NEW ENERGY FOR INDUSTRY

EJECTOR TECHNOLOGIES FOR PERFORMANCE INCREASE OF INDUSTRIAL HEAT PUMPS

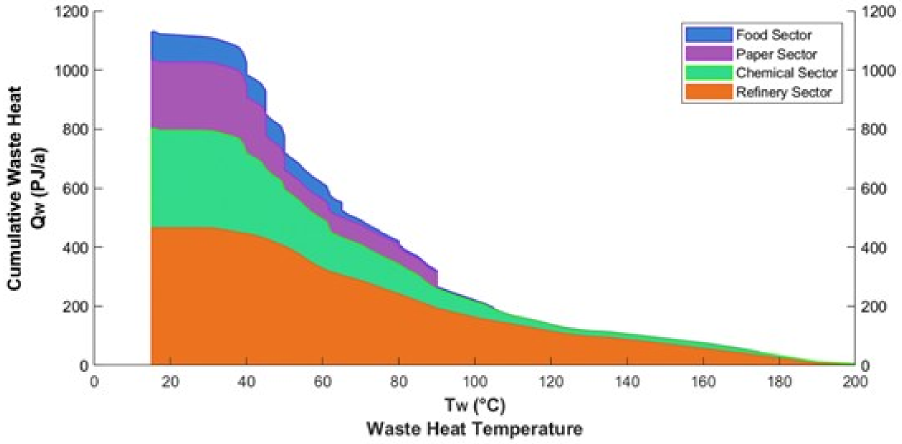
G. DREXLER-SCHMID

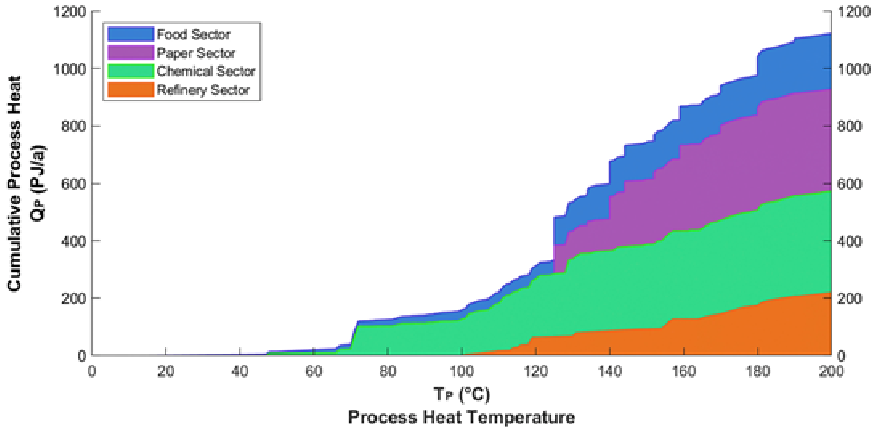
NEFI-Conference, Linz, 15.10.2022

NEFI is an Energy Model Region funded by the Austrian Climate and Energy Fund.

MOTIVATION

- Large potential of industrial heat pumps esp. in pulp & paper, chemical and food industries
- Supply temp. of >100°C with heat sink temp. mostly < 60°C
- High temperature lifts come with losses in expansion process.
- Ejectors allow recuperation of expansion energy. +27% reported in literature.





