Integration of Air-Source HP in Large Non-retrofitted MFB: Lessons Learned in Actual Conditions and Numerical Simulation

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HP_sim&app23 - Carnot User Meeting 2023

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Overall challenge

Reduction of CO2 emissions :

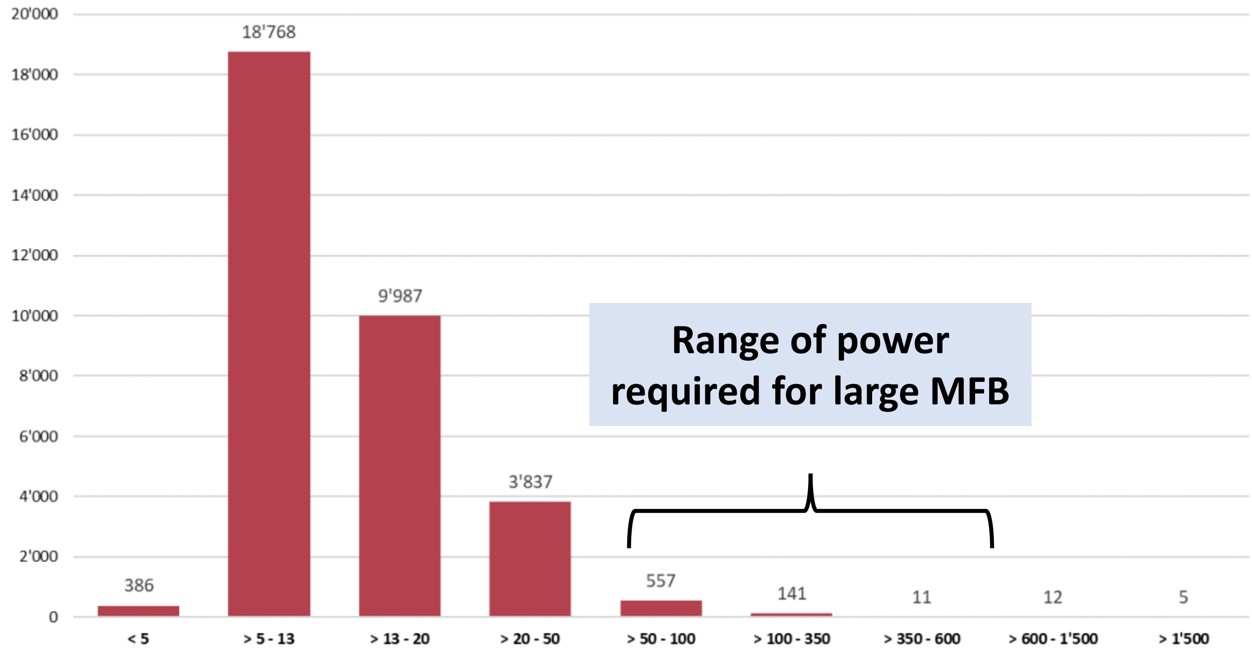
- Retrofit of building envelope
- **Switch to renewable energy**

Outside air is often the **only source for HP in urban areas**

Air-water HP are rarely installed in large existing MFB

Requested HP capacity : > 50 kW

Heat pump sales in 2021 according to power capacity (kW)



Groupement professionnel Suisse pour les pompes à chaleur (GSP). Statistiques 2021

Contraints of air water HP in large existing MFB

HP weight in the roof

Limited space in the boiler room

Keep existing equipment

Demand can change over time

non-renovated → renovated

- HP > 50 kW_{th} not designed for the residential sector
- High investment cost
- Noise emissions
- HP integration in existing system (designed for boilers)
- Electricity power available on site
- …..

- **Lack of monitoring case studies proving the feasibility**

  → Monitoring mainly on single family houses

- **Lack of standardized hydronic concepts :**

  → Only hydronic concepts up to about 15 kW_{th}
  → Design literature mainly on single family house

Air-water HP in large MFB is an exception rather than a standard solution !

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Pilot projects in Geneva in non-retrofitted buildings

1. Monovalent system

Construction year	1972
Envelope	non-retrofitted
Heated floor area	4047 m^2
New heating system	312 kW$_{th}$ @ 7 °C/45 °C
HP type	2 x Industrial HP
Monitoring period	2 years

2. Hybrid system

Construction year	1992
Envelope	non-retrofitted
Heated floor area	7563 m^2
New heating system	204 kW @ 7 °C/45 °C + Existing boiler
HP type	6 x HP for single-family houses
Monitoring period	2 years

