Development of a gas absorption heat pump for residential applications

Tommaso Toppi, Lorenzo Pistocchini, Marco Guerra, Luigi Tischer, Pietro Brevi

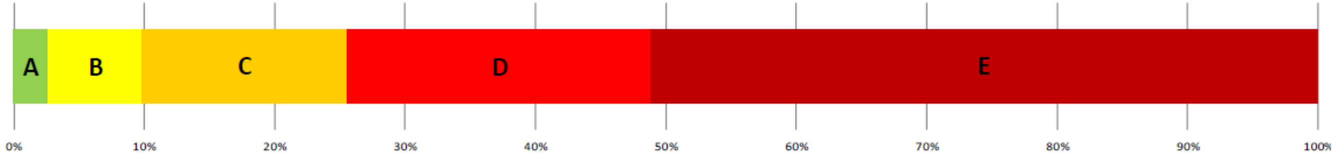
Background / Motivation

Building market in Europe:

- 75% of the building are inefficient (label D or E);
- Most of these buildings are equipped with radiator with supply temperature > 50 °C;
- In many countries there is a high (about 3) electricity/gas price ratio;
- In many countries the carbon intensity of the electricity is still high, especially in winter.

This implies that about 90% of the energy for space heating is used in building which need:

- High supply temperature and capacity at the same time;
- High efficiency also at high supply temperatures (= no use of inefficient back-up systems);
- A cost-effective solution to decrease CO_2 emissions and reduce the operating costs.



Source: Building Performance Institute Europe

The project

Scope

To develop the thermodynamic cycle and the associated technologies for a gas absorption heat pump for the residential market, able to meet the requirements of the existing buildings.

Two phases:

1. Development of the thermodynamic cycle and introduction of innovative solutions (MGS, Politecnico di Milano, Ariston)
2. Industrialization of a range of products based on the developed concept (Ariston)

Funding

- i-GAP research project, supported under the Call “Agreements for Research and Innovation of the Lombardy Region” co-financed by the ERDF ROP 2014-2020 of the European Commission. Project ID: 241736.
- LombHe@t Project, funded by Lombardy Region under the - Call Hub Ricerca e Innovazione.