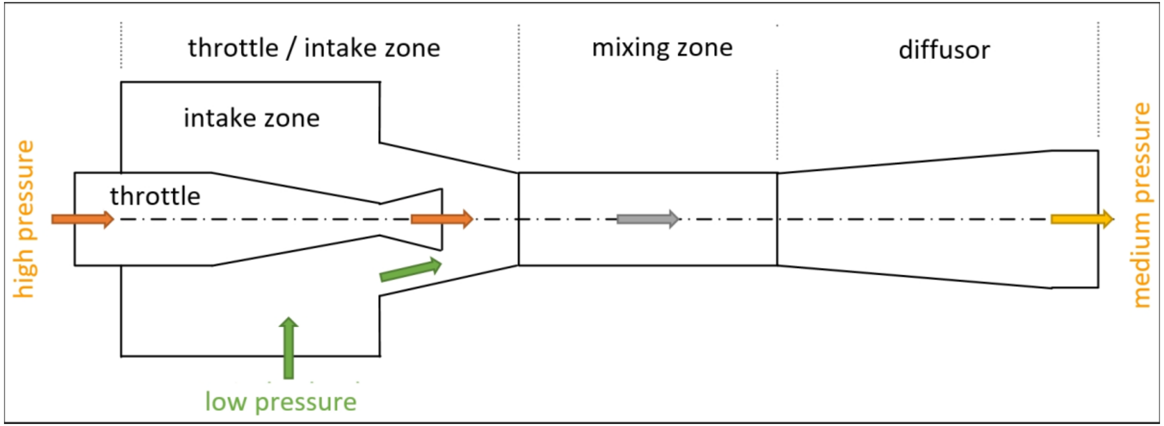
A. Marina et al. An estimation of the European industrial heat pump market potential", Renewable and Sustainable Energy Reviews, Volume 139, 2021.

Methods used for assessing technical feasibility of ejector technologies in industrial heat pump applications

METHODS (1)

NEW ENERGY FOR INDUSTRY

SIMULATIONS ON EJECTOR LEVEL



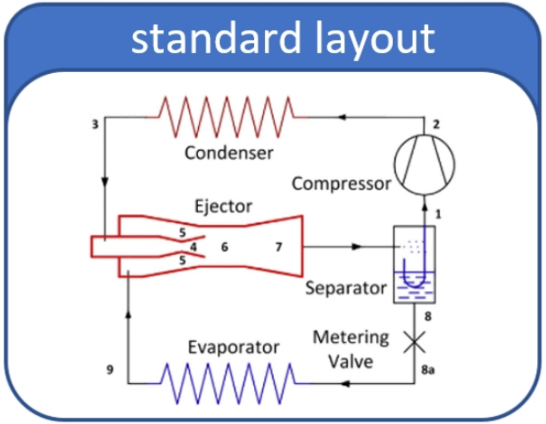
- Butane used as refrigerant for simulation of two-phase ejectors
- CFD simulations performed with Ansys Fluent® based on homogenous flow model

Entrainment ratio $$\mu = \frac{\dot{m}_s}{\dot{m}_p}$$

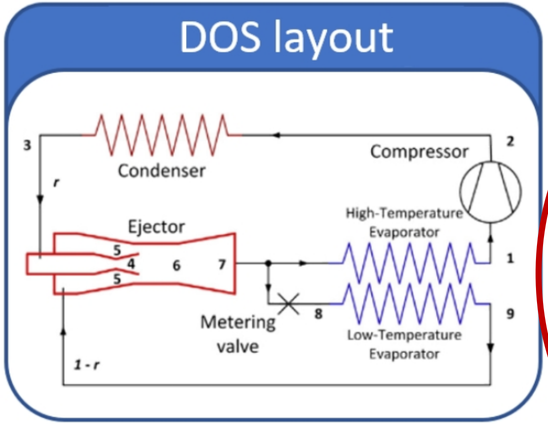
Pressure recovery ratio $$pr = \frac{p_t}{p_s}$$

METHODS (2)

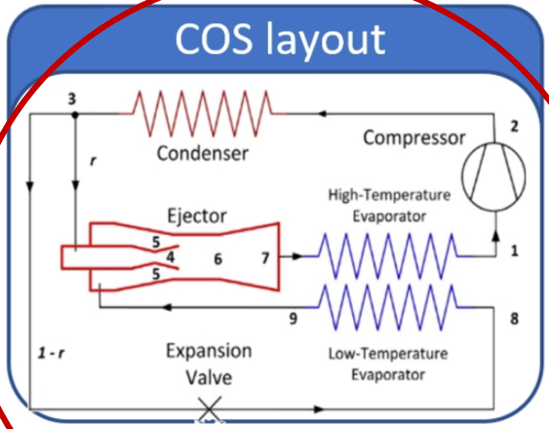
SIMULATIONS ON HEAT PUMP LEVEL - INTEGRATION LAYOUTS