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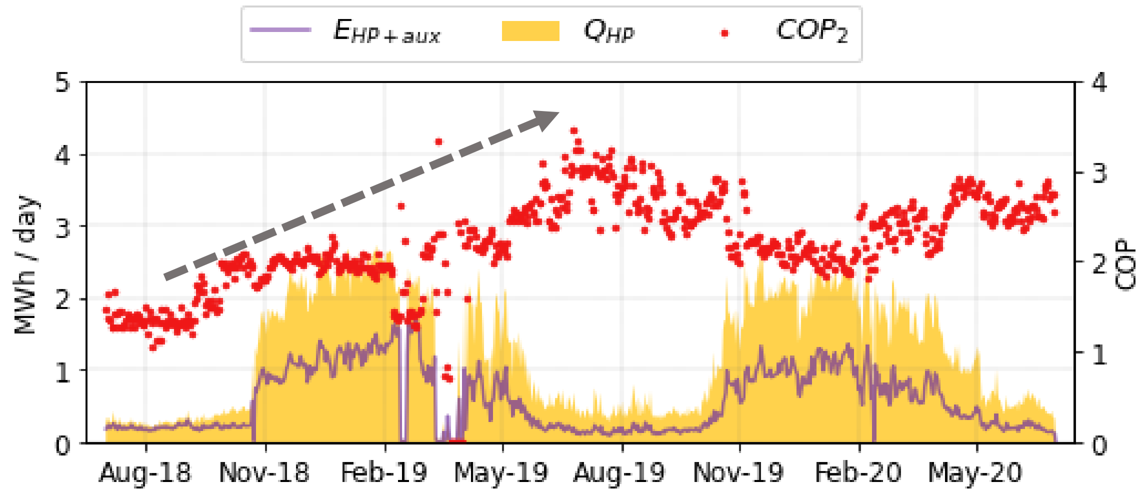
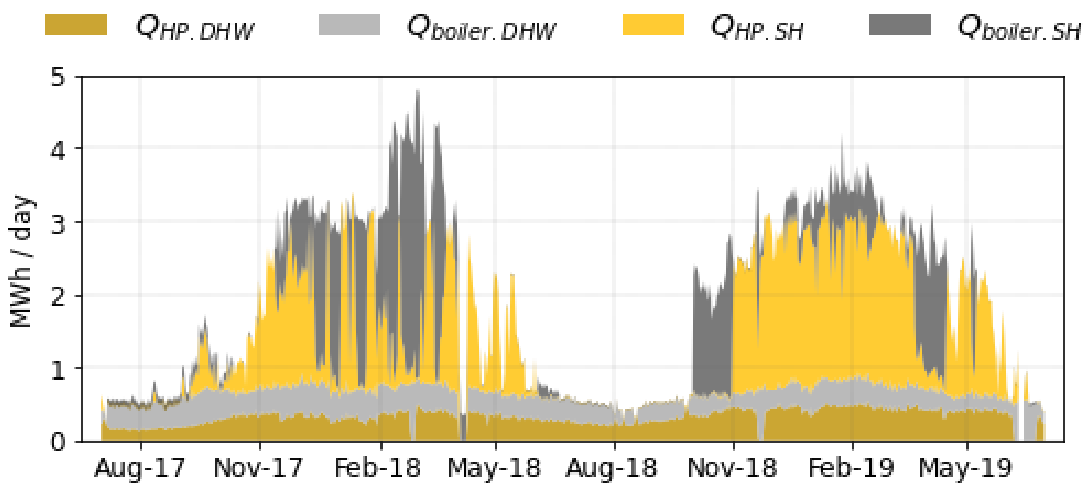
Results

1. Monovalent system



Increase of the COP from 1.5 to 3.4

2. Hybrid system



Increase of the annual HP fraction from 50% to 67%

Identified issues:

(i) Circulation pumps ON (24h/24)

(ii) Heating curve not taken into account

(iii) HP oversized (+146 %)

Identified issues:

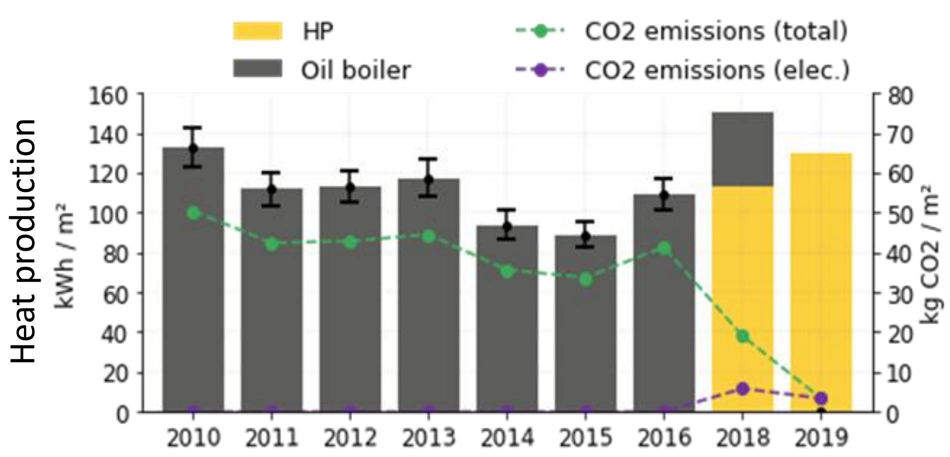
(i) HP shutdowns → high return temperatures from boiler

(ii) Master/slave control (limited to 2 slaves)

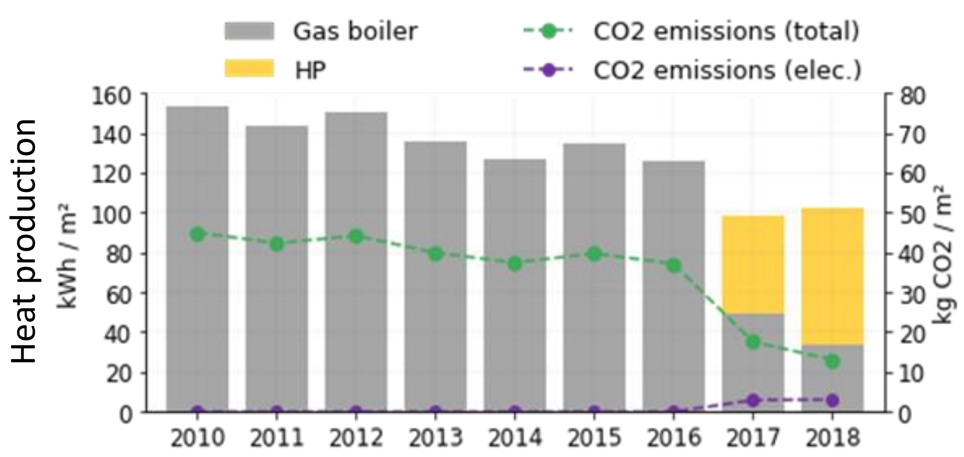
(iii) Significant heat losses in the pipes