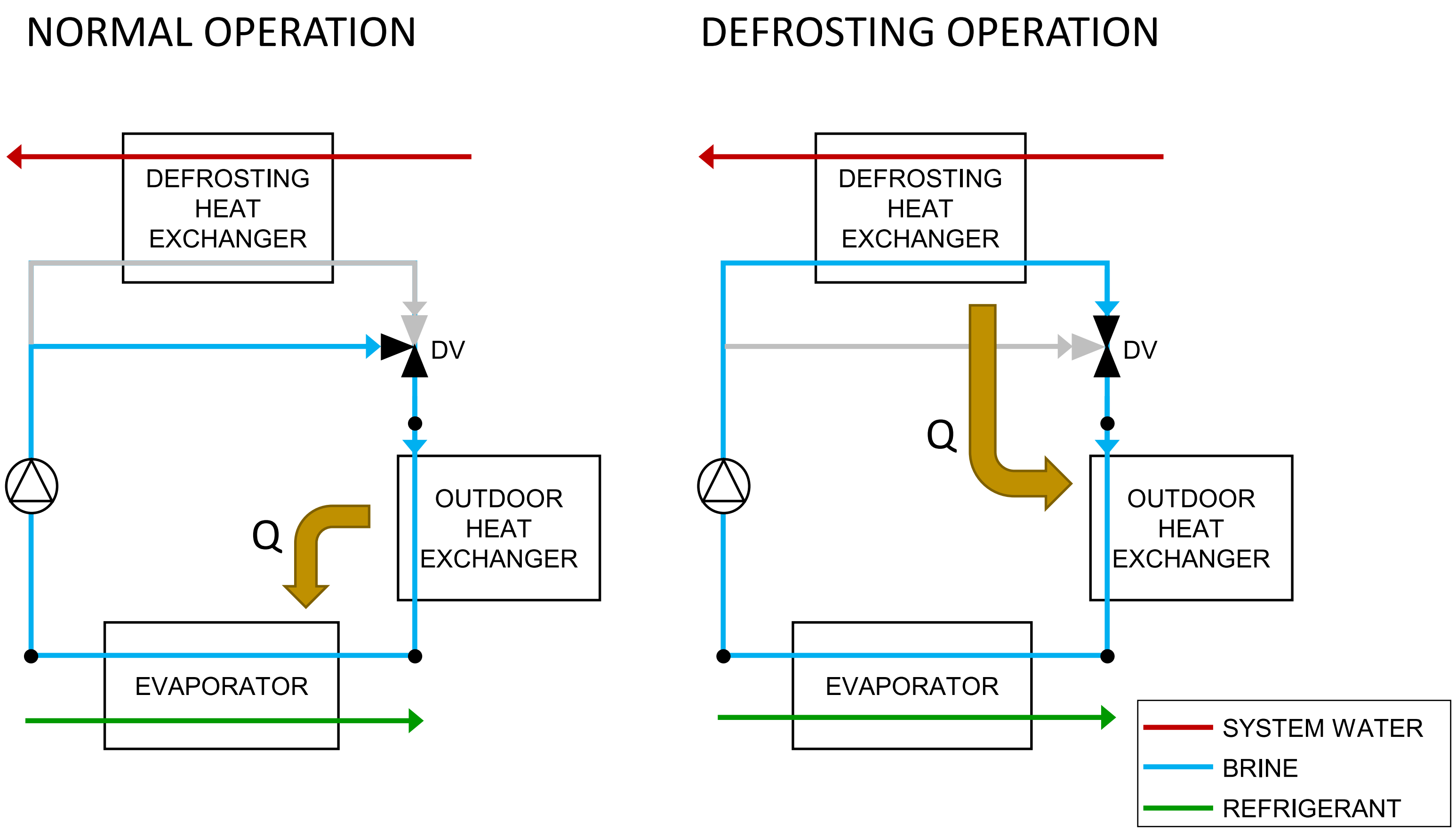
Content

In this presentation the main outcomes of the first phase will be described:

1. Main technological solution implemented in the GAHP to enhance efficiency and flexibility
    - Innovative defrosting process
    - The booster function
    - Use of a two-stage restrictor on the solution branch
2. Seasonal efficiency according to the European Standard EN 12309
3. Operating range

Innovative defrosting process

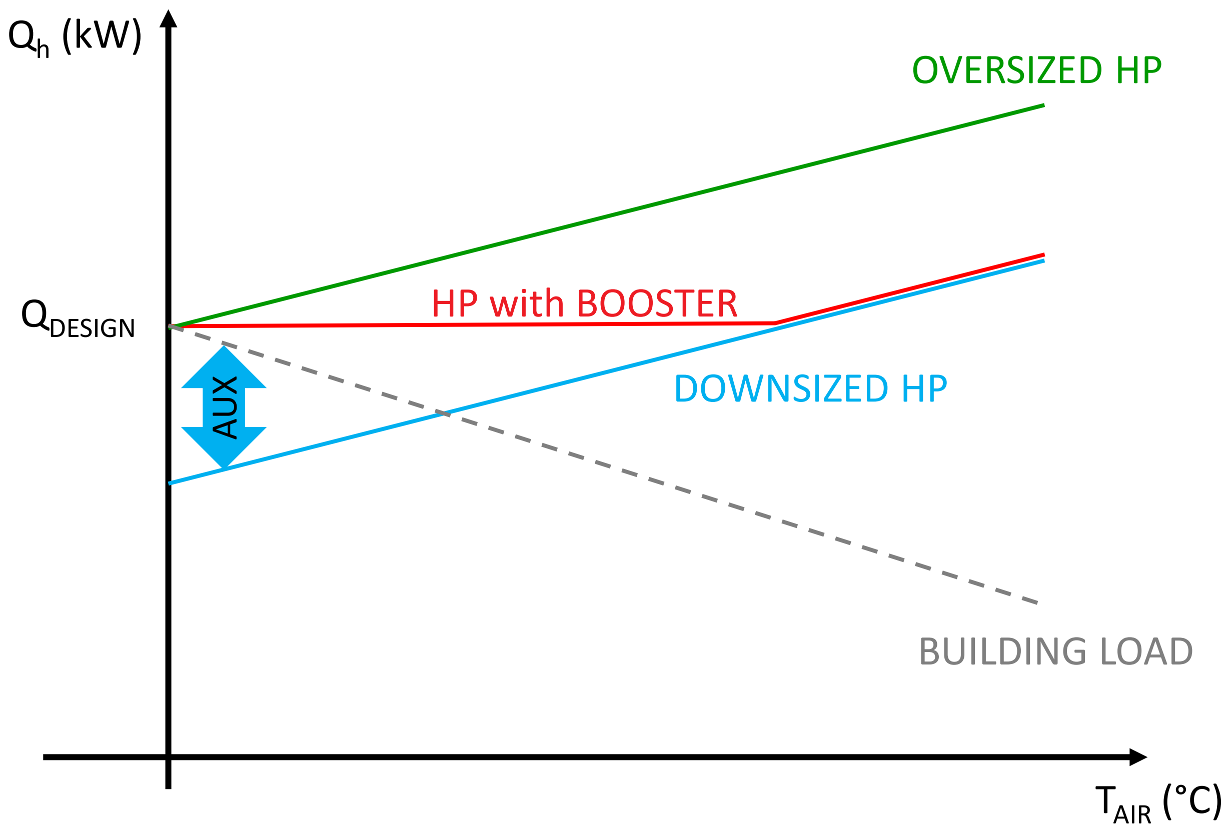
- The GAHP is equipped with an auxiliary brine loop which allows indirect evaporation.
- <u>Normal operation</u>
  the brine loop carries the ambient heat to the evaporator.
- <u>Defrosting operation</u>
  the brine loop is heated by the system water and provides heat to the finned tube heat exchanger for melting the ice.