1



2

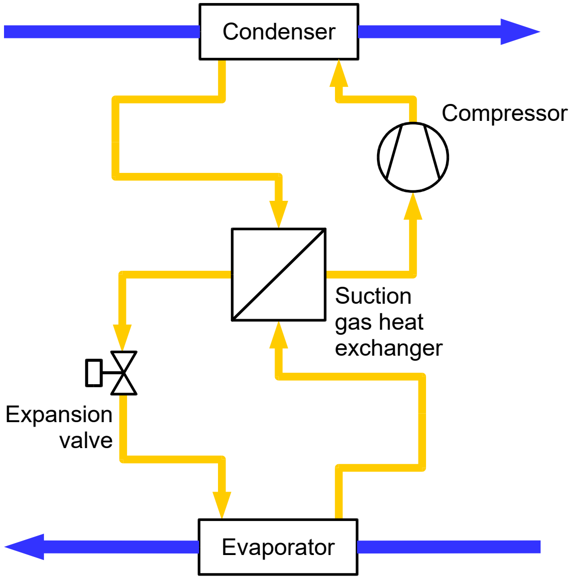


3

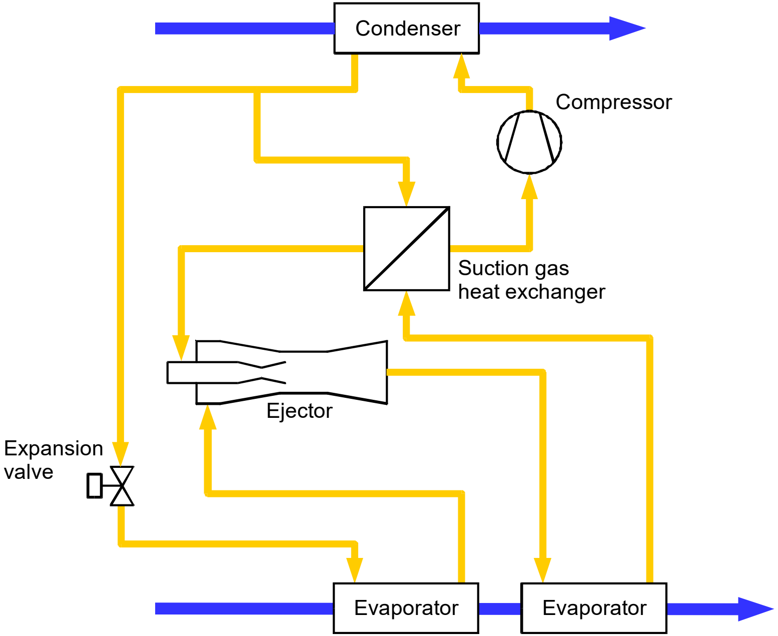
METHODS (3)

NEW ENERGY FOR INDUSTRY

STEADY-STATE SIMULATIONS OF DIFFERENT OPERATING CONDITIONS



a) REFERENCE REFRIGERANT CIRCUIT



b) EJECTOR – COS CIRCUIT

METHODS (4)

NEW ENERGY FOR INDUSTRY

CONTROL STRATEGIES OF THE MODEL

Component	Setpoint	Controlled variable
Compressor	Heat output	Speed
Valve	Superheat after evaporator	Valve position
Admixing valve on suction gas superheater	Superheat after compressor	Valve position

PARAMETERS APPLIED TO COMPARE REFERENCE & COS EJECTOR CONFIGURATION

Use case	Refrigerant	Heat source	Heat sink	Source cooling
Industrial steam production	R600	60-100°C	130°C	5 resp. 10 K
Industrial drying	R1336mzz-Z	60-100°C	160°C	5 resp. 10 K

