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High Performance Buildings

Performance analysis of a mini exhaust air heat pump integrated into a low energy detached house: experimental on-site performance

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Introduction

- In new buildings, the ventilation can account for 30 to 60 % of the total building heating demand.
- Consequently, highly efficient heat recovery systems on the ventilation must be developed.
- In that context, the **simple exhaust ventilation system + exhaust air heat pump** is an interesting solution.
- The on-site performance of this system were monitored in 2017 for a residential building situated in Belgium to assess the potential of the system.

Table of contents

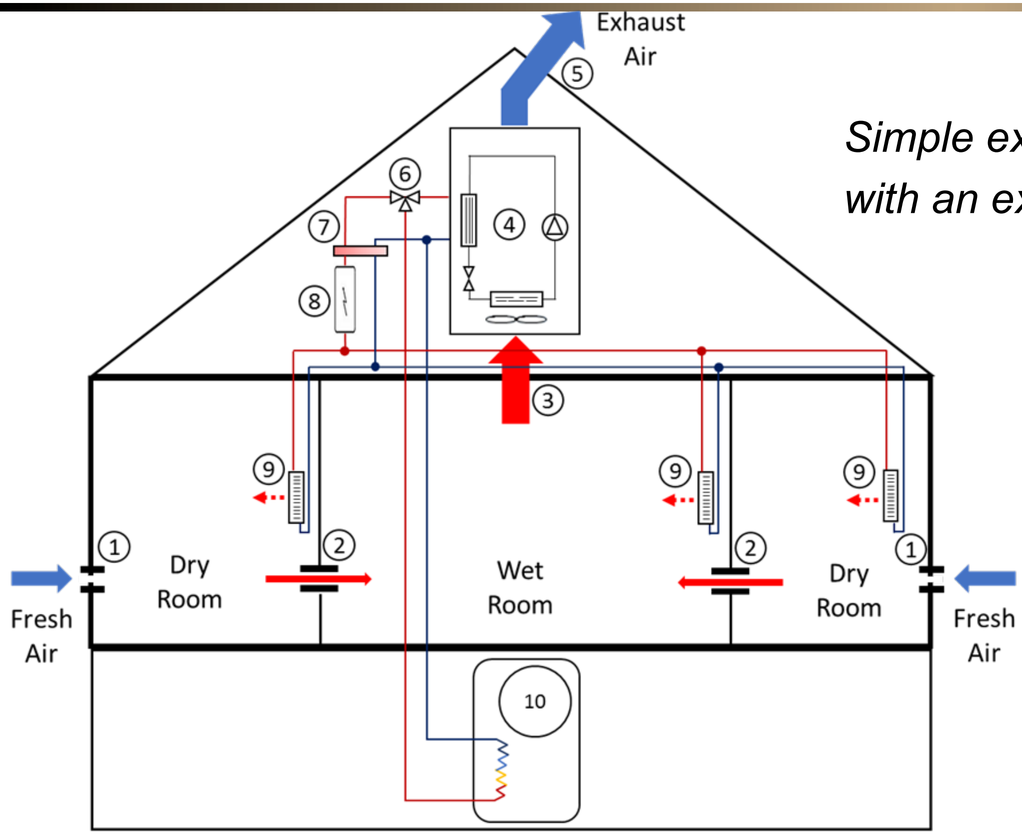
Building characteristics

- New residential building built in 2016
- Wooden two-story freestanding house
- Floor area: 155 m²
- Total exposed area: 389 m²
- $n\_50=0.6\ Vol/h$
- U-values:

Wall type	Composition	Area [m²]	U-value [W/m²-K]
Outer wall	Wood structure + 40 cm cellulose	139	0.11
Roof	Wood structure + 40 cm cellulose	127.2	0.15
Floor	Concrete slab floor + 65 cm cellular glass	82.7	0.07
Window	Triple-glazed + aluminum frame	18.5	0.84

