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16-17 March 2015 in Brussels

Development of CO_2 heat pump for DHW production suitable for European climates

ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Next Heat Pump Generation NxtHPG

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EUROPEAN PROJECT:
Next Heat Pump Generation working with natural fluids

Next Heat Pump Generation NxtHPG

R&D WORKING ORGANIZATION:

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

KTH VETENSKAP OCH KONST

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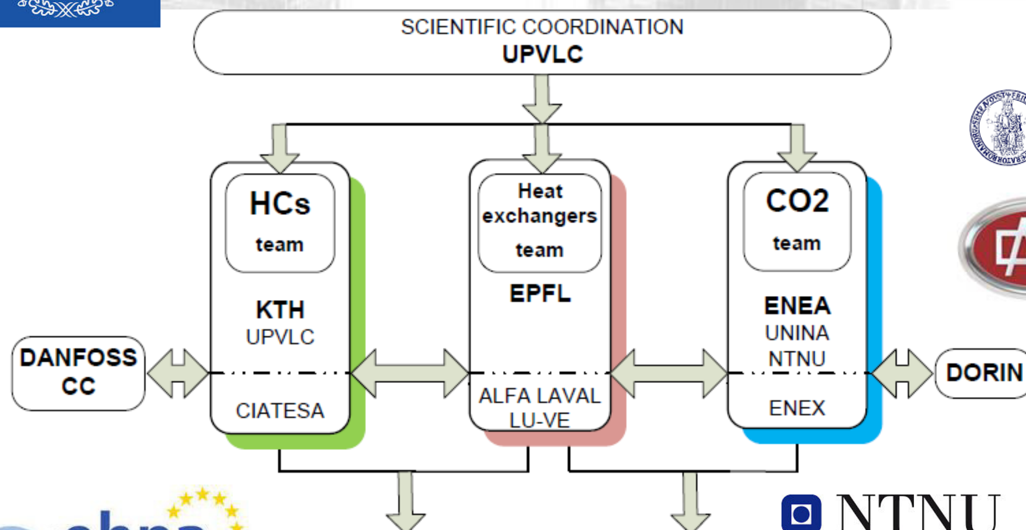

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LU-VE GROUP leadership with passion

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ALFA LAVAL

ehpa european heat pump association

NTNU Norwegian University of Science and Technology

CASES STUDY OF THE PROJECT: three R290 HPs AND two CO_2 HPs
(Project duration from December 2012 to December 2016)

THE CO_2 HPs PROTOTYPE

Case	Fluid	Source	T(ºC)	Sink	T(ºC)	Application	(kW)
4 (ENEA)	CO2	Air	-10 to 10 (winter) 20-35 (summer) (outdoor air)	Water	60 (up to 80)	Domestic hot water production	30
CASE 4 is an air to water heat pump for hot water production at 60ºC or up to 80ºC for high temperature applications.							
5 (ENEA)	CO2	Air	-10 to 35 (outdoor air)	Water	80 (return water 40)	Heating & DH water production (DHW in summer)	50
CASE 5 is an air to water heat pump for heating applications. It targets the renovation market for the replacement of old gas boiler heating systems (5-6 family houses) with high temperature radiators as terminal units. Main role is hot water production for heating but it must also provide DHW all along the year. Therefore, the development will be targeted for winter operation, although the unit will be also used during summer for DHW production.							

THE HP TEST FACILITY: THE ENEA CALORIMETER

MAIN TECHNICAL FEATURES

- *temperature range: -15°C/+35°C (± 1°C);*
- *relative humidity range: 10% - 95% R.H. (into the range +10°C÷+35°C with precision: ±3%…± 5% R.H);*
- *mobile pedestal to support the control probes;*
- *pressure compensating valve;*
- *maximum thermal power: 50 kW.*

DIMENSIONS: 4900x5700x4800 mm;
VOLUME: 120 m³.