The booster function

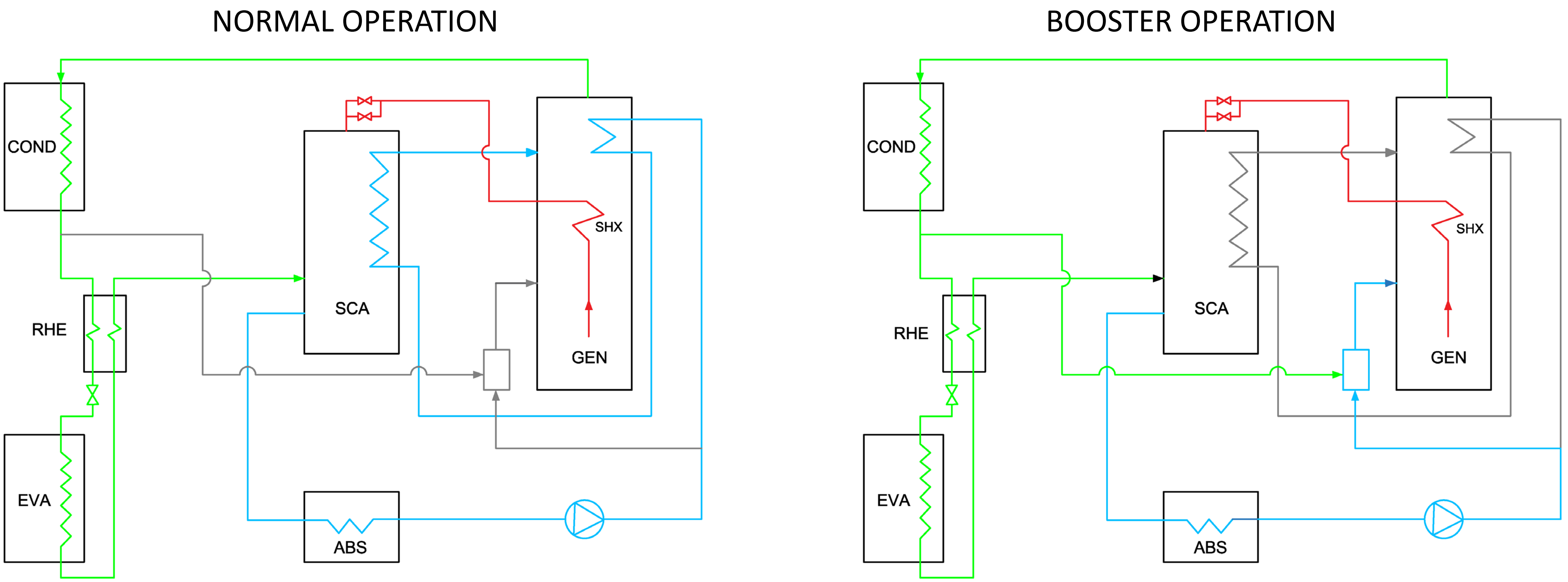
Principle

- Heat pumps usually experience a capacity reduction at high thermal lift i.e., when the capacity demand is high.
- This leads either to:
  - Oversizing of the unit (with bad operation at part load conditions);
  - Need for an auxiliary heating system (frequently electrical resistor or condensing boiler).
- With the booster* function the capacity remains constant by allowing a gas input above the nominal value, while keeping the generator temperature below the maximum value.



