Laboratory characterization of a cascade heat pump system with intermediate water loop

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Introduction

- **Buildings** are responsible for **40 %** of the **energy demand** and **36%** of the **CO2 emissions** in Europe. Decarbonisation of existing buildings plays a key role to reach the overall climate protection targets. However, current **renovation rates** lie in the order of **1%**.
- The European Commission, with **REPowerEU** (communication 2022/230) sets the goal of installing 10 millions of heat pumps by 2027; this means **doubling** the actual **installation rate**.
- Several MFH buildings are old and present barriers for the installation of heat pumps. In the H2020 project **HAPPENING** a **cascade heat pump system** with intermediate **water-loop** has been developed for the **renovation of heating systems in existing buildings**.

Introduction

The cascade heat pump system with intermediate water-loop presents different advantages:

- The water loop works with neutral distribution temperature: minimization of heat distribution losses and higher efficiency than high-temperature systems.
- The existing distribution system is not replaced.
- In summer, the DHW load can be balanced with the SC load.
- The source heat pump can be decoupled to the loads: more flexibility and increase of self-consumption.
- The storage can guaranty flexibility.

Introduction

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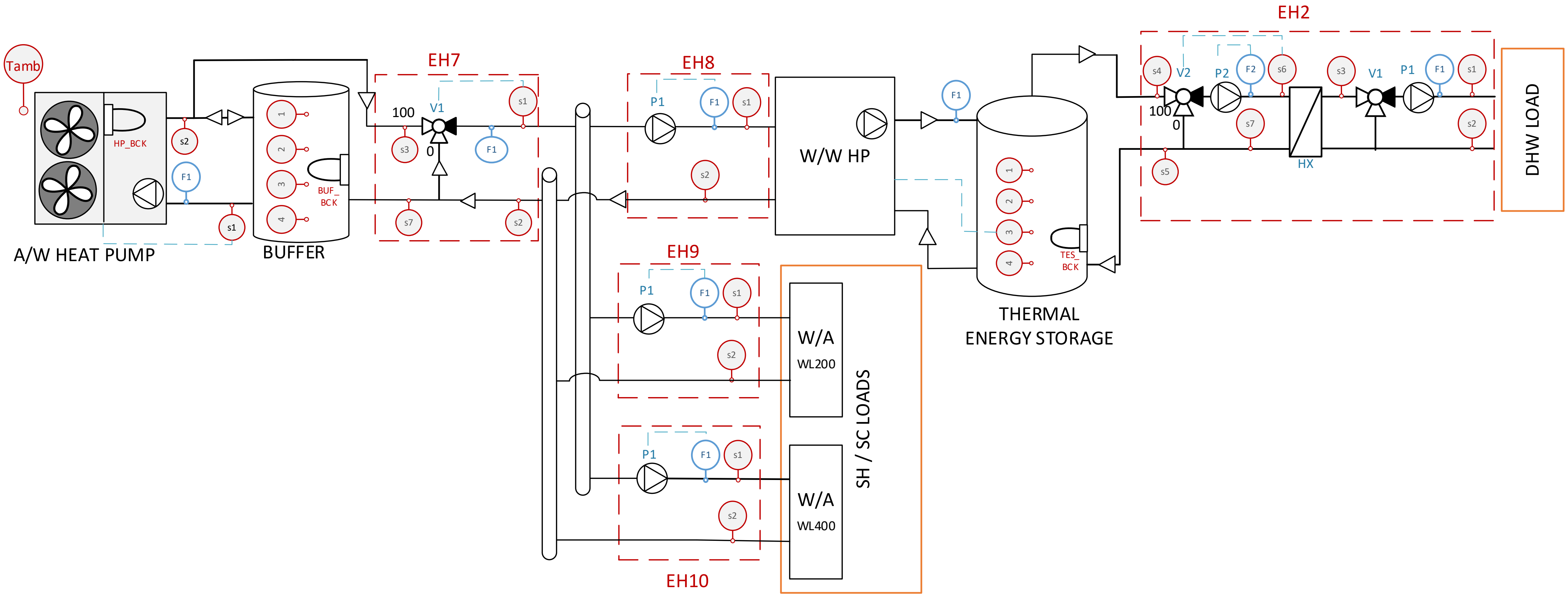

