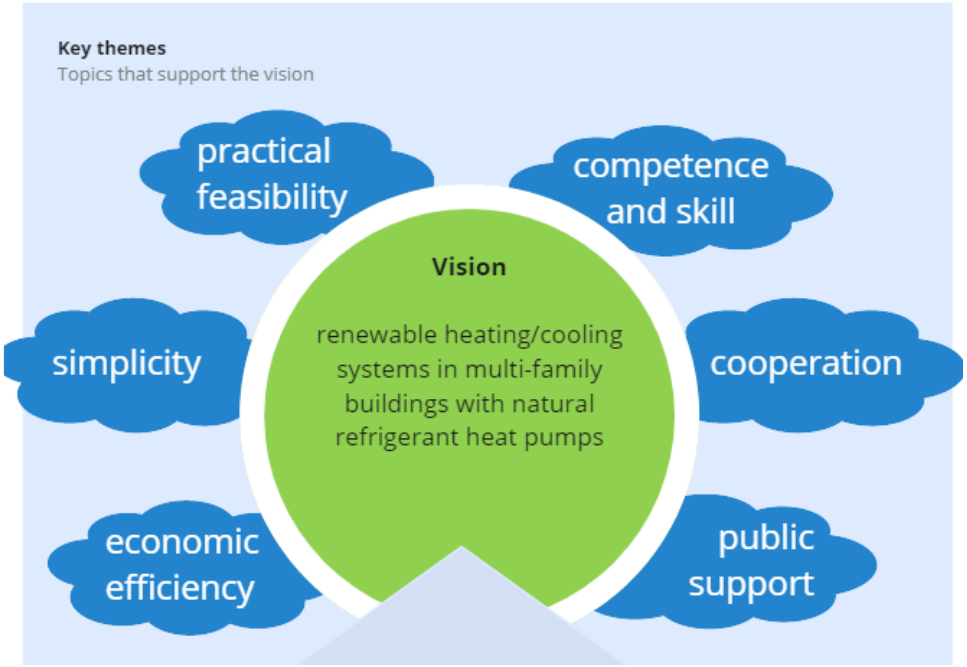
- high GWP and ODP of synthetic refrigerants as a threat to HP acceptance
- is climate friendly always good for the environment?
- higher efficiency of NR
- NR as sustainable long-term solution
- only little knowledge on NR among many stakeholders!

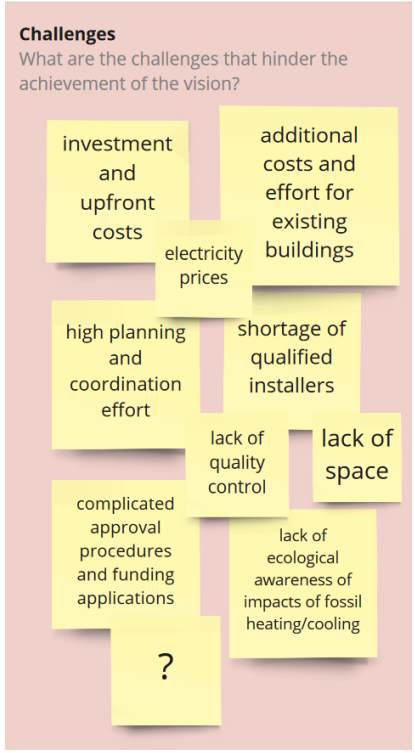
National Stakeholder Workshops

Stakeholder	Germany	Switzer-land	Spain	Norway
heat pump associations	X		X	X
heat pump (component) manufacturer	X	X	X	X
HVAC planners / energy counselling	X	X	X	X
installing / tradesmen associations	X			X
investors / housing company	X	X		X
facility management / energy contracting	X	X	X	X
architects / building engineers	X	X	X	
other		X	X	X

- 4 national stakeholder workshops
- June 2021
- online
- 2-3 hours
- ∅ 12 stakeholder

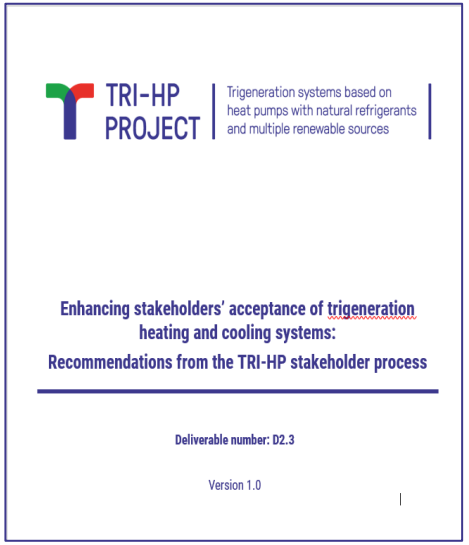
National Stakeholder Workshops





National Stakeholder Workshops

- important overall **challenges**:
  - investment and upfront costs
  - shortage of skilled workers
  - high planning and coordination effort (especially in existing buildings)
- suggestions for **solutions** (among others):
  - consideration of economic efficiency of H/C systems over the entire life cycle
  - more support for new business models such as energy contracting and new finance schemes
  - new finance and funding schemes
  - simplifying systems and providing easy-to-use planning tools
- frequently mentioned **key actors to drive solutions**: building owners, heating installers, HVAC planners



full report available at:
https://zenodo.org/communities/tri-hp

Conclusions

- **rapid market uptake** of HP has to address hindrances of key market actors and needs more **policy support**:
  - addressing the “lack of skills” with installers through a **structured training programme** which addresses the different needs in different Member States;
  - fostering a switch to **natural refrigerants** requiring additional safety measures in comparison to traditional ones (based on HFCs/HFOs).
- better support at EU-level for **new business models** for upscaling existing and developing new supply chains (collective purchases / procurement actions of heat pumps).
- need for a clear **roadmap** for the **phase-out** of **fossil-fuel based boilers** combined with a strategy for stronger market uptake of alternative solutions such as heat pumps.
- update of **Ecodesign & Energy Labelling** requirements at EU level for heating & cooling systems.
- **awareness raising** on HP benefits among stakeholders and general public.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this event lies with the organisers. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.

stiess@isoe.de
friedrich@isoe.de

www.tri-hp.eu

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Session 1: Heat pumps based on natural refrigerants

Q&A SESSION

07 February 2023: 14:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

TRI-HP Final Event:
Heat pumps on natural refrigerants in the context of the F-Gas Regulation Revision

SESSION 2: Phasing down F-Gases in Heat pumps

07 February 2023: 16:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

TRI-generation systems

- Based on electrically driven **natural refrigerant heat pumps** coupled with PV to provide **heating**, **cooling** and **electricity** to multi-family residential **buildings**

- Targets:
  - **80 % renewable on-site share** with net-zero energy concept (20 % exchanged with the grid)
  - **Cost reduction by 10 – 15 %** compared to current HP technologies with same energetic efficiency
  - **75 % GHG emissions reductions** respect to gas boiler and air chillers with grid purchased electricity.

www.tri-hp.eu

TRI-HP Final Event:
Heat pumps on natural refrigerants in the context of the F-Gas Regulation Revision

Session 2 – 16:00 – 18:00: F-Gas Regulation: Phasing down HFCs & HFOs in heat pumps	
16:00 – 16:20	**Overview of the F-Gas Regulation Revision** Arno Kaschl – Policy Officer at DG CLIMA, European Commission
16:20 – 16:35	**Opinion of European Economic and Social Committee on the Revision** Kęstutis Kupšys – Rapporteur of the European Economic and Social Committee (EESC) on the Revision
16:35 – 16:50	**Comparing the use of HFCs & HFOs with natural refrigerants in heat pumps** Prof. Dr. Michael Kauffeld – Karlsruhe University of Applied Sciences
16:50 – 17:05	**Negotiations in ENVI on the F-Gas Regulation Revision** Stelios Kympouropoulos – Shadow-Rapporteur (EPP) ENVI Committee for European Parliament
17:05 - 17:20	**Risks of rapid deployment of heat pumps based on natural refrigerants** Coen van de Sande - President Association of Refrigeration, Air Conditioning and Heat Pump contractors (AREA)
17:20 – 18:00	**Panel Discussion on the phase-down of F-Gases in heat pumps:** - Hilde Dhont - Refrigeration Task Force Member at EHPA - Veerle Beelaerts – European Heating Industry - Davide Sabbadin – European Environmental Bureau - Prof. Dr. Michael Kauffeld – Karlsruhe University of Applied Sciences

Session 2: Phasing down F-Gases in Heat pumps

OVERVIEW OF THE F-GAS REGULATION REVISION

Arno Kaschl
Policy Officer - DG CLIMA, European Commission

07 February 2023: 16:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

REHVA – TRI-HP project
Brussels, 7.2.2023

DELIVERING THE EUROPEAN GREEN DEAL

F-gas Regulation

The international context

Montreal Protocol on substances that deplete the ozone layer [and HFCs]:

- Since 1989 => Ozone hole recovery expected in second half of century
- Since 2019 phasing down HFCs (as greenhouse gases, not ozone depleting)

Protocol's contribution to Paris Agreement (max increase 2°C, ideally only 1.5°C)

- Global ODS phase-out avoiding at least 2°C increase in 2070 compared to historic baseline
- Global HFC phase-down avoiding around 0.4°C increase by the end of the century compared to historic baseline

Building on a great success!

Some highlights: within 5 years only (2015-2019)

- EU F-gas demand dropped 13%, HFC demand dropped 47% (CO2e)
- F-gases in imported equipment dropped by 33% (CO2e)
- Emission in the refrigeration sector dropped 62% (CO2e)
- More reclaimed gases and smaller leakage rates
- The F-gas Regulation has been an innovation driver:
  - companies using *natural* alternatives increased >60% from 2013 to 2016
  - >50,000 transcritical *CO2* systems installed in Europe, more than the rest of the world combined
  - >80% of refrigeration manufactures increased R&D (2011 to 2016).

