Optimization of SPF or CO_2 emissions?

Impact of control strategies on a bivalent waste water HP system for high energy standard buildings

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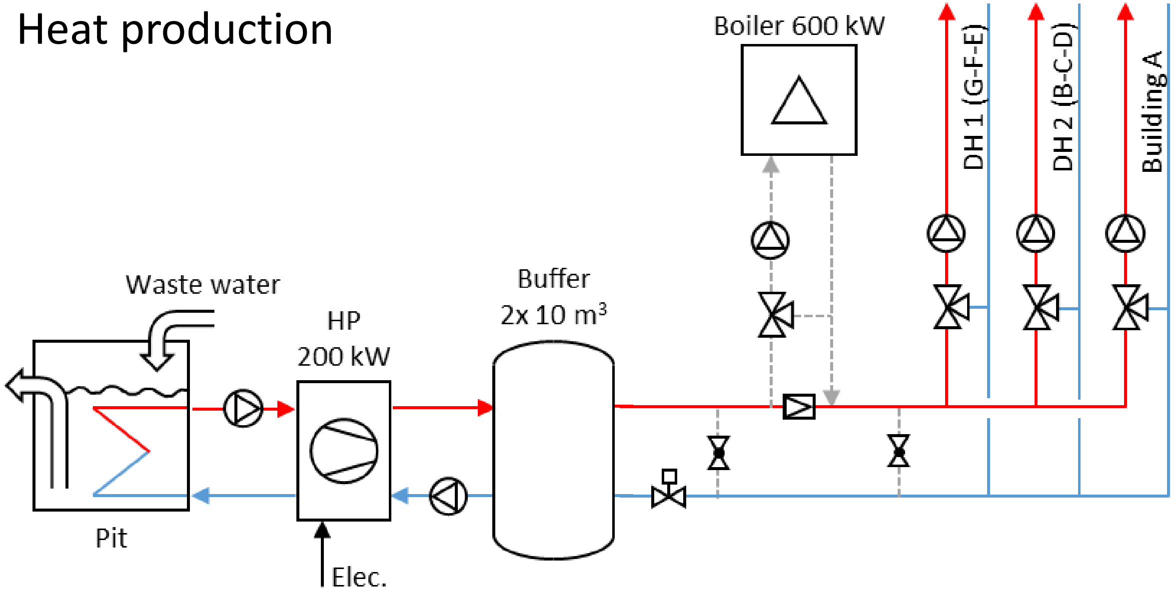
Case study (Carouge, Geneva)

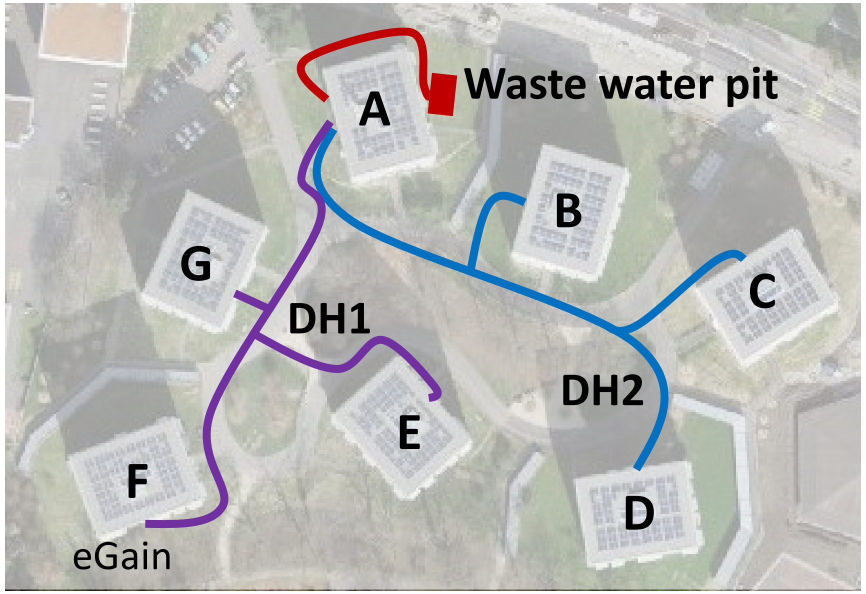
Buildings:

- 7 buildings (constructed 2014 – 2019)
- Heated floor area: 30’400 m2
    - Social housing (97%)
    - Extra-scholar activities (3%)
- High / very high energy performance standard

Case study (Carouge, Geneva)

Heat production

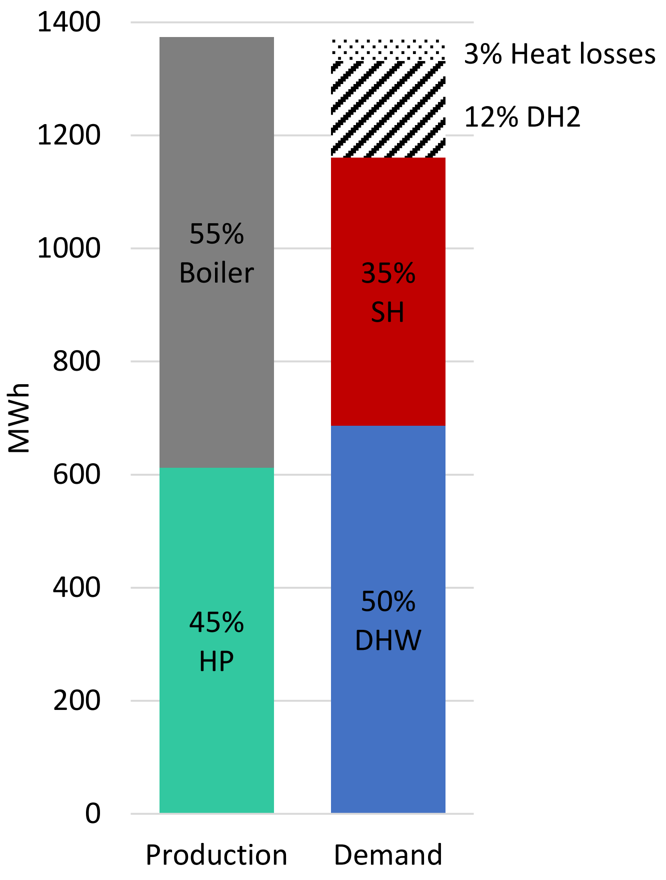




- Base load: HP on waste-water (200 kW)
- Peak load: Gas boiler (600 kW)
- Local district heating

First year of operation (2018): only 4 buildings!

Annual energy balance (first year of operation)



Demand

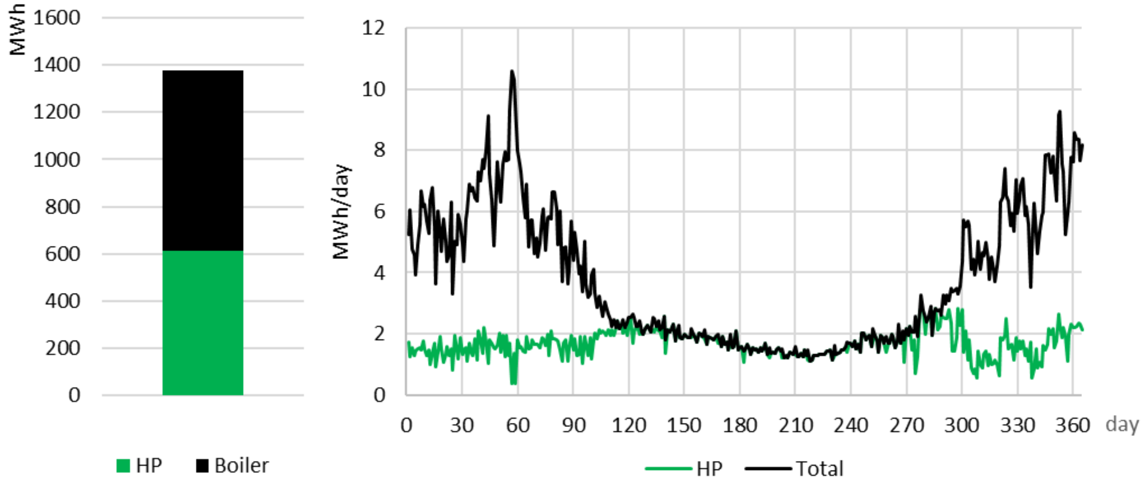
- DH1: 1’161 MWh
  - DHW: 39.5 kWh/m2 (59%)
  - SH: 27.3 kWh/m2 (41%)
- DH2 + Heat losses: 212 MWh