Method

Component characterization

- A/W heat pump
- W/W heat pump
- W/A heat pumps

Modelling and control development

- Theoretical performance of the system
- System model
- Development of control strategies

System characterization

- Test with traditional controllers
- Test with predictive controller

Method – Test conditions

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	Source Temperature	Load temperature	Flow	Part Load Ratio
A/W – space heating	-15 °C, -7 °C, -2 °C, 0 °C, 2 °C, 7 °C, 12 °C	30 °C, 45 °C	1.4 m^3/h, 1.96 m^3/h	100%, 60%, 35%, 20%
A/W – space cooling	20 °C, 25°C, 30 °C, 35 °C, 40 °C	7 °C, 13 °C, 22°C	1.96 m^3/h	Nominal
W/A – space cooling	10 °C, 17 °C, 25 °C, 30 °C, 40 °C	23 °C, 26 °C	200 l/h, 300 l/h	100%, 75%, 50%, 25%
W/A – space heating	10 °C, 17 °C, 25 °C, 30 °C, 40 °C	19 °C, 22 °C	200 l/h, 300 l/h	100%, 75%, 50%, 25%
W/W – domestic hot water	10 °C, 25 °C, 30 °C	45 °C, 58 °C	1.58 m^3/h	100%, 75%, 50%

Results – W/A Heat Pump

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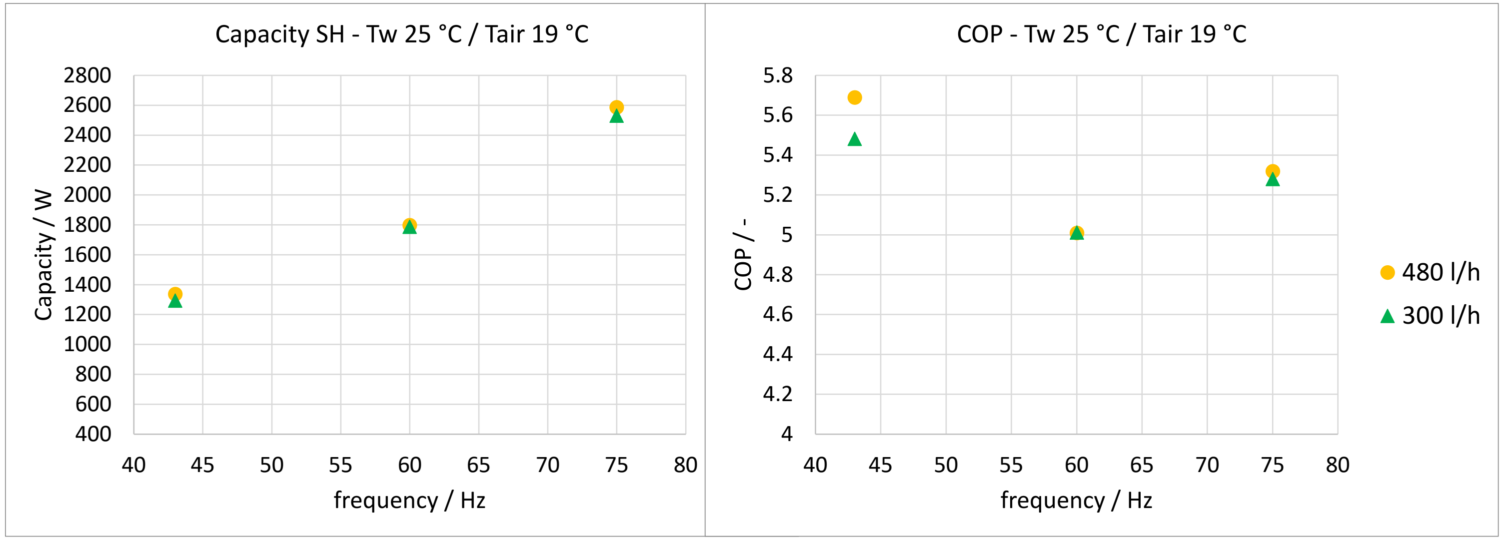
Tested 2 units: WL400 and WL200.

Identification of operative limits and performance.

- The nominal flow of WL400 is 480 l/h but in the demo case the flowrate will be between 200 and 300 l/h. Identification of minimum flow rate. Comparison of performance between nominal and application.
- Identification of unit envelope according to different load and loop temperatures.

