Research and developments in the European heat pump industry based on the European Heat Pump Summit 2013

IZW e.V.

Information centre on heat pumps and refrigeration Germany

Dr. Rainer Jakobs

Agenda

- Markets and challenges
- Components
- Research and development
- Systems

Nuremberg, 15–16.10.2013

EUROPEAN HEAT PUMP SUMMIT 2013

Powered by Chillventa

Symposium + Expo

Industrial • Commercial • Residential
Heating & Cooling • Components & Equipment

Germany

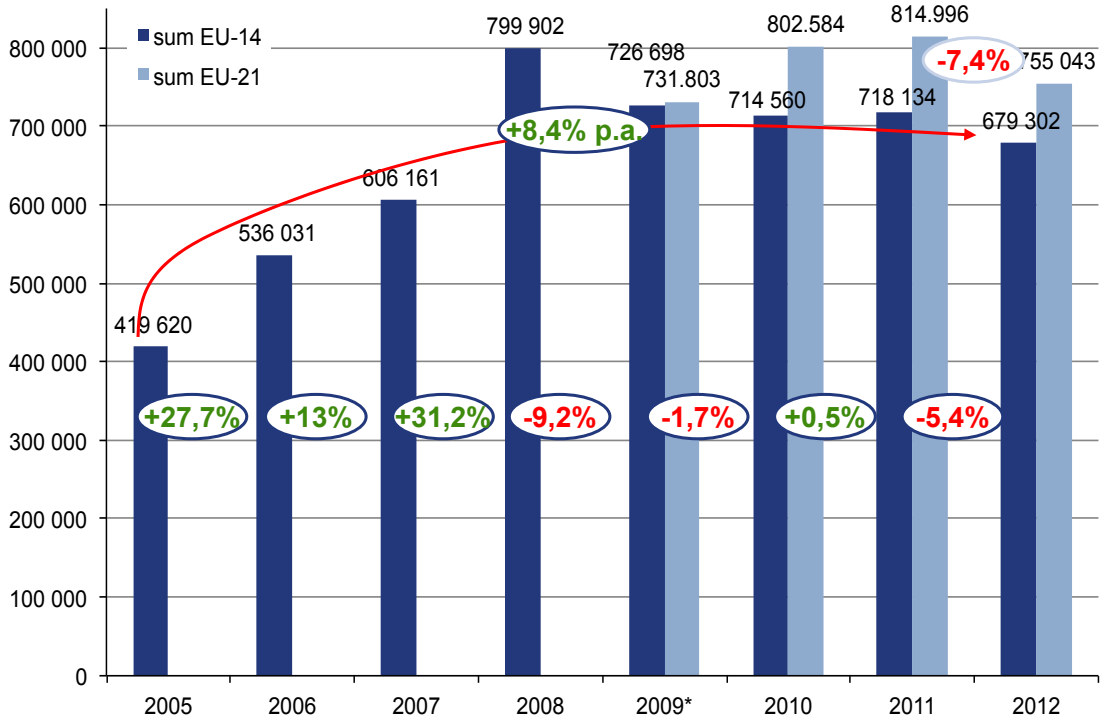
Sources:

- **Symposium European Heat Pump Summit 2013**
- **IEA- International Energy Agency**
  The IEA Heat Pump Programme HPP
- **EPEE European Partnership for Energy and Environment**
- **ehpa european heat pump association**
- **Information Centre on Heat pumps and refrigeration IZW e.V.**

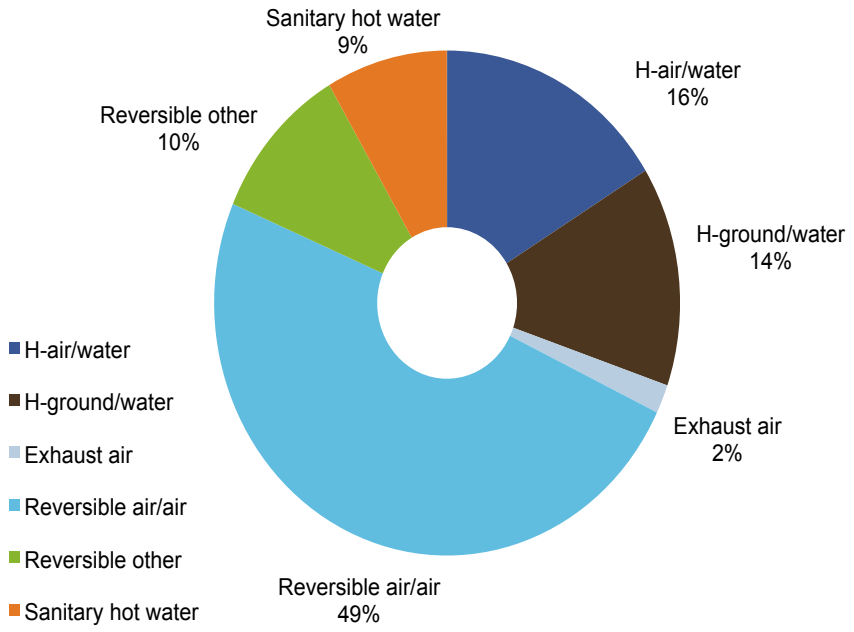
Agenda

- **Markets** and challenges
- Components
- Research and development
- Systems

Market development 2005-2012
Accumulated: 5,4 million units installed



Split of heat pump sales 2012: by type



Sanitary hot water heat pumps

Agenda

- Markets and **challenges**
- Components
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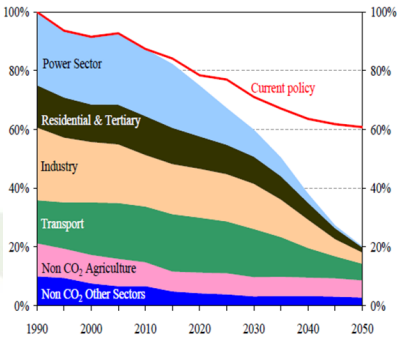
- Systems

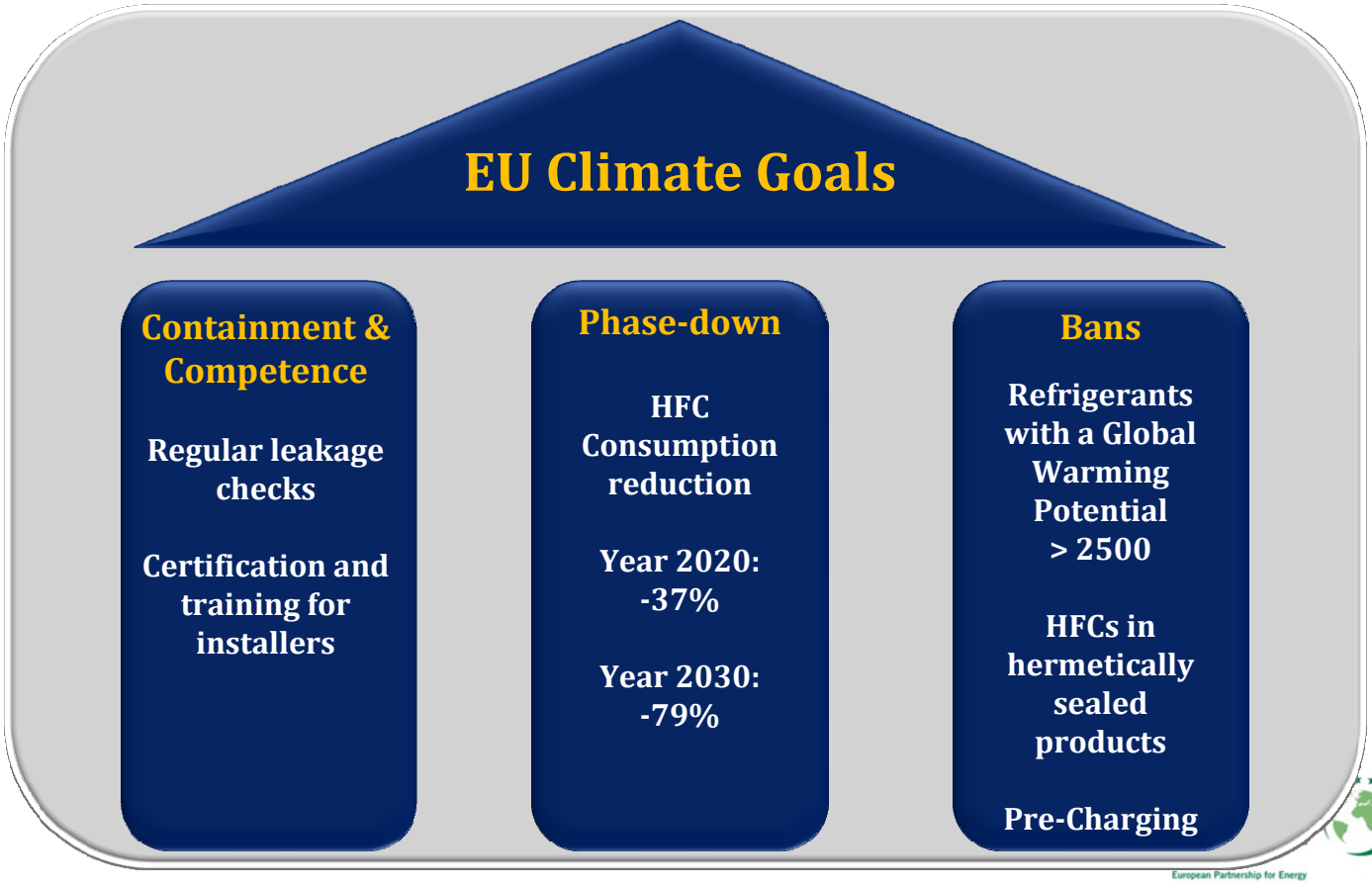
Why a revision of the F-Gas Regulation?

- The EU low carbon roadmap aims for **72% emission reduction** for F-Gases, Methane, N2O in 2030
- The existing F-Gas Regulation is expected to **stabilise emissions** at today's level
- To achieve the goals of the low carbon roadmap **more action** is needed
- The **international context has evolved** with discussions of a global phase-down of HFCs under the Montreal Protocol, bilateral discussions between the US and China, the US and India and the recent G-20 agreement.



EPEE
European Partnership for Energy and the Environment

The EU Commission's Proposal (Nov 2012)



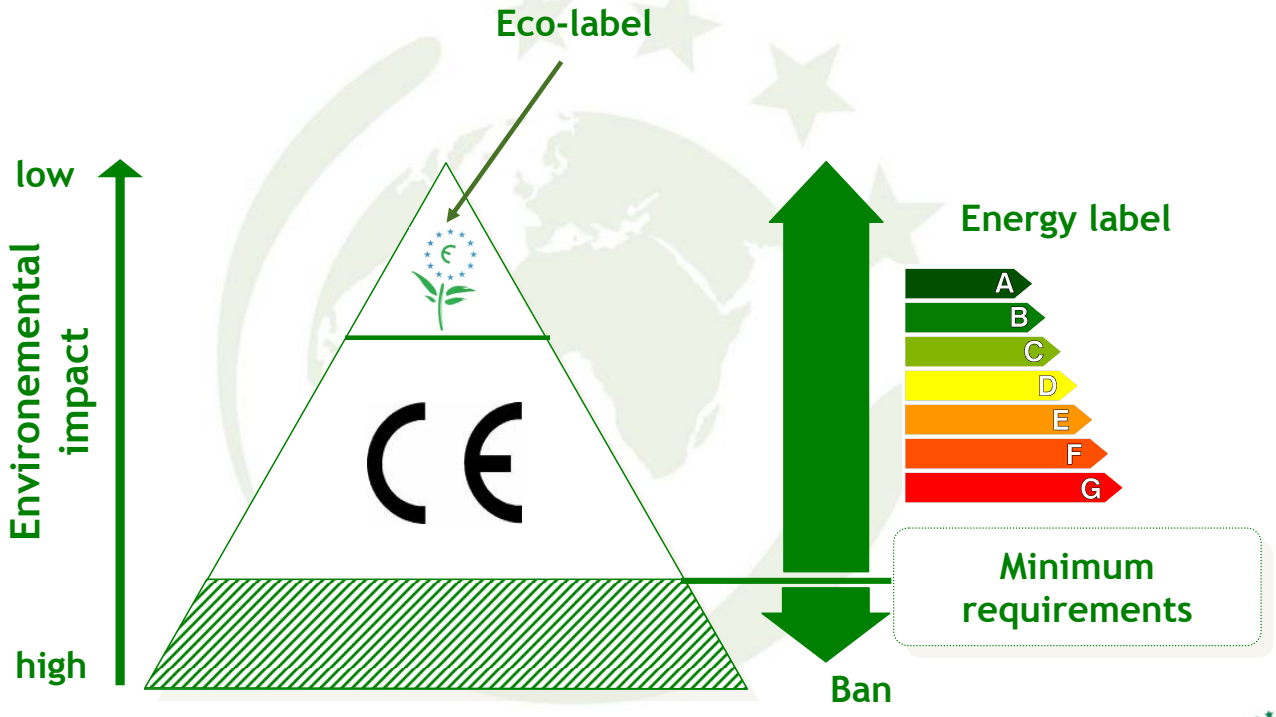
European Partnership for Energy and the Environment

What are the current positions?