Industry says: ***"EU F-gas Regulation is the Gold Standard" or***

"EU F-gas Regulation is in fact a World F-gas Regulation"

European Commission

Main changes to the F-gas Regulation

repealing (EU) 517/2014

A. Align to the Green Deal climate ambition

- Steeper phase down & new F-gas prohibitions
  Technically feasible, safe and energy efficient

B. Streamline with Montreal Protocol (Kigali Amendment)

- Phase down after 2030, remove some exemptions, new production phase-down

C. Better implementation and enforcement

- Specific customs related rules, quota allocation price, more standardised penalties and certification of technicians to include climate friendly gases.

D. Improve monitoring and reporting

E. Coherence and clarifications

European Commission

Most important new prohibitions for heatpumps

- Self-contained AC & heat pumps from 2025 (GWP 150)
- Smaller AC & heat pumps split systems from 2027 (GWP 150)
- AC & heat pumps split systems >12 kW from 2027 (GWP ≥ 750)

In addition to strict HFC phase-down (bans steering demand)

Impacts of the proposal

- **Emission reductions:** Avoid cumulatively 310 MtCO2e on top of the 420 MtCO2e achieved through current Regulation by 2050 (i.e. in total same as GHG emissions in 2019 in BENELUX + FRANCE)
- **Climate neutrality**: Emissions in 2050 estimated to be 14 MtCO2e (92 MtCO2 in 2019).
- **Overall costs** to consumers will be moderate and even negative due to energy savings in refrigeration and AC
- **Reducing HFC use = lowering EU dependency** on imports
- **Better control** and less illegal trade
- Green **innovation and growth**

Links between the F-gas proposal, and climate and energy targets

- F-gas Regulation is part of the “honeycomb of measures” to achieve 2030 and 2050 (climate neutrality) targets!

- F-gas emissions are part of Effort Sharing Regulation on non-ETS sectors!

- Link to other areas: Heat pumps are essential to achieve GHG emissions from buildings and heating and cooling (RED II, EED, EPBD targets)

Repower EU

- REPowerEU, asks for around 30 million new heatpumps by 2030

  → Huge business opportunity for the sector

- **Production capacties are needed**, let‘s make them future-proof!

- Fgas rules enable companies to **make the shift to climate-friendly alternatives now**. This is a first mover advantage.

- **Enought quotas ystem for all heatpumps requiring HFCs**. This has been modelled. The additional heatpump growth does not exceed 10% of available quota per year. There are large buffers in the quota system

- **Avoid locking in direct emissions** for decades from leaking HFC equipment

- End-users will have **energy savings**. Overall consumer costs will not increase. HFC dependencies (China) are reduced.

On-going negotiations

„Co-legislators“:

- Council (Member States): working on a joint position on the basis of which they will negotiate with the European Parliament
- European Parliament:
  - Industry, Research and Energy (ITRE) Committee voted in January
  - Environnment, Public Health and Safety (ENVI) committee planned vote in March.
  - Plenary vote likely to be in April.
- Trialogues between the Council and the Parliament to be held in May/June?

→ A conclusion of the negotiations by summer could mean the Regulation would apply from 1 January 2024

Thank you

arno.kaschl@ec.europa.eu

European Commission

Session 2: Phasing down F-Gases in Heat pumps

OPINION OF EUROPEAN ECONOMIC AND SOCIAL COMMITTEE ON THE REVISION

Kęstutis Kupšys
Rapporteur on the Revision, European Economic and Social Committee (EESC)

07 February 2023: 16:00 - 18:00 L42, Rue de la Loi 42, Brussels

WHAT DOES ORGANISED CIVIL SOCIETY MEAN?

It comprises all the groups and organisations in which people work cooperatively:

Employers

Employers federations, Chambers of Commerce, SME organisations…

Workers

Trade Unions

Civil Society Organisations

Farmers, Consumers, NGOs, Professions, Disabilities, Academics, Cooperatives…

They are committed to defending their interests and causes, and they often act as intermediaries between decision-makers and citizens.

Key points of the EESC Opinion on Revision of the F-gas regulation

Adopted on 15 June 2022

EESC:

- Welcomes the new Commission's proposal on fluorinated gases as a step into the right direction but **sees room for more ambition to maintain the global EU leadership in climate action**.
- Believes that improving the Commission's current proposal presents an additional opportunity to significantly reduce direct climate impacts by promoting natural solutions with a low global warming potential (GWP) instead of continuing to use hydrofluorocarbons (HFCs) with a high global warming potential.
- Is therefore **in favour of a ban on all refrigerants with a GWP >5 after 2030** for heat pumps, room air-conditioners, chillers, and refrigeration applications alternatives. This sends a clear message to the market, is administratively easy to implement, and faces a low risk of circumvention.
- Strongly recommends **combining REPower EU ambition with the F-gas phase-out**, aiming for refrigerants with the lowest possible GWP, especially in the field of heat pumps.

EESC also:

- Believes that **fears of market bottlenecks in the sector are unfounded** due to the increased production capacity of the industry, which will be mostly based on natural refrigerants. The EU has a clear opportunity to make this an **exemplary case in setting global green standards**.

- Considers the current quota charge too low and **calls for a mechanism to increase income from quota sales**. This income can be earmarked to boost customs controls at Member State level, to help with the adoption of low-GWP alternatives and to provide sufficient training to the installers of the equipment concerned.

- Believes that **addressing training needs on HFC alternatives is key**. Skilled technicians, as well as qualification, certification and registration schemes are essential for promoting low-GWP natural refrigerants.

Concrete steps in the right direction?

AREA campaign entitled
Grow your business: Get ready for flammable refrigerants!

Thank you for listening!

Għandkom xi mistoqsijiet?

Spørgsmål?

Имате ли въпроси?

Avez-vous des questions à poser?

Domande?

Kysymyksiä?

Kas on veel küsimusi?

Έχετε ερωτήσεις;

Vannak-e kérdések?

Any questions?

An bhfuil aon cheist agat?

Perguntas?

Máte dotazy?

¿Alguna pregunta?

Haben Sie noch Fragen?

Întrebări?

Czy mają Państwo jakieś pytania?

Frågor?

Ima li pitanja?

Jautājumi?

Vragen?

Otázky?

Vprašanja?

Ar turite klausimų?

Session 2: Phasing down F-Gases in Heat pumps

NEGOTIATIONS IN ENVI ON THE F-GAS REGULATION REVISION

Stelios Kympouropoulos
Shadow-Rapporteur (EPP) ENVI Committee,
European Parliament

07 February 2023: 16:00 - 18:00 L42, Rue de la Loi 42, Brussels

Session 2: Phasing down F-Gases in Heat pumps

COMPARING THE USE OF HFCs & HFOs WITH NATURAL REFRIGERANTS IN HEAT PUMPS

Michael Kauffeld
Professor in Refrigeration Engineering
Karlsruhe University of Applied Sciences

07 February 2023: 16:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Hochschule Karlsruhe
University of
Applied Sciences

Institut für
Kälte-, Klima- und Umwelttechnik

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

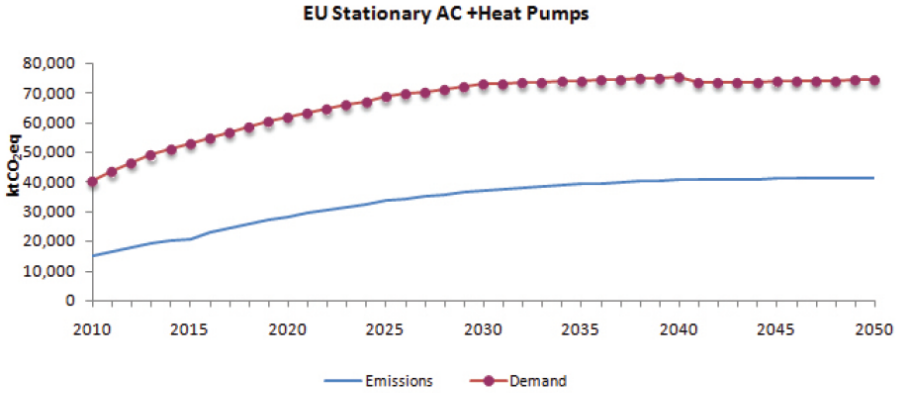
Comparing the use of HFCs & HFOs with natural refrigerants in heat pumps

Prof. Dr.-Ing. habil. Michael Kauffeld
Karlsruhe University of Applied Sciences
Institute of Refrigeration, Air-Conditioning and Environmental Engineering

Tuesday, 7th February 2023

HFC emissions from heat pumps

Kauffeld, M.: Availability of low GWP alternatives to HFCs Feasibility of an early phase-out of HFCs by 2020. EIA report – Environmental Investigation Agency, May 2012