Results – W/A Heat Pump

Comparison of performance between nominal and application flow rates.



Minimum flow rate = 160 l/h.

Results – W/A Heat Pump

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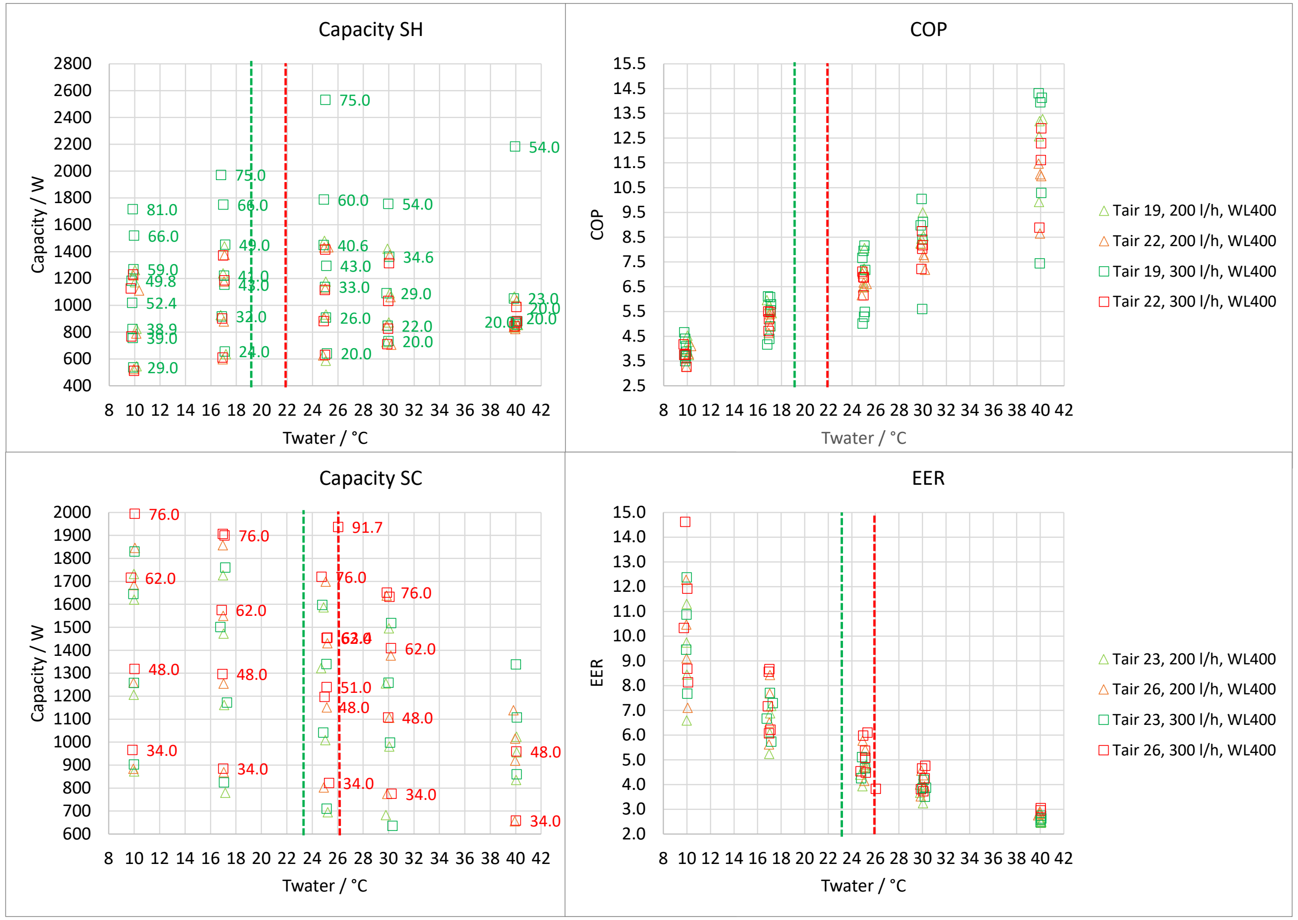