30 kW CO_2 PROTOTYPE (AIR-WATER) FOR DHW IN TEST

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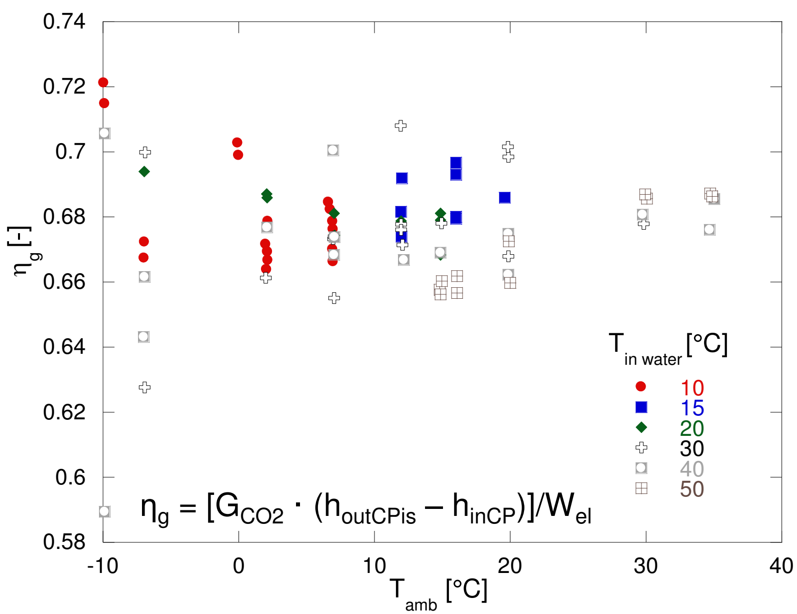
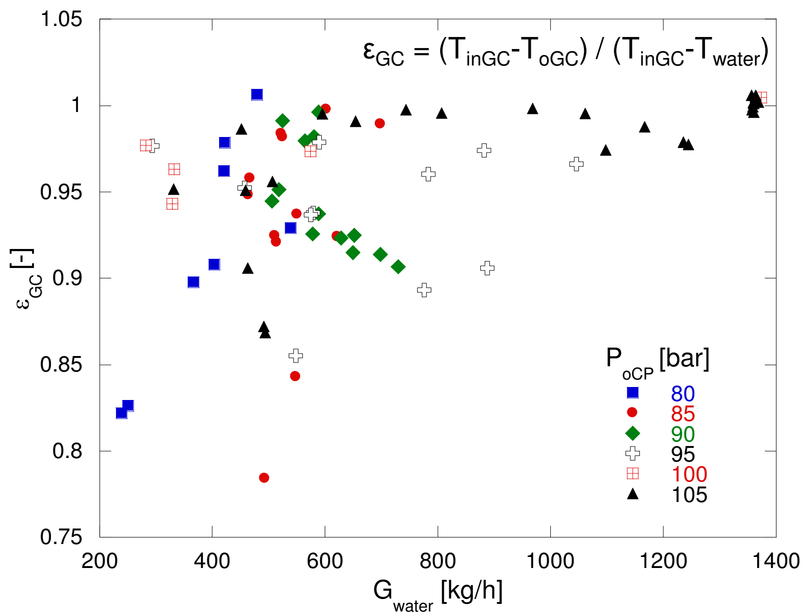
30 kW CO_2 PROTOTYPE FOR DHW: EXPERIMENTAL RESULTS

	Minimum and maximum values of the acquired parameters in tests									
	Air Temperature	Water Temperature at GC inlet	Water Temperature at GC outlet	Water Mass flow	CO_2 Temperature at GC inlet	Low pressure	High pressure	Electric power	Gas cooler efficiency	Thermal power
	[°C]	[°C]	[°C]	[m³/h]	[°C]	[bar]	[bar]	[kW]	[-]	[kW]
MIN	-10	10	55	0.25	100	23	76	7.40	0.78	11
MAX	+35	55	80	1.40	167	47	106	10	1.00	32

Global efficiency η_g vs. ambient temperature (parameter inlet water temperature)



Gas cooler efficiency ε_{GC} vs. water mass flow rate G_{water} (parameter compressor discharge pressure)