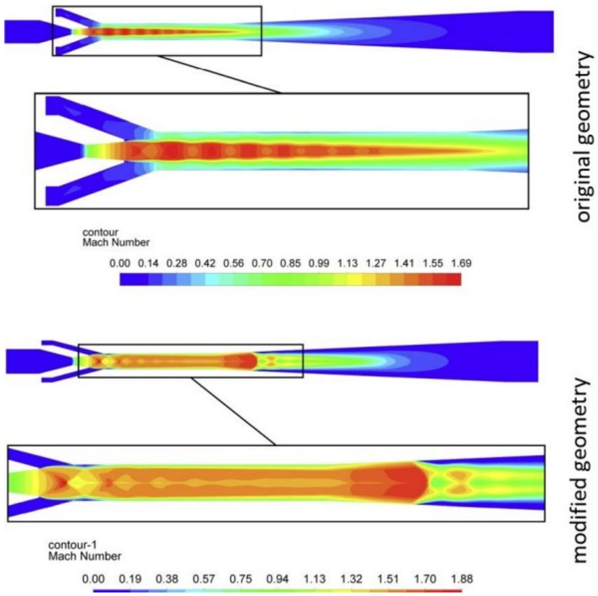
Results of work performed in the technical feasibility study

EJECTOR LEVEL: CFD SIMULATIONS

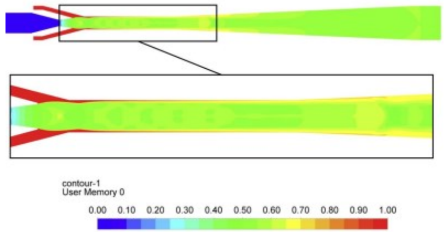
NEW ENERGY FOR INDUSTRY

Main result:

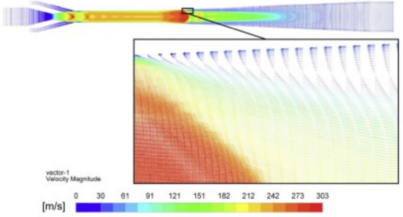
- Numerical simulations very promising
- flow behaviour and vapor quality very sensitive on ejector geometry details



a) Comparison of Mach number



b) Comparison of vapour quality



c) Velocity vectors within ejector geometry

EJECTOR LEVEL

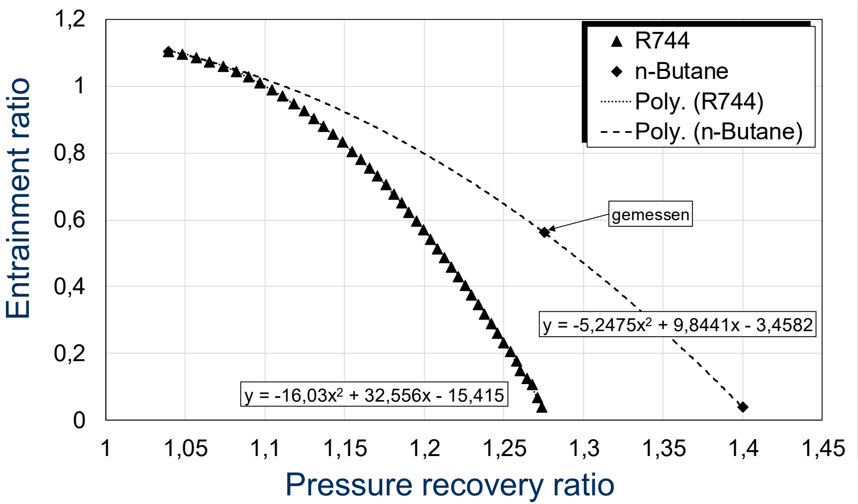
NEW ENERGY FOR INDUSTRY

R744

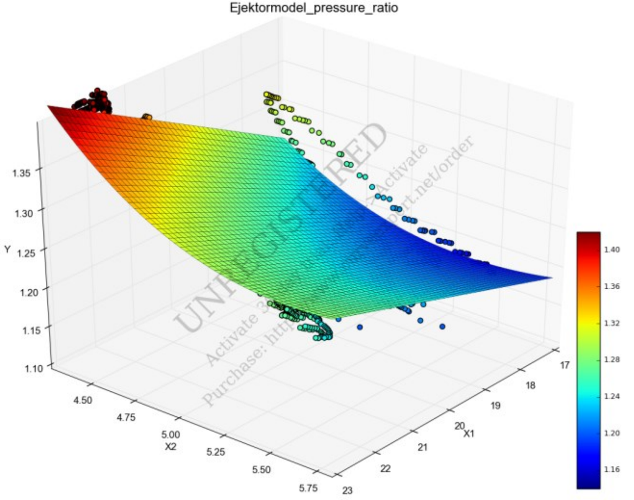
$$\mu = \frac{\dot{m}_s}{\dot{m}_p} = -16{,}03\,pr^2 + 32{,}556\,pr - 15{,}415$$