Results – W/W Heat pump

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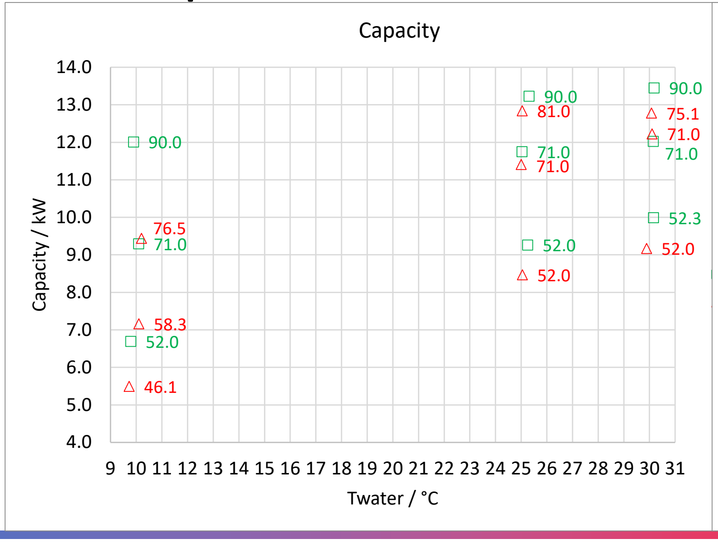
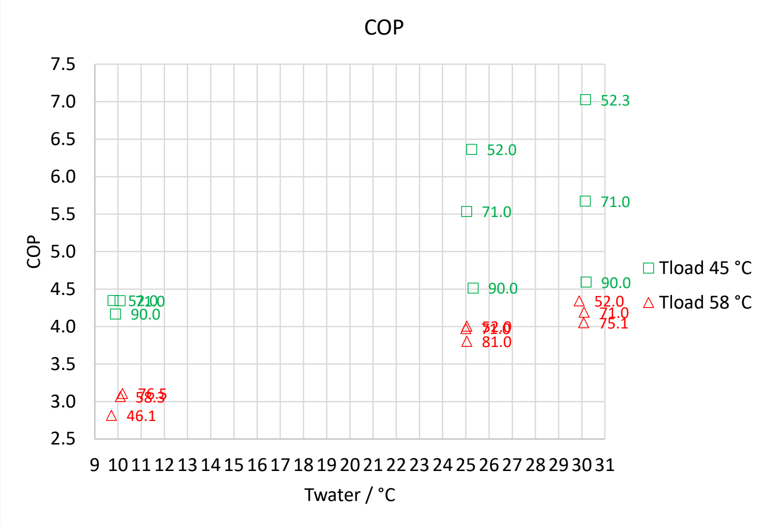
Identification of unit envelope and performance according to:

- two load temperatures
- three loop temperatures
- compressor modulation between 60% and 100%.





Results – A/W Heat pump

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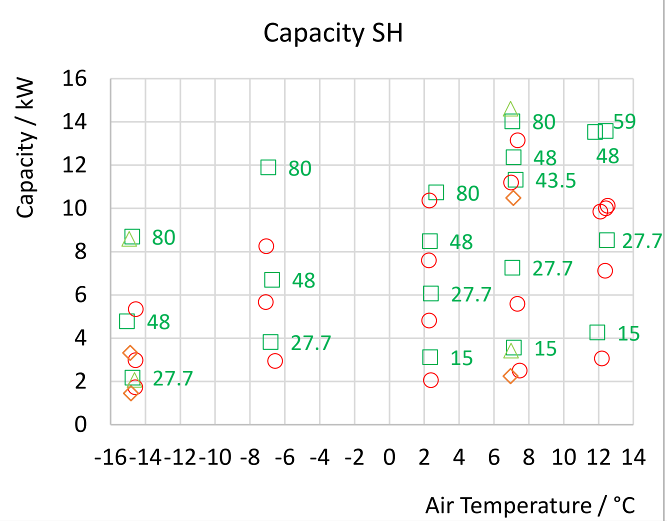
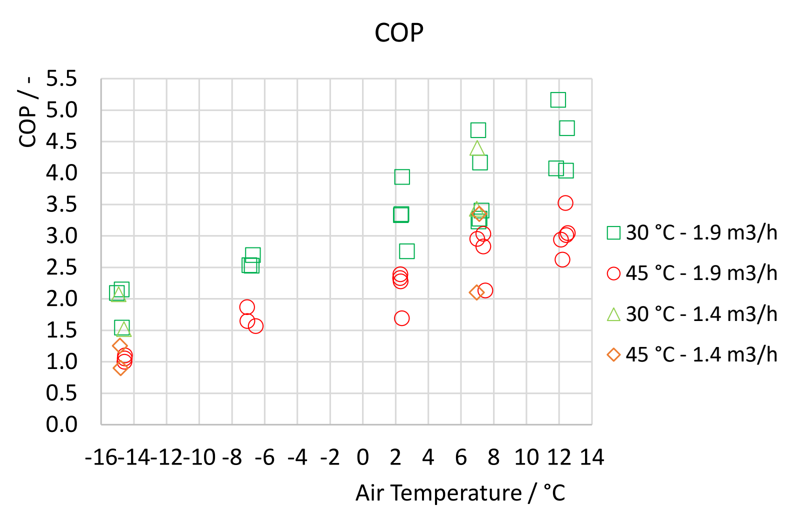
Identification of unit envelope and performance according:

- two load temperatures and five air temperatures
- compressor modulation between 20% and 100%.





Results – COP of the system (SH)

Comparison of the Cascade COP with a single stage A/W

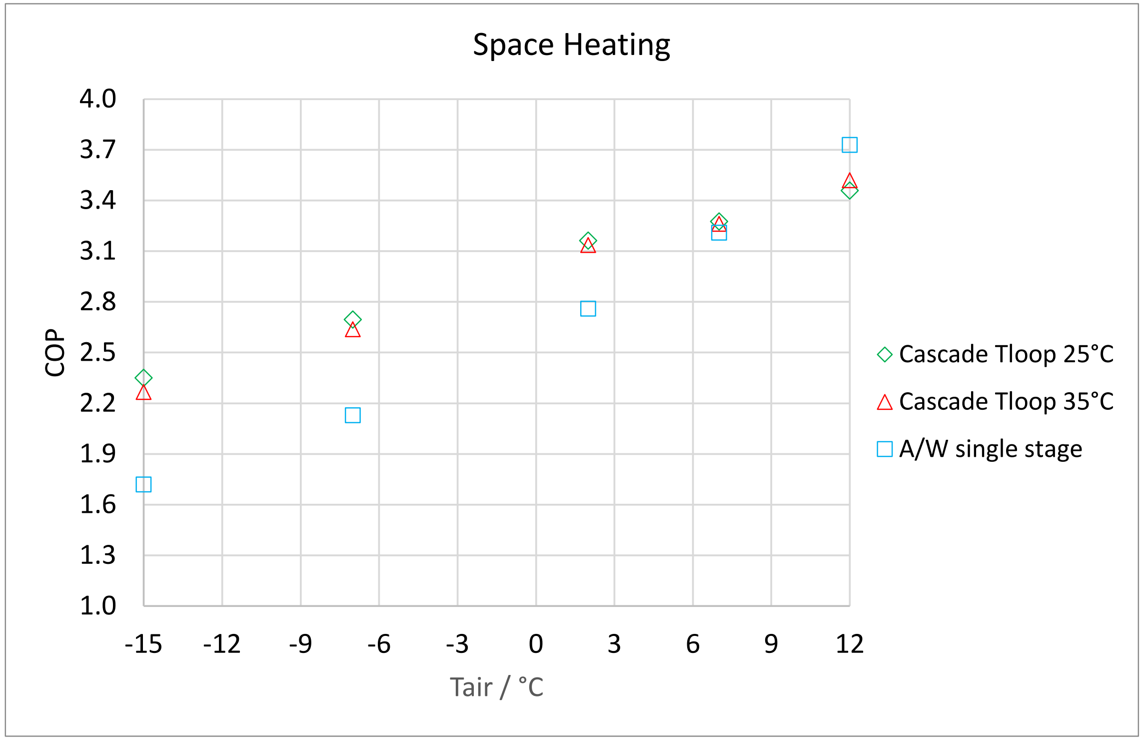
$$COP_{syst} = \frac{COP_1 \cdot COP_2}{(COP_1 + COP_2 - 1)}$$

COP1 is the COP of the A/W heat pump.

COP2 is the COP of the W/A heat pump.

W/A load temperature of 22°C.

A/W single stage heat pump load temperature of 45°C.