Results

a) Monovalent system



b) Hybrid system



→ Normalized to standard weather (SIA 381/3, 1982)
→ HP emissions : Hourly CO_2eq content of the Swiss electricity mix (Romano Elliot, 2018. https://archive-ouverte.unige.ch/unige:131622)

	Monovalent (2019)	**Hybrid (2018)**
SPF_{sys}	2.29	2.28
SPF_{global}	2.29	1.28
% HP production	100%	67%
Emissions savings	92%	68%

4 centralized ASHP systems for the whole building (TRNSYS simulations)

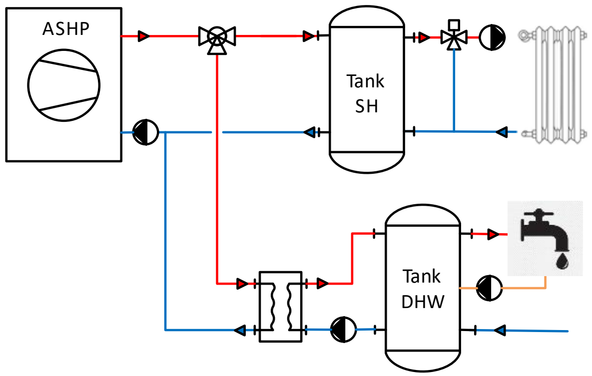
Model validation with in-situ monitoring (TRNSYS)

Sensitivity analysis

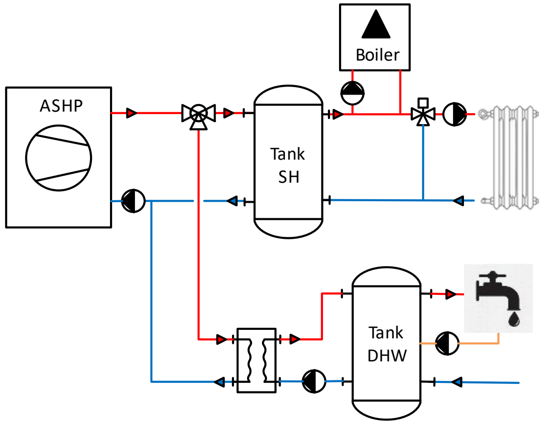
Fuel-switch scenarios based on :
- Discussions with experts in the field
- Long-term in-situ monitoring of pilot projects (Montero, O., 2022)