n-Butan

$$\mu = \frac{\dot{m}_s}{\dot{m}_p} = -5{,}2475\,pr^2 + 9{,}8441\,pr - 3{,}4582$$



$$pr(p_p, p_s) = a\frac{p_p}{p_s} + b\,p_p\,p_s + c\,p_p + d\,p_s + e(p_p - p_s) + f$$



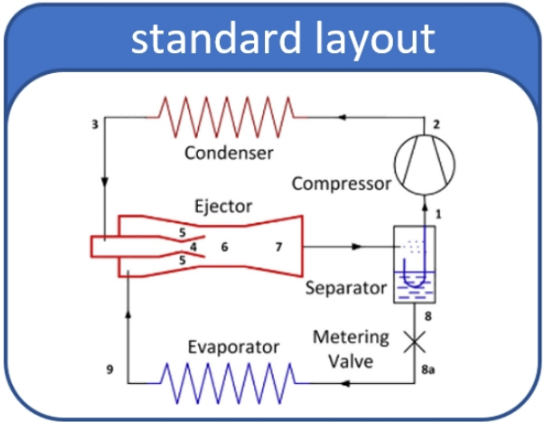
Model representation for the pressure recovery ratio; measured values plotted against model values

Banasiak & Hafner, 1D Computational model of a two-phase R744 ejector for expansion work recovery, International Journal of Thermal Sciences Volume 50, Issue 11, November 2011, Pages 2235-2247

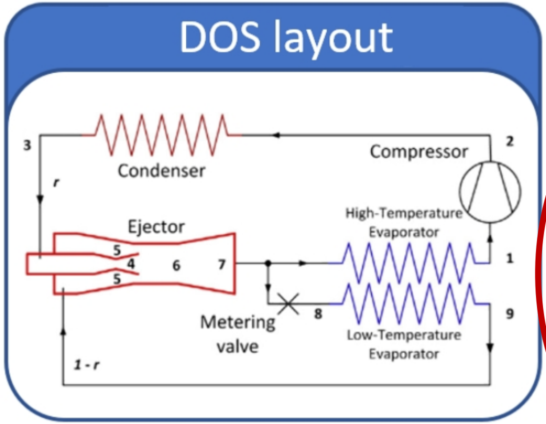
HEAT PUMP LEVEL

NEW ENERGY FOR INDUSTRY

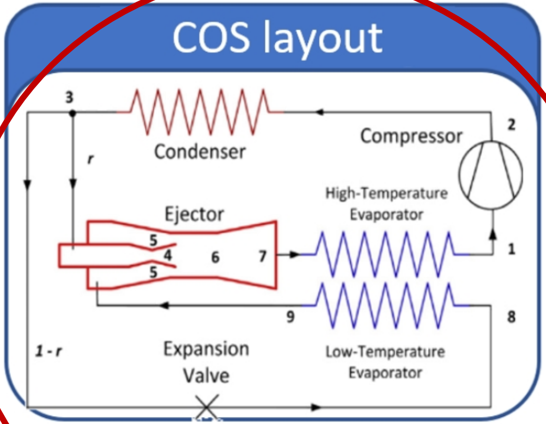
SIMULATIONS ON HEAT PUMP LEVEL - INTEGRATION LAYOUTS