Results – COP of the system (DHW)

Comparison of the Cascade COP with a single stage A/W

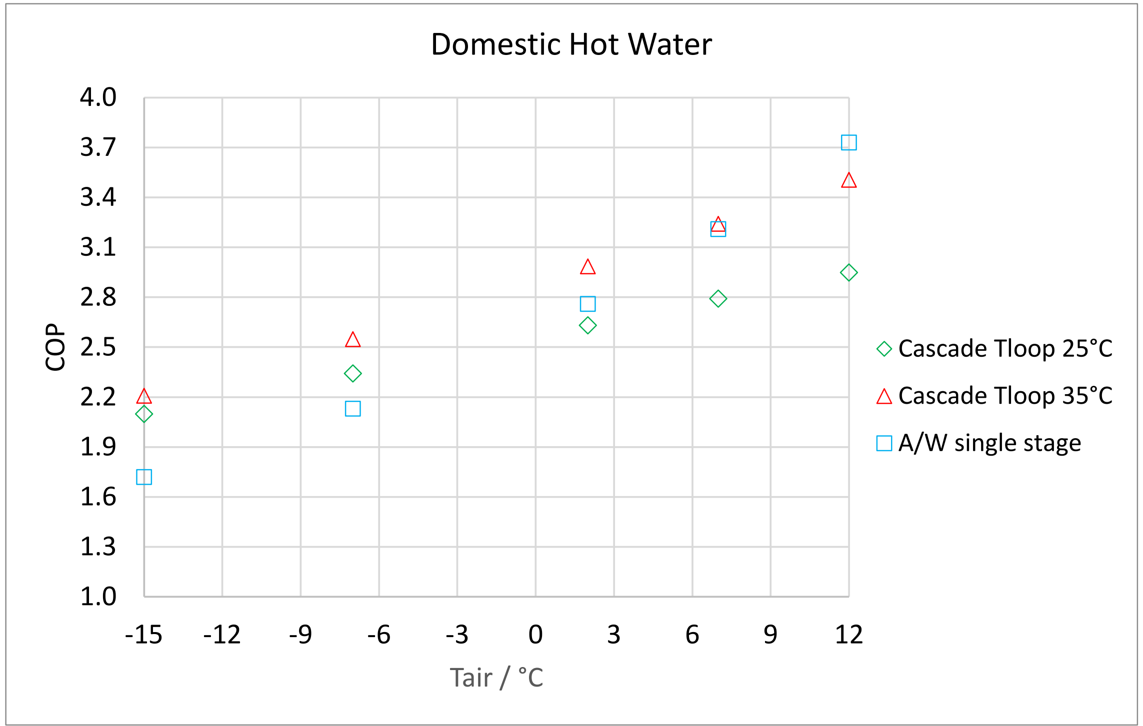
$$COP_{syst} = \frac{COP_1 \cdot COP_2}{(COP_1 + COP_2 - 1)}$$

COP1 is the COP of the A/W heat pump.

COP2 is the COP of the W/W heat pump.

W/W load temperature of 45°C.

A/W single stage heat pump load temperature of 45°C.



System test – next steps

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We tested the whole system with dynamic test evaluating different traditional controls and the predictive control developed in the project.

Conclusions

- The performance **characterization of a cascade heat pumps system** has been performed in the "**Heat Pumps Lab**" of Eurac research.
- The system has been characterized in two phases; the first phase presented in this paper, we investigated the **operational limits** and have defined a **performance map** of each heat pump.
- The results of the detailed performance map provided the **possibility** to the manufacturer to further **optimize the units' controllers** (e.g. control at PLR to optimize SCOP, management of the ventilation and the supply temperature).

Conclusions

- The **performance of the cascade** heat pump system with intermediate loop was **compared to** a system with **a single stage air-to-water heat pump** obtaining similar COPs.
- Despite the higher cost needed for the installation and similar performance, the cascade system presents **several advantages**: balance of DHW and SC load; the decoupling of the generation and the loads and the management of the storages (thermal and electrical) guarantee flexibility and renewable energy utilization.
- The second step will be the **dynamic whole system test**. In this test we will evaluate a **traditional control strategy** and the model **predictive control** developed with the **HAPPENING project**.

Acknowledgements

14th IEA HEAT PUMP CONFERENCE

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HAPPENING

He**A**t **P**um**P**s in existing multi-family buildings for achieving union's **EN**ergy and env**I**ro**N**mental **G**oals

Thank you

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