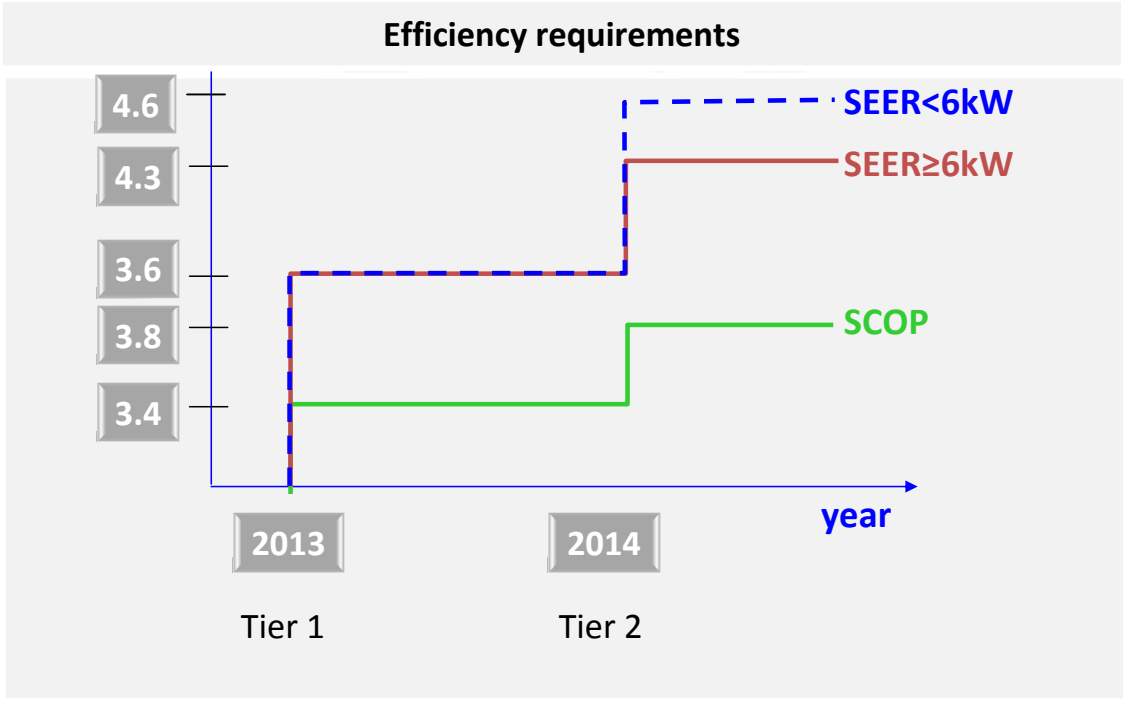
European Commission "want to be a global leader"	Member States "north-south divide and difficult economic situation of many"	European Parliament "very ambitious and elections 2014"
Phase-down: •Phase-down of HFCs by -79% in 2030	• Support of Commission proposal	• Phase down of HFCs by -84% in 2030
Service & Maintenance Ban: •Service and maintenance bans for refrigerants with a GWP > 2500 •Entry into force: 2020	• Support for a service and maintenance ban for refrigerants with a GWP > 2500 • Exemption of charge sizes <40t CO2-eq • Exemption of applications <-50°C • Allow recovery/recycling until 2030 • Entry into force: 2022	• Support for a service and maintenance ban for refrigerants with a GWP > 2500 as in Council Position • Allow recovery/recyling until 2022 • Entry into force: 2017
Bans: •HFCs in hermetically sealed products	• No additional bans	• Additional HFC blanket bans in stationary a/c and refrigeration as of 2020
Quota Allocation and Fees: •Free Grandfathering proposal to handle the quota of the phase-down	• Support of Commission proposal	• Proposal to introduce allocation fees per tonne of CO2eq.
Pre-Charging •Ban on pre-charged equipment	• Traceability system based on declaration of conformity (DOC).	• Support of Commission proposal

European Partnership for Energy and the Environment

The Ecodesign Directive 2009/125/EU & the Energy Labelling Directive 2010/30/EU

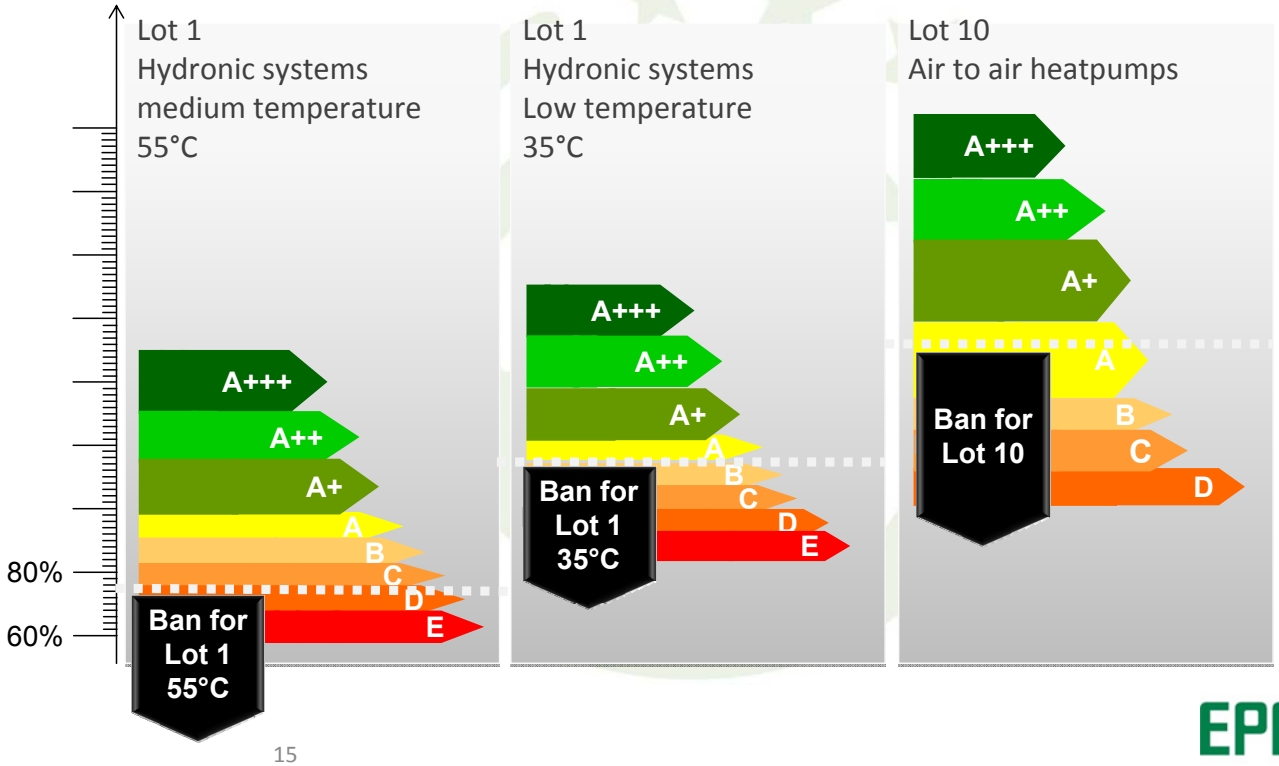


ENER Lot10: Regulation 206/2012 Air/Air heatpumps <12kW



Requirements mandatory from 30.03.2012

Impact of ENER Lot and ENER Lot10

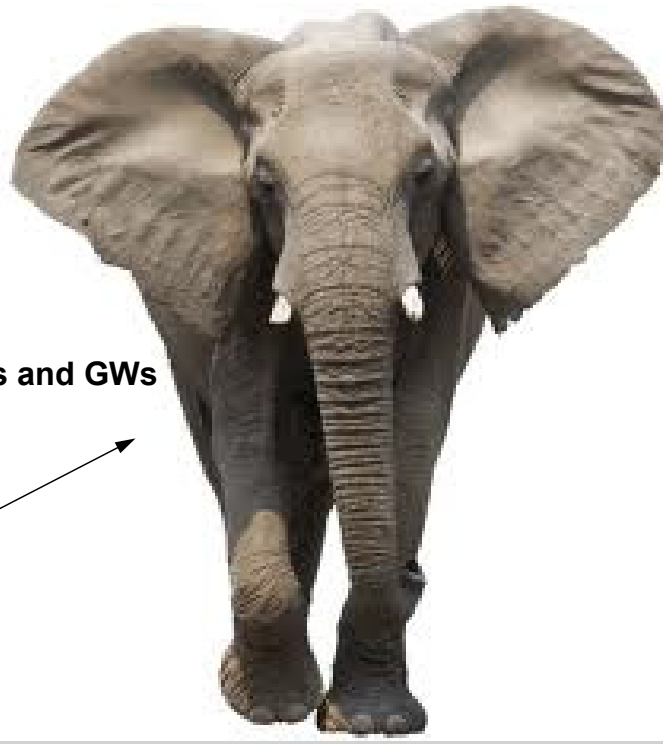


EPEE
European Partnership for Energy and the Environment

A low carbon future means utilities have to think in a new way

DELTA
Energy & Environment

Generation
Decarbonisation



MWs and GWs

Utility of the past….