- Global heat transfer coefficient: 0.2 W/m^2 - K

HVAC systems characteristics



Simple exhaust ventilation system combined with an exhaust air heat pump

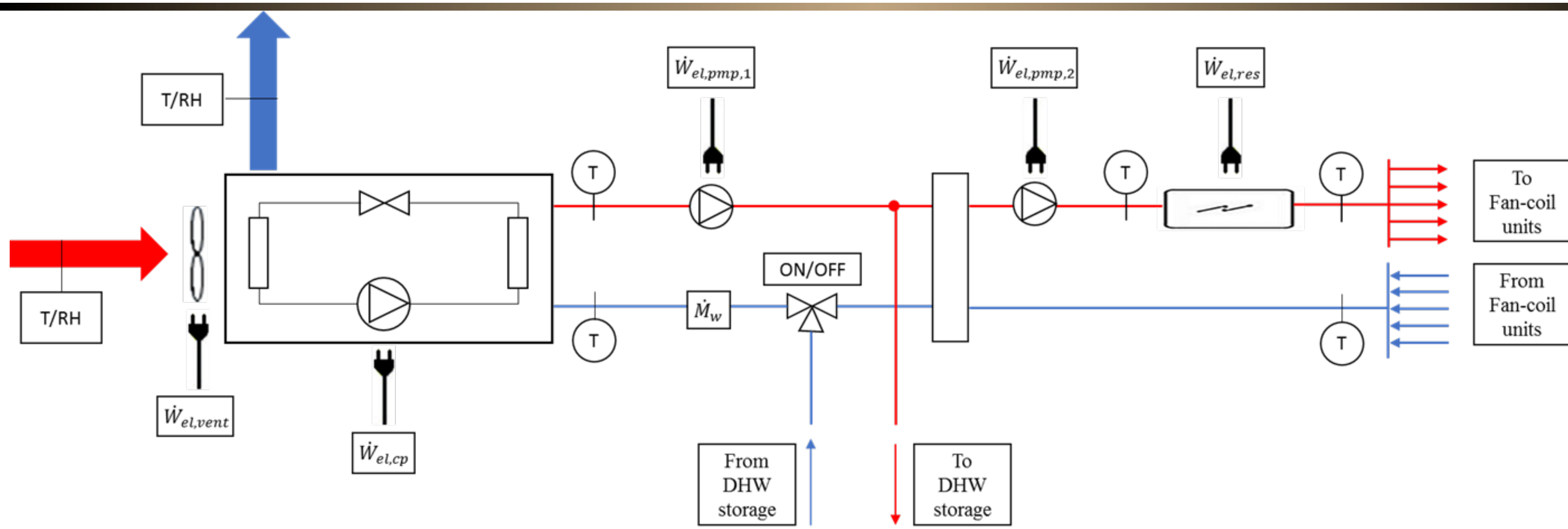
Legend:

- (1) : Fresh air inlet
- (2) : Transfer orifice
- (3) : Exaust air extraction
- (4) : Exhaust air heat pump
- (5) : Exhaust air evacuation
- (6) : Three-way valve
- (7) : Hydraulic separator
- (8) : Back-up electrical resistance
- (9) : Fan-coil unit
- (10) : Domestic hot water storage tank

- Ventilation: active 24 hours, 200 m3/h
- Heat pump water exhaust temperatures:
  - DHW: 25-55°C
  - Space heating: 40-45°C
- Nominal Heat pump capacity: 1400 W (A20W35)
- 3000 W electric resistance

Table of contents

System instrumentation



To measure the performance:

- 5 water temperature sensors
- 1 water flow meter
- 3 electric meters: compressor, resistance, total