* Marco Guerra, *Absorption heat pump for overfeed generator operating conditions*, Patent application EP2372273B1/ US8950212B2, 2011.

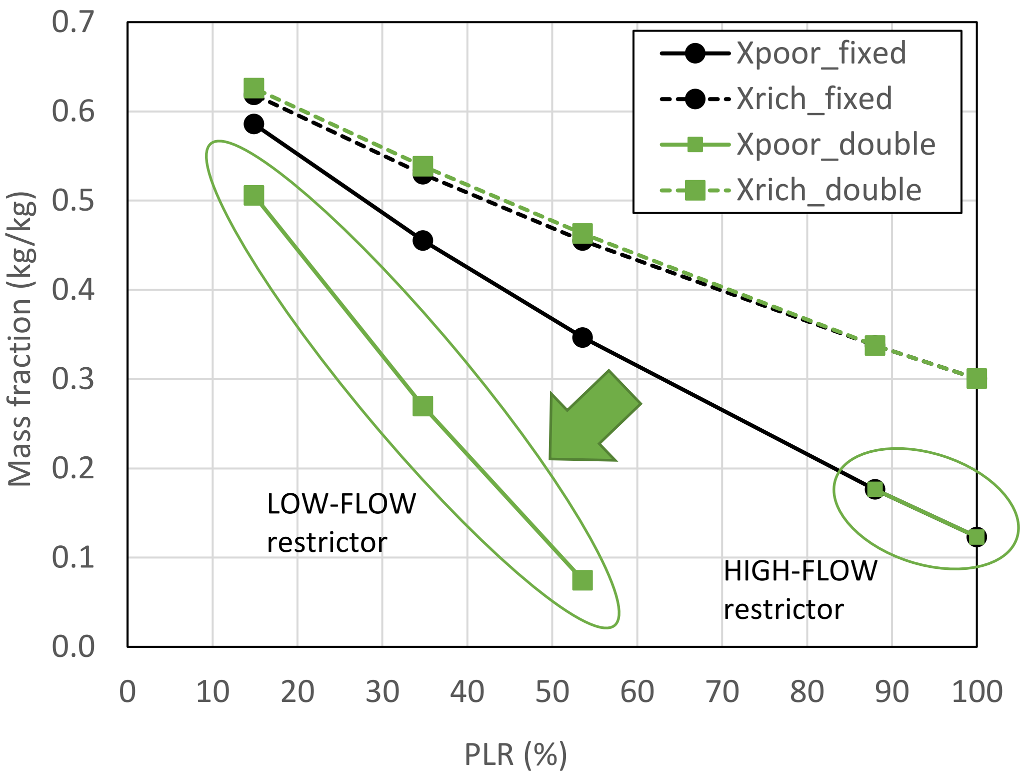
The booster function



Two-stage restrictor

- Part load operation are critical for GAHP with fixed restrictor due to:
  - Reduction of the generator temperature
  - Lower mass fraction spread and high circulation ratio
  - Reduced GAX effect.
- This causes the GAHP to operate under sub-optimal or beyond cut-off conditions.
- This issue can be prevented by adjusting the flow rate of the solution leaving the generator.
- For the developed GAHP a <u>two-stage restrictor</u> has been selected.