Production

- HP: 613 MWh (45%)
- Boiler: 761 MWh (55%)
- HP SPF: 3.03

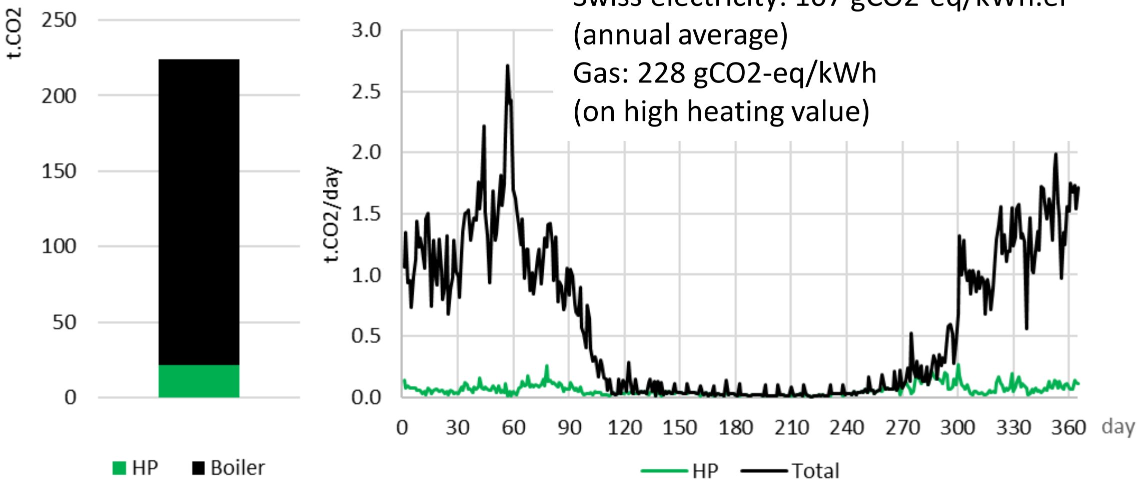
Energy *vs* CO_2

Heat production ➔ HP : 45%



GHG emissions ➔ HP : 10%

Swiss electricity: 107 gCO2-eq/kWh.el (annual average)
Gas: 228 gCO2-eq/kWh (on high heating value)



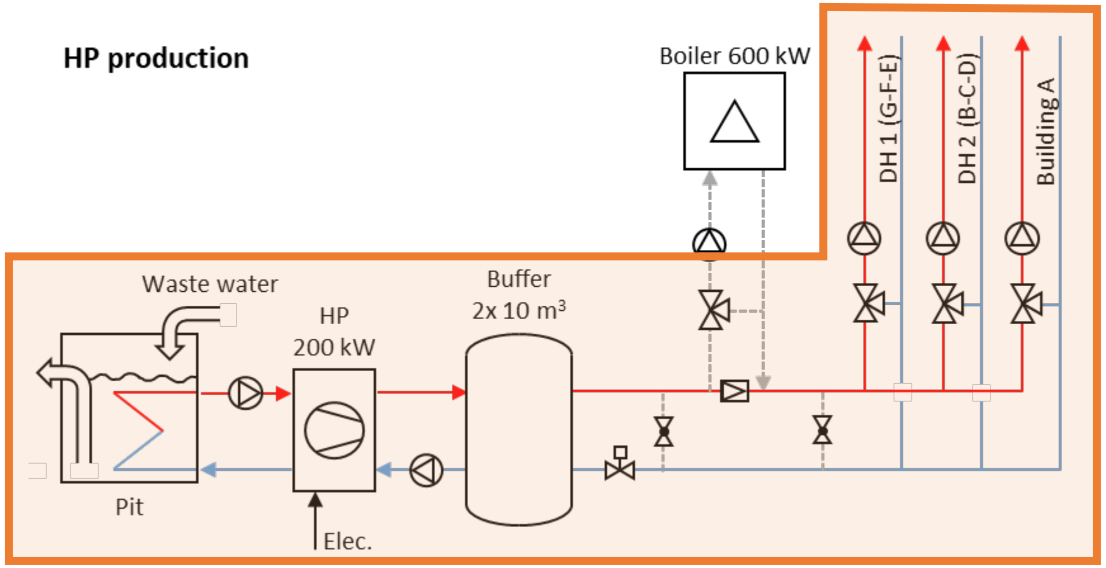
Need to increase HP share (even with lower SPF)

➔ Control strategy

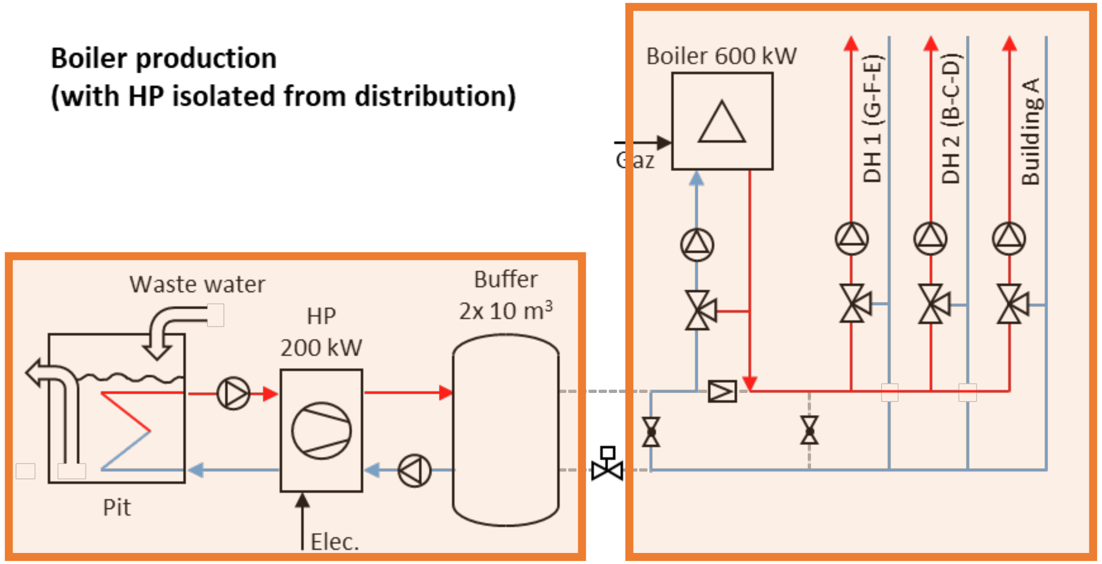
➔ Temperature regimes

Control strategy

Alternate production mode



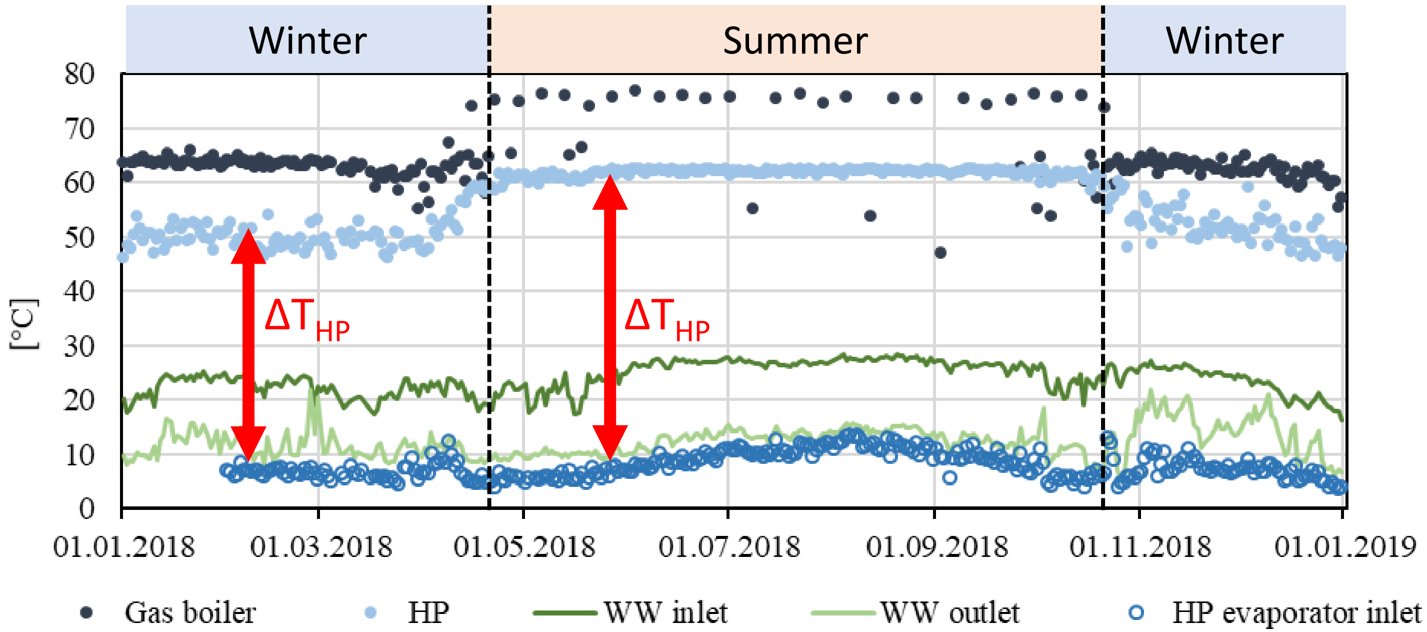
$$\text{If} \quad Q_{HP} \geq Q_{DH} \;\text{ and }\; T_{HP} \geq T_{DH}$$



$$\text{If} \quad Q_{HP} < Q_{DH} \;\text{ or }\; T_{HP} < T_{DH}$$

Temperature regime

Differentiated summer / winter HP setpoints



Summer:

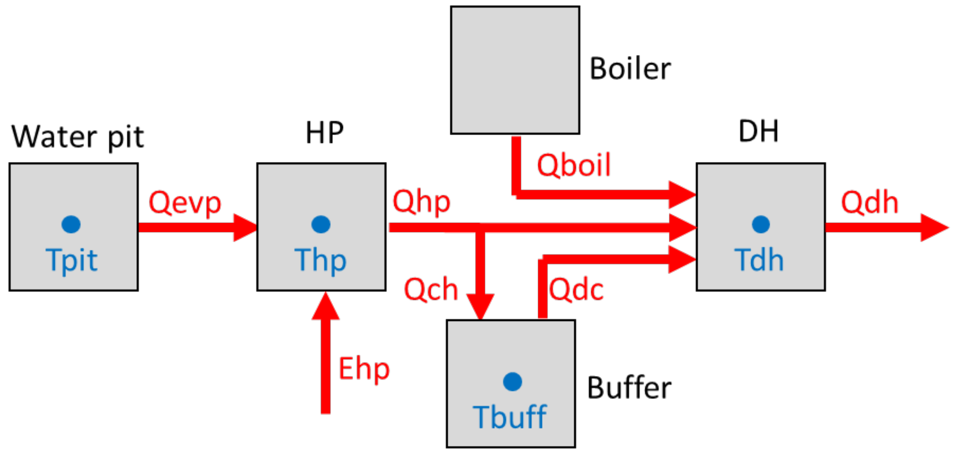
- HP ➔ 63°C (DHW)
- Boiler ➔ 75°C (Anti-Legionella, 2h once a week)

Winter:

- HP ➔ 45°C (SH) or 55° (Buffer)
- Boiler: 63°C (DHW) + 75°C (Anti-Legionella, 2h once a week)

Numerical simulation

Numerical model



Inputs:

- Tpit: 5°C (Jan) – 12°C (Jul)
- Qdh: hourly monitoring values

Parameters

- Ehp: 50 kW
- HP efficiency: 45% (relative to Carnot)
- Buffer: 20m3 (non stratified)
- Boiler efficiency: 86% (on HHV)

Algorithm:

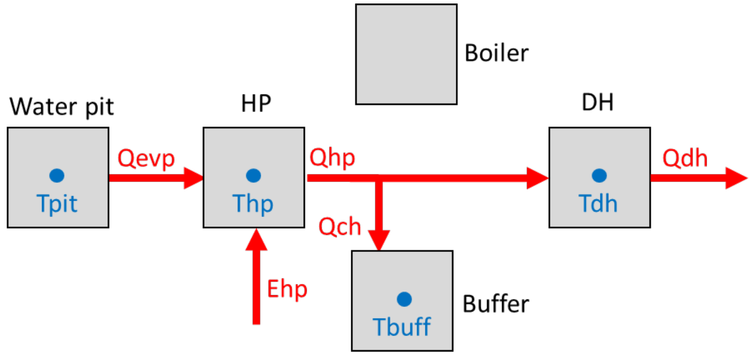
- Hourly energy balance
- Integrated in spreadsheet

Numerical simulation

Control strategy

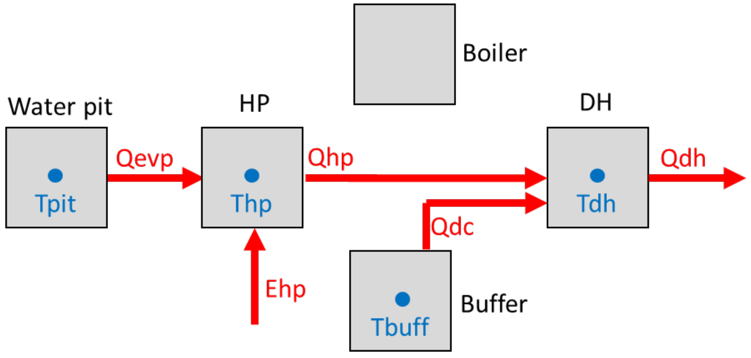
1) HP + Buffer charge

- Qhp ≥ Qdh
- Thp ≥ Tdh
- Tbuf < Tbuf.max



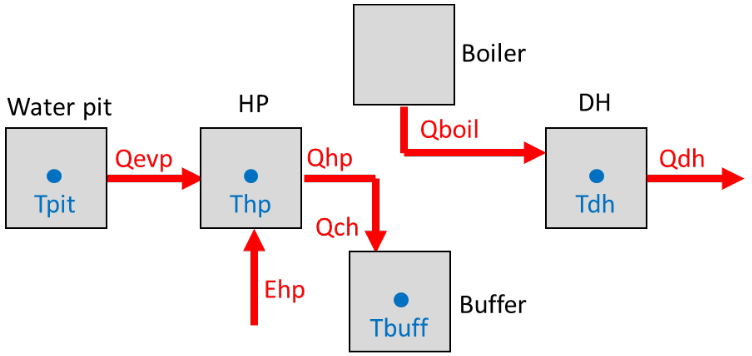
2) HP + Buffer discharge

- Qhp < Qdh
- Thp ≥ Tdh
- Tbuf > Tdh

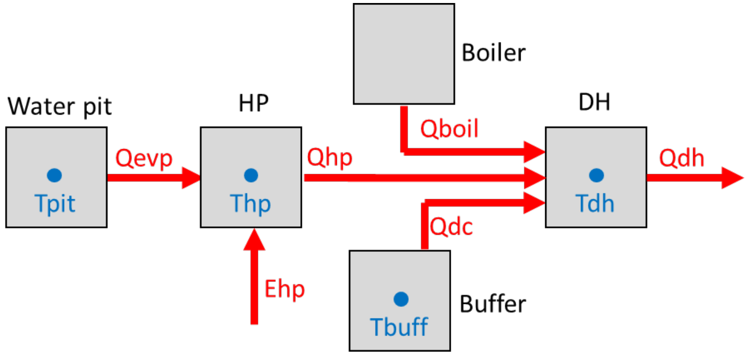


3a) Boiler (Alternate mode)

- Thp < Tdh
- Tbuf < Tdh

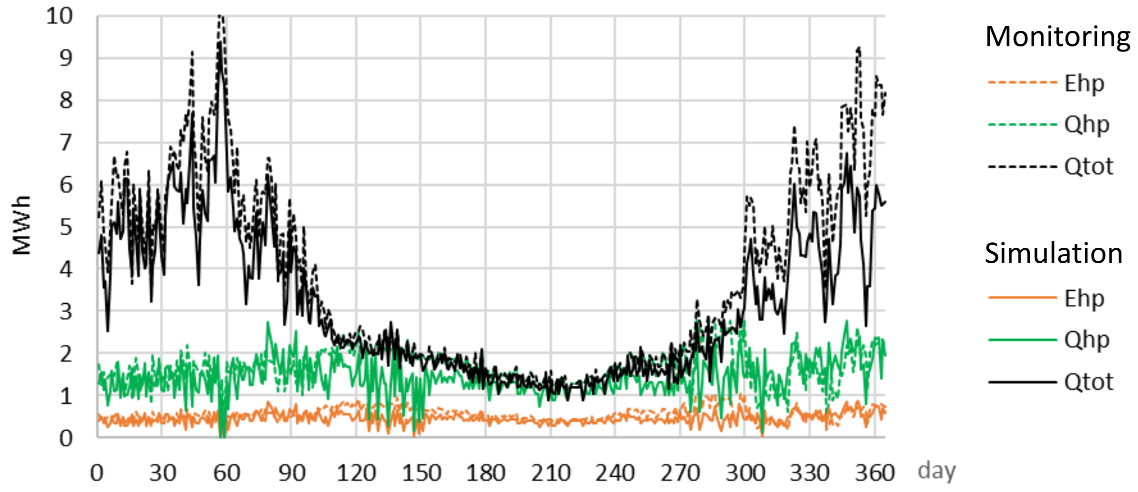


3b) HP + Boiler (Series mode)



Numerical simulation

Validation

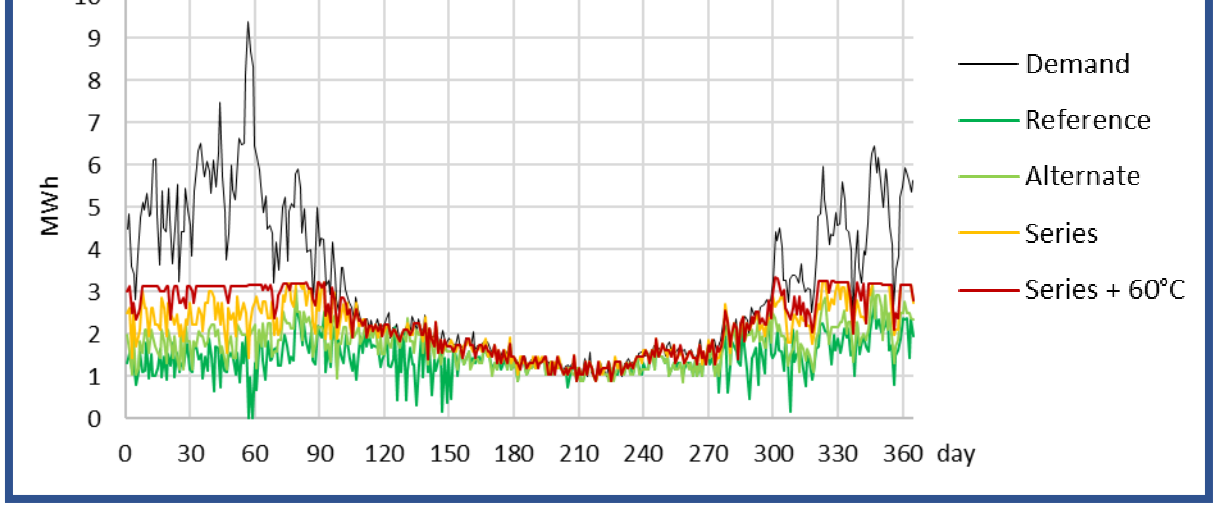


Scenario	HP setpoint	HP / Boiler	DH
Reference	63°C / 45°C	Alternate	≤ 65°

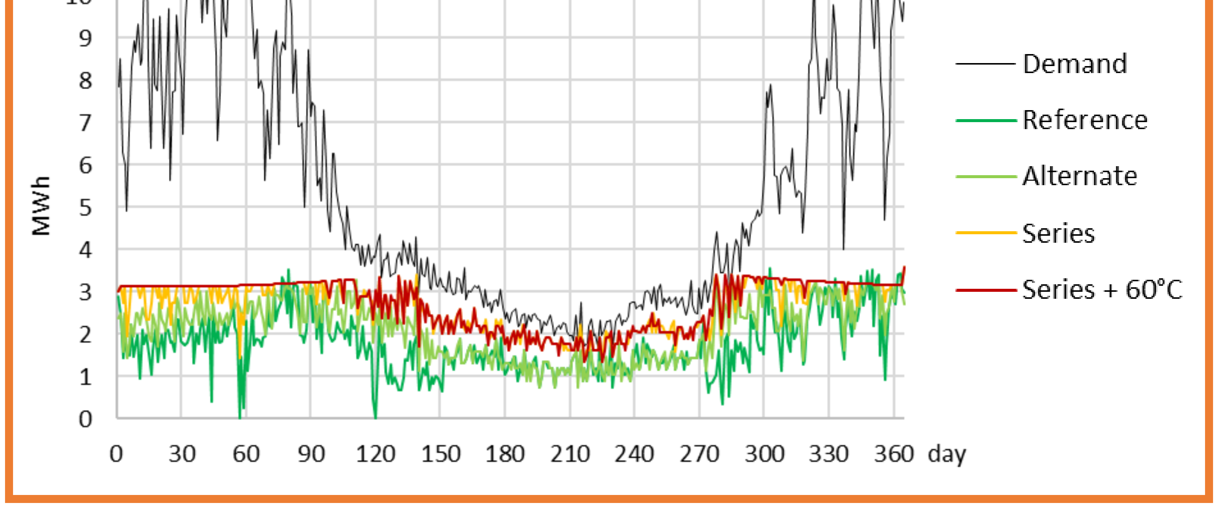
Sensitivity analysis

Scenario	HP setpoint	HP / Boiler	DH
Reference	63°C / 45°C	Alternate	≤ 65°
Alternate	63°C	Alternate	≤ 65°
Series	63°C	Series	≤ 65°
Series + 60°C	63°C	Series	≤ 60°

4 Buildings

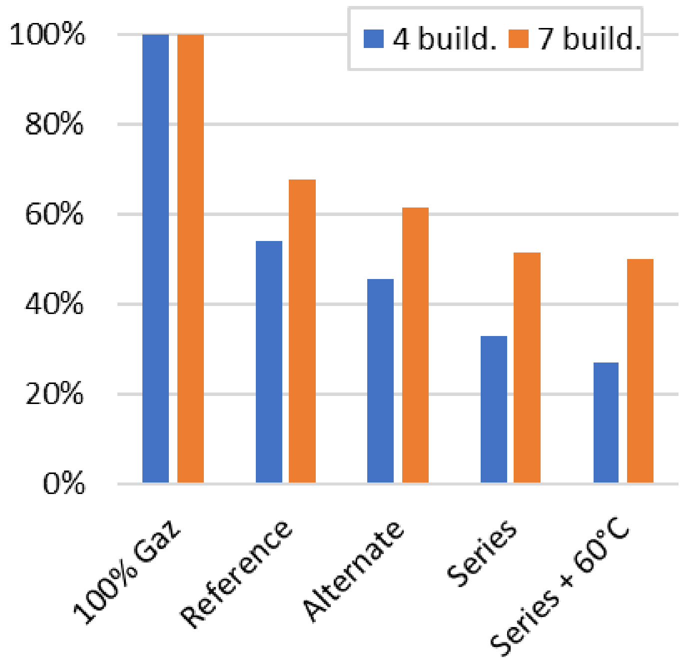


7 Buildings

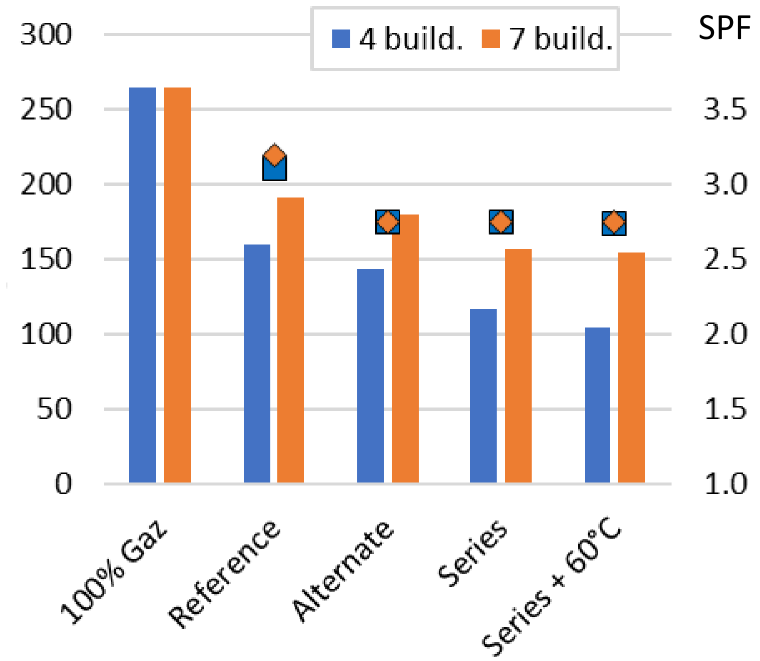


Sensitivity analysis

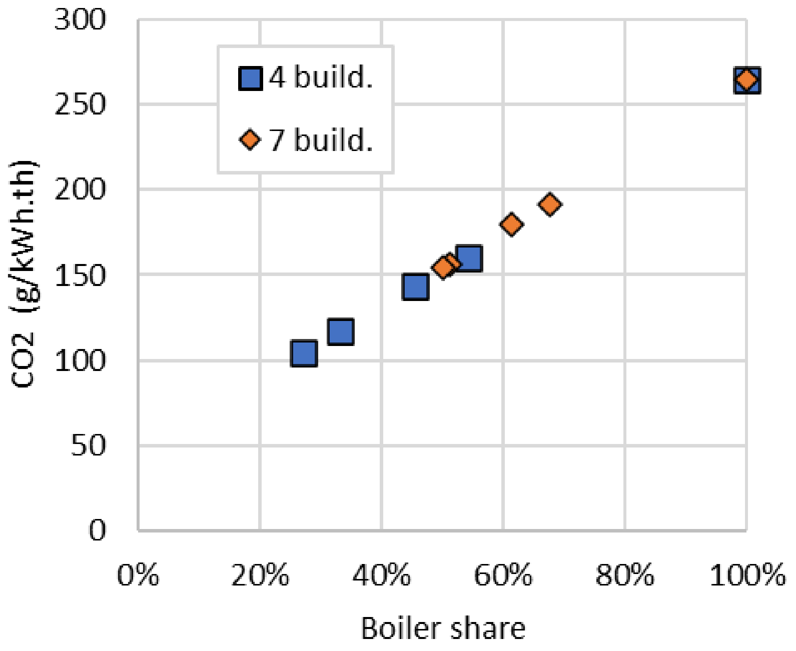
Boiler share



Emissions (g.CO_2-eq/kWh$_{th}$)



Emissions *vs* Boiler share



Conclusions

- Monitored heat balance: 45% HP & 55% boiler.

- Simulation of alternative control strategies (HP setpoint change, serial operation of HP & boiler):
  - HP share up to 70%,
  - Lower CO_2 emissions despite possible SPF decrease.

  → trade-off between CO_2 & SPF optimization.

- Current system's performance is already much better than 100% fossil fuel production.

Acknowledgments for funding

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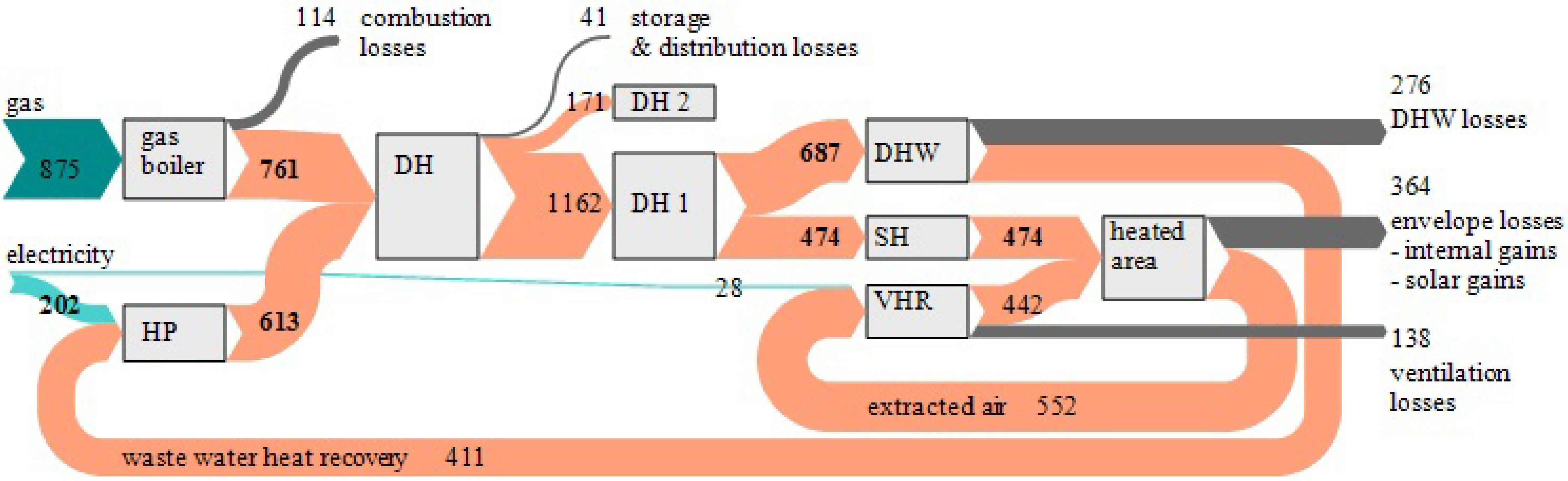
Office cantonal de l'énergie de Genève (OCEN)

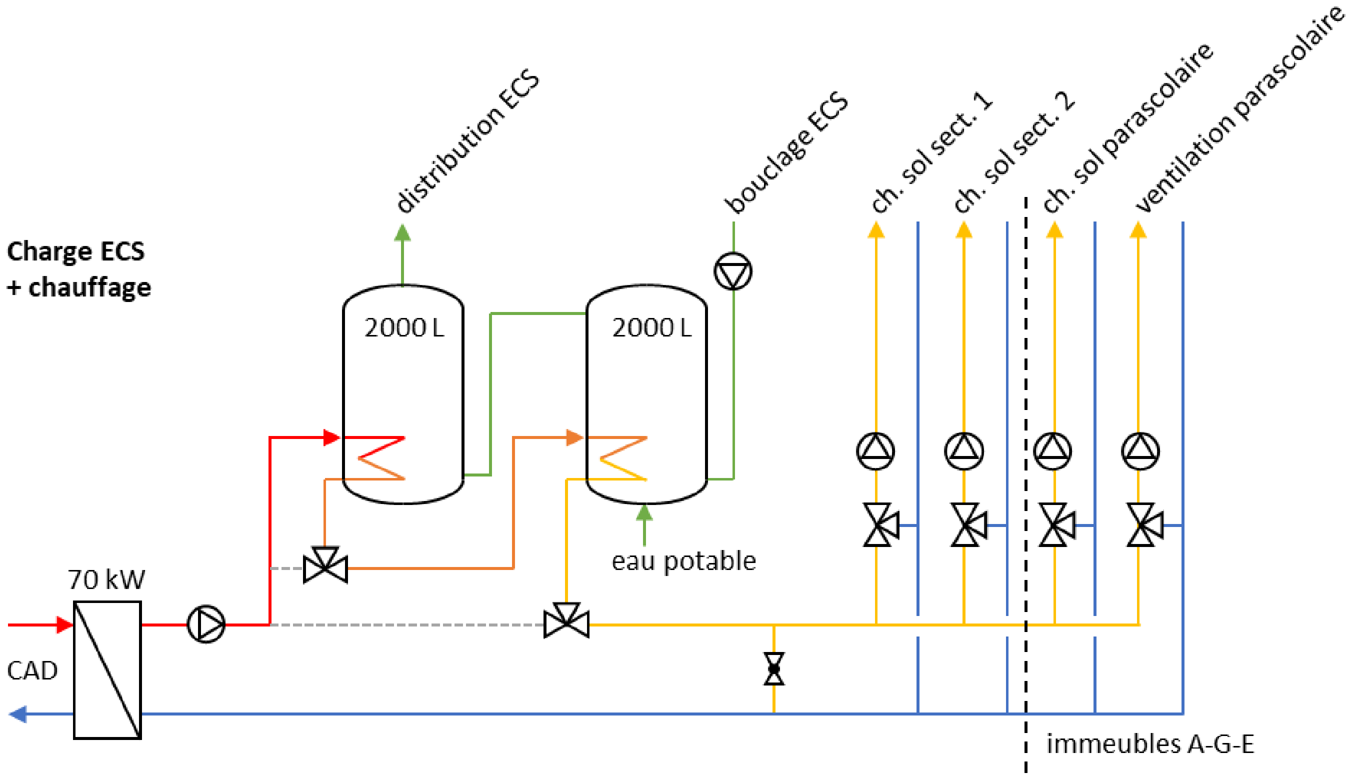
Services industriels de Genève (SIG)

Annexes

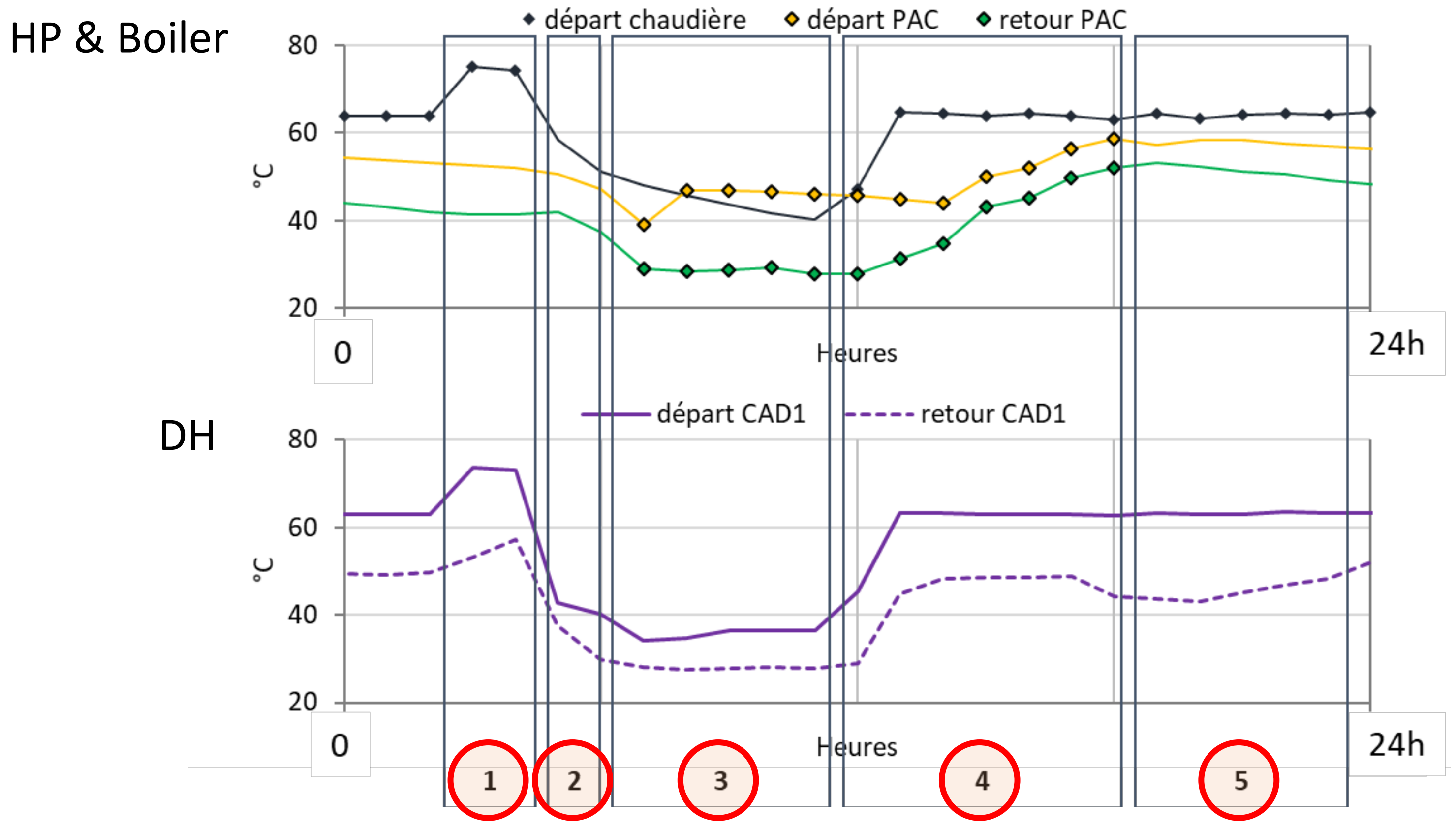
Sankey diagarm (first year of operation)



Substation


Charge ECS
+ chauffage
distribution ECS
bouclage ECS
ch. sol sect. 1
ch. sol sect. 2
ch. sol parascolaire
ventilation parascolaire
2000 L
2000 L
eau potable
70 kW
CAD
immeubles A-G-E

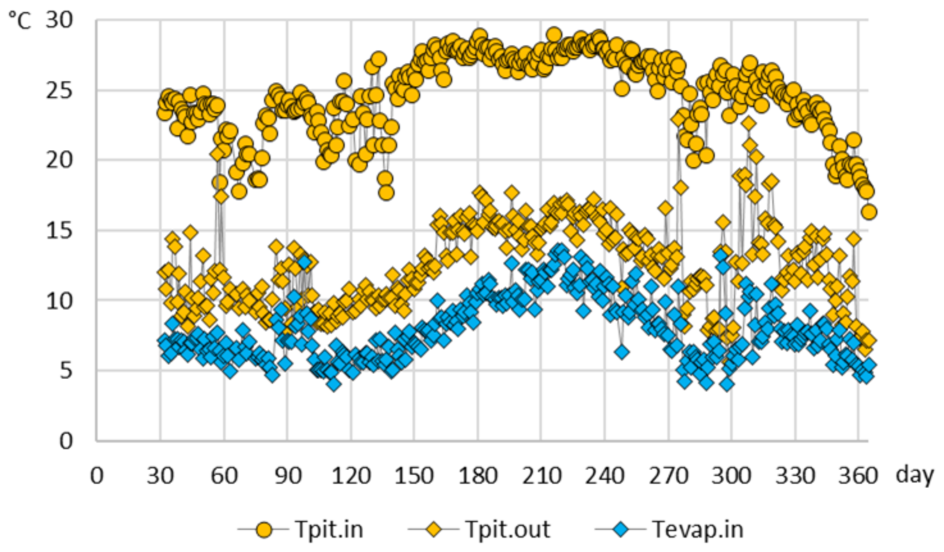
Production dynamic (24 h)

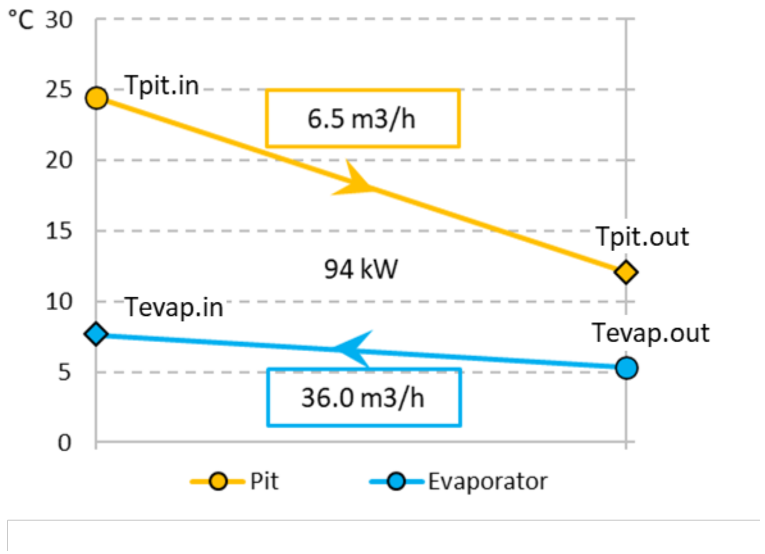


Production (14 January 2018):

1) Boiler ➔ Antilegionella (75°C)
2) Buffer ➔ SH + DHW preheating (40 – 60°C)
3) HP ➔ SH (45°C)
4) Boiler ➔ DHW (65°C)
   HP ➔ Buffer (45 – 60°C)
5) Boiler ➔ DHW (65°C)

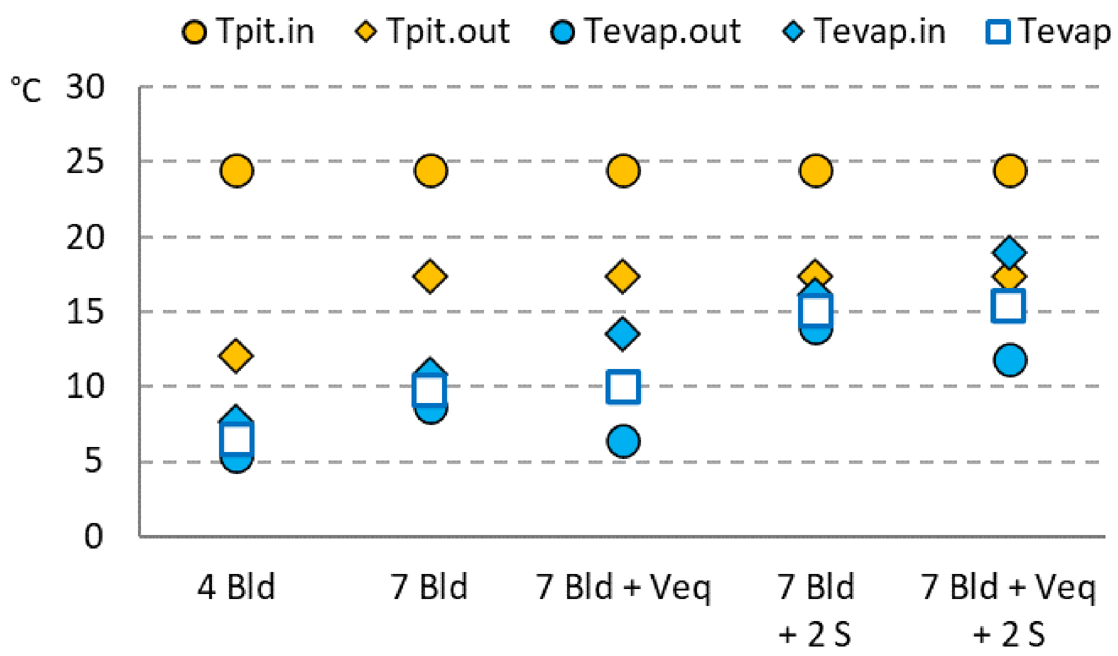
Waste water heat recovery

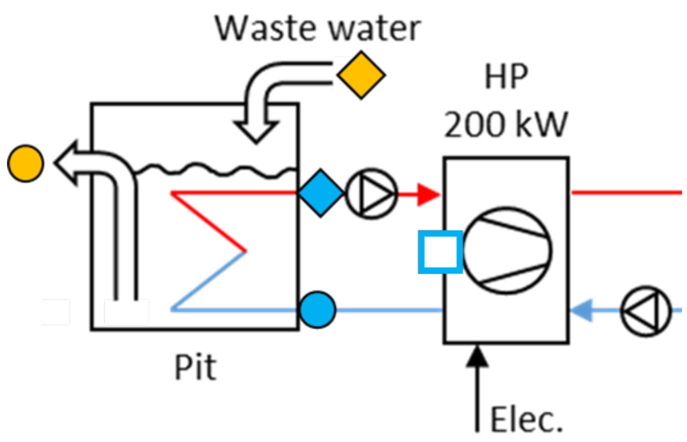




Unbalanced flows between Waste-water and HP-evaporator
➔ Low evaporator temperature

Waste water heat recovery



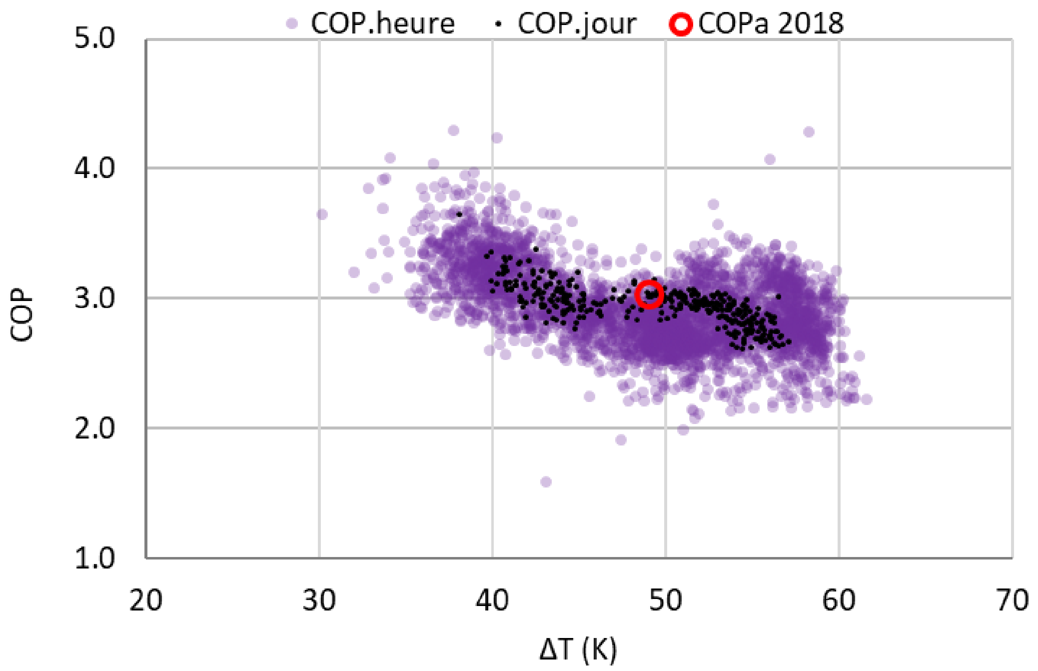


	Build.	Flow ww.	Flow evp.	Flow ratio	Exch.
		m3/h	m3/h		kW/K
4 Bld	4	6.5	36.0	18%	8.5
7 Bld	7	11.3	36.0	31%	8.5
7 Bld + Veq	7	11.3	11.3	100%	8.5
7 Bld + 2S	7	11.3	36.0	31%	17.1
7 Bld + Veq + 2S	7	11.3	11.3	100%	17.1

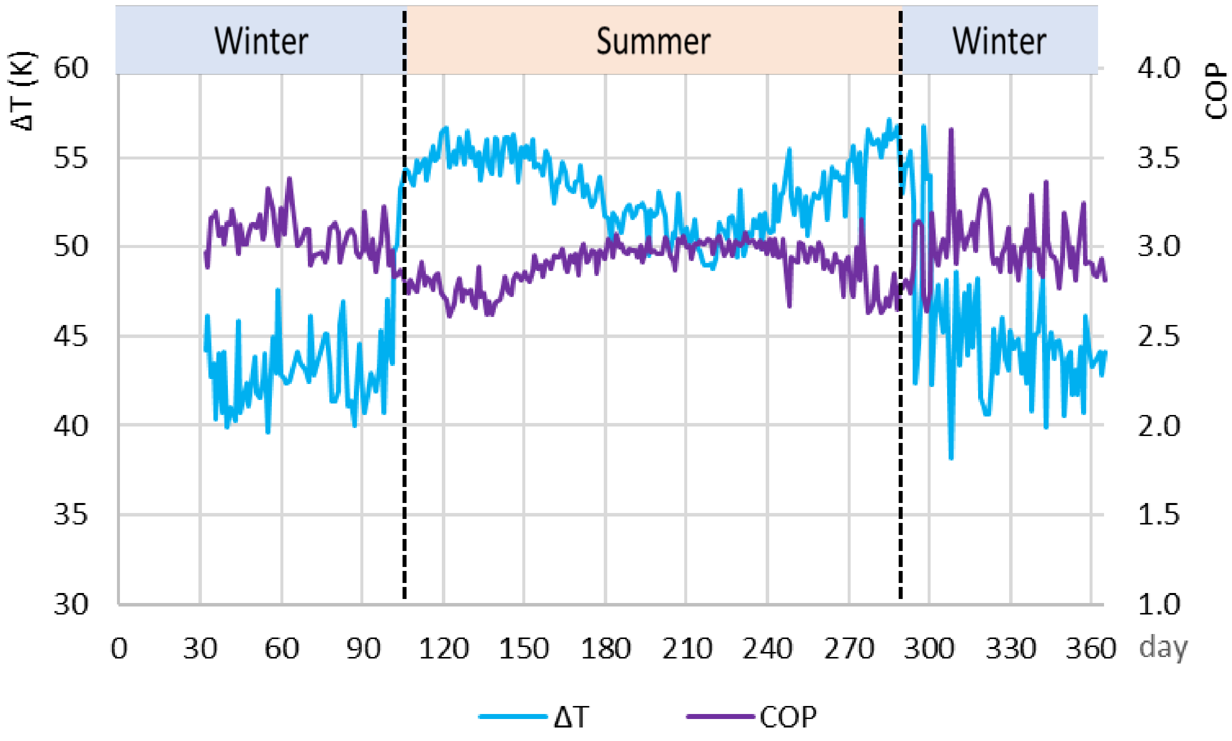
Tevap:

- All 7 buildings ➔ + 3.3 K
- All 7 buildings & Heat exchanger x 2 ➔ + 8.6 K

Heat pump

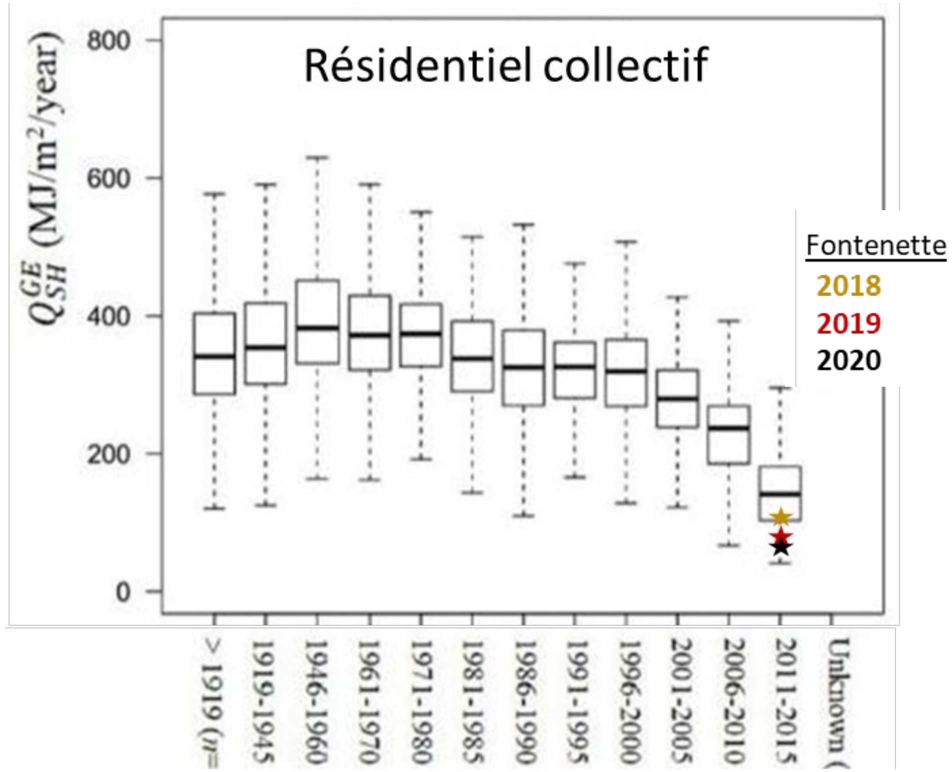


COP.heure
COP.jour
COPa 2018
5.0
4.0
3.0
2.0
1.0
COP
20
30
40
50
60
70
ΔT (K)

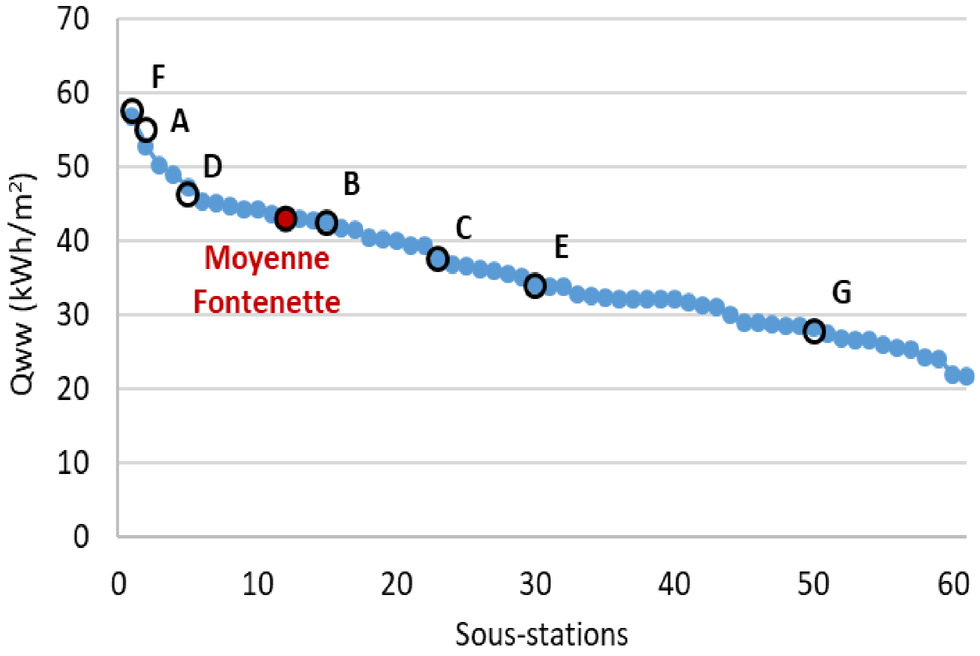


Winter
Summer
Winter
ΔT (K)
60
55
50
45
40
35
30
4.0
3.5
3.0
2.5
2.0
1.5
1.0
COP
0
30
60
90
120
150
180
210
240
270
300
330
360
day
ΔT
COP

SH and DHW



Résidentiel collectif
Q_{SH}^{GE} (MJ/m²/year)
800
600
400
200
0
Fontenette
2018
2019
2020
< 1919 (n=
1919-1945
1946-1960
1961-1970
1971-1980
1981-1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-2010
2011-2015
Unknown (



70
60
50
40
30
20
10
0
Qww (kWh/m²)
F
A
D
B
C
E
G
Moyenne
Fontenette
0
10
20
30
40
50
60
Sous-stations

Energy signatures