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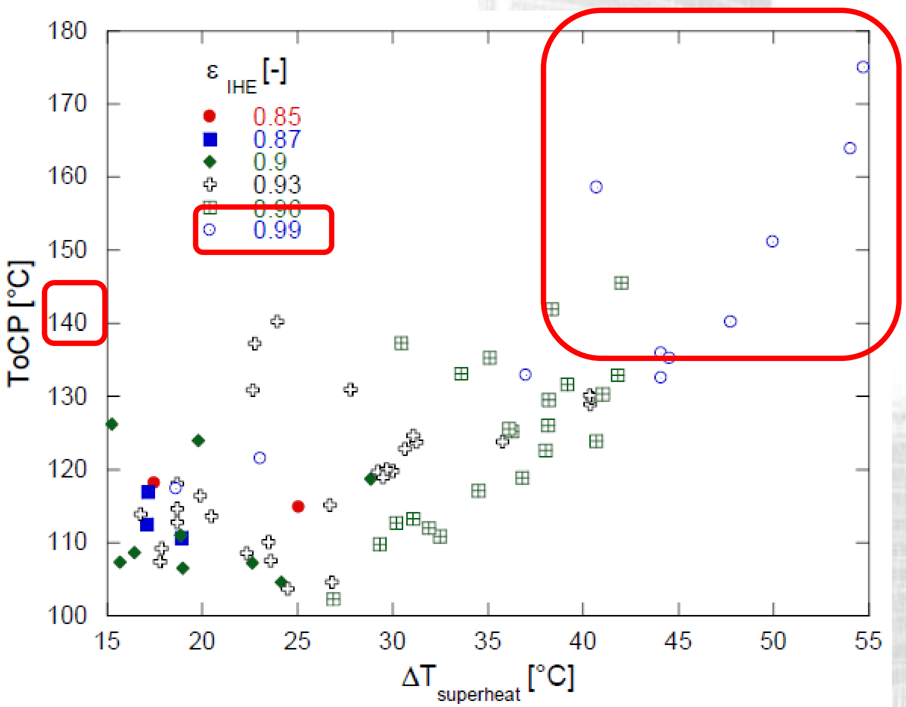
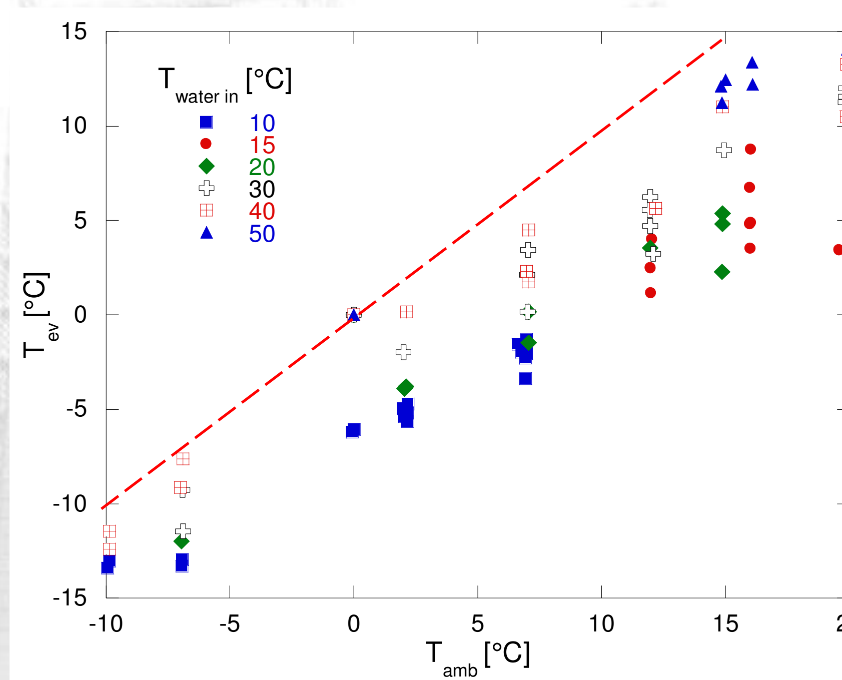
30 kW CO_2 PROTOTYPE FOR DHW: EXPERIMENTAL RESULTS

Discharge temperature T_{oCP} vs. CO_2 suction superheating (parameter IHE efficiency)



Evaporation temperature T_{ev} vs. T_{amb} (parameter inlet water temperature)



$\varepsilon_{IHE} = (T_{iIHEh} - T_{oIHEh}) / (T_{iIHEh} - T_{iIHEc})$ or $\varepsilon_{IHE} = (T_{oIHEc} - T_{iIHEc}) / (T_{iIHEh} - T_{iIHEc})$

(if the fluid with the lower thermal capacity is on the hot side or in the cold side of the IHE)

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30 kW CO_2 PROTOTYPE FOR DHW: PROTOTYPE IMPROVEMENTS

- ✓ The **COMPRESSOR** shows high mass flow and consequent high input power in many operating conditions so the improvements focus on the electric motor, the suction reeds, the valve plate and the discharge port.
- ✓ The **CONTROLLER** of the gas cooler pressure p_{gc} must be improved because at this moment it is optimized only for ambient temperature lower than 20 °C when the water inlet temperature is lower than 30°C .
- ✓ The **IHE (Internal Heat Exchanger)** shows very high efficiency that brings about high superheating at compressor inlet. This component must be improved using a co-current arragement or installing a bypass on LP side.
- ✓ The **EVAPORATOR** must be optimized increasing the circuit number, to reduce the pressure drop, improving the air distribution, using fan-shroud facing upwards, and reducing the electrical fan consumption using EC motor fan.