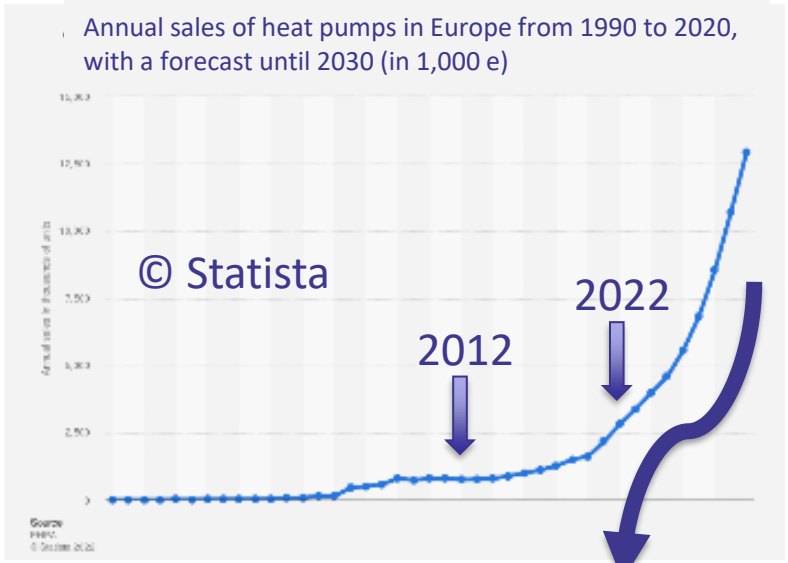
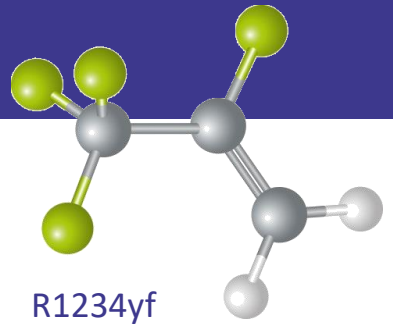


Figure 2.11

Trend of HFC demand and emissions under the current European F-Gas Regulation scenario in stationary air conditioning and heat pumps. Before 2035 where the market is saturated, considerable growth is assumed, which makes stationary air conditioning the largest individual HFC sector in Europe. The demand includes HFCs in imported pre-filled systems.[128]

Much higher GHG-emissions to be expected, due to (unexpected) increase in HP sales

Low GWP Refrigerants



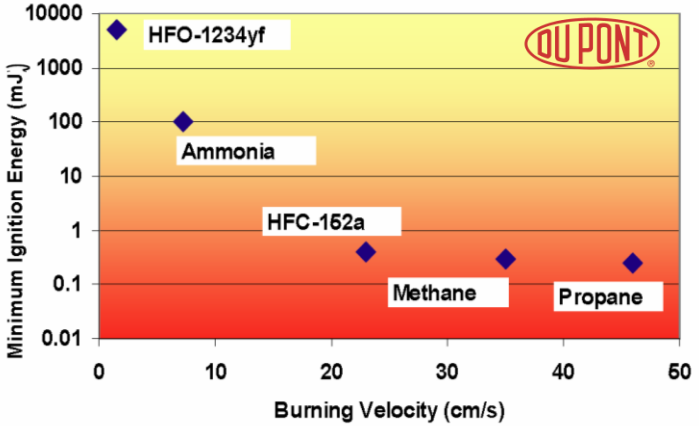
R1234yf

© www.autofficinecarrozzerie.it

The Answer from the Chemical Industry: HFO = unsaturated HFC

e.g. R1225ye(Z), R1225ye(E). R1234yf, R1234ze(Z) or R1234zf
or Blends of HFO + HFC *(Temperature Glide !!!)*

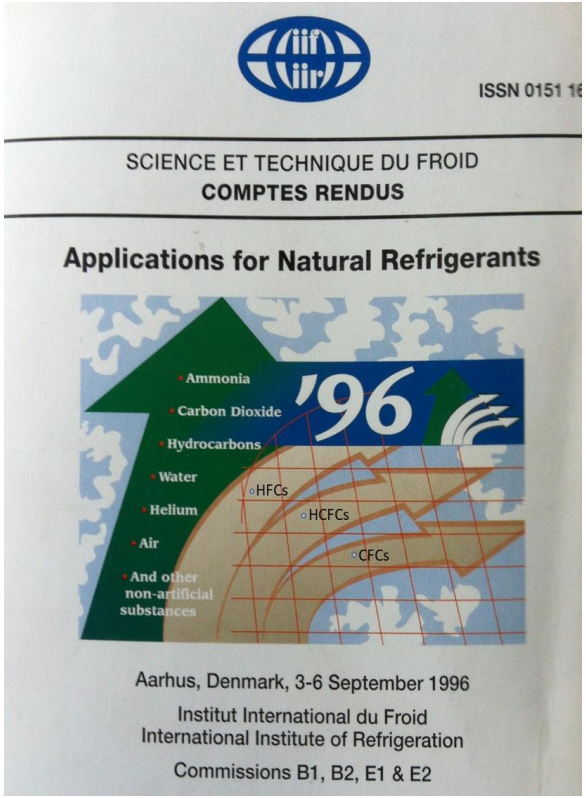
- ☐ Quick break down in atmosphere → GWP of 1 – 5
- ☐ 4 – 5 times more TFA after break down in atmosphere than R134a
  - → From car air conditioning alone up to twice the TFA-concentration in atmosphere than before (natural + man made)
  - → TFA is very stable in environment → Accumulation in terminal water bodies
- ☐ (Mildly) flammable → ASHRAE class 2L
  - ■ Flame propagation velocity lower than for HCs (1.5 cm/s instead of 46 cm/s)
  - ■ Required ignition energy much higher than for HCs (5,000 – 10,0000 mJ instead of 0.25 mJ)
  - ■ Heat of combustion 5-times lower than HC
  - ■ Auto ignition temperature similar to HCs, i.e. ≈ 400 °C
- ☐ Form Hydrogen Fluoride (HF) upon combustion
- ☐ Health issues at high concentrations for prolonged time periods due to high reactivity
- ☐ HCFC by-products during manufacturing
- ☐ Still very expensive



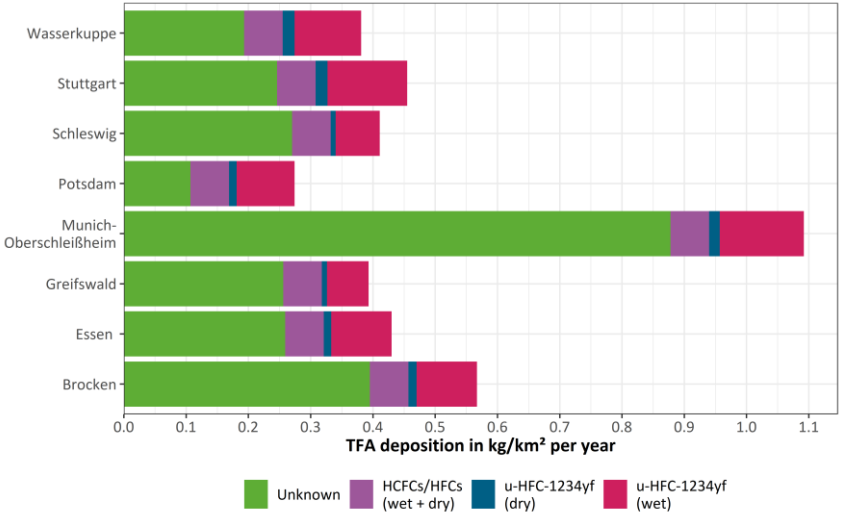
HFO – a personal view (initially shown at Euroshop 2017)

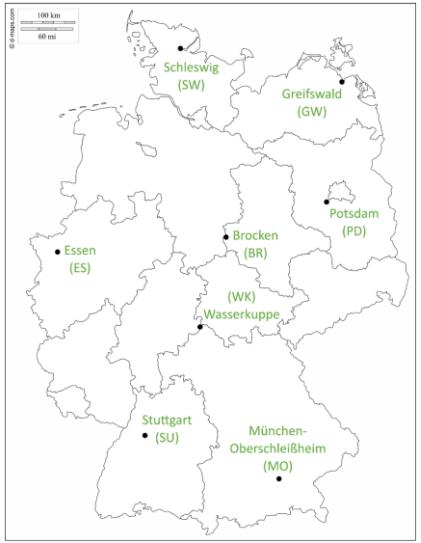
60 – 30 – 15

- It took 60 years (1930 to 1990) to find out that CFCs damage the ozone layer
- It took 30 years (1990 to 2020) to acknowledge HFCs contribute noticeable to global warming
- It will take 15 years to accept that HFOs are harmful to the local environment *(fitter's health and terminal water bodies)*



German UBA Study 2021

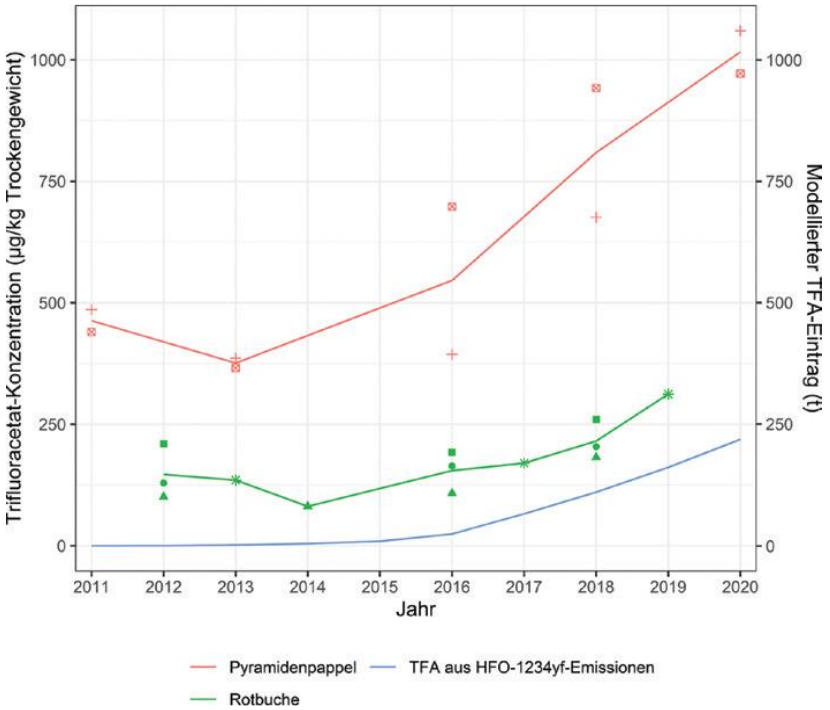




Behringer, D.; Heydel, F.; Gschrey, B.; Osterheld, S.; Schwarz, W.; Warncke, C.; Feeling, F.; Nödler, K.; Henne, S.; Reimann, S.; Bleep, M.; Jörß, W.; Liu, R.; Ludig, S.; Rüdenauer, I.; Gartiser, S.: (2021). Report No. FB000452/ENG, Persistent degradation products of halogenated refrigerants and blowing agents in the environment: type, environmental concentrations, and fate with particular regard to new halogenated substitutes with low global warming potential, Published by German Environment Agency May 2021.