A low carbon future means utilities have to think in a new way

DELTA Energy & Environment

Demand-side
Electrification, growth of Distributed Generation

A single 10 kW HP is insignificant…

UTILITY

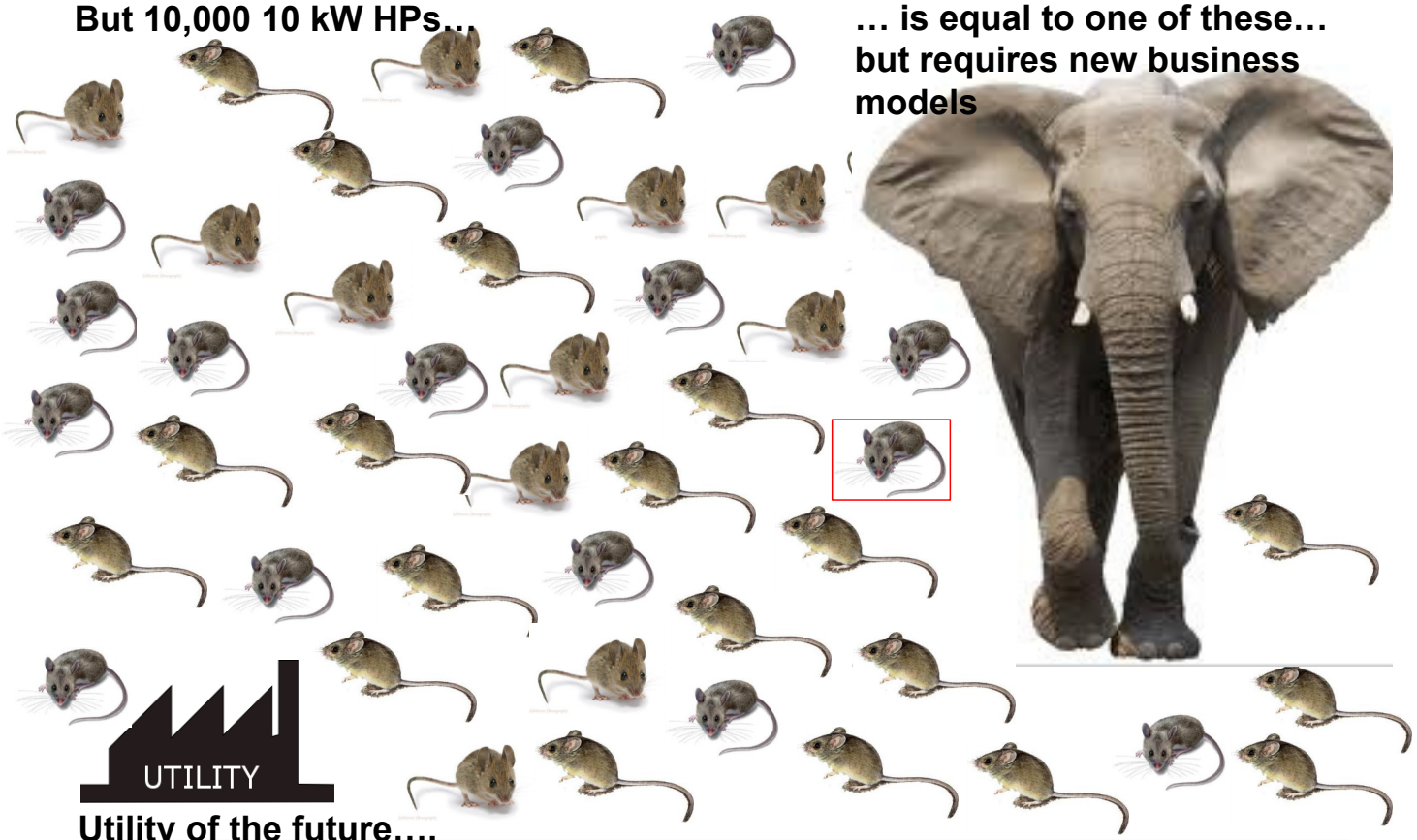
Utility of the future….

A low carbon future means utilities have to think in a new way

DELTA Energy & Environment

But 10,000 10 kW HPs…

… is equal to one of these… but requires new business models



UTILITY

Utility of the future….

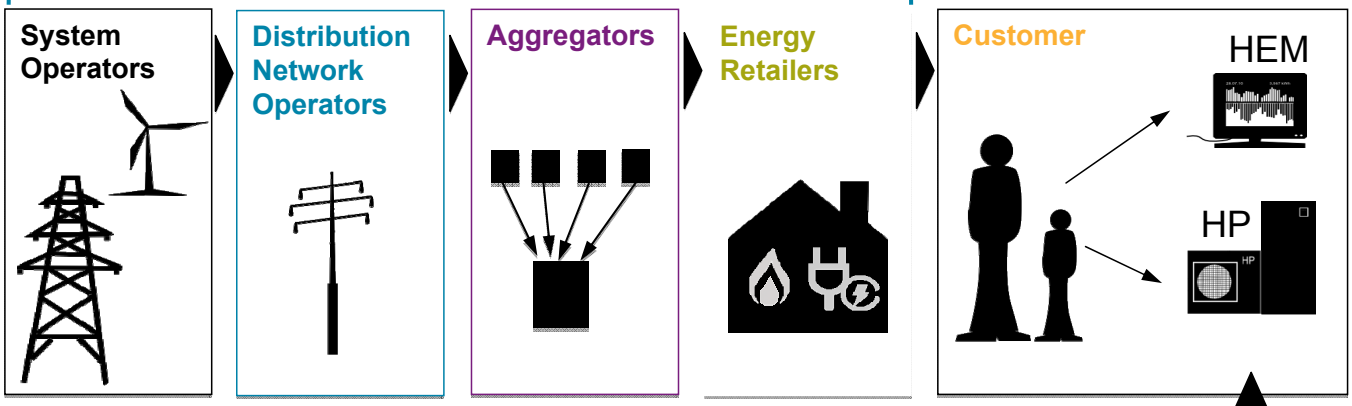
Winning approaches to smart heat pumps?

DELTA Energy & Environment

Make it easy for utilities / aggregators to access heat pump flexibility

Optimise end-user comfort

Make it easy for customers to capture future value



With customers on board, smart will be a significant driver of the future heat pump market

Germany

Agenda

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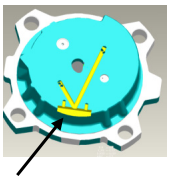
Scroll Compressor
Heating Application Optimization

EMERSON Climate Technologies

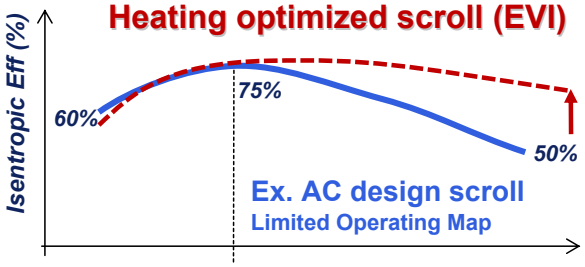
Innovation:
-Vapor injection scroll (EVI)
-BPM variable speed

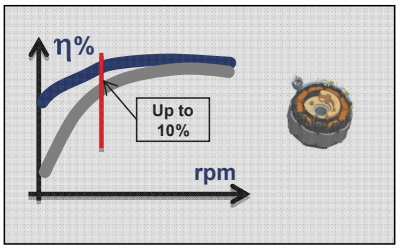
EVI



Injection Ports

Heating optimized scroll (EVI)

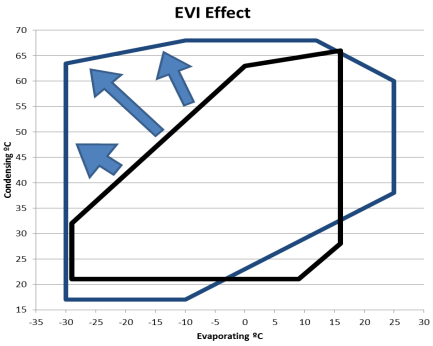


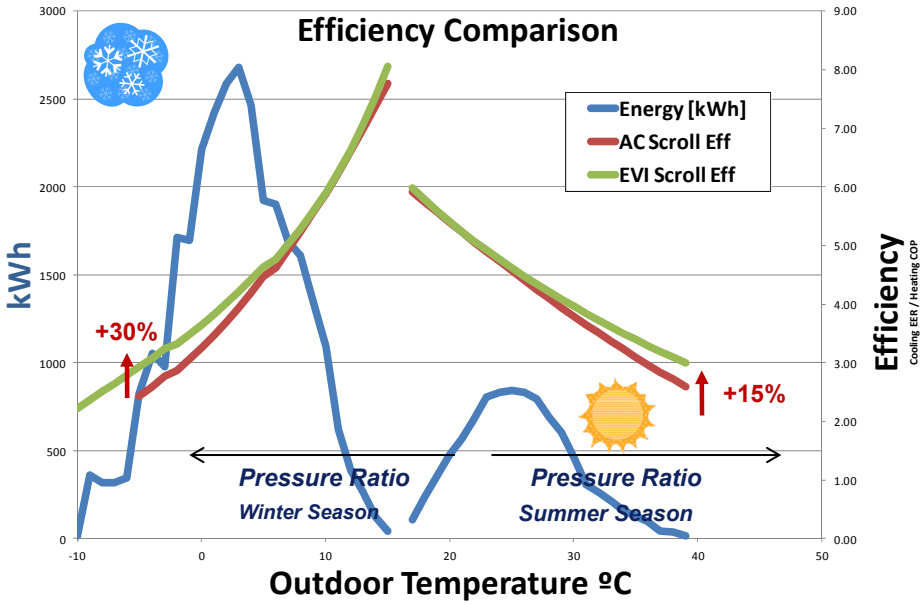


High efficiency motor and drive

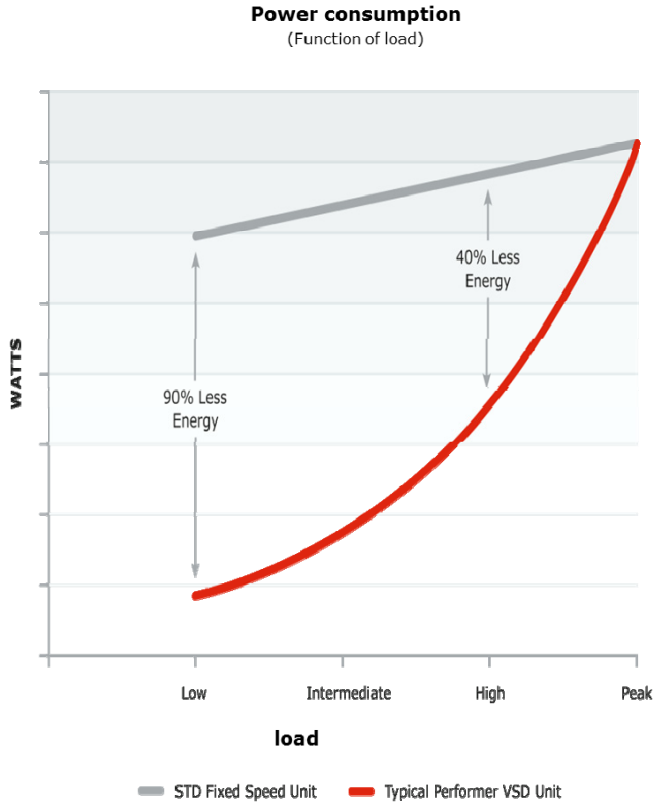
High efficiency increase @ high pressure ratio

Extended Operating Map





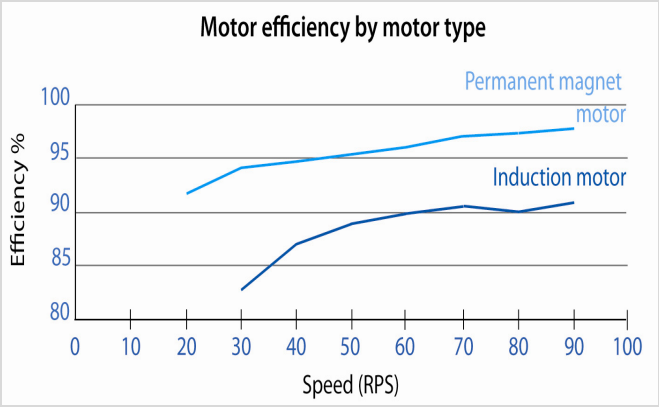
Danfoss



Advanced energy efficiency
with Inverter Scroll technology

- Compressor capacity always matches heating or cooling demand
- Efficiency boost in part load operation : compressor runs slower
- Less capacity at slower speeds : unit becomes effectively over-sized
- No on/off pressure cycling and transient losses

Advanced energy efficiency
with Inverter Scroll technology



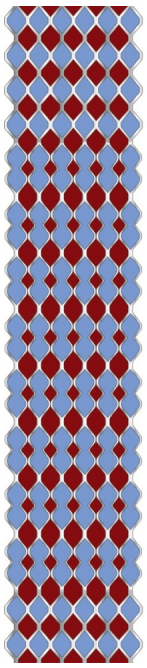
Source HVAC tool Average consumption index based on simulation for 10-30TR compressors in apps with low pressure ratio.