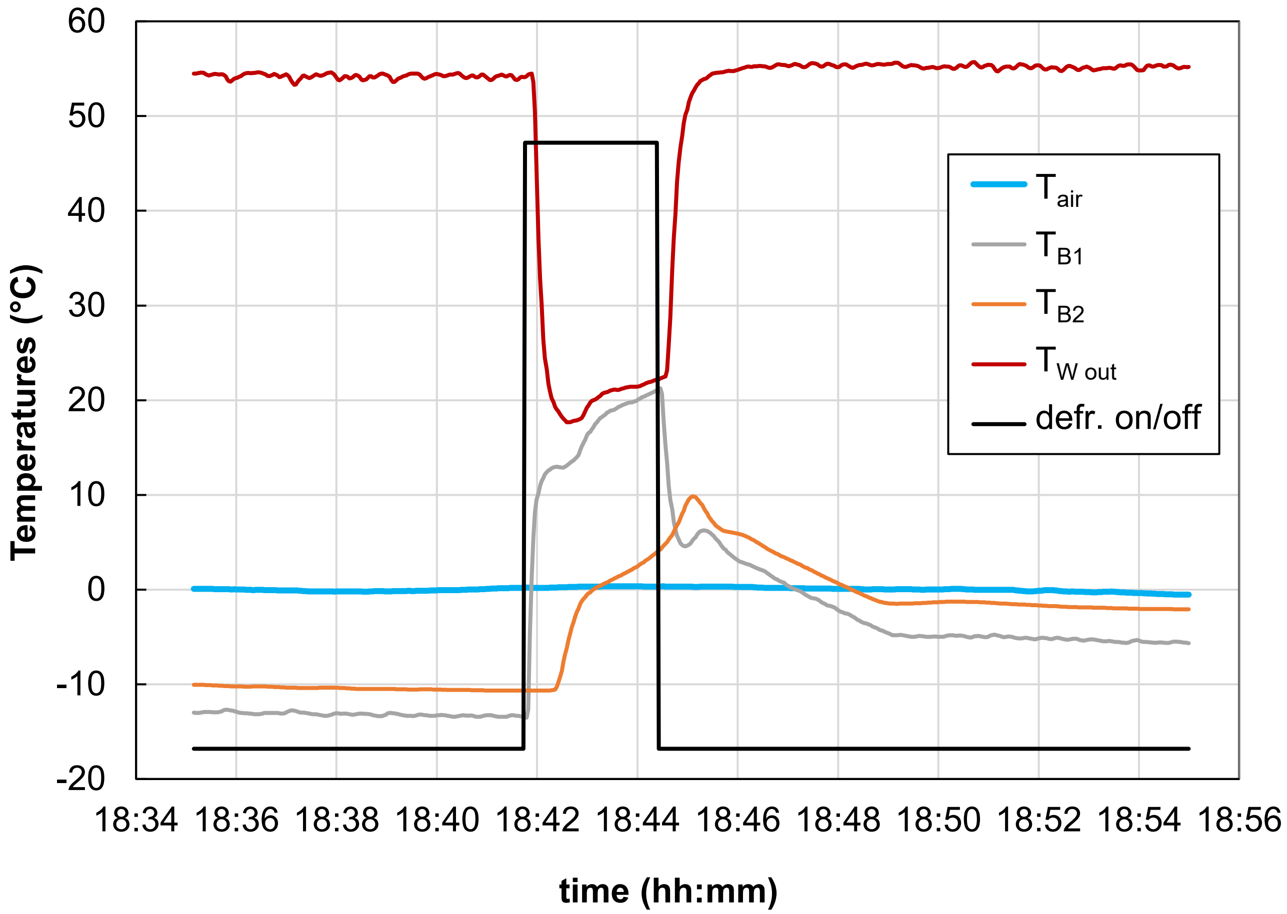
From numerical calculations:



Defrosting operation

- Defrosting is performed in just about <u>2 minutes</u>
- The operation has <u>no impact</u> on the thermodynamic cycle

- Even without any additional control, the supply temperature (and the capacity) returns to the set value after about 3 minutes from the beginning of the process.



Effect of the booster

When activated, the booster function causes:

- A reduction of the generator temperature

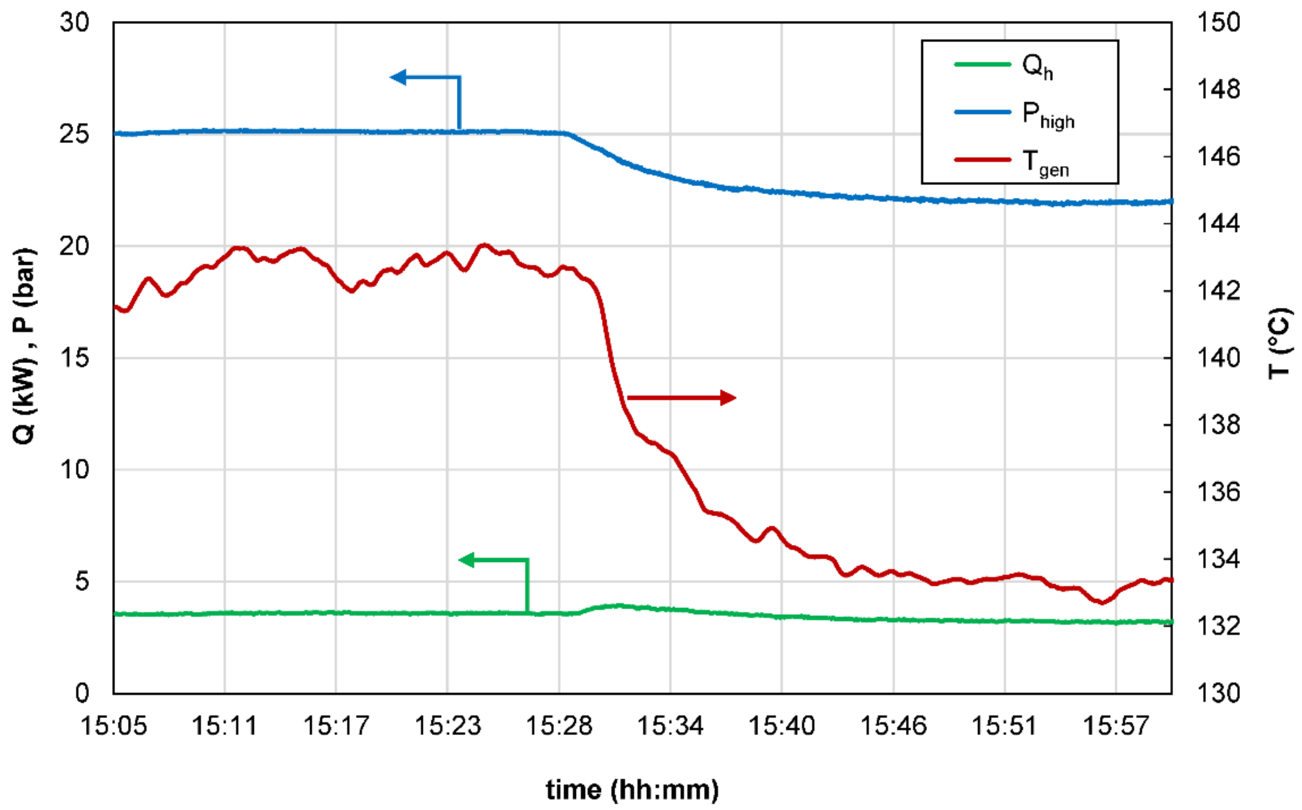
Possibility to increase the gas input

- A reduction of the high pressure

Possibility to increase the water temperature

Test conditions of the example:

- T_{air} = 20 °C; T_w = 50/65 °C; Q_h = 3.6 kW
- Objective: increase both water outlet temperature and heating capacity.



Effect of the double restrictor

With the two-stage restrictor the poor solution leaving the generator can be set to a low- or to a high-flow

- The low-flow restrictor has been designed to allow stable operation at minimum capacity and low thermal lift
- The high-flow restrictor has been designed to keep the generator temperature below 180 °C at the design conditions

In a range of intermediate conditions both configurations can be used, allowing for the optimization of the performances.

	T_{air} = 0 °C, T_w = 40/55 °C		T_{air} = 7 °C, T_w = 40/55 °C	
	Low flow	High flow	Low flow	High flow
P_{high} (bar)	15.8	16.4	19.2	19.5
P_{low} (bar)	2.7	2.5	4.2	4.3
T_{gen} (°C)	**169**	**144**	**172**	**138**
Q_{gas} (kW)	5.24	5.47	4.32	4.43
Q_h (kW)	6.33	6.63	6.26	6.27
GUE (-)	**1.21**	**1.21**	**1.45**	**1.42**

No impact on the Gas Utilization Efficiency (GUE)

Higher efficiency with the Lower flow

Seasonal performances

The seasonal performances have been calculated based on the European standard EN 12309

Test conditions related to:

- the average climate (T_{design} = -10 °C)
- high temperature application ($T_{w\ nom}$ = 55 °C)