Assuming that the concentrations in Bayreuth in 1995/1996 (Klein 1997) were representative for the whole of Germany, the trifluoroacetate deposition in these periods amounted to 54 to 65 g/km^2 or 19 to 23 tonnes, which would also be about 3 to 5 times lower than the values determined in February 2018 to January 2020.

Trifluoroacetate – TFA is accumulating in biosphere



TFA concentration in rain water increased by a factor of 3 to 5 over the past 23 years in Germany reaching concentrations of 38 µg/L in 2018.

In the USA, the concentration of TFA in surface waters increased by a factor of 6-fold in 23 years to as much as 2.79 µg/L in 2021, and in China between 2002 and 2012 by a factor of 17 to up to 0.83 µg/L.

TFA has been detected in almost all recent ground- and spring water samples of recently investigated drinking water sources in Germany; in some cases concentrations are up to 12.4 µg/L, which is above the threshold value of the UBA of 10 µg/L for drinking water.

Behringer, David. "TFA als persistentes Abbauprodukt fluorierter Kohlenwasserstoffe" *Public Health Forum*, vol. 30, no. 4, 2022, pp. 269-272. https://doi.org/10.1515/pubhef-2022-0077

TFA in the Rhine river

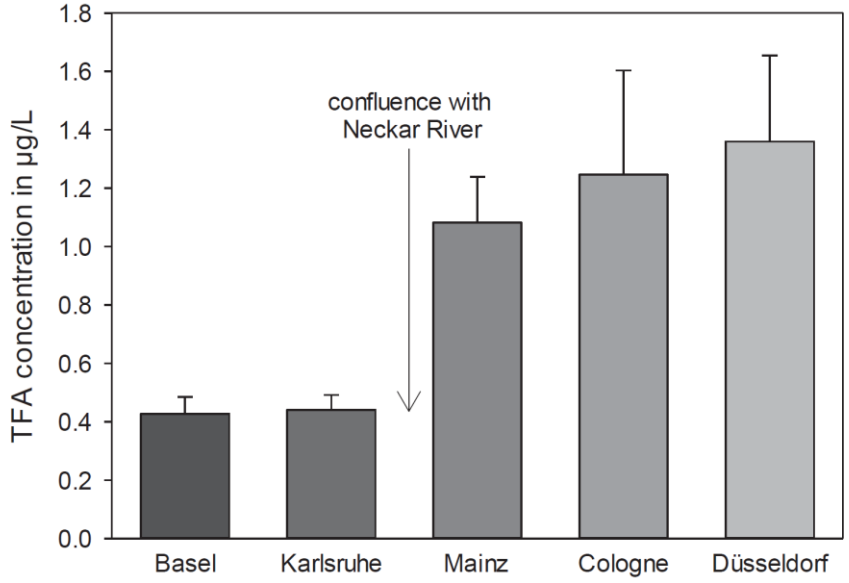


Fig. 2. Mean TFA concentrations at sampling points along the Rhine River. Samples were taken at 28 d intervals (n = 4 for Basel, n = 6 for Karlsruhe and n = 5 for all other sampling points).

Scheurer, M.; Nödler, K.; Freeling, F.; Janda, J.; Happel, O.; Riegel, M.; Müller, U.; Storck, F.R.; Fleig, M.; Lange, F.T.; Brunsch, A.; Brauch, H.-J.: Small, mobile, persistent: Trifluoroacetate in the water cycle – Overlooked sources, pathways, and consequences for drinking water supply. Water Research, Vol. 126, 2017, P. 460-471, ISSN 0043-1354, https://doi.org/10.1016/j.watres.2017.09.045

TFA in Swiss lakes

German DVGW in Karlsruhe analyzed 9 selected water samples on behalf of Swiss environmental organisation ohneGift

TFA concentrations in drinking water obtained from Lake Zurich, Lake Biel and Lake Murten correspond to the concentrations in the respective lake.

The treatment processes of the Swiss lake water works are powerless against TFA. Roman Wiget, drinking water expert and managing director of Seeländische Wasserversorgung (SWG) warns: **"At present, no method is known by which TFA could be removed from the water cycle by proportionate means, i.e. without very high technical and financial expenditure. The substance particularly affects those drinking water users who receive treated lake water"**.

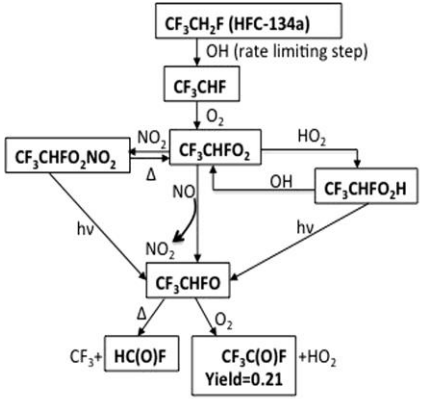
Drinking water of Birrwil, which comes from a groundwater well, is also contaminated with TFA.

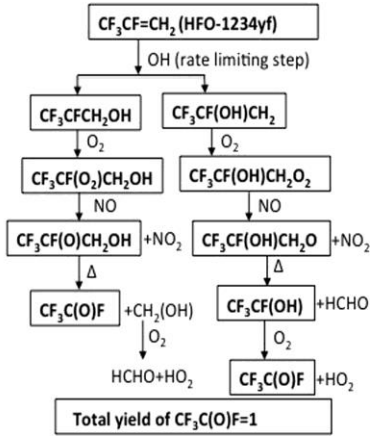
The affected population does not receive any information on TFA.

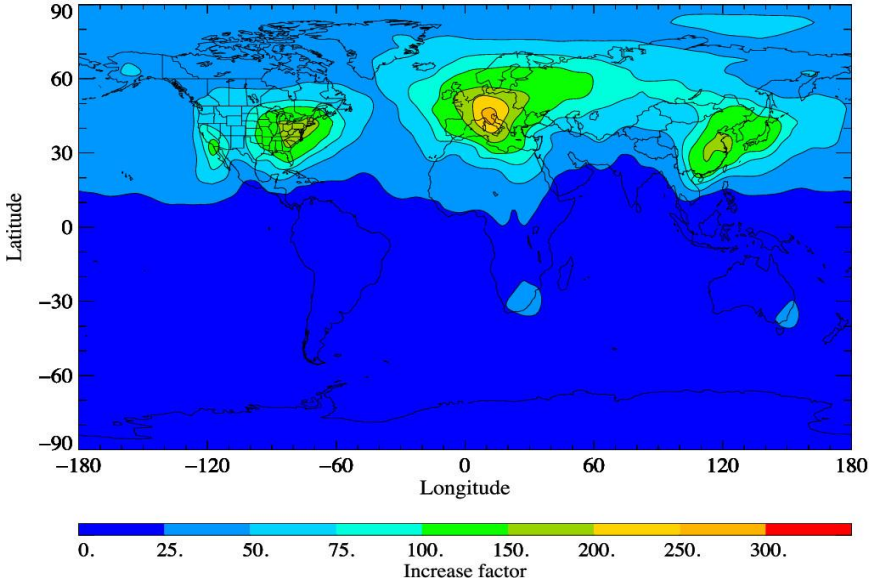
Place of sample	TFA in lake water (µg/l)	TFA in drinking water (µg/l)
Biel	0.41	0.45
Murten	0.91	0.80
Zurich	0.25	0.25
Birrwil	0.54	0.67
Limmat, Schlieren, 2 km after ARA Werdhölzli Zürich	0.33	