- 97% efficiency at full load
- Above 92% efficiency at part-load over the full speed range
- High motor efficiency means less heat transferred from the motor to the refrigerant giving better compression efficiency

Functions for intelligent electronic expansion valve control

1. **Expansion valves**
2. **The system electronic expansion valve**
3. **Minimum stable superheat (MSS)**
4. **Maximum operating pressure (MOP)**
5. **De-humidifying (Te control)**
6. **Defrost funtions**
7. **Loss of charge detection (LOC)**
8. **Bleed function**
9. **Sensor placement tips**

B26 Family – Asymmetric in every way



Gas cooling area

Gas cooling area with low dP to facilitate desuperheating of hot gas

Asymmetric condensing area

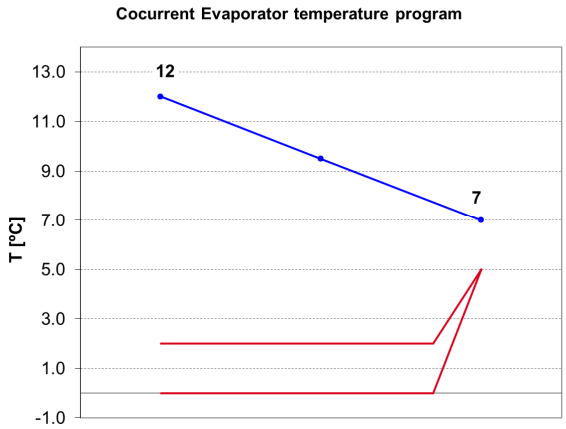
Highly asymmetric area optimized for condensing operation

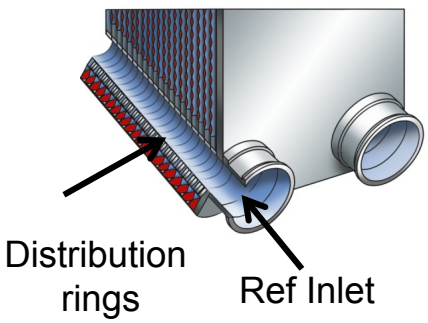
Sub cooling area

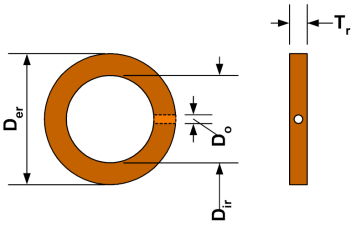
Sub cooling area

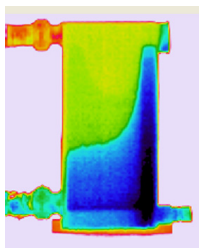
Distribution system for reversed evaporator duty

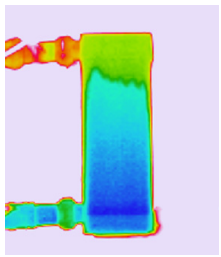
- Better refrigerant distribution decrease necessary superheat
- Very important for Co-current evaporator operation
- Verified for condenser operation









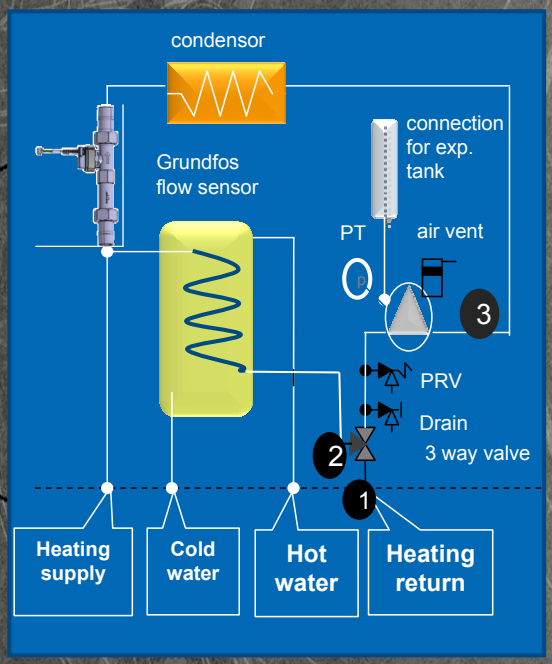


Efficient water hydraulics

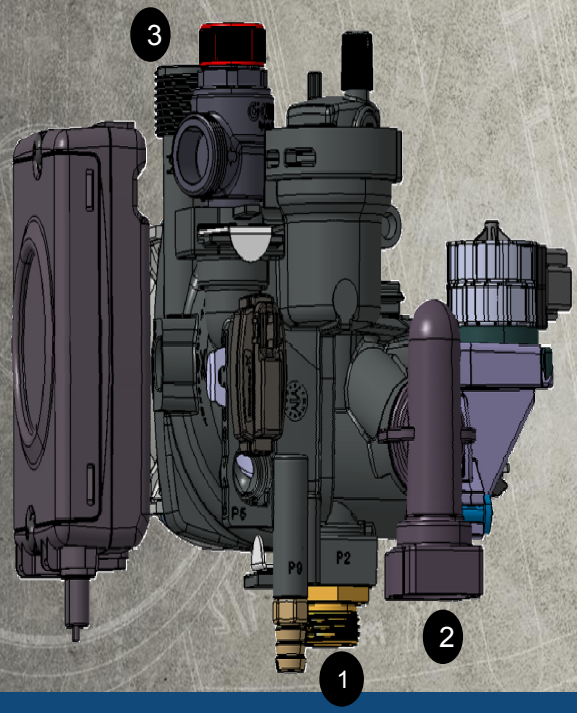
Hydraulic solution for *small* Heat Pump Systems

HEAT PUMP SYSTEMS

Heat pump unit with storage tank



Compact Hydro Block for Heat Pumps



Efficient water hydraulics

Available today: Compact Hydro Block for integration

HEAT PUMP SYSTEMS

Benefits with an integrated solution

High degree of pre-design
Most important functionality built into the housing

High modularity
Easy extensions with standard or customized components

Significant cost reduction
Pre-fabricated modularity highly benefits in customized projects to a positive project economy due to less development and tooling costs

Outstanding reliability and robustness
Safe due to a wide scope of testing methods and assessments

High serviceability
Easy access to different components

Flow straightener FlowGrid
Specific flow energy

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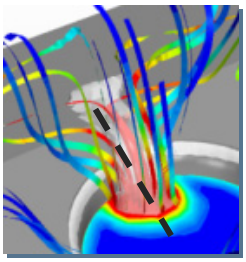
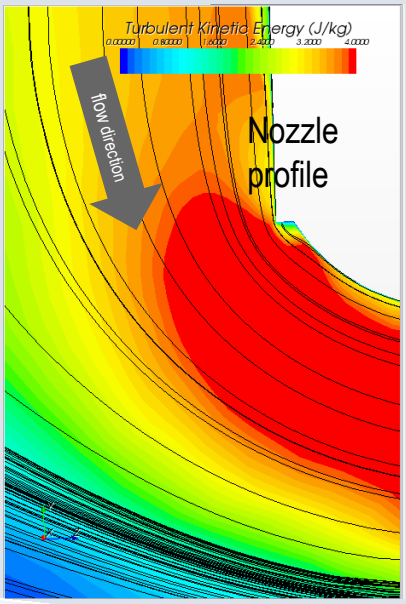
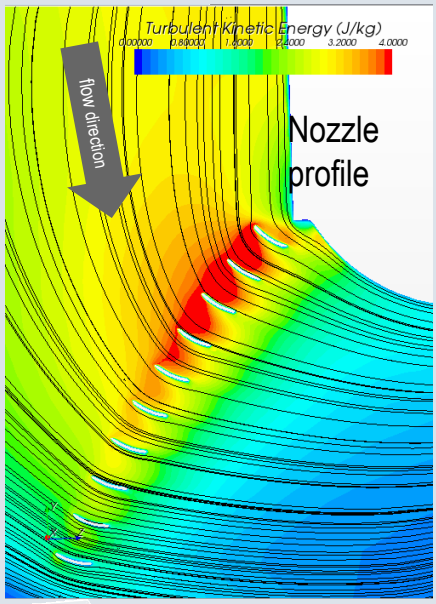


- Sectional plane
- through vortex
- string



w/o flow grid



with FlowGrid

Improve Fan Air Flow

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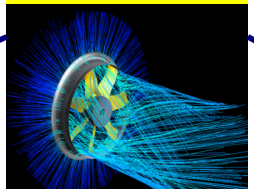
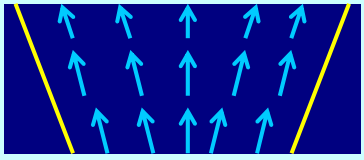
Actual



Guide Vane

Reduce dynamic pressure of rotating flow components

Diffussor



Reduce dynamic pressure by increase of cross flow section

ZAplus

FP7 Project GreenHP

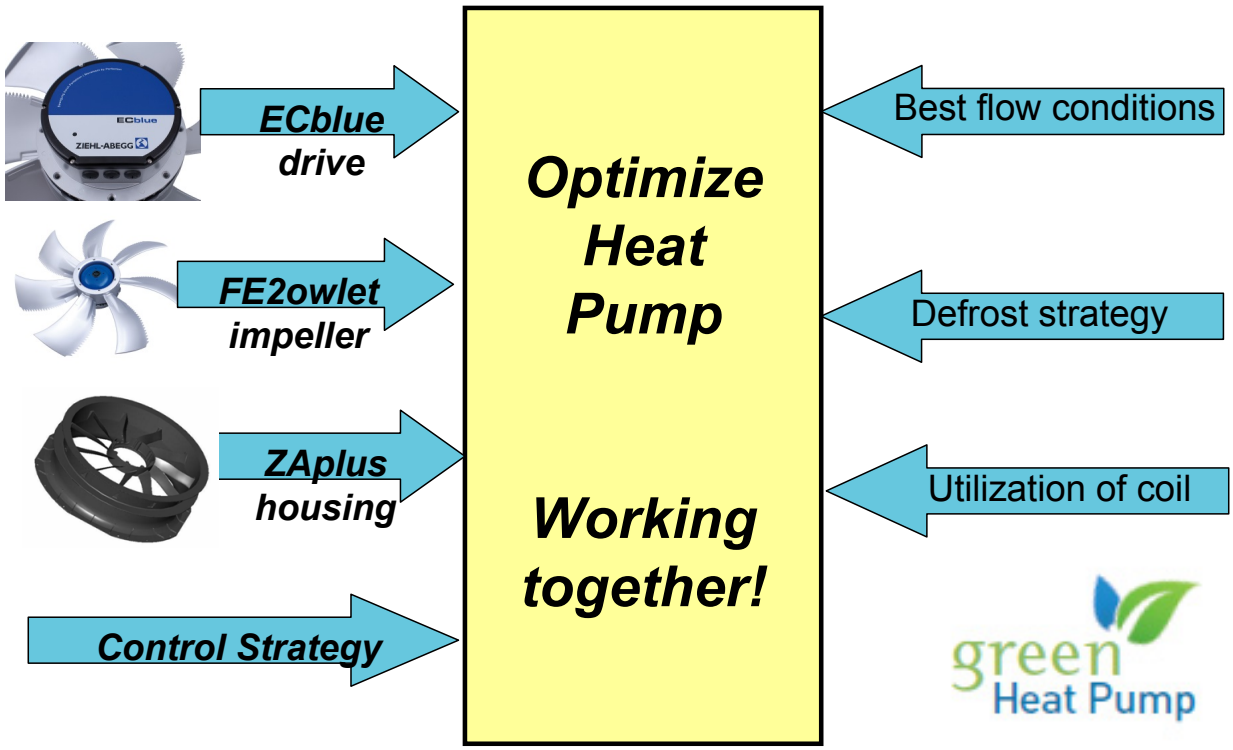
GreenHP: Next Generation Heat Pump for Retrofitting Buildings