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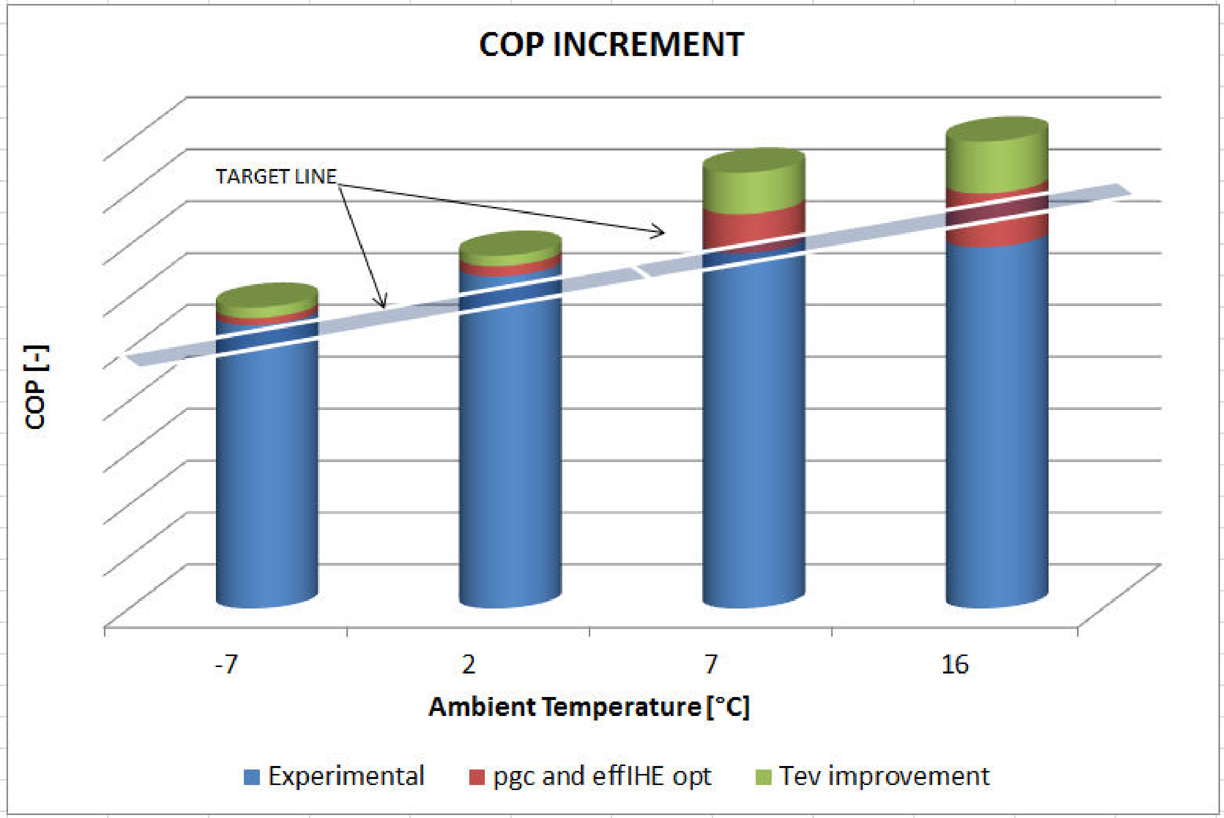
30 kW CO_2 PROTOTYPE FOR DHW: SIMULATION FOR THE IMPROVEMENTS

- ✓ Utilization of a MATLAB code to evaluate the effects of possible modifications on performances of Heat Pump.
- ✓ The performance, in terms of COP, are greatly improvable when the ambient temperature is greater than 2 ° C: the simulation shows how much the COP could increase reducing the IHE efficiency and increasing the evaporation temperature
- ✓ The effects of other possible actions on the heat pump layout were not considered (reduction of pressure drops and of thermal dispersions etc.)



COP Improvement					
T_{win} [°C]	T_{wout} [°C]	Ambient Temperature [°C]			
10	60	-7	2	7	16
p_{GC} and eff_{IHE} opt [%]		0.3	1.8	3.1	7.9
T_{ev} improvement [%]		3.8	4.4	10.9	15.2

30 kW CO_2 PROTOTYPE FOR DHW: CONCLUSIONS

- ✓ **Very good results with ambient temperature lower than 2 °C: performance target reached**

- ✓ **Modifications needed to improve performances when ambient temperature is greater than 2° C:**

  - ➢ Optimization of gas cooler pressure by internal control
  - ➢ Optimization of IHE efficiency
  - ➢ Optimization of working conditions at Evaporator

- ✓ **Matlab simulation shows the possibility to reach the performance target also with these boundary conditions through the modifications above described.**

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Thank you very much!