Source: Trifluoracetat – für immer in unserem Trinkwasser? | Naturschutz.ch

Increase in TFA distribution when changing from HFC to HFO







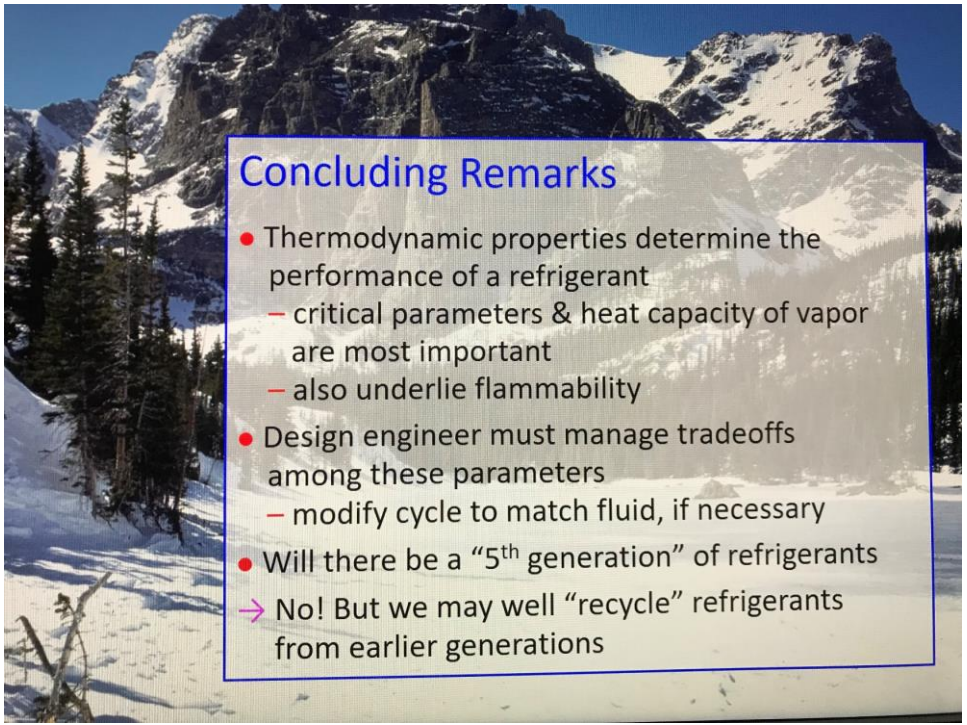
Degradation Mechanisms of HFC-134a and HFO-1234yf Oxidation by OH

For HFO-1234yf, the formations of organic hydroperoxides (reaction between a peroxy radical and HO_2 radicals) and peroxy nitrates (reaction of peroxy radicals with NO_2) from the OH-initiated oxidation products, and their fates, occur in the same way as shown for HFC-134a but are not shown in the diagram.

Surface distribution plot depicting the multiplicative increase in TFA distributions predicted by changeover from the STO-HFC-SCI scenario to the STO-HFO-SCI scenario.

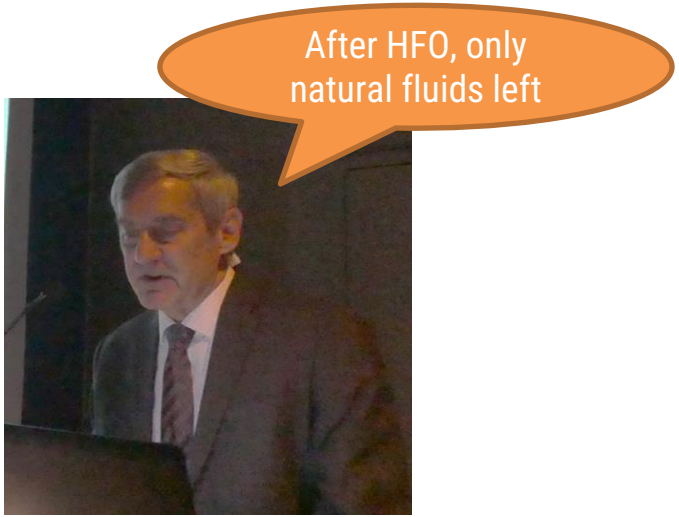
Holland, R.; Khan, M.A.H.; Driscoll, I.; Chantyal-Pun, R.; Derwent, R.G.; Taatjes, C.A.; Orr-Ewing, A.J.; Carl J. Percival, C.J.; Shallcross, D.E.: 2021. Investigation of the production of Trifluoroacetic Acid from two Halocarbons, HFC-134a and HFO-1234yf and its fates using a global three-dimensional chemical transport model. ACS Earth Space Chem.

There will not be a 5th Refrigerant Generation !!!



Mark McLinden, NIST: ***Thermodynamics of the new refrigerants****. IIR ICR 2019, Montreal*

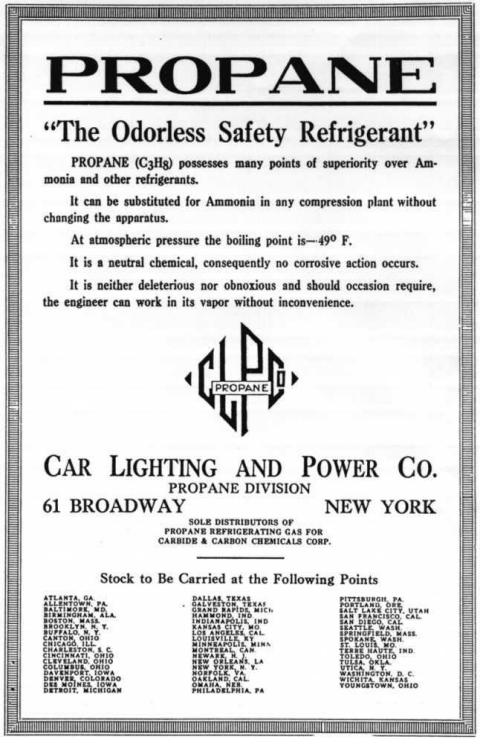
Thermodynamic Analysis of **60 Mio. Chemicals**



There are Alternatives to HFO

- ☐ Ammonia
- ☐ CO_2
- ☐ Propane
- ☐ Propene
- ☐ Iso-Butane
- ☐ Water

Ad in American refrigeration magazine (1922)



PROPANE

"The Odorless Safety Refrigerant"

PROPANE (C_3H_8) possesses many points of superiority over Ammonia and other refrigerants.

It can be substituted for Ammonia in any compression plant without changing the apparatus.

At atmospheric pressure the boiling point is—49° F.

It is a neutral chemical, consequently no corrosive action occurs.

It is neither deleterious nor obnoxious and should occasion require, the engineer can work in its vapor without inconvenience.

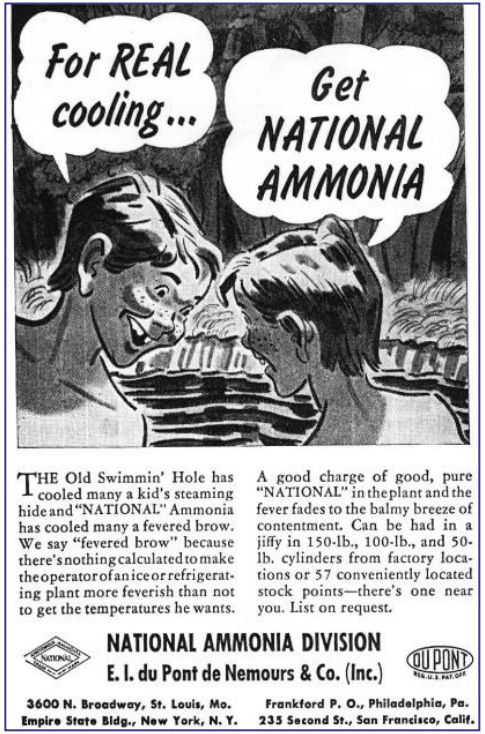
CAR LIGHTING AND POWER CO.
PROPANE DIVISION
61 BROADWAY NEW YORK

SOLE DISTRIBUTORS OF
PROPANE REFRIGERATING GAS FOR
CARBIDE & CARBON CHEMICALS CORP.

Stock to Be Carried at the Following Points

ATLANTA, GA.
ALLENTOWN, PA.
BALTIMORE, MD.
BIRMINGHAM, ALA.
BOSTON, MASS.
BROOKLYN, N. Y.
BUFFALO, N. Y.
CANTON, OHIO
CHICAGO, ILL.
CHARLESTON, S. C.
CINCINNATI, OHIO
CLEVELAND, OHIO
COLUMBUS, OHIO
DAVENPORT, IOWA
DENVER, COLORADO
DES MOINES, IOWA
DETROIT, MICHIGAN
DALLAS, TEXAS
GALVESTON, TEXAS
GRAND RAPIDS, MICH.
HAMMOND, IND.
INDIANAPOLIS, IND.
KANSAS CITY, MO.
LOS ANGELES, CAL.
LOUISVILLE, KY.
MINNEAPOLIS, MINN.
MONTREAL, CAN.
NEWARK, N. J.
NEW ORLEANS, LA.
NEW YORK, N. Y.
NORFOLK, VA.
OAKLAND, CAL.
OMAHA, NEB.
PHILADELPHIA, PA.
PITTSBURGH, PA.
PORTLAND, ORE.
SALT LAKE CITY, UTAH
SAN FRANCISCO, CAL.
SAN DIEGO, CAL.
SEATTLE, WASH.
SPRINGFIELD, MASS.
SPOKANE, WASH.
ST. LOUIS, MO.
TERRE HAUTE, IND.
TOLEDO, OHIO
TULSA, OKLA.
UTICA, N. Y.
WASHINGTON, D. C.
WICHITA, KANSAS
YOUNGSTOWN, OHIO

Ad in American refrigeration magazine (1943)