1



2

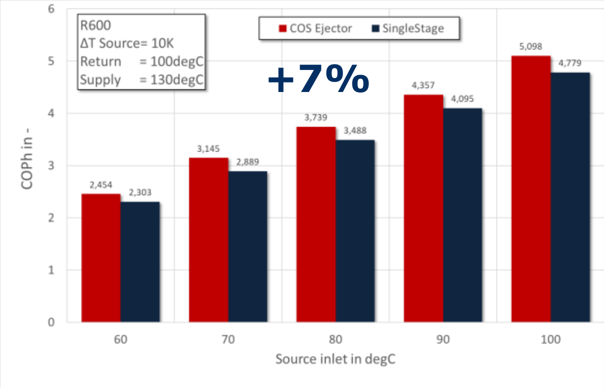


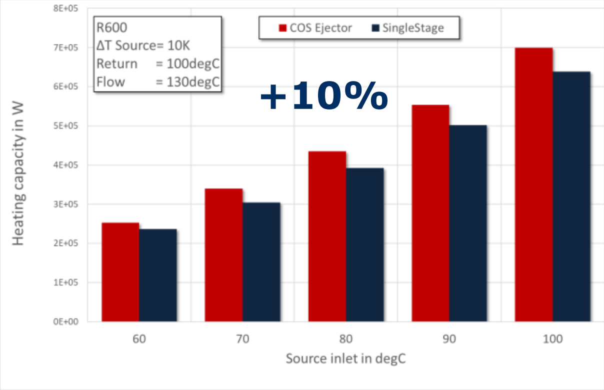
3

HEAT PUMP LEVEL: SOURCE COOLING 10K

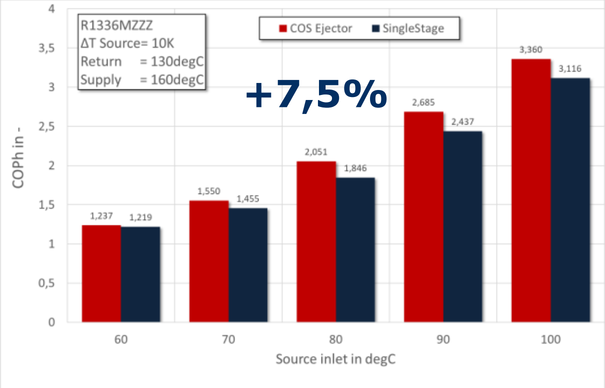
NEW ENERGY FOR INDUSTRY

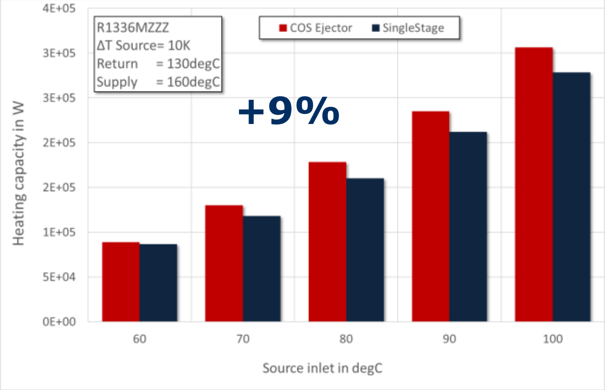
a) Steam production (130°C, R600)





b) Industrial drying (160°C R1336mzz-Z)