Duration: 45 months, start: December 2012

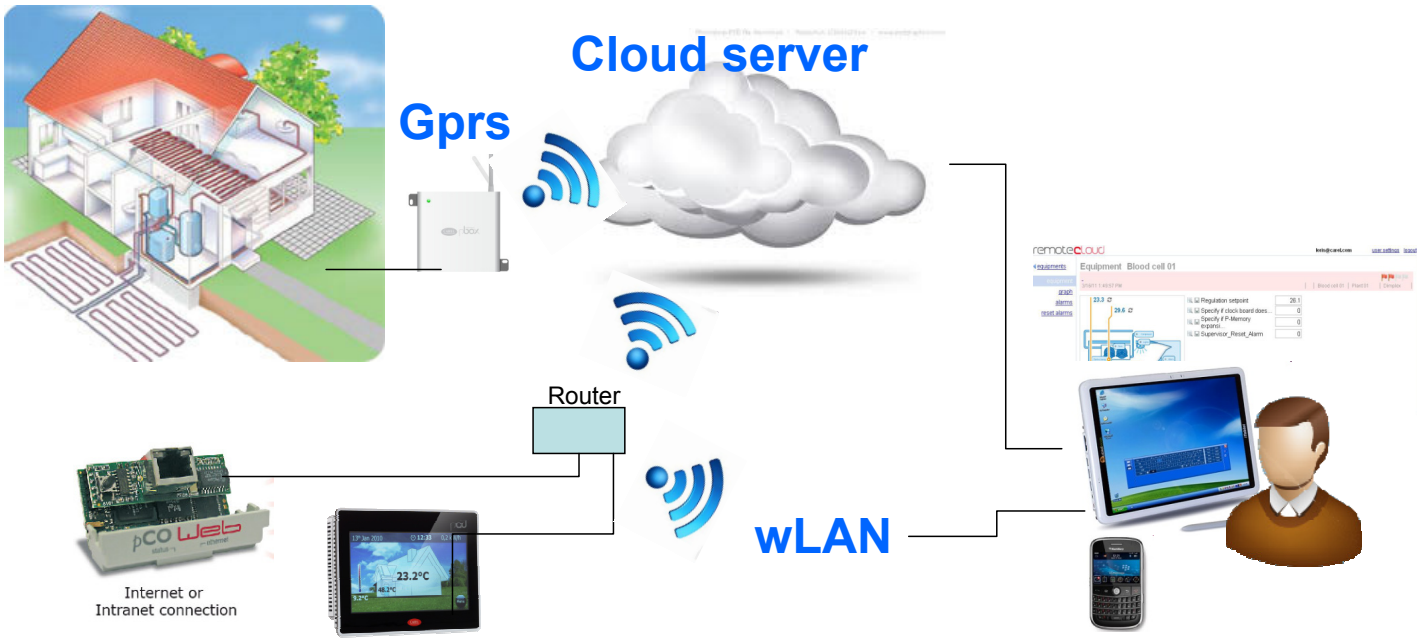
Aim: to develop a 30kW prototype of a next generation heat pump system designed for retrofitting buildings in future smart cities in moderate climates.

Budgets: TOTAL: ~ 5,2 Mio. EUR

Summary



Web integration



DirectCurrent-Inverter-Technology

Integrated Control Solution

Unit safeguard and performance

Extra features

Managed function
Compressor start failure management
Compressor equalization at start-up
Drive alarm management
Speed regulation according to the application needs
Drive parameter pre-set for different compressors
Drive custom parameters load and save management
Drive complete user interface

Agenda

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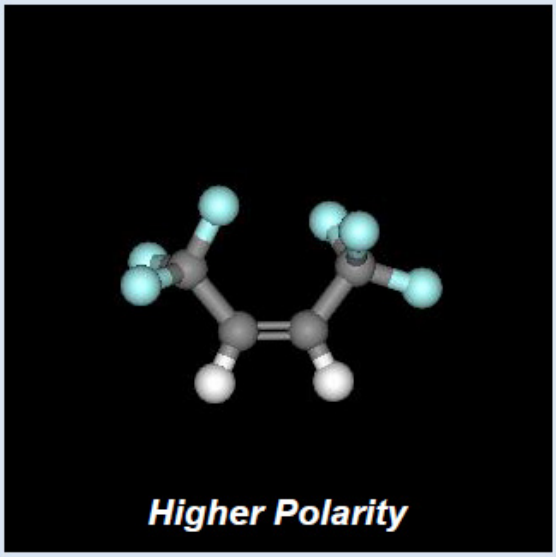
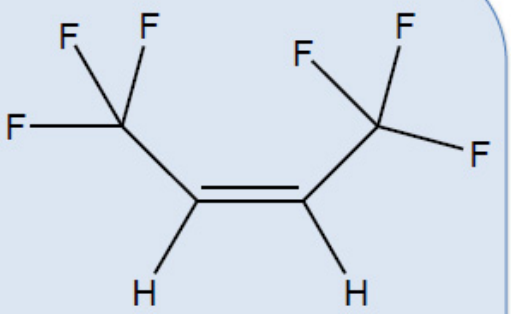
- Systems

Refrigerants

DR-2: HFO-1336mzz-Z





Developmental Refrigerant for High Temp Heat Pumps: DR-2

	HFC-245fa	DR-2
Chemical Formula	$CF_3CH_2CHF_2$	HFO-1336mzz-Z
ASHRAE Std 34 Safety Class	B1	A1 (expected)
ODP	None	None
GWP_{100}	1,030	9.4
T_b [°C]	15.1	33.4
T_{cr} [°C]	154	171.3
P_{cr} [MPa]	3.65	2.9

Very Low GWP AND Non-Flammable

Fluid selection based upon properties

Property \ Fluid	NH_3 [1]	R114 [1]	R245fa [2]	DR-2 [3]	LG6 [4]
Flammable	yes	no	no	no	no
Toxic, Harmful	yes	no	no	no	no
Ozone depletion potential (must be zero)	0	0.85	0	0	0
Global warming potential (future law restrictions?)	<1	9200	950	9	1
Critical temperature [°C]	133	146	154	171	>165
Available	yes	no	yes	?	yes

e.g. GEA [5], Vilter [6]

e.g. EDF [7]

Fluid development of DuPont [3]

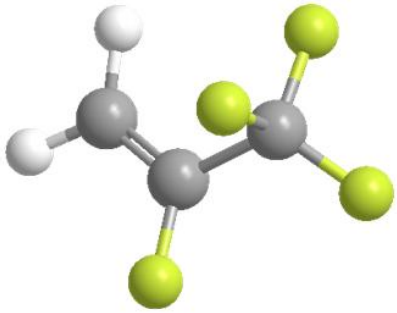
Research at Siemens / FAU with future-proof fluids

Sources
1 Solvay Fluor, Solkane pocketbook, 2010
2 Honeywell, Material and safety data sheet, 2011
3 Kontomaris, Working fluids for high temperature heat pumps, Chillventa, Nuremberg, 2012
4 Confidential source
5 Dietrich, Fredrich, GEA Grasso heat pumps using ammonia – the megawatt range. Achema, Frankfurt, 2012
6 Pearson, Nellissen, Application of industrial heat pumps. Achema, Frankfurt, 2012
7 Bobelin, Experimental results of a heat pump using R245fa as working fluid. European heat pump summit, Nuremberg, 2011

New Solstice™ molecules

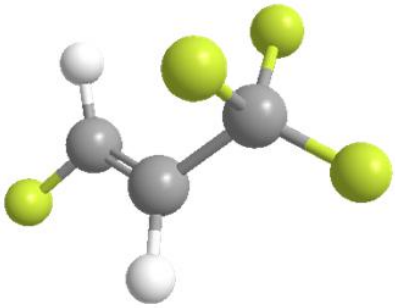
Honeywell

Solstice yf



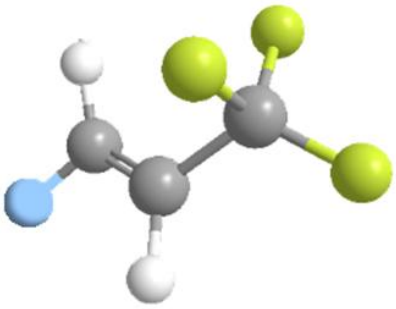
- GWP_{100} = 4
- Mildly flammable
- Commercially available

Solstice ze



- GWP_{100} = 6
- Mildly flammable
- Commercially available

Solstice zd



- GWP_{100} = 5
- Non-flammable
- Available for sampling

Developed and Commercialized 3 HFO molecules with low GWP

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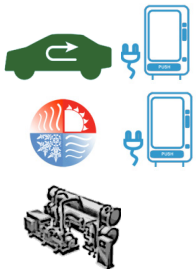
Honeywell's Solstice™ low GWP refrigerants

Honeywell

Solstice™ HFO's – low and medium pressure applications			
Current Product	**Non Flammable** (ASHRAE A1)	**Mildly Flammable** (ASHRAE A2L)	**Examples of Potential Applications**
HFC-134a GWP=1430		Solstice yf GWP = 4	Auto A/C, Vending, Refrigerators
		Solstice ze GWP = 6	Chillers, CO_2 Cascades Refrigerators
R-123 GWP= 77	Solstice zd GWP <5		Centrifugal Chillers



Solstice™ HFO Blends			
Current Product	***Solstice™ N Series*** **Reduced GWP Option Non Flammable (ASHRAE A1)**	***Solstice™ L Series*** **Lowest GWP Option Mildly Flammable (ASHRAE A2L)**	**Examples of Potential Applications**
HFC-134a GWP=1430	N-13 – GWP ~600		Chillers, Med-temp Refrigeration
HCFC-22 GWP=1810	N-20 - GWP ~1000	L-20 - GWP <300	Stationary A/C, Refrigeration
R-404A GWP=3922	N-40 - GWP~1300	L-40 - GWP 200-300	Low-Temp Refrigeration
R-410A GWP=2088		**L-41 - GWP <600**	Stationary A/C Applications

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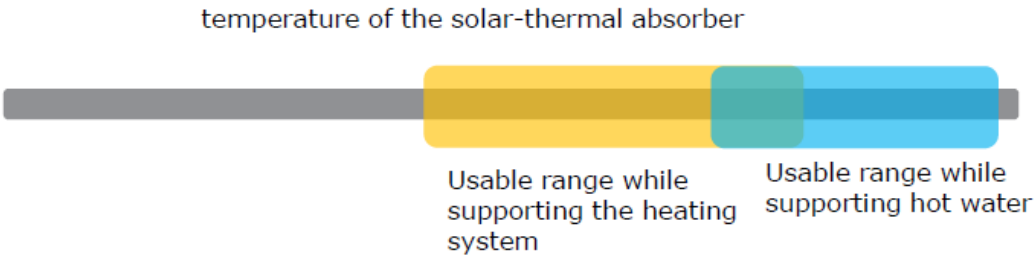
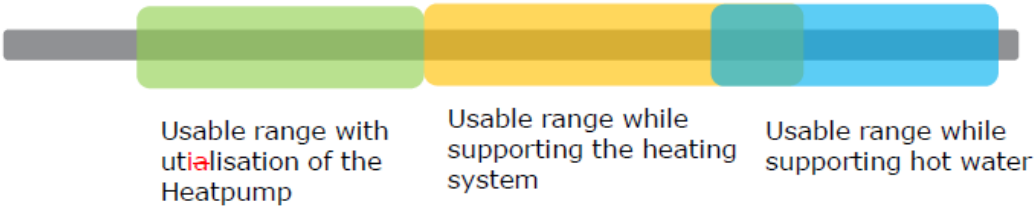
Motivation – Hybrid principle