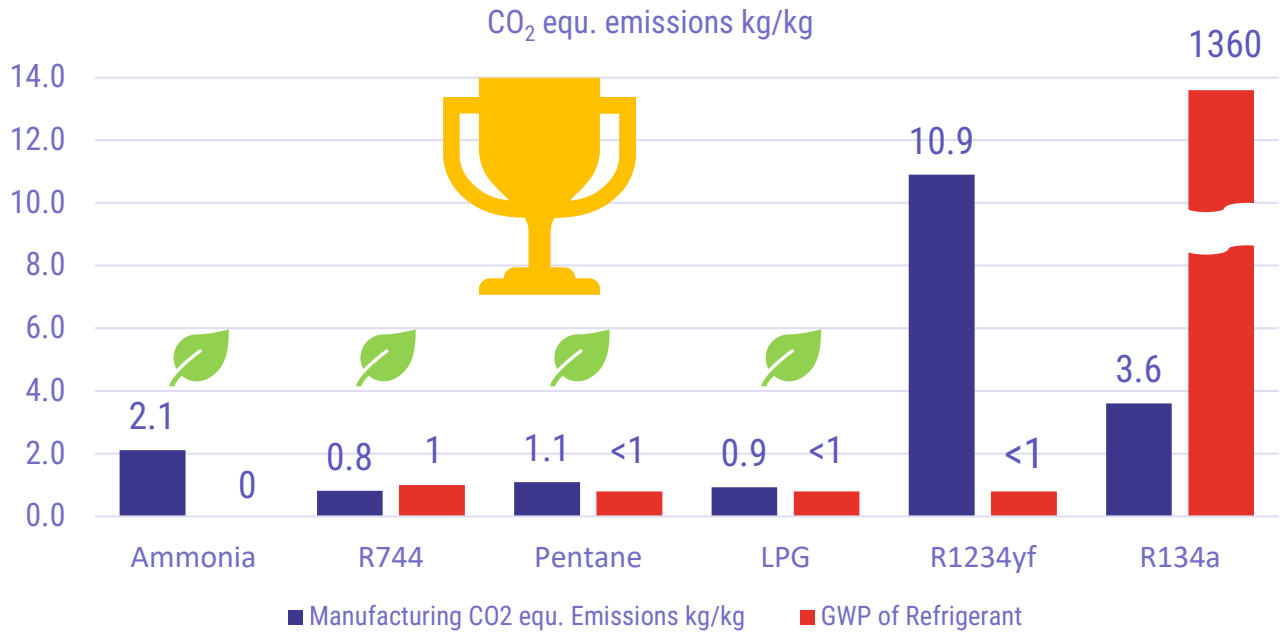
THE Old Swimmin' Hole has cooled many a kid's steaming hide and "NATIONAL" Ammonia has cooled many a fevered brow. We say "fevered brow" because there's nothing calculated to make the operator of an ice or refrigerating plant more feverish than not to get the temperatures he wants.

A good charge of good, pure "NATIONAL" in the plant and the fever fades to the balmy breeze of contentment. Can be had in a jiffy in 150-lb., 100-lb., and 50-lb. cylinders from factory locations or 57 conveniently located stock points—there's one near you. List on request.

NATIONAL AMMONIA DIVISION
E. I. du Pont de Nemours & Co. (Inc.)

3600 N. Broadway, St. Louis, Mo.
Empire State Bldg., New York, N. Y.
Frankford P. O., Philadelphia, Pa.
235 Second St., San Francisco, Calif.

Refrigerant Production related CO_2 emissions



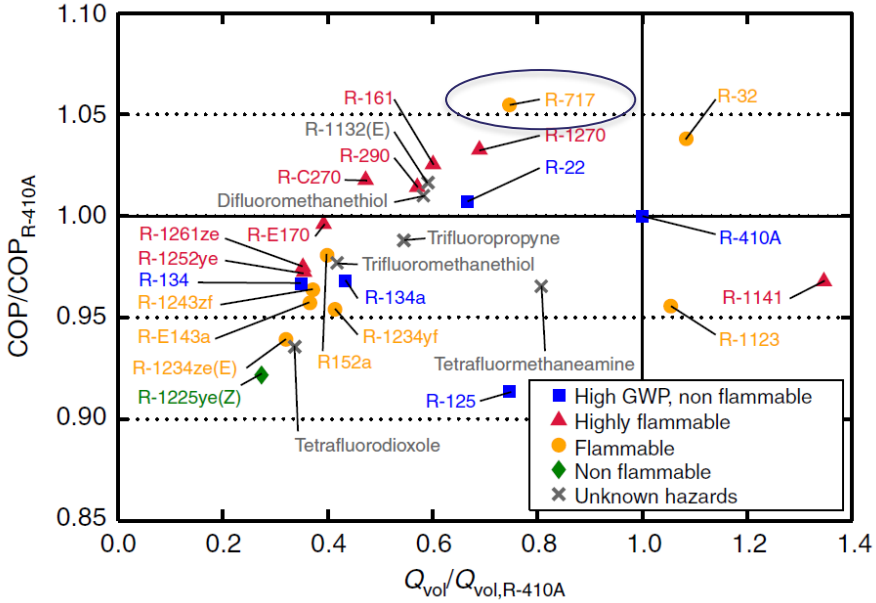
Refrigerant	GWP_{20}
Ammonia	0
R744 (CO_2)	1
Pentane	1,4
R1234yf	1
R1234ze	4
R134a	3810

GWP_{20} from UNEP RTOC 2018 Assessment report

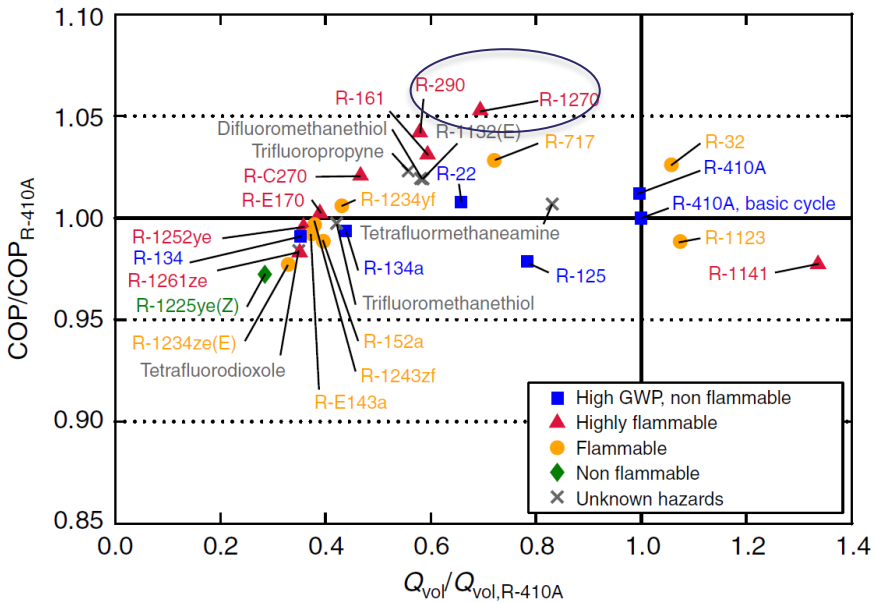
- *Baral, A.; Minjares, R.; Urban, R.A.: Upstream climate impacts from production of R-134a and R-1234yf refrigerants used in mobile air conditioning systems. International Council on Clean Transportation, 2013*
- *Wood, S.; Cowie, A.: A Review of Greenhouse Gas Emission Factors for Fertiliser Production. IEA Bioenergy Task 38, June 2004*
- *Winnipeg Sewage Treatment Program South End Plant. Process selection report. Appendix 7, 2011*

Energy efficiency of selected heat pump fluids

Without suction line heat exchanger



With suction line heat exchanger



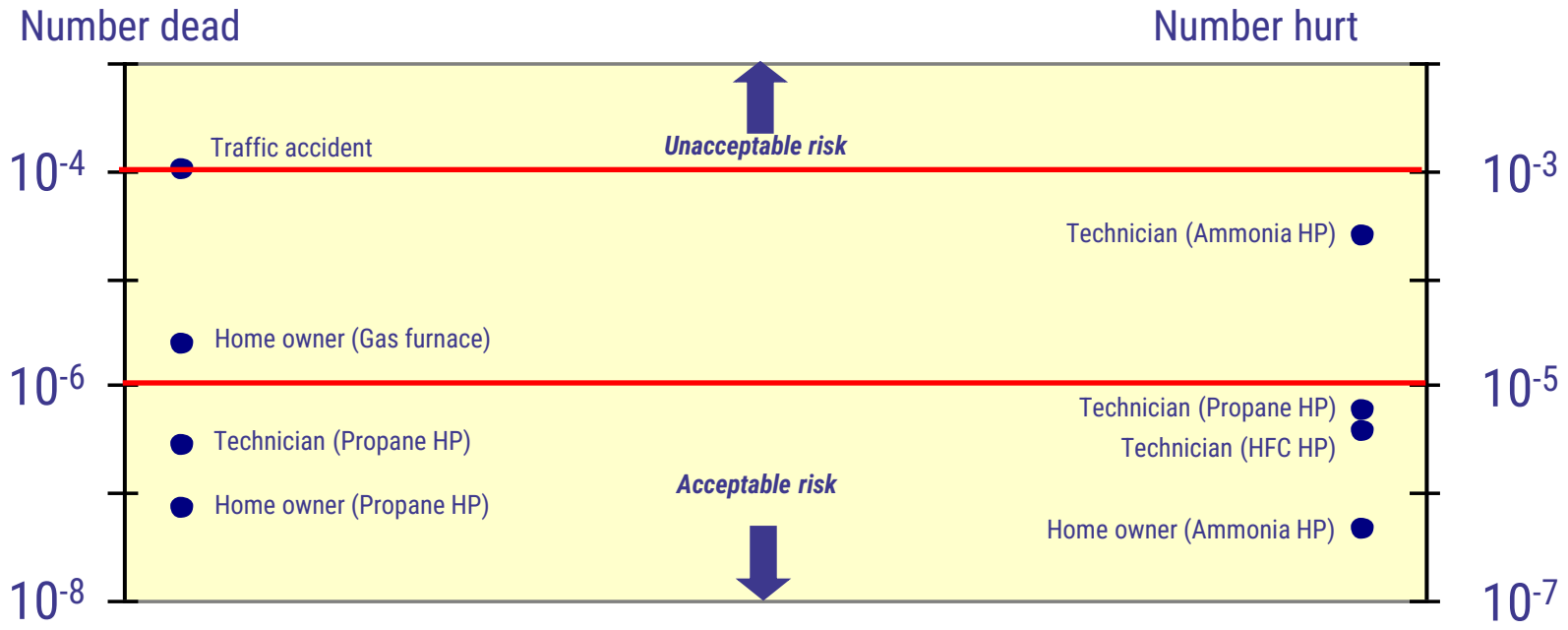
McLinden, M., Brown, J., Brignoli, R. *et al.* Limited options for low-global-warming-potential refrigerants. *Nat Commun* **8**, 14476 (2017). https://doi.org/10.1038/ncomms14476