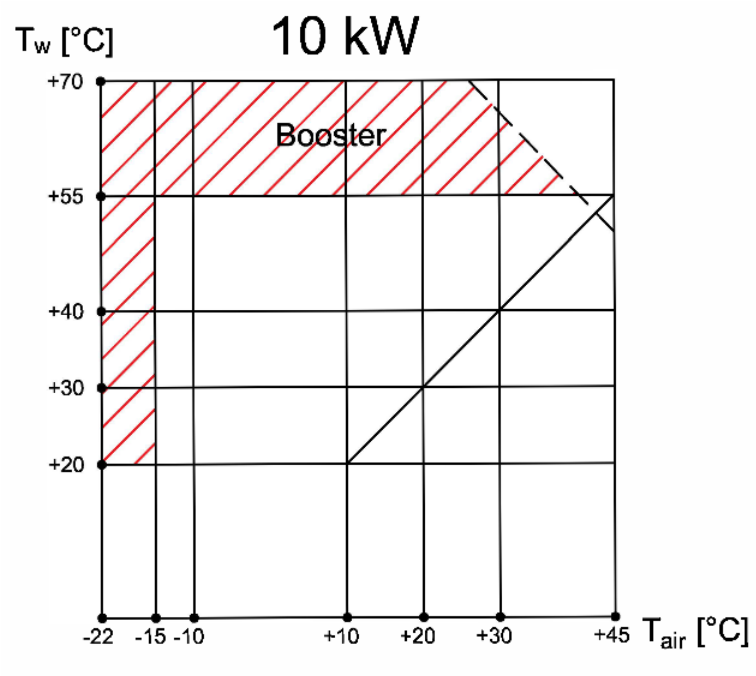
part load ratio	T_{air} (°C)	$T_{air\ WB}$ (°C)	$T_{w\ out}$ (°C)	$T_{w\ in}$ (°C)	GUE_{NCV}
100%	-10	-11	55.0	41.4	1.26
88%	-7	-8	52.0	39.4	1.33
54%	2	1	42.0	32.7	1.53
35%	7	6	36.0	28.7	1.61
15%	12	11	30.0	24.7	1.38

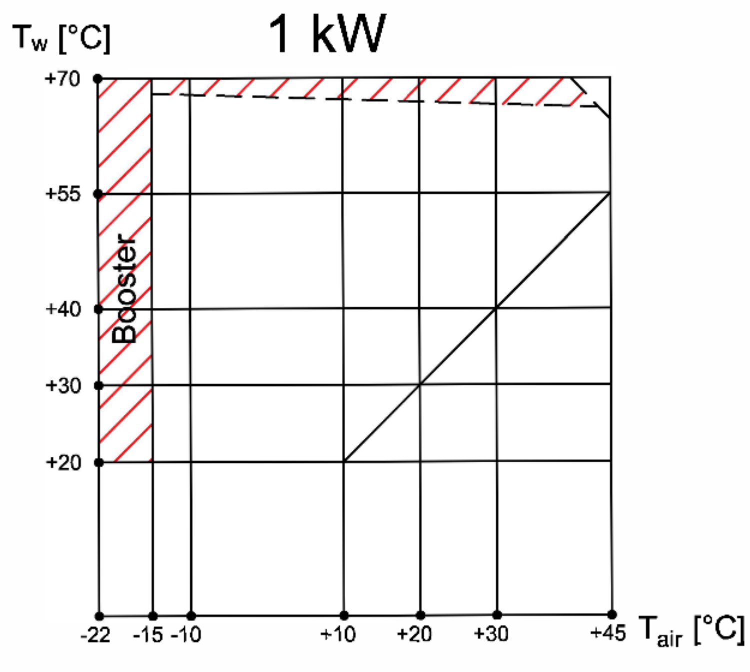
Based on the measured values, through interpolation and the use of a bin method the seasonal values are calculated.

Seasonal Gas Utilization Efficiency: **$SGUE_{NCV}$ = 1.50**
$SGUE_{GCV}$ = 1.35

Seasonal Primary Energy Factor: $\mathbf{SPER = 1.27}$
With f_{GAS} = 1 and f_{EL} = 2.5

Working envelope





Thanks to the combined action of the two-stage restrictor and the booster the GAHP:

- Can provide the design capacity in the entire operating range
- Can deliver water up to 70 °C
- Can modulate down to 1/10 of the design capacity

Conclusions

The developed solutions allowed to build a flexible and efficient GAHP suitable for the residential market.

In particular, the GAHP provides at the same time:

- High supply temperature suitable for radiators and DHW production
- Full capacity across the entire working range
- Better efficiency than a condensing boiler even at design conditions
- Lower running costs than a condensing boiler thanks to a seasonal efficiency at least 30% higher

Based on the developed concept, Ariston derived a range of products based on two aeraulic configuration, to address the requirements of the different markets

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