Ejector shows **positive effect** at prevailing pressure difference

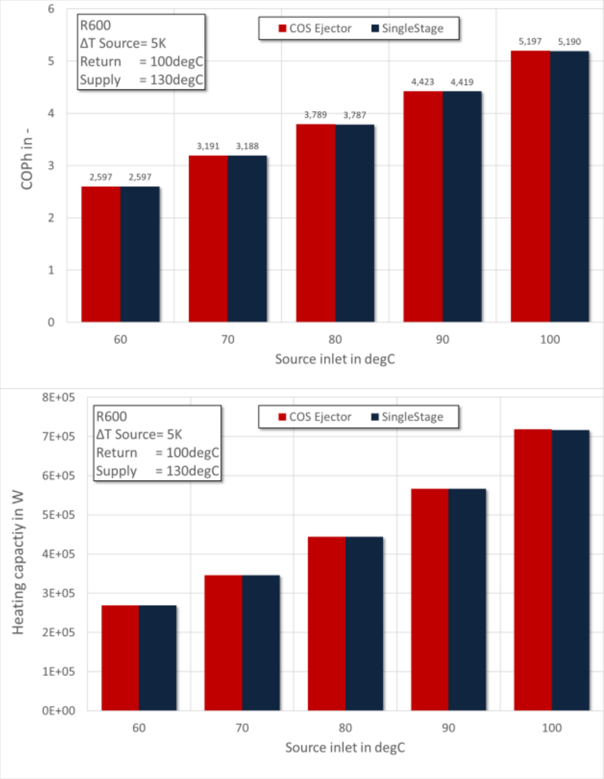
Heating capacity & COP increase

Maximum achieved for both in the middle range of source temperature (from 70 to 90°C)

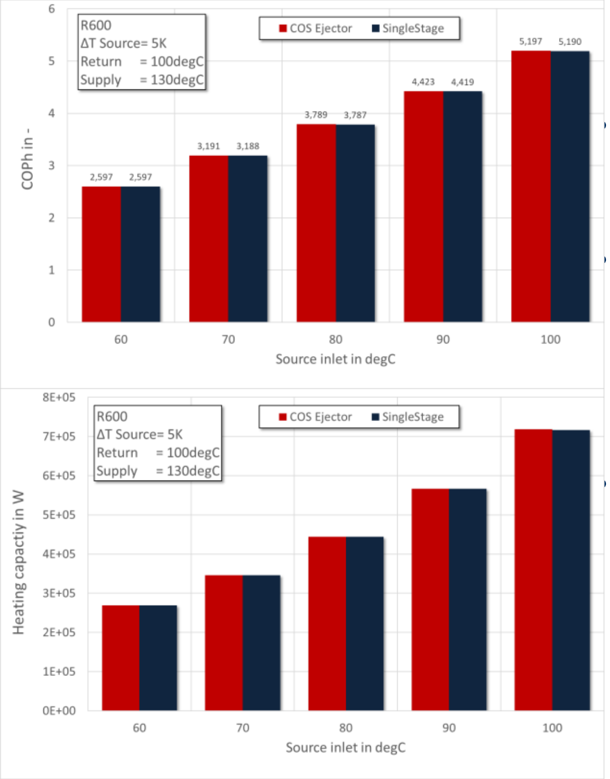
HEAT PUMP LEVEL: SOURCE COOLING 5K

NEW ENERGY FOR INDUSTRY

a) Steam production (130°C, R600)



b) Industrial drying (160°C, R1336mzz-Z)



- Ejector circuit **no significant advantage**
- Ejector is „locked“ into low-pressure difference between the two evaporators
- Operation in a single-stage mode without loss of efficiency resp. heating performance

CONCLUSIONS & OUTLOOK

NEW ENERGY FOR INDUSTRY

Conclusio

- Ejector technology has the potential to increase performance of industrial heat pumps
- Further R&D to be conducted

R&D

- Development of hermetic ejector design & tools for efficient ejector design
- Further development of models for simulation
- Experimental validation of ejectors operated under different heat pump conditions

Info

- More information on energy-intensive industrial processes with demand for high temperature heat pumps (sink temp. >100°C) and large temp. lifts (50 - 100 K) required

HOW CAN YOU SUPPORT?

NEW ENERGY FOR INDUSTRY

Your input

As **industrial end-user**: participate in **expert interviews** to assess potential of ejector technology in your company; most promising processes will be evaluated in more detail in a feasibility study **free-of-charge**.

As **engineering company**: participate in **expert interviews** to assess obstacles / barriers for market diffusion of ejector technology

Contact

Annemarie Schneeberger
+43 664 815 79 83
Annemarie.Schneeberger@ait.ac.at

NEW ENERGY FOR INDUSTRY

ANY QUESTIONS?

THANK YOU!

The results presented have been achieved in the "VWE" project, which was supported by FFG Österreichische Forschungsförderungsgesellschaft mbH (project no. 871723). Further nationally co-financed R&D work in this field is currently performed in the "ETHP" project (project no. FO999888433)