› Gas heating system



› Gas-driven-heatpump



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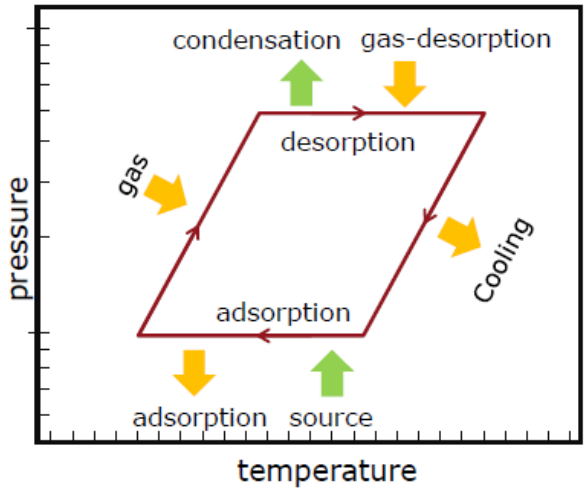
Aluminium Zeolith –HP Modul

› A thermodynamk cycle is formed with the combination of adsorption and desorption



$$COP = \frac{Q_{Condensation} + Q_{Adsorption} + Q_{Cooling}}{Q_{Gas} + Q_{Gas,Desorption}}$$

Ad- / Desorber

Evaporator/ Condensator

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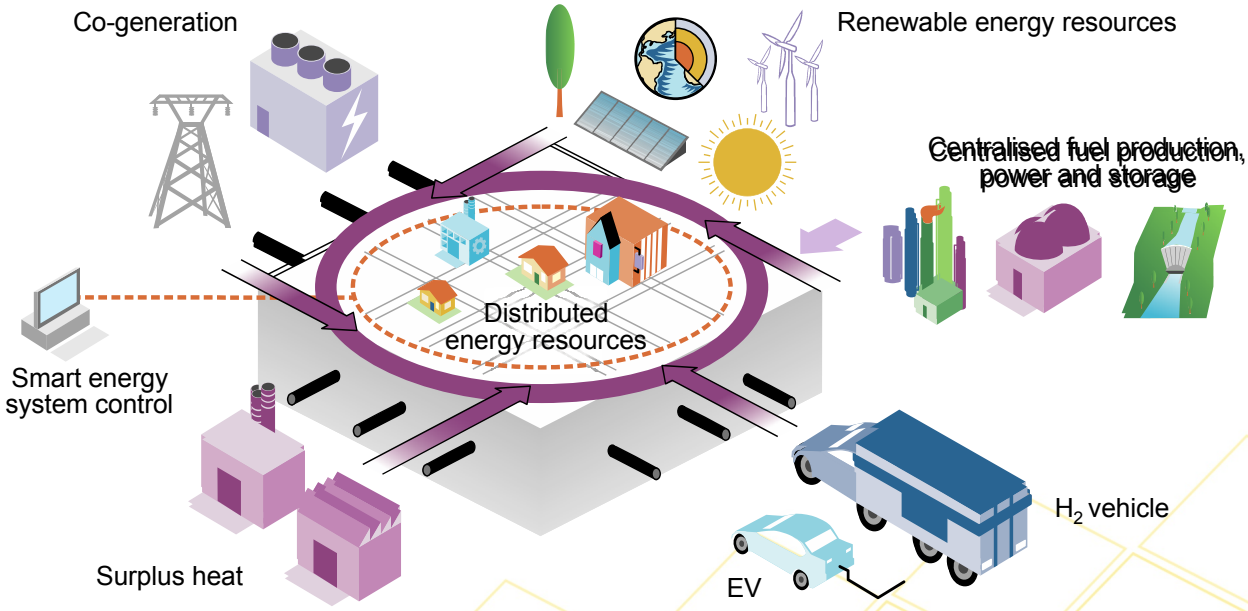
IEA - Annex 42
'Heat Pumps in Smart Grids'
by
Peter P.M. Wagener

OPERATING AGENT:

B D H

A smart, sustainable energy system



A sustainable energy system is a smarter, more unified and integrated energy system

B D H

Source: IEA-ETP 2012

Existing storage capacity

Pumped storage

4 TWh/a[1]

Hot water storage

6 TWh/a[2]

Heat Pumps

3 TWh/a[3]

Source: 1) Wikipedia 2) Fraunhofer IBP, Bericht ES-342 01/2012 3) BWP-Branchenstudie

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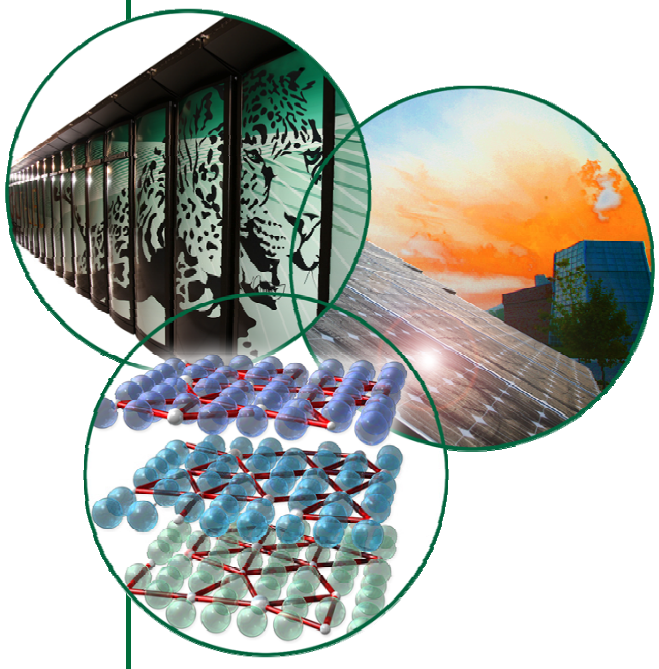
IEA HPP Annex 41 – Cold Climate Heat Pumps: Improving Low Ambient Temperature Performance of Air-Source Heat Pumps

Van D. Baxter
Oak Ridge National Laboratory

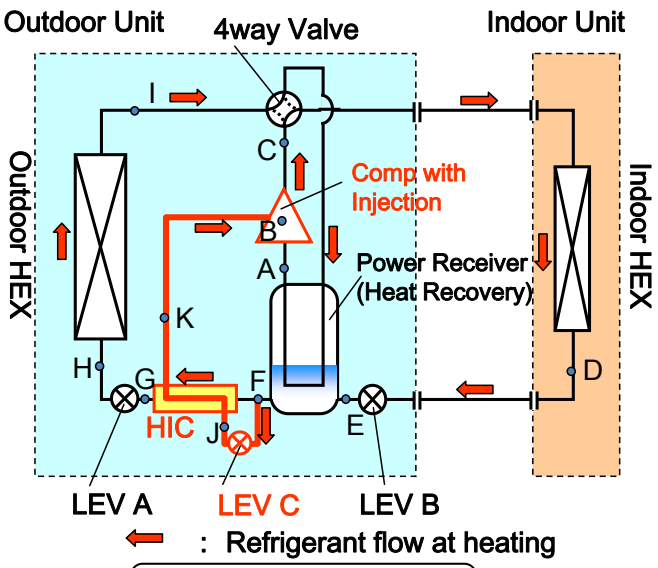
European Heat Pump Summit
Nuremberg, Germany
October 15, 2013



U.S. DEPARTMENT OF ENERGY

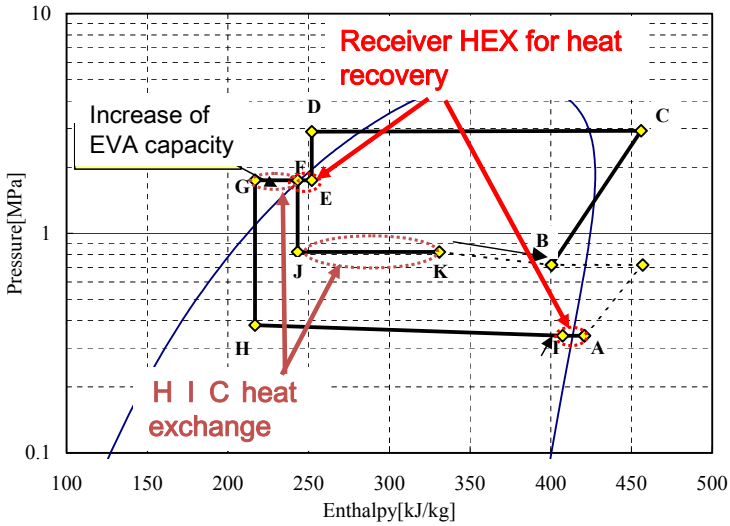
OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

ZUBADAN Refrigerant Circuit for Cold Climate Application (Flash Injection plus Power Receiver)



HIC : Heat Inter Changer
LEV : Linear Expansion Valve

Refrigerant Circuit



Refrigerant Circuit Diagram

① Increase of condensing capacity by the injection of outlet fluids of HIC
② Start-up super heat control using Power Receiver

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University of Stuttgart
Institute for Energy Economics and the Rational Use of Energy IER

Refrigerants for high temperature heat pumps

name	formula	ODP *	GWP *	NBP *	T_{crit}	p_{crit}	savety group
				[°C]	[°C]	[bar]	
R600a	C_4H_{10} [i]	0 [h]	3 [i]	-12 [h]	135 [j]	36.3 [j]	A3 [i]
R245fa	$C_3H_3F_5$ [a]	0 [c]	820 [c]	15 [a]	154 [c]	36.4 [c]	B1 [e]
R717	NH_3 [g]	0 [g]	0 [g]	-33 [g]	133 [g]	114.2 [a]	B2 [g]
R744	CO_2 [g]	0 [g]	1 [g]	-57 [g]	31 [g]	73.8 [a]	A1 [g]
DR-2	unknown	0 [d]	9,4 [d]	33 [d]	171 [d]	29.0 [d]	A1 (expected) [d]

**) ODP: Ozone Depletion Potential GWP: Global Warming Potential NBP: Normal Boiling Point*

Sources:
a) IFA, b) Solvay Fluor GmbH 2010, c) Honeywell International Inc. 2010, d) Kontomaris 1/10/2011, e) Klein 2009, f) Riva et al. 2006, g) Bitzer Kühlmaschinenbau GmbH 2010, h) UNEP 2007, i) Tyczka 2013, j) Higashi 2006

Integration of a high temperature heat pump

Project partners and roles:

- Dürr Ecoclean Manufacturer of industrial part cleaning systems
  - manufacturing of the part cleaning system
  - integration of the heat pump into a part cleaning system
  - testing of the system
- Combitherm Manufacturer of heat pumps and refrigeration equipment
  - construction and manufacturing of the heat pump
  - integration of the heat pump into a part cleaning system
- IER Energy research institute at University of Stuttgart
  - testing of the system
  - monitoring and scientific documentation

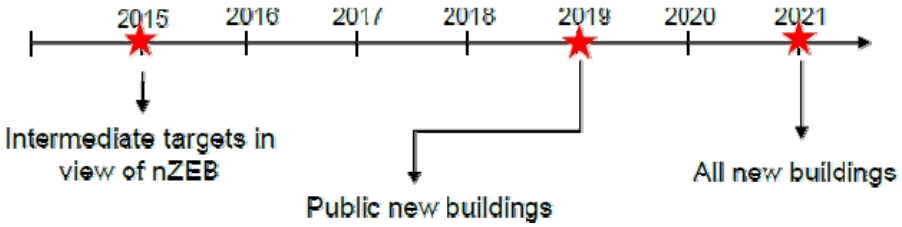
Background

- Next step of high performance buildings shall be nZEB

EU Definition of nZEB in EPBD recast (2010)

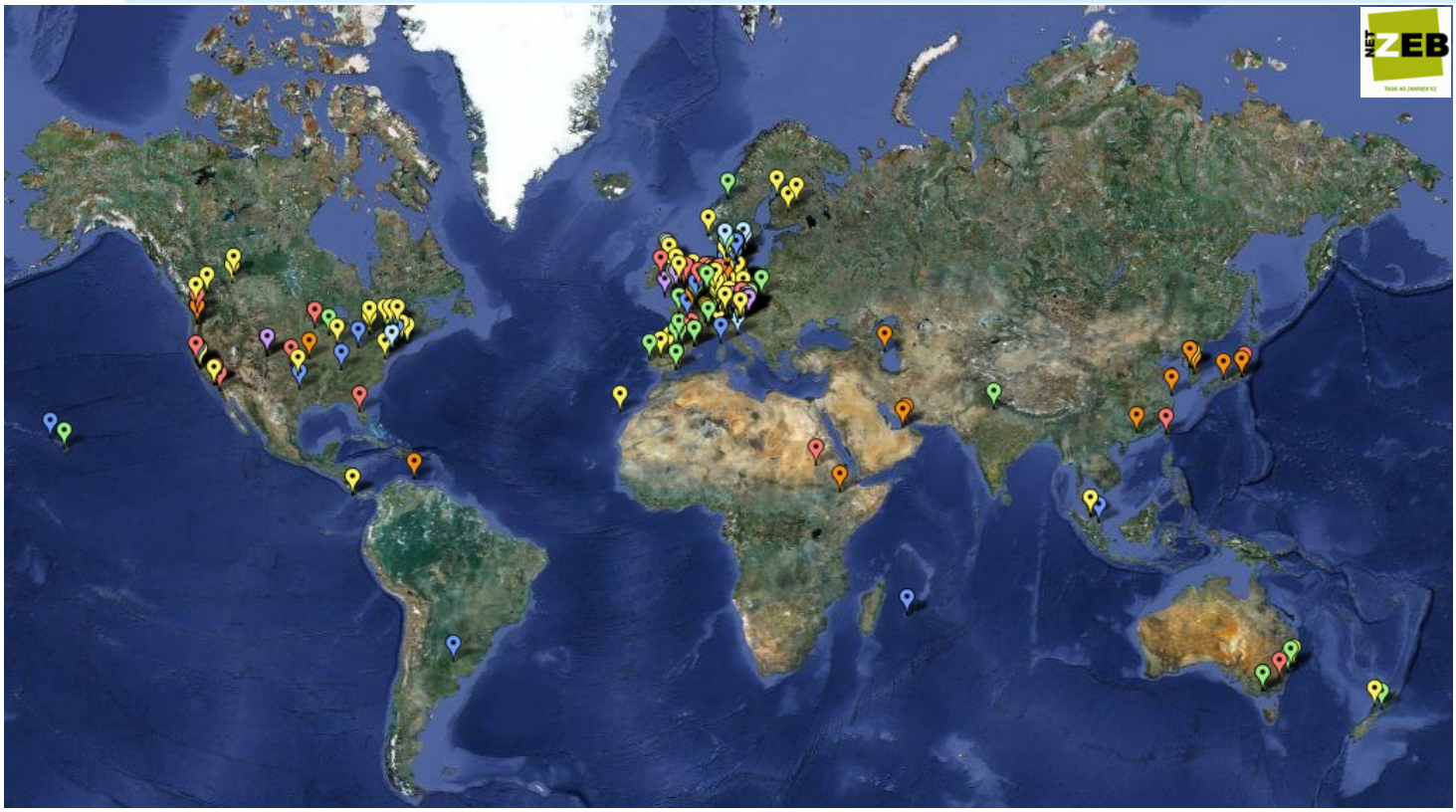
- Building that has a ***very high energy performance***
- ***Nearly or very low energy amount*** should be covered to a ***very significant extent*** by energy from renewable sources, including renewable energy ***produced on-site or nearby***

- EPBD time frame for the introduction of nZEB



source: Dieryckx

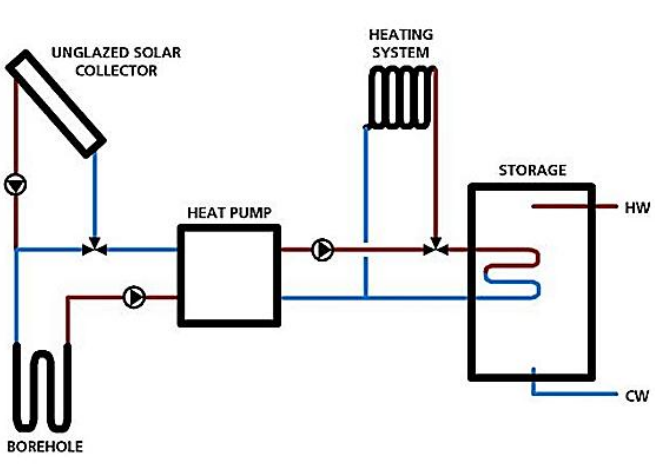
Worldwide nZEB

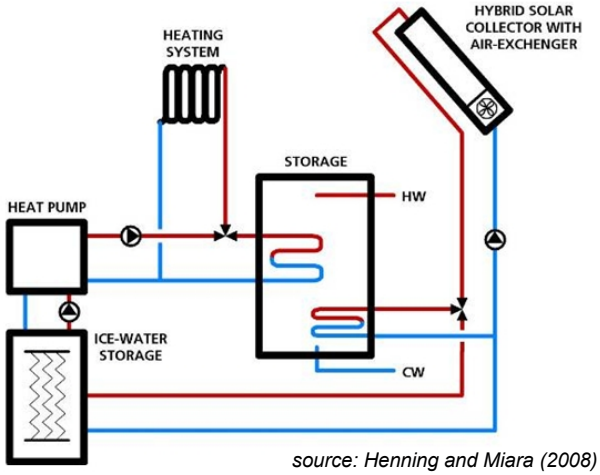


Integrated systems

- Different combinations of heat pump and solar technologies are entering the market
- Active regeneration/ solar heat source

Integration with ice-storage as heat source





source: Henning and Miara (2008)

Germany: example

- Brine/water heat pump with solar roof tile collectors and geothermal heat source
- Multi-family house in Füssen (Bavaria)

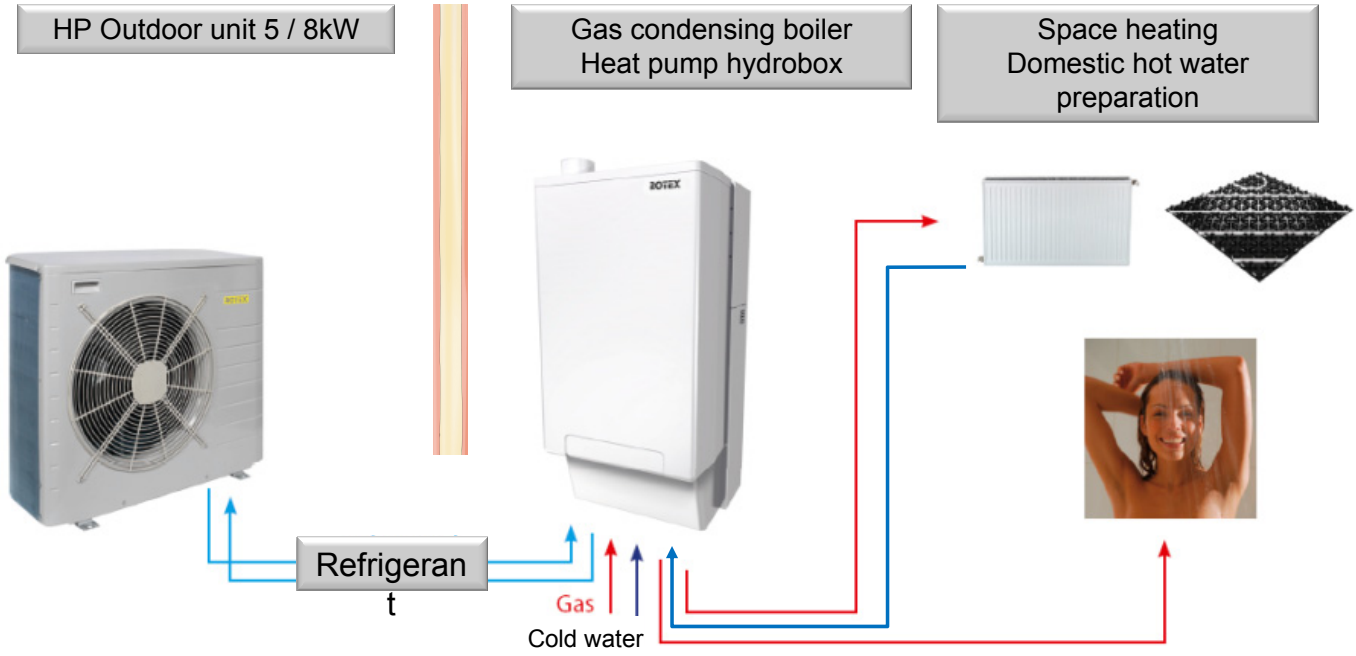
Germany

Agenda

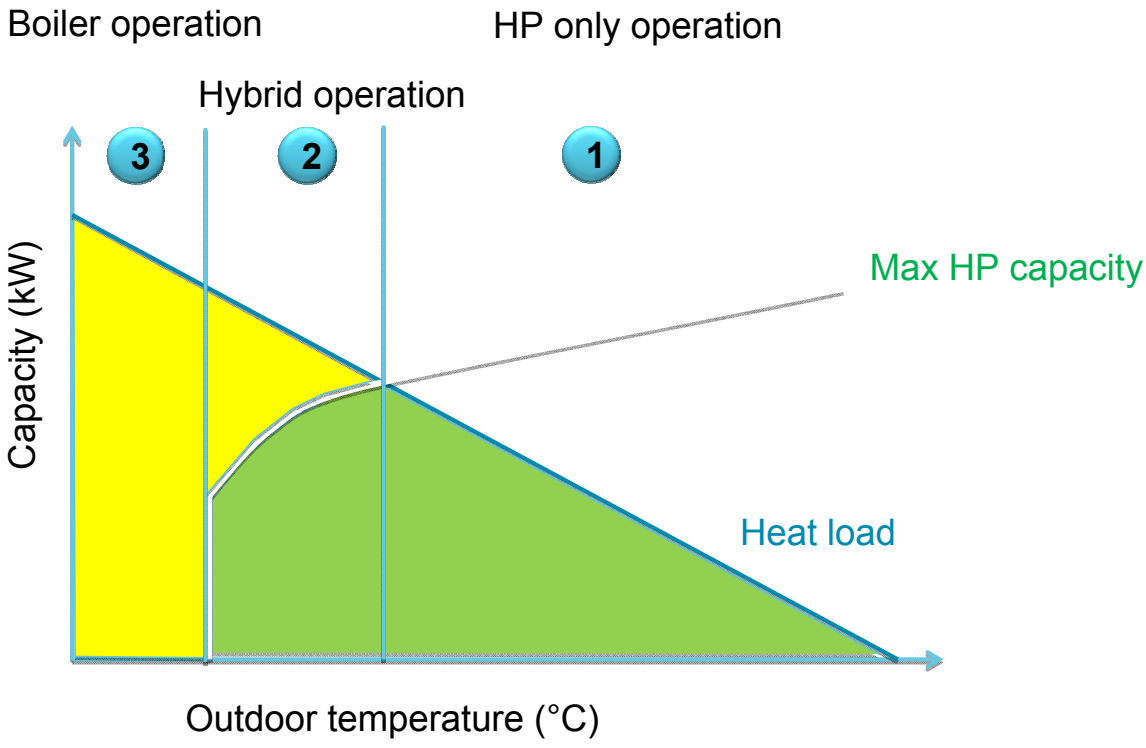
- Markets and challenges
- Components
- Research and development
- **Systems**

The Solution: ROTEX HPU hybrid Gas-Hybrid-Heat Pump

- Combination of heat pump and high efficient gas condensing boiler



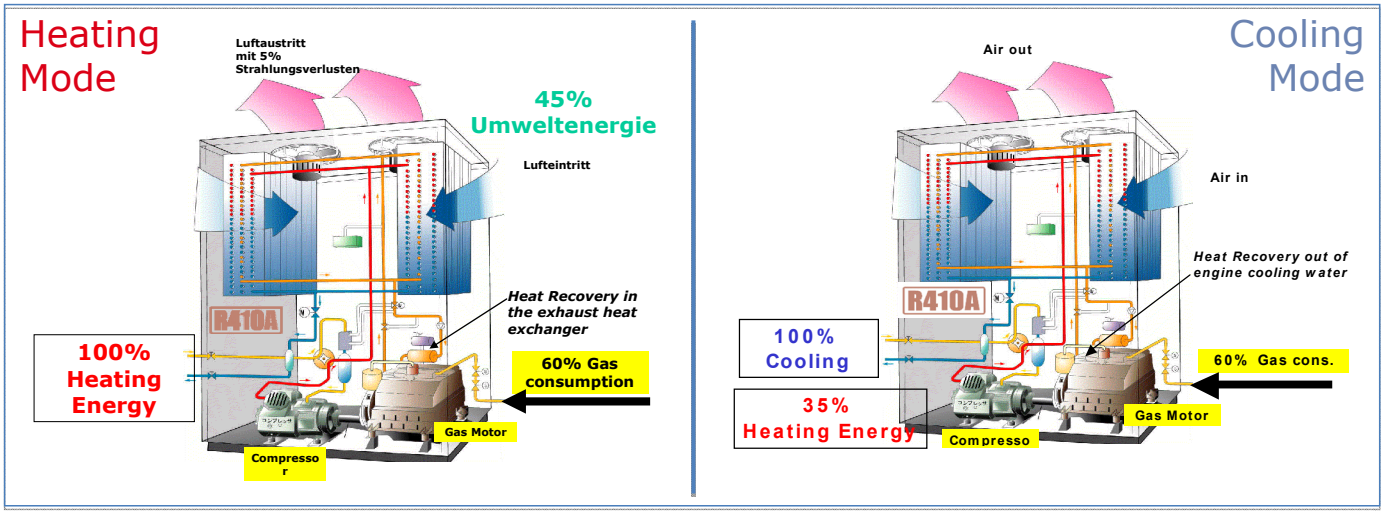
Operation modes



YANMAR

KKU CONCEPT

Gas Heat Pump – Performance Characteristics



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TECHNIK FÜR MENSCH UND UMWELT

MITSUBISHI ELECTRIC
Changes for the Better

for a greener tomorrow eco Changes

VRF heat pump technology replaces conventional oil heating system

Air-to-Air heat pumps
for a sanatorium in Hungary

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Facts & figures

- 17.000 sqm building built in early 1920
- 400 patient rooms
- 34 Air-to-Air heat pumps
- 568 indoor units
- 18 kilometers copper pipes
- 25 kilometers wire for BUS-communication

- 60% reduction in thermal heating demand
  - 2 MegaWatth before renovation
  - 840 KWh post renovation

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Advantages (heat pump technology)

Before

After

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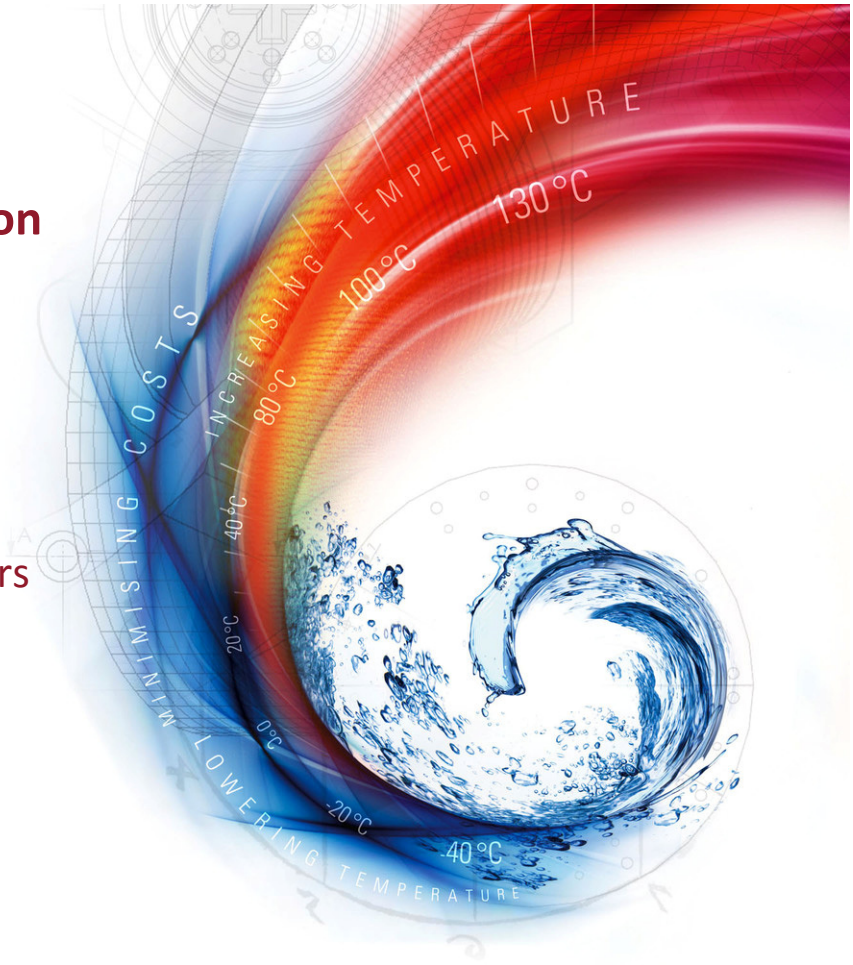
Energy efficiency and sustainability in production and building technology

> CO_2 – heat pumps

> CO_2 – chillers

> CO_2 – compressed air dryers



Heat recovery
Refrigeration
Heat-cold-coupling
Refrigeration drying

thermea. Energiesysteme

Project: datacenter Zurich/Rumlang (CH)Heat-Cold-Coupling for server cooling and district heating outlet till 90 °C
Implementation possibility at certification of Green IT – standards

thermea. Energiesysteme

Project: compressed air refrigeration dryer car manufacturer in Germany

General Description

Customer: Car Manufacturers, Germany

Application: Replacement of existing refrigeration dryer with refrigerant R22

Operating conditions:

Flow: 26.500 Nm³/h

Air pressure: 6 bar (ü)

Pressure dew point: 5˚C

Cooling water temperatures:

$t_{W..E}$ = 28˚C

$t_{W..A}$ = 36˚C

Cooling capacity:

330 kW

thermea. Energiesysteme

Spectrum:
Heat pump with speed controlled screw compressor

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ENERGIEN OPTIMAL EINSETZEN.

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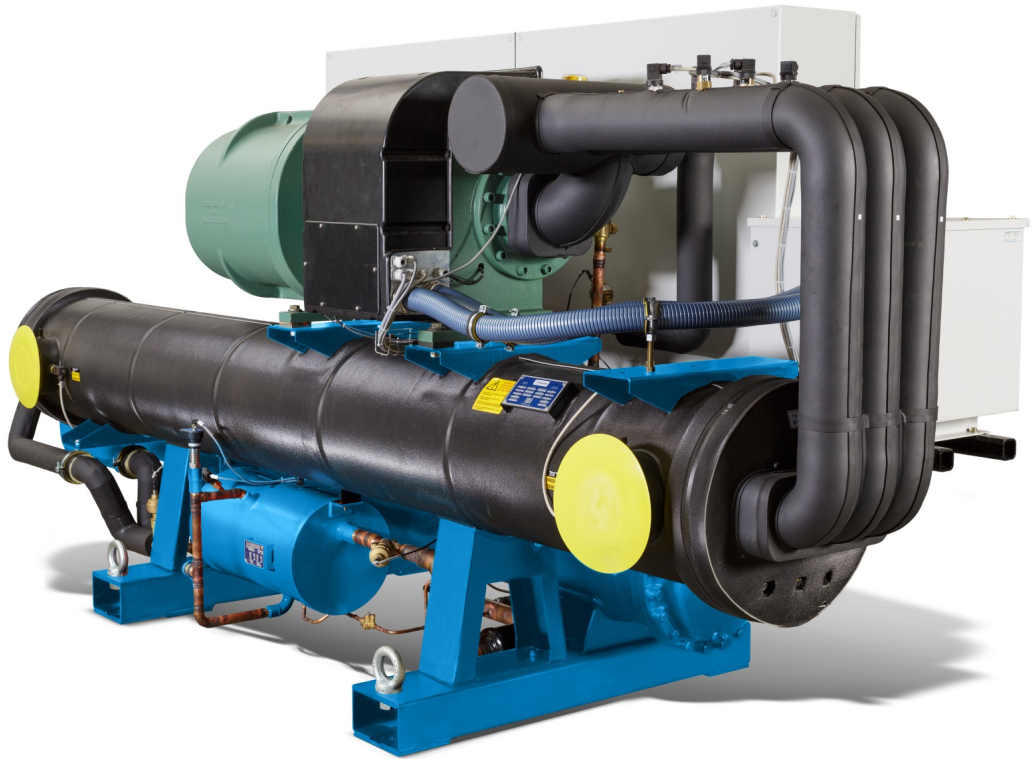
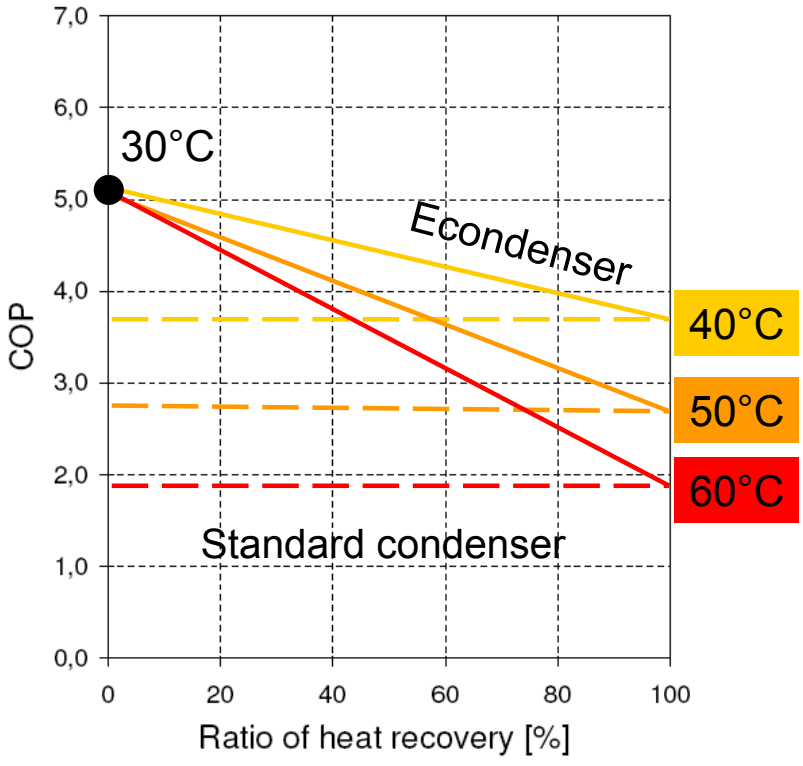
COFELY GDF SUEZ

Industrial Design



Example Standard Condenser vs. Econdenser



- Cooling AND heating demand
- Constant cooling demand (7/12 °C)
- Ambient temperature 20°C
- Variable heat demand

$$COP = \frac{\dot{Q}_{cool}}{P_{el}}$$

Germany

Trends

- Hybrid Heat pumps
  - Gas-boiler + A/W HP in one system
- HP in combination with Photovoltaic
- DHW HPs get more acceptance
- HPs →

Germany

Challenges

- Energiewende
- Electricity price increase
- Gas – price decrease, → shale gas
- nearly zero energy building


Thank you for your attention