Energy efficiency of selected heat pump fluids

Example air-to-water HP for multi-family house

Manufacturer	Refrigerant	$SCOP_H$	Max. t in °C
Ochsner	R407C	3.83	65
Aereco	R410A	4.92	60
Hitachi	R410A	4.3	60
Austria Email	R452B	4.4	60
Hisense	R32	5.1	60
Swegon	R32	5.0	58
Hoval	R290	5.7	70
Wolf	R290	5.46	70

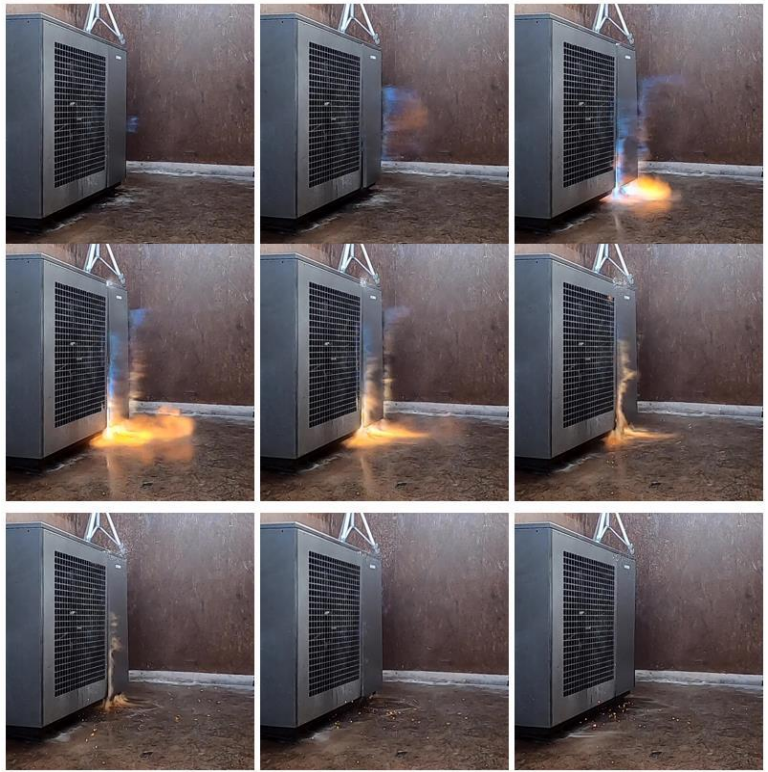
Risk with heat pump with flammable/toxic refrigerant



Heat pump with 1 kg refrigerant charge in separate room in basement

Wolfer, M.; Seitz, E.: Ammoniak und Kohlenwasserstoffe als Kältemittel: Risikoanalyse, Produktshaftpflicht und Strafrecht. Schlussbericht BFE-Forschungsprogramm Umgebungswärme, Zürich, Nov. 1999

Risk with heat pump with flammable/toxic refrigerant



Igniting an optimal Propane / Air mixture in the compressor compartment
(conc. 4,2…5,2 Vol.-% R290 / Air)

- 0.16 s flame, max 50 cm from housing
- No explosion
- No flame going into the system
- No parts which are blown away

H. König, Th. Hackensellner, G. Jager: Risikoanalyse für Wärmepumpen mit R-290, Entwicklung einer Risikomatrix als Akzeptanzkriterium. DKV Tagung 2022 in Magdeburg

LC150 – a benchmark for small heat pumps using propane

Results

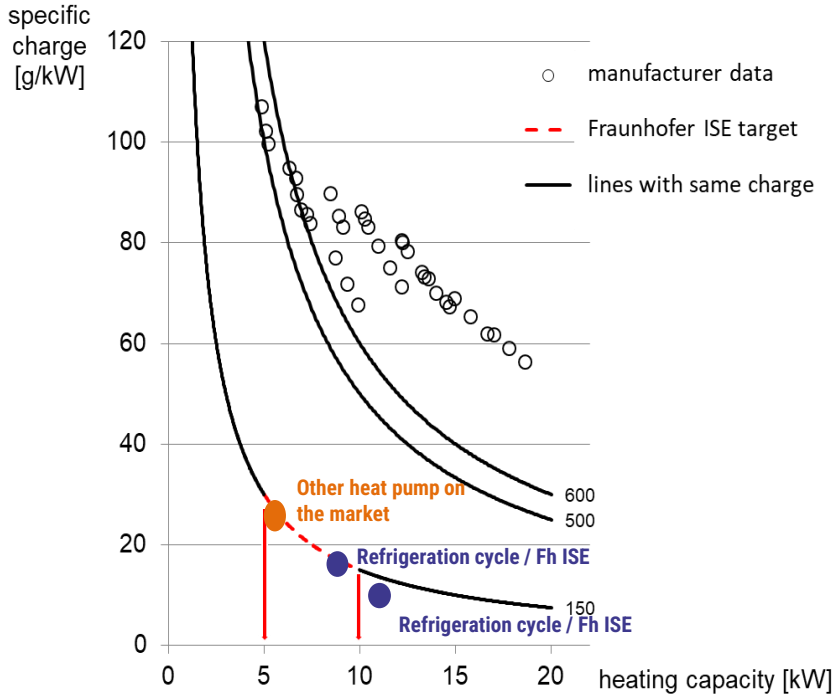
– **Reduction of refrigerant charge by up to 75%:**

» Refrigeration circuits with 150 g R290 and a heating capacity of 8-12 kW and good efficiencies (SCOP > 4.3).

– **Comprehensive database for components;** simulation-based and experimental evaluation of more than 30 different refrigeration circuits

– **Evaluated and Automated test procedure** for refrigeration circuits at different refrigerant charges and operation conditions, automated data evaluation

– **Recent work**: long-term testing of best-off circuits, evaluation of safety concepts



Manufacturer data from Market research by Fh ISE. Year 2019

Future heat pumps

1. Low direct emissions of greenhouse gases
   - Use low GWP natural refrigerants
     - NOT use HFOs due to TFA formation in atmosphere
   - Reduced refrigerant charge quantity, especially when using hydrocarbons
2. Reduce indirect greenhouse gas emissions
   - Reduce energy consumption – propane is one of the most energy efficient fluids
   - Run on renewable energies
   - Utilize waste, for example heat from refrigeration and air conditioning systems
   - Use refrigerants with low GHG emissions during manufacturing
3. Thermal energy storage

Questions?

Prof. Dr.-Ing. habil. Michael Kauffeld

Karlsruhe University of Applied Sciences

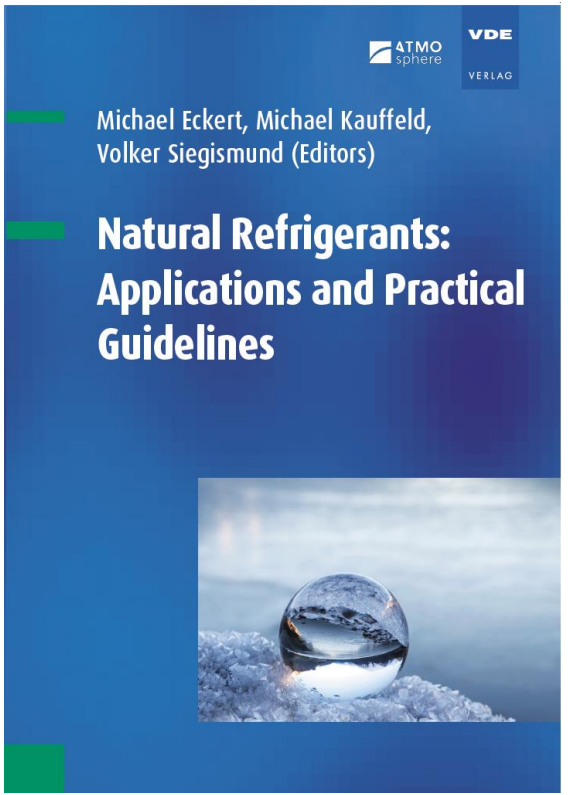
Institute of Refrigeration, Air Conditioning and Environmental Engineering