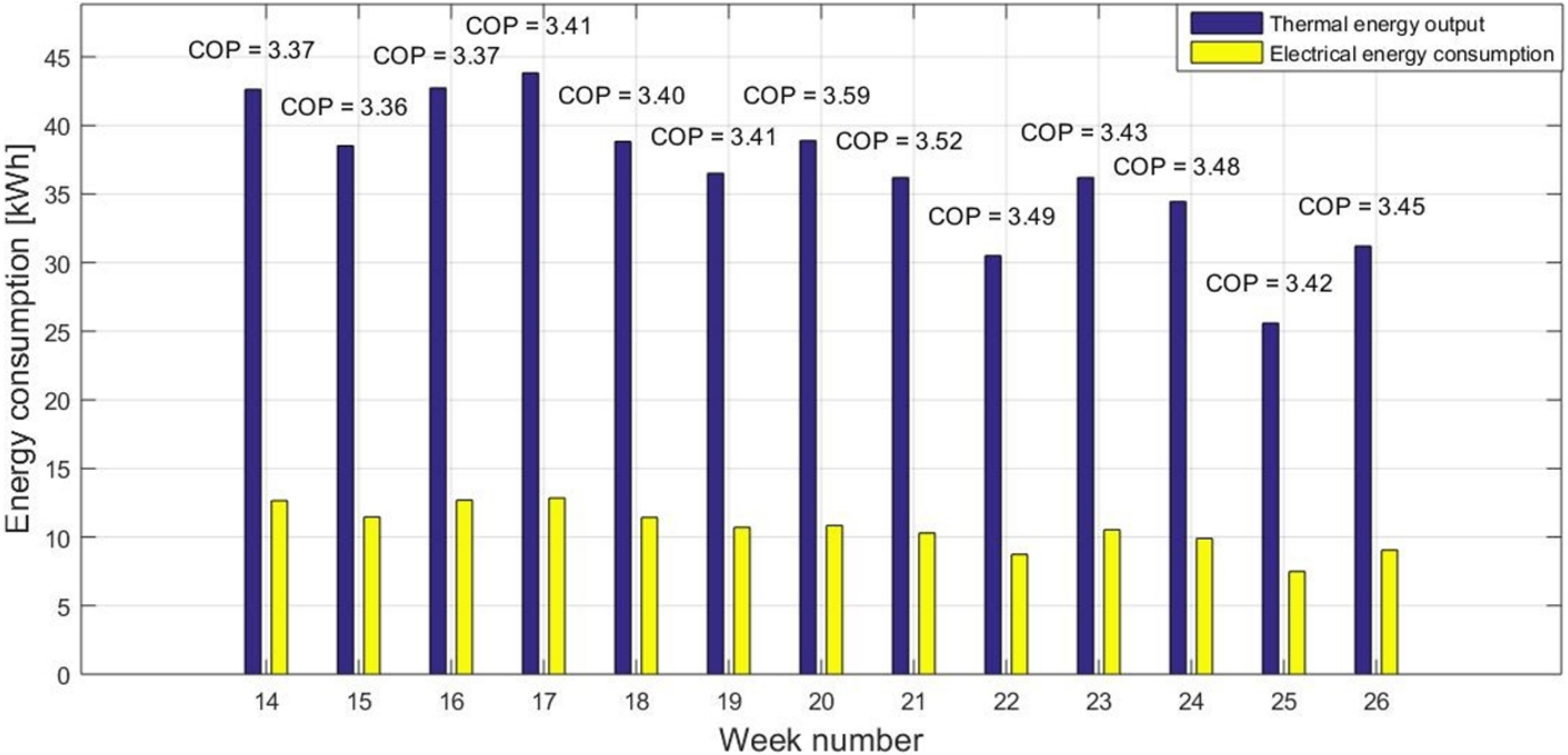
Additional measurements:

- Temperature and humidity of air: supply and exhaust
- Weather station (less than 8 km)

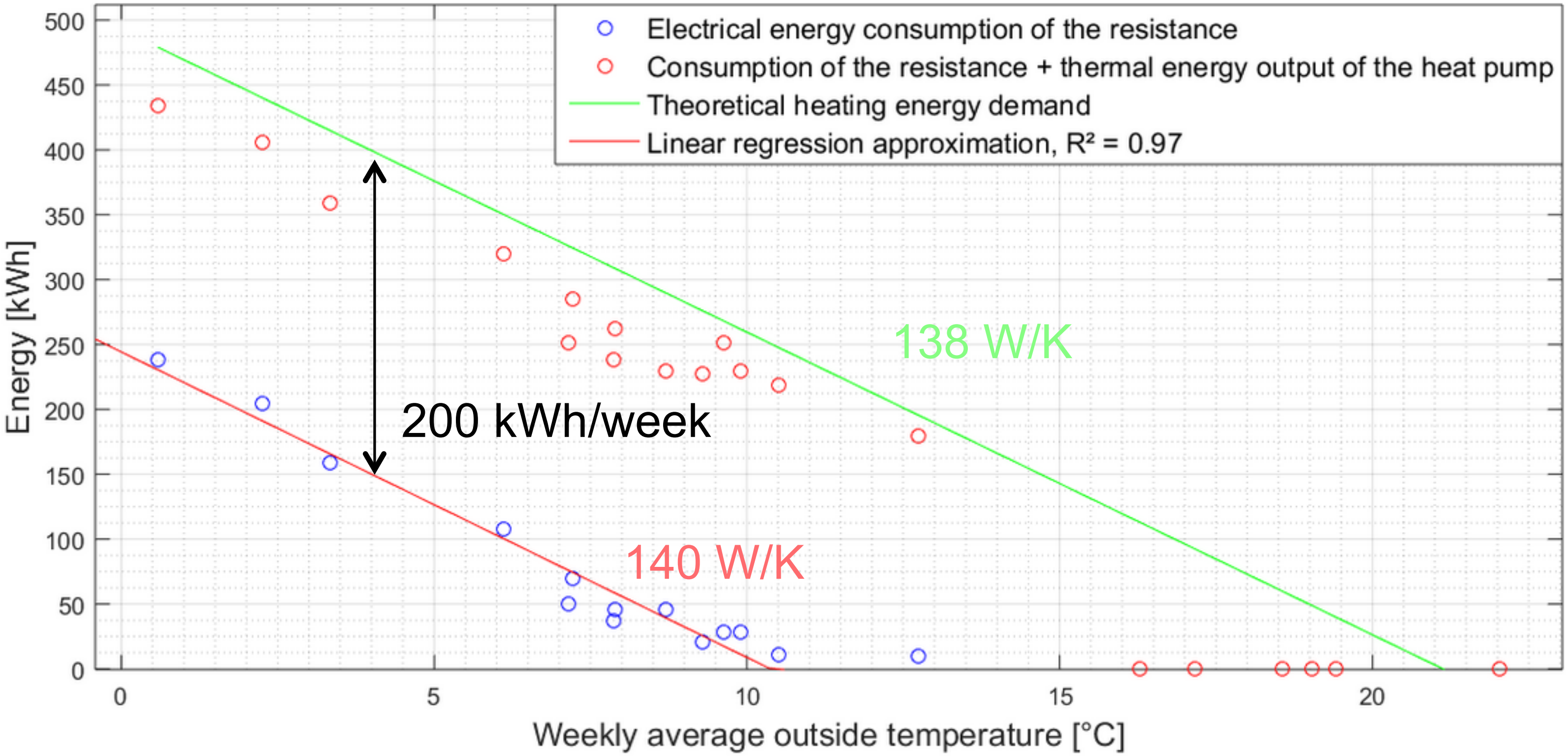
Table of contents

DHW production mode

- The COP of the machine is relatively constant over the weeks (from 3.36 to 3.59 for the weeks 14 to 26).
- The thermal energy output varies from 44 to 25 kWh/week

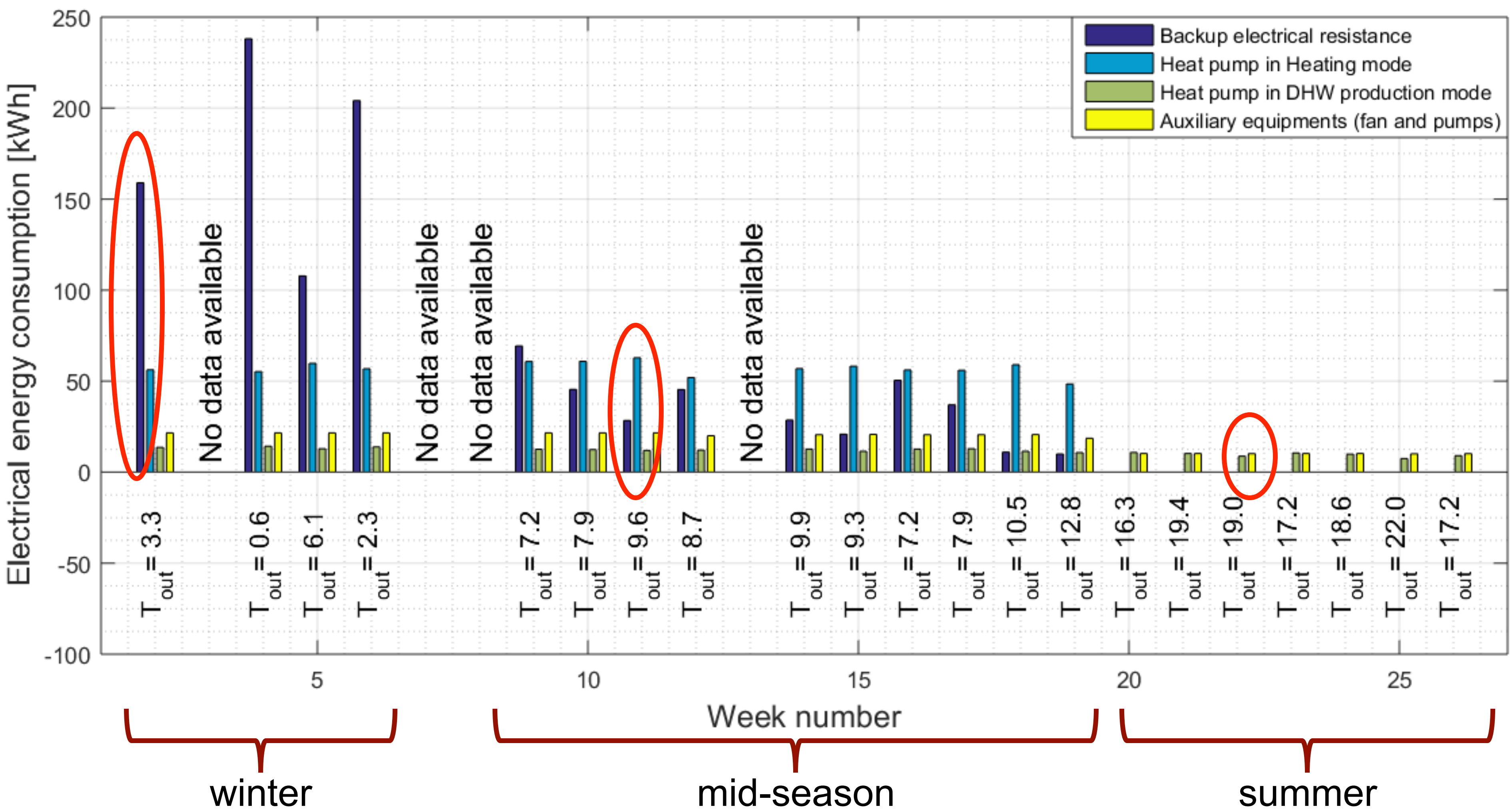


Space heating mode



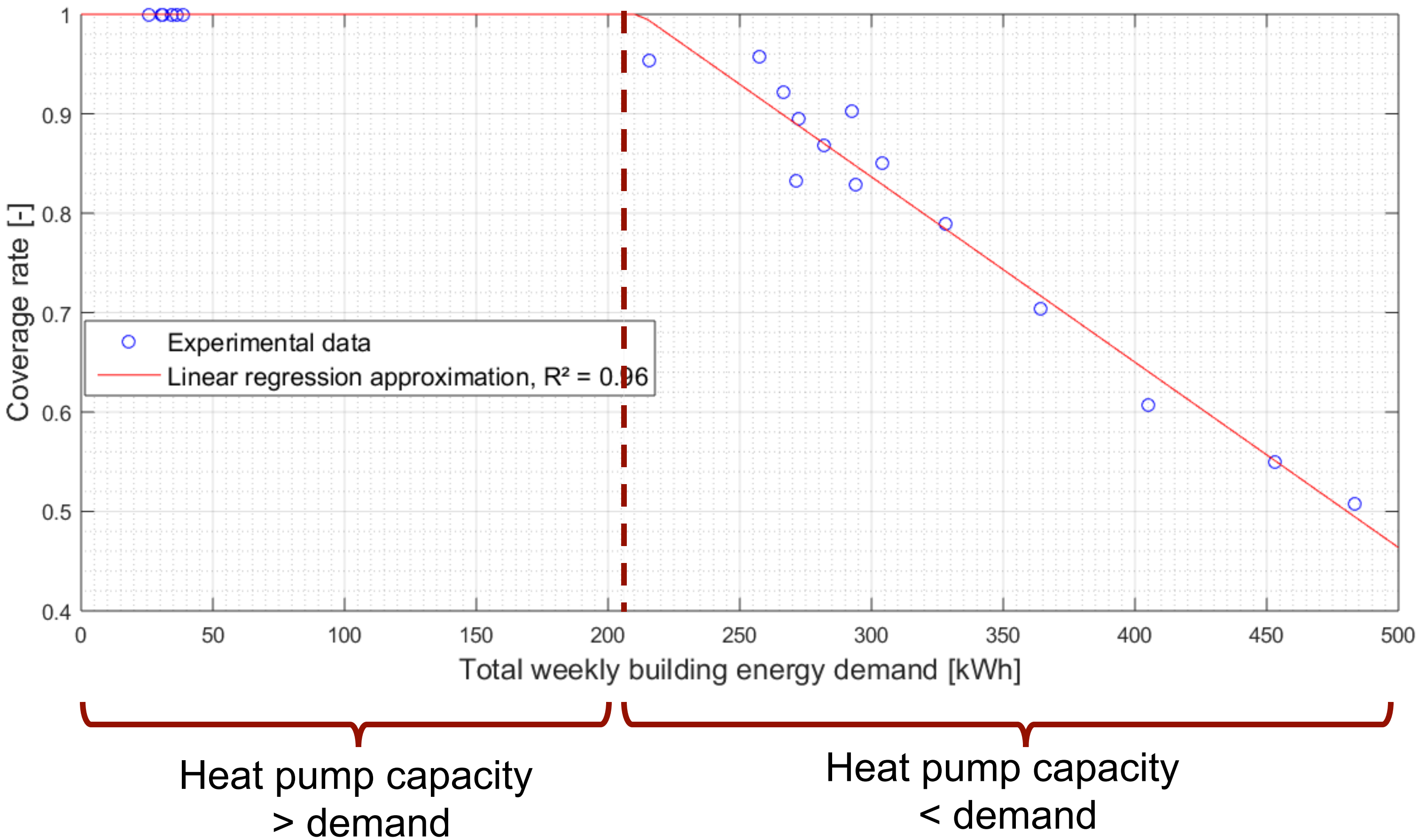
- The backup electrical resistance consumption varies from 240 to 0 kWh/week
- Production of the heat pump in heating mode is almost constant (200 kWh/week)
- Measured overall heat transfer coefficient is close to the theoretical one

Whole system consumption (DHW + space heating)



Coverage factor

- HP Coverage factor: $\tau = \dfrac{Q_{HP,DHW,week} + Q_{HP,Heating,week}}{Q_{HP,DHW,week} + Q_{HP,Heating,week} + W_{res,week}}$



Performance for Standard weather conditions

- Experimental results cover only part of the year: January 8th to July 2nd 2017
- During spring 2017, temperatures were above seasonal normal temperatures

=> Heat pump system performance is extrapolated over one year with a standard climate by means of the heating demand computed in the EPB certificate (= approximation).

Performance for Standard weather conditions

	$T_{out,avg}$ [°C]	$Q_{Heating}$ [kWh]	Q_{DHW} [kWh]	τ [-]	$Q_{HP,Total}$ [kWh]	$Q_{HP,DHW}$ [kWh]	$Q_{HP,Heating}$ [kWh]	W_{Res} [kWh]	$W_{HP,DHW}$ [kWh]	$W_{HP,Heating}$ [kWh]
Jan	3.2	1545	180	0.58	994	180	814	731	52	229
Feb	3.9	1278	162	0.71	1024	162	862	415	47	243
Mar	5.9	1084	180	0.80	1005	180	825	259	52	232
Apr	9.2	548	174	1.00	722	174	548	0	51	154
May	13.3	74	180	1.00	254	180	74	0	52	21
Jun	16.2	0	174	1.00	174	174	0	0	51	0
Jul	17.6	0	180	1.00	180	180	0	0	52	0
Aug	17.6	0	180	1.00	180	180	0	0	52	0
Sep	15.2	10	174	1.00	184	174	10	0	51	3
Oct	11.2	376	180	1.00	556	180	376	0	52	106
Nov	6.3	1061	174	0.81	999	174	825	236	51	232
Dec	3.5	1511	180	0.59	1001	180	822	689	52	231
Total		7487	2118		7273	2118	5156	2330	615	1451
Average	10.2			0.76						

EPB

Measured correlation

COP of 3.55 in heating mode and 3.44 in DHW

=> Seasonal coverage factor of 76% and COP of 2.18 (heat pump + back-up resistance)

Conclusion

- Performance of a mini exhaust air heat pump integrated inside a low-energy residential building has been measured for part of 2017:

    - The COP of the machine in DHW production mode varies from 3.36 to 3.59
    - Due to the limited capacity of 1500 W, the backup resistance is frequently switched on in winter
    - Consequently, the efficiency of the whole system decreases

- An extrapolation of the results over one year gives an estimated coverage factor of 76 % and a seasonal COP of 2.18.

Future work

- Development of a model of the building and the machine to investigate different strategies to improve the annual coverage factor of the system:
  - ✓ Study the possibility for **increasing the heating capacity** of the machine, and study the impact on the frost formation and on the COP
  - ✓ Study the possibility for a **demand-controlled ventilation** strategy and study the impact on the machine heating capacity and on the COP
  - ✓ Study different control **strategies for the heating system**
  - ✓ Study the **impact of the occupant behavior**

Thank you for your attention!