Normalization to reference conditions
- Climate, space heating and DHW demand

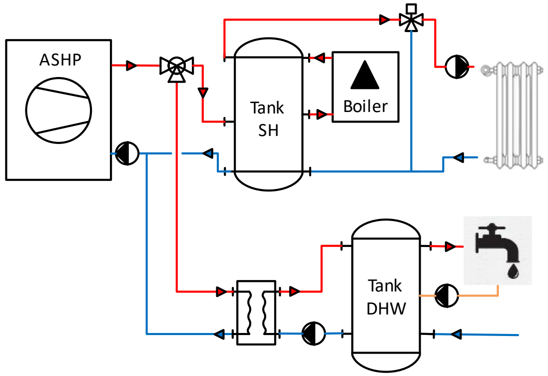
Conclusion and recommendations



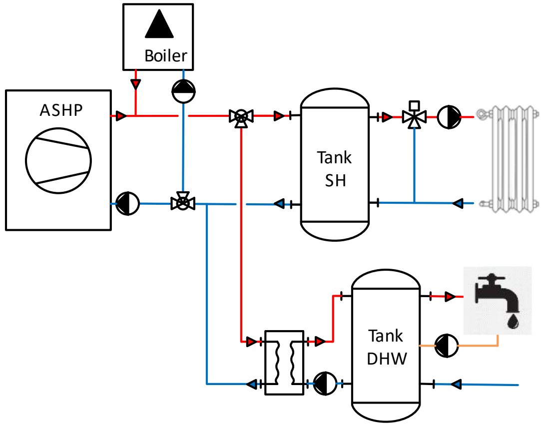
Monovalent



Hybrid
Parallel operation
Modulating boiler



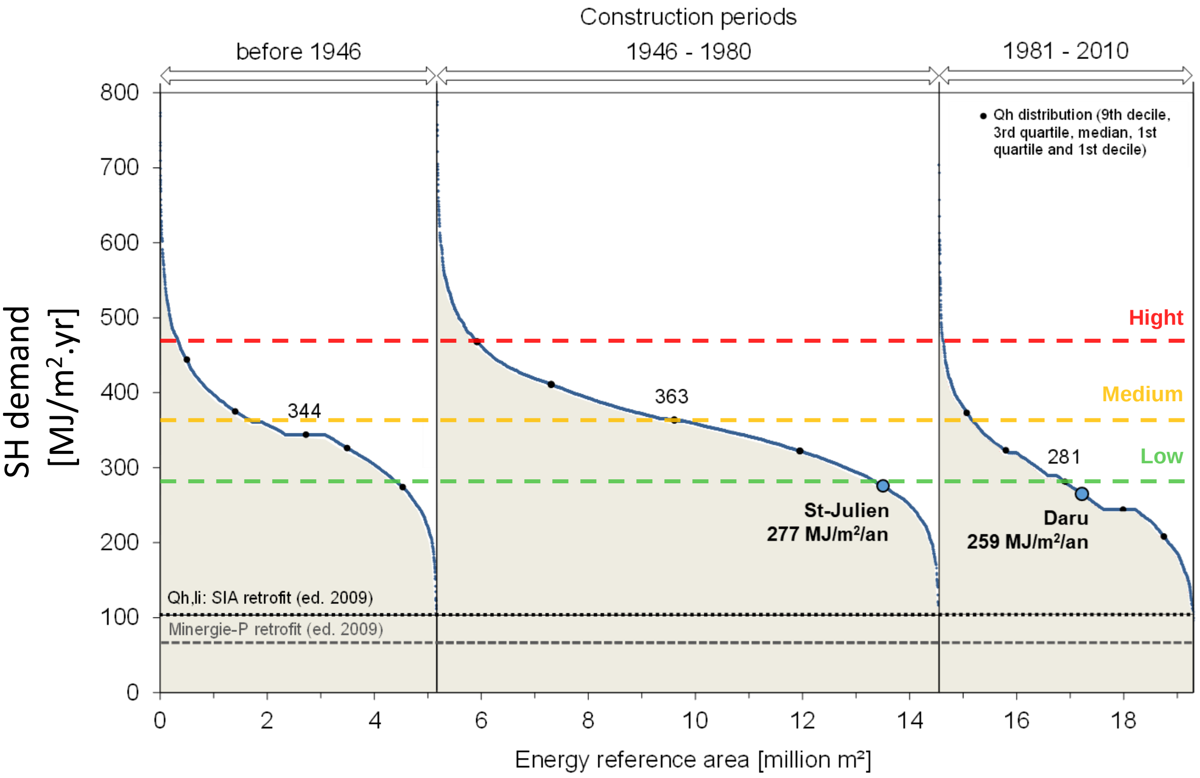
Hybrid
Parallel operation
Non-modulating boiler



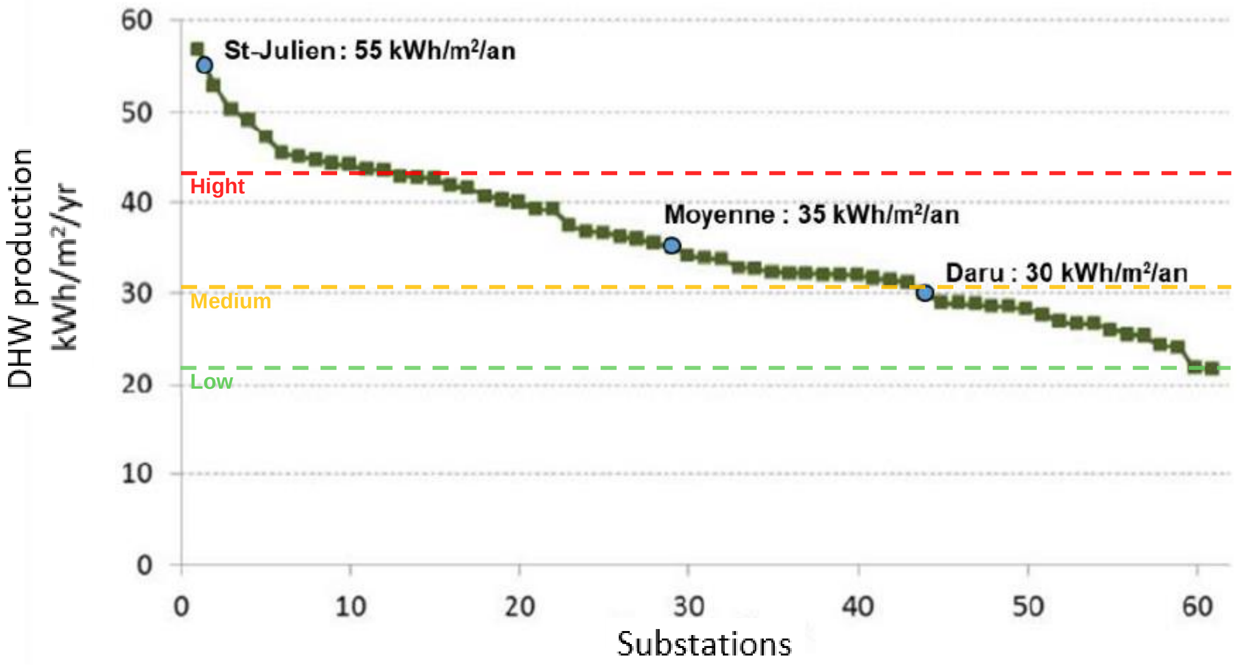
Hybrid
Alternative operation
Non-modulating boiler

Sensitivity analysis

→ Variation of SH and DHW demand (low/medium/high)



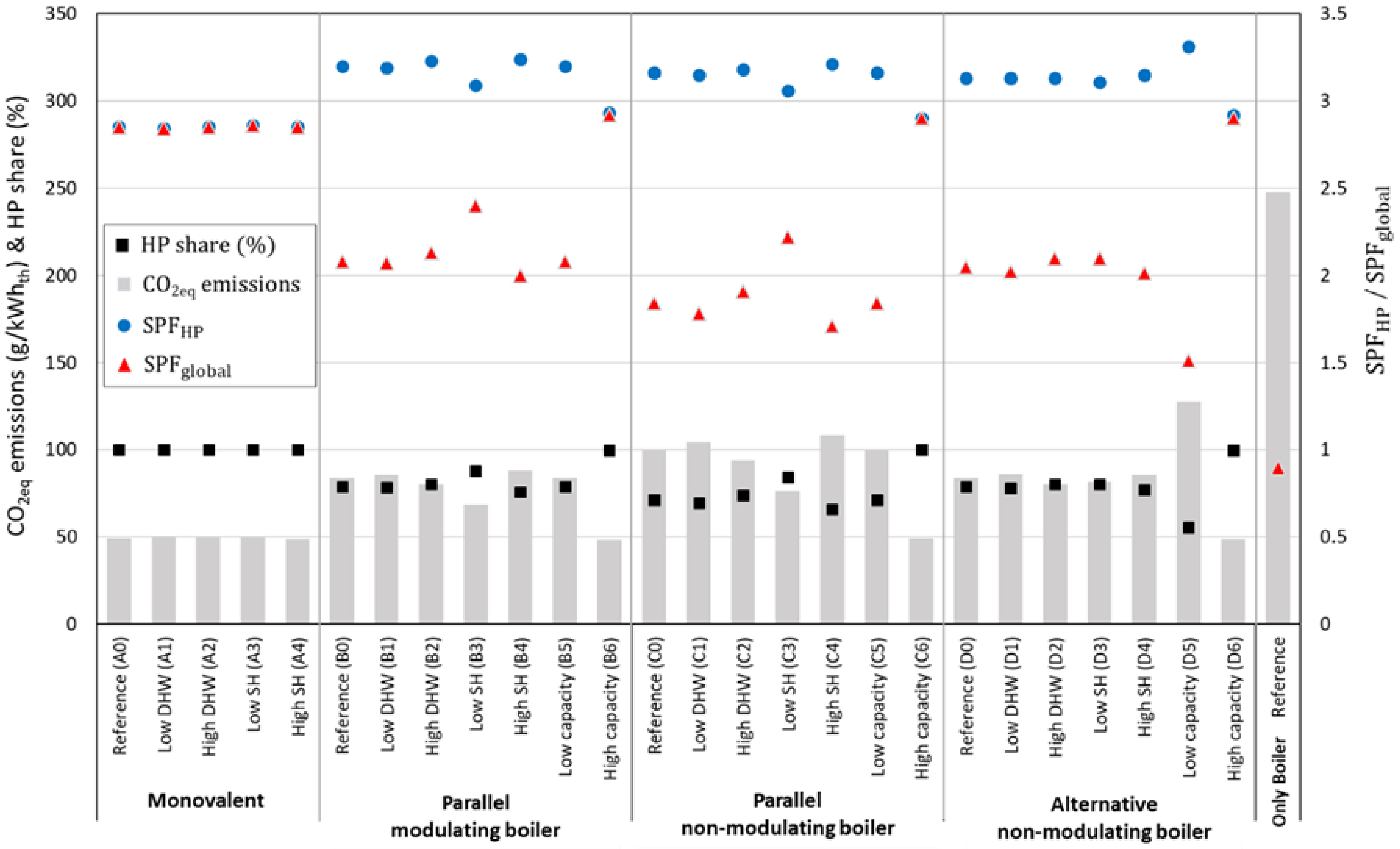
SH demand of Geneva's multifamily building stock sorted in three construction periods Khoury, Jad. 2014. https://doi.org/10.13097/archive-ouverte/unige:48085.



Distribution of the DHW demand of residential buildings (one million m2 of heated area). Quiquerez, Loic. 2017. https://archive-ouverte.unige.ch/unige:91218.

Results

26 cases (4 reference cases + 22 variants)



	Mono. scenarios	Hybrid scenarios	Boiler only
*Emissions gCO_{2eq}/kWh_{th}	49	68 -127	247
SPF_{HP}	2.85	3.06 - 3.31	-
SPF_{global}	2.85	1.52 - 2.40	0.9
HP fraction	100 %	56% - 88%.	-

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Results

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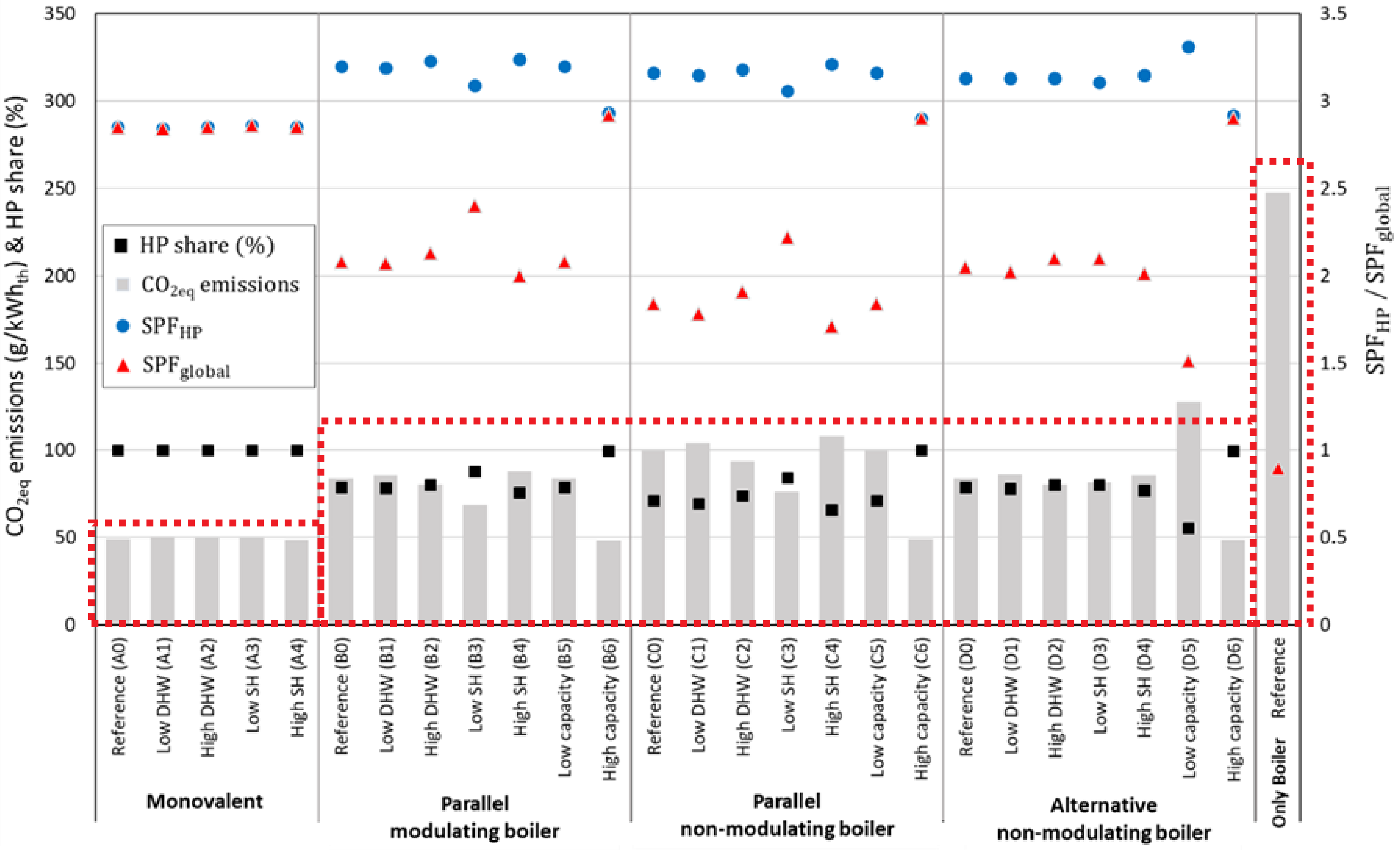

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*HP emissions: **Hourly** CO_2eq content of the **Swiss electricity mix** (Romano, Elliot 2018. https://archive-ouverte.unige.ch/unige:131622)

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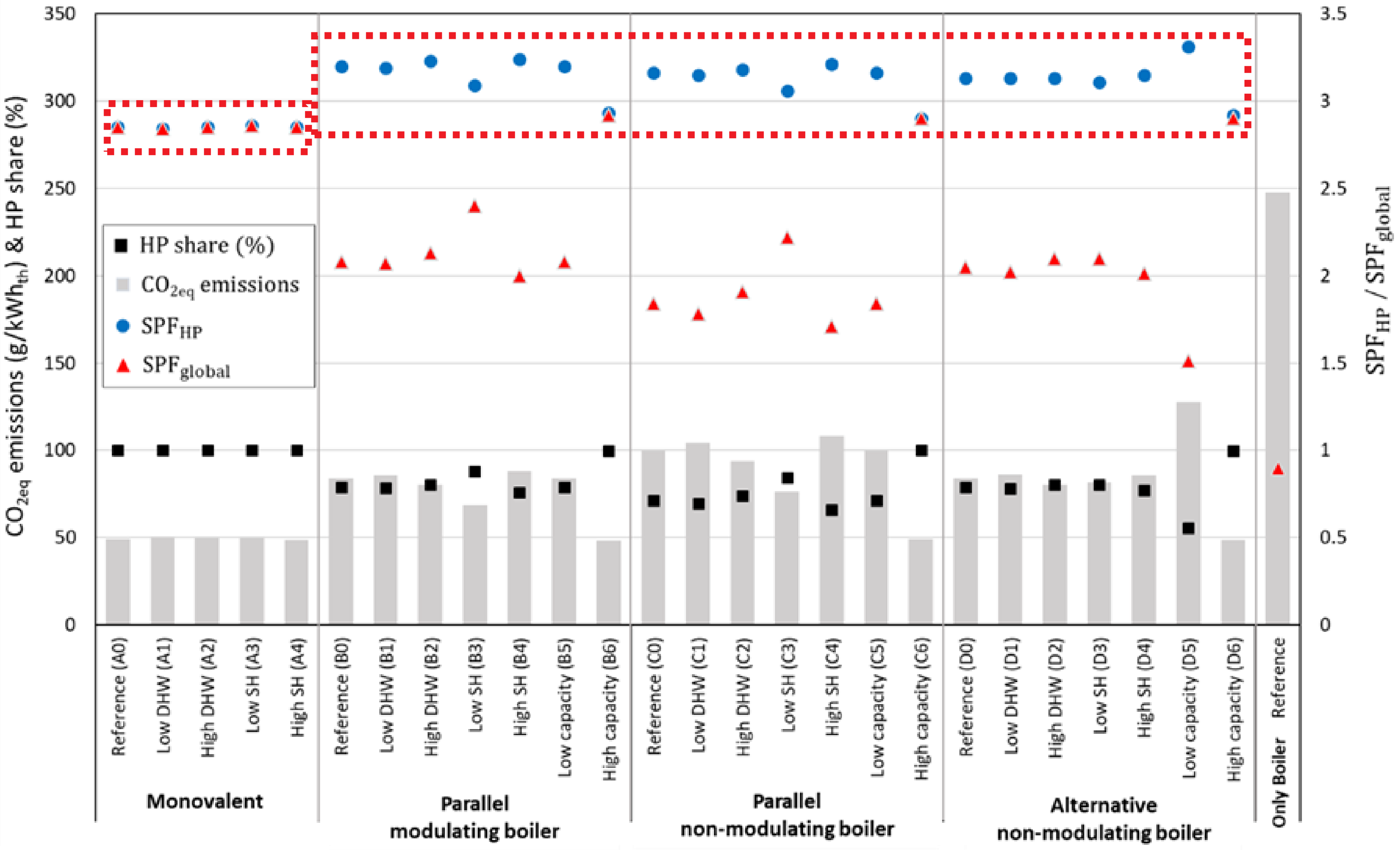

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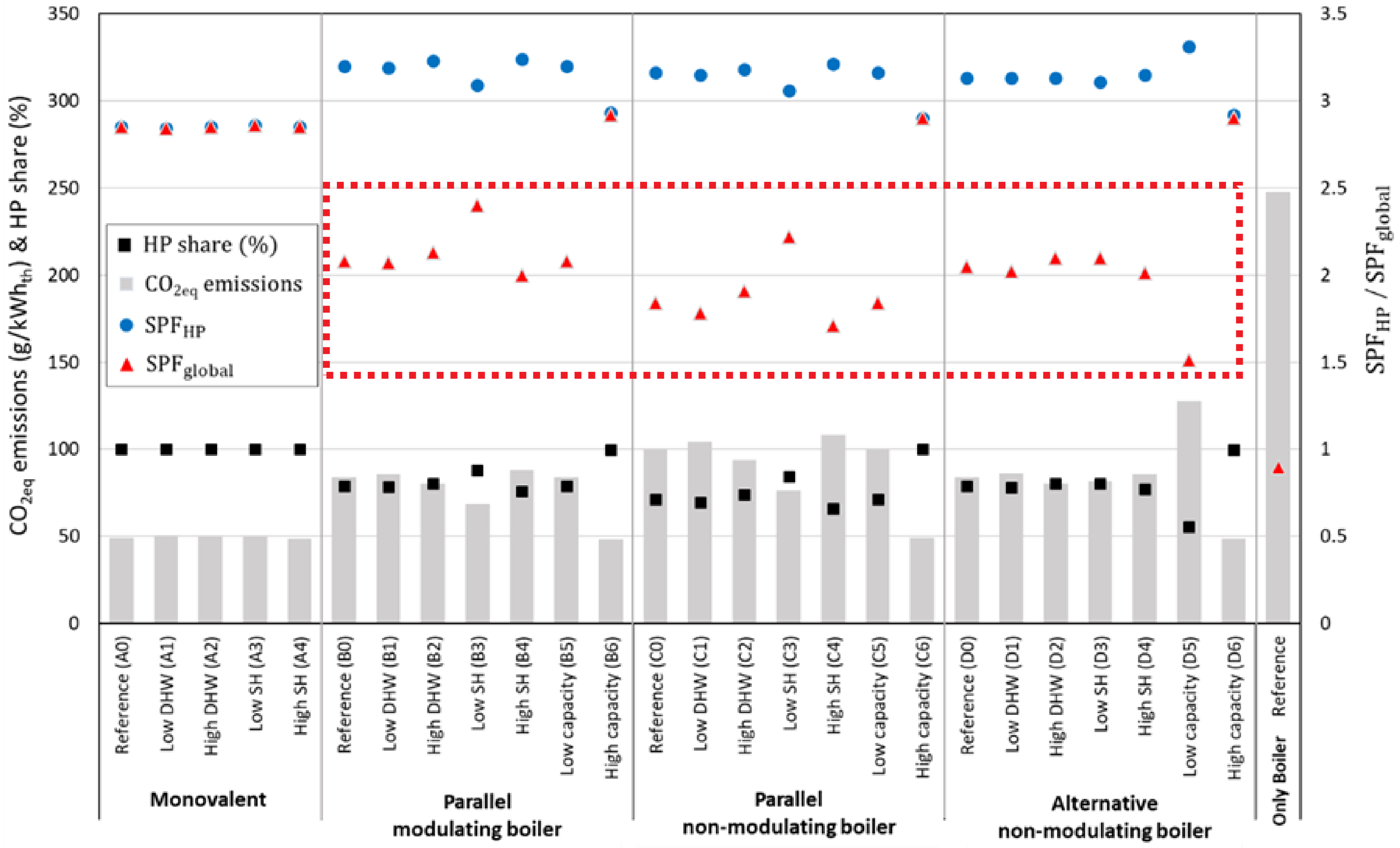

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Conclusions

- **Air-source HP can replace boilers, even in non-retrofitted buildings** without reducing thermal comfort
- **Significant emissions savings** due to the low-carbon Swiss electricity mix, despite low monitoring performance
- **Monovalent systems**:
  - → **Emissions are 5 times lower** than a fossil boiler
  - → **Easier to control and simple hydraulic diagram**
  - → Higher HP capacity and extra measures (noise, rooftop static, etc.) which **increases the capital cost**
- **Hybrid systems**:
  - → **Emissions are 2.3-3.5 times lower** than a fossil boiler
  - → **Complex to control** to achieve high performances and HP share production
  - → **Good transitional solution**, while awaiting an envelope renovation

Thank you for your attention!

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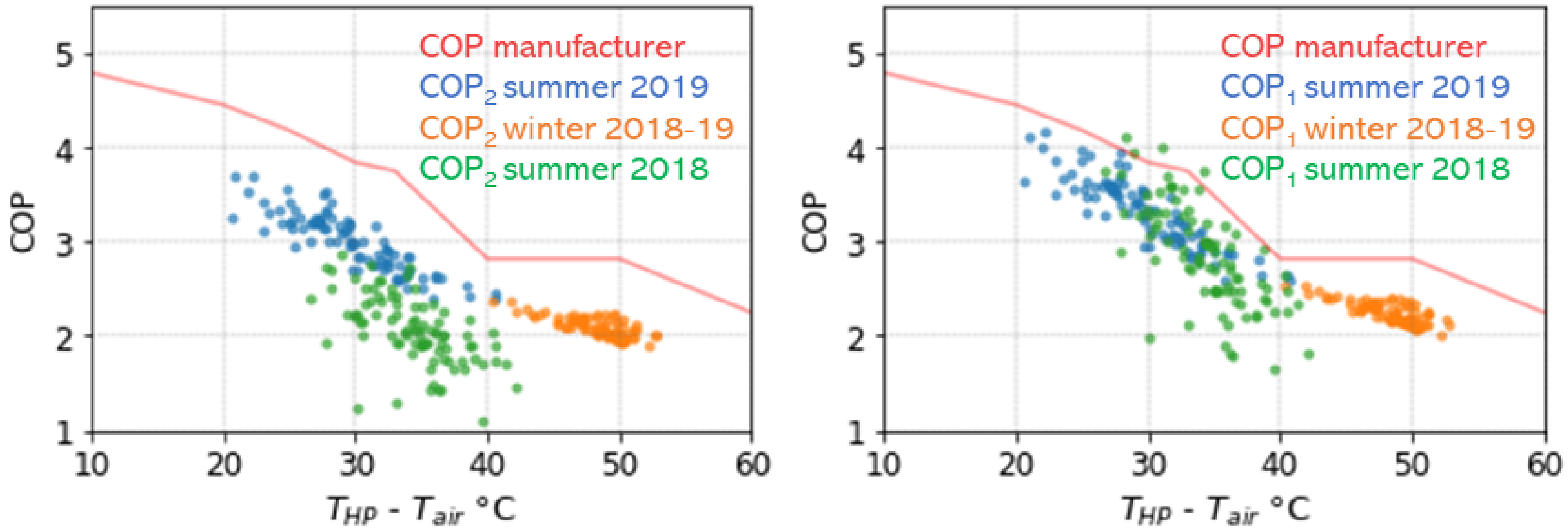
Annexe

Comparison between the Actual Performance and Manufacturer

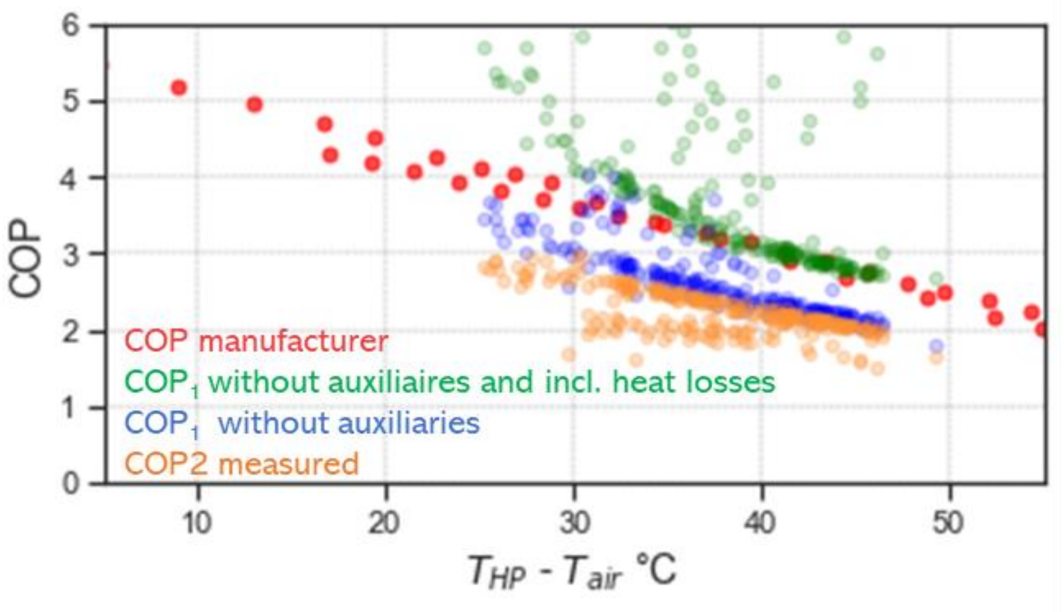
Monovalent system



(a) (b)

Comparison between the Actual Performance and Manufacturer

Hybrid system



Sizing monovalent

Power capacity for space heating
@ -7/ heating courbe

$$P_{HP,SH} = \frac{\max(E_{SH,daily})}{t_{SH}}$$

$E_{SH,daily} = Daily\ SH\ demand$
t_{SH} = time for SH (24h-6h =**18h**)

Power capacity for DHW
@ -7/65°C

SIA 385/2

45 L/day.person
30% of storage and distribution losses
6 daily charging cycles with a duration of 1 hour each (6h)

Power for SH
@ 7°C/45°C

Power for DHW
@ 7°C/45°C

Installed capacity
@ 7°C/45°C
MAX ($P_{HP,SH}$, $P_{HP,DHW}$)

Sizing hybrid systems

Power capacity for space heating

- Identification of the bivalent point
- Calculate the energy supplied each hour by the heat pump for SH
- Guarantee that the machine covers 80 % of the total head demand

Power for SH
@ 7°C/45°C

Power capacity for DHW
@ -7/65°C

SIA 385/2

45 L/day.person
30% of storage and distribution losses
6 daily charging cycles with a duration of 1 hour each (6h)