Moltkestr. 30

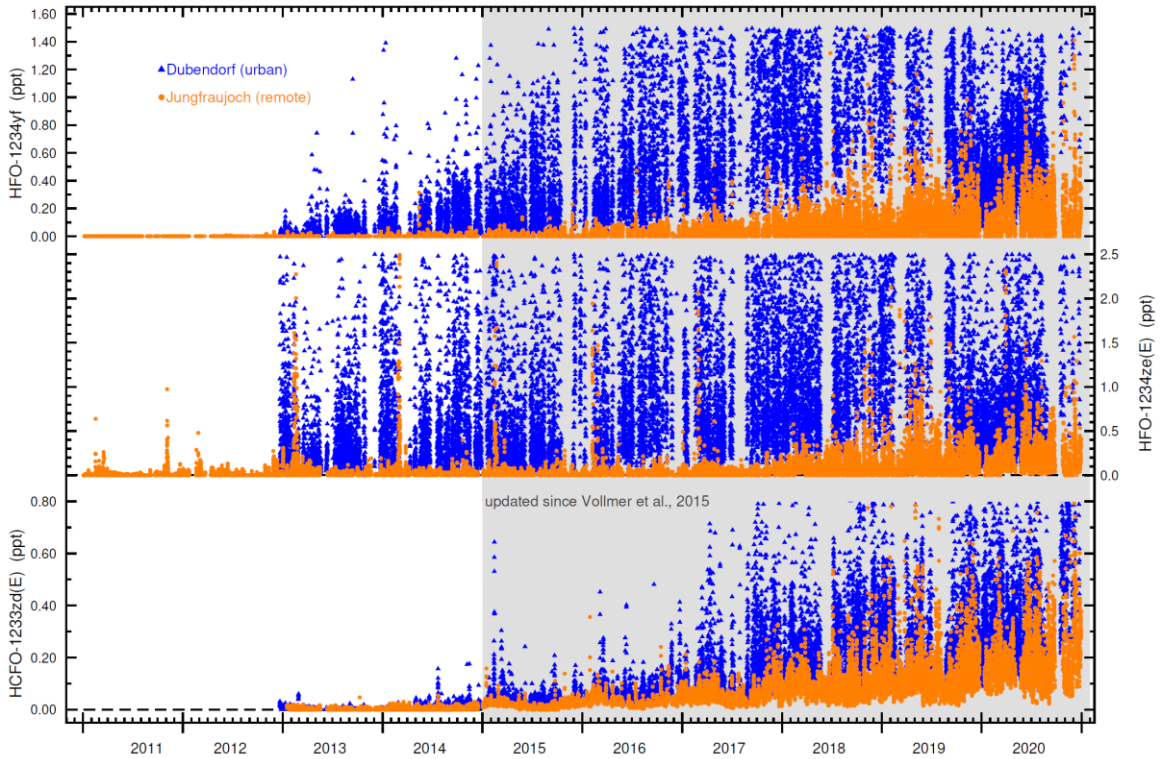
76133 Karlsruhe

Germany

Tel.: +49 721 925 1843
Fax: +49 721 925 1915
E-Mail: michael.kauffeld@h-ka.de



EMPA – Measurements at Jungfraujoch and in Zürich, Switzerland



Maximum value beyond scale not shown

Results are expressed as dry-air mole fractions in parts-per-trillion (ppt, pmol mol^{-1}). To expand the y-axes for better illustration of some of the smaller mole fractions, the results are omitted above the largest tick mark labels for each compound.

https://www.empa.ch/documents/56101/190047/HFO+update+Report/fe3b26b5-fcb6-4cd9-a6f6-5c39ac01f20a

Heat pump penetration and number of heating degree days in 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this event lies with the organisers. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.

Michael.Kauffeld@h-ka.de

www.tri-hp.eu

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Session 2: Phasing down F-Gases in Heat pumps

RISKS OF RAPID DEPLOYMENT OF HEAT PUMPS BASED ON NATURAL REFRIGERANTS

Coen van de Sande
President of the Association of Refrigeration, Air Conditioning and Heat Pump contractors (AREA)

07 February 2023: 14:00 - 18:00 L42, Rue de la Loi 42, Brussels

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

About AREA

European association of national refrigeration, air conditioning and heat pump (RACHP) associations, representing RACHP contractors and engineers.

- 24 national member associations
- 21 countries
- 13,000 companies employing 110,000 people
- 90% SME's
- Annual turnover €23 billion

Contractors are the essential link between end users and manufacturers.

EU ambitions

The European RACHP contracting industry fully subscribes to the EU's decarbonisation and climate neutrality ambitions set out in:

European Green Deal

Fit for 55 package

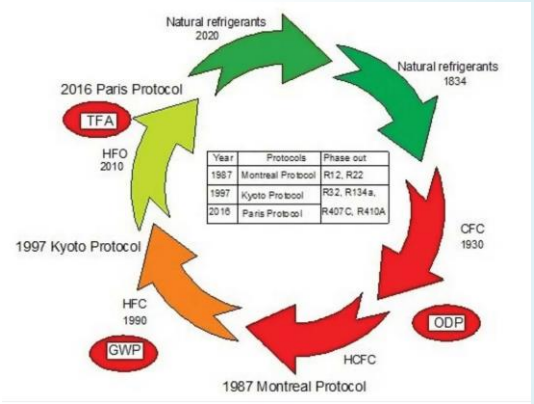
F-gas regulation

Contractors play an important role in the various transitions that are needed to meet the ambitions of the EU

Transitions

The main identified 4 transitions for our sector to meet the EU ambitions are:

- Transition from gas boilers to heat pumps
- Transition from HFC's to low GWP refrigerants
- Transition from separate heating, cooling & ventilation units to integrated solutions
- Digitalisation



Natural refrigerants in heat pumps

This transition introduces:

- Shift from environmental to safety
- Low risk profile HP's to high risk profile HP's
- Not only for installers but for the entire chain/sector: operators, enforcers, public, animals, buildings etc.

Natural refrigerants in heat pumps

- Consequences for our companies:
  - Training/certification installers, engineers, warehouse employees
  - Investments in tools, equipment, storage, transport, personal protection equipment
  - Draft safety procedures, work instructions, risk assessments

Natural refrigerants in heat pumps

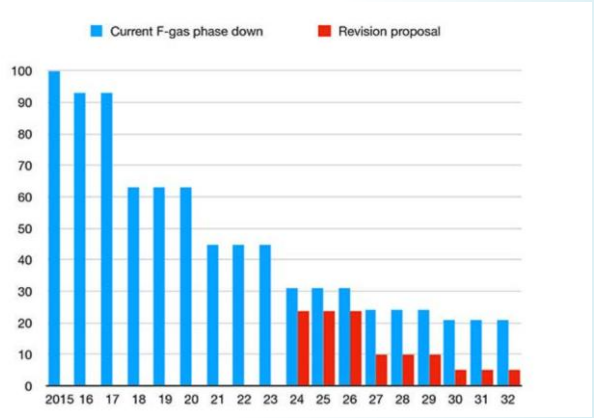
- Consequences for stakeholders in our sector:
  - Plummers/heating contractors need to make a huge step from gas boilers to heat pumps charged with natural refrigerants
  - Building owners/operators need to train their employees, revise their safety procedures, request for new permits etc.
  - Transporters need to adapt their trucks, train their employees (ADR regulation)
  - Enforcers need to be trained and revise their protocols
  - Certification Bodies need to be trained, revise their protocols
  - Schools/training centers need to revise their teaching materials
  - Standardization institutes need to revise standards

AREA

Natural refrigerants in heat pumps

To mitigate risks AREA pleads for:

- Mandatory certification for companies and employees that work with natural refrigerant in art. 10 f-gas regulation
- Art. 5,6,7,8.1 of f-gas regulation applicable not only for systems charged with f-gasses but also for natural refrigerant
- Realistic phase down f-gasses and prohibitions placing on the marked HP's
- Holistic EU-view regarding refrigerants > no contradictions between f-gas regulation and PFAS
- We need at least to 1-1-2028 to prepare the sector to this transition



Panel Discussion: Phasing down F-Gases in Heat pumps
17:20 – 18:00

Davide Sabbadin
Deputy Policy Manager for Climate
European Environmental Bureau

Hilde Dhont
Refrigerant Task Force Member
European Heat Pump Association

Veerle Beelaerts
Head of Technology
European Heating Industry

Michael Kauffeld
Professor in Refrigeration Engineering
Karlsruhe University of Applied Sciences

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Panel Discussion Topics

- Introduction Round
- REPowerEU Targets
- Manufacturing: Impact on value chain and production line
- Training: Addressing the skills gap
- Open questions from the audience

Panel Discussion: Introduction Round

Davide Sabbadin
Deputy Policy Manager for Climate
European Environmental Bureau

Hilde Dhont
Refrigerant Task Force Member
European Heat Pump Association

Veerle Beelaerts
Head of Technology
European Heating Industry

Michael Kauffeld
Professor in Refrigeration Engineering
Karlsruhe University of Applied Sciences

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Panel Discussion: REPowerEU Targets

Davide Sabbadin
Deputy Policy Manager for Climate
European Environmental Bureau

Hilde Dhont
Refrigerant Task Force Member
European Heat Pump Association

Veerle Beelaerts
Head of Technology
European Heating Industry

Michael Kauffeld
Professor in Refrigeration Engineering
Karlsruhe University of Applied Sciences

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Panel Discussion: Impact on value chain & production

Davide Sabbadin
Deputy Policy Manager for Climate
European Environmental Bureau

Hilde Dhont
Refrigerant Task Force Member
European Heat Pump Association

Veerle Beelaerts
Head of Technology
European Heating Industry

Michael Kauffeld
Professor in Refrigeration Engineering
Karlsruhe University of Applied Sciences

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Panel Discussion: Addressing the skills gap

Davide Sabbadin
Deputy Policy Manager for Climate
European Environmental Bureau

Hilde Dhont
Refrigerant Task Force Member
European Heat Pump Association

Veerle Beelaerts
Head of Technology
European Heating Industry

Michael Kauffeld
Professor in Refrigeration Engineering
Karlsruhe University of Applied Sciences

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Panel Discussion: Open questions

Davide Sabbadin
Deputy Policy Manager for Climate
European Environmental Bureau

Hilde Dhont
Refrigerant Task Force Member
European Heat Pump Association

Veerle Beelaerts
Head of Technology
European Heating Industry

Michael Kauffeld
Professor in Refrigeration Engineering
Karlsruhe University of Applied Sciences

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Thank you for attending our final event!

Funded by the European Union

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 814888. The sole responsibility for the content of this event lies with the organisers. It does not necessarily reflect the opinion of the European Commission (EC). The EC is not responsible for any use that may be made of the information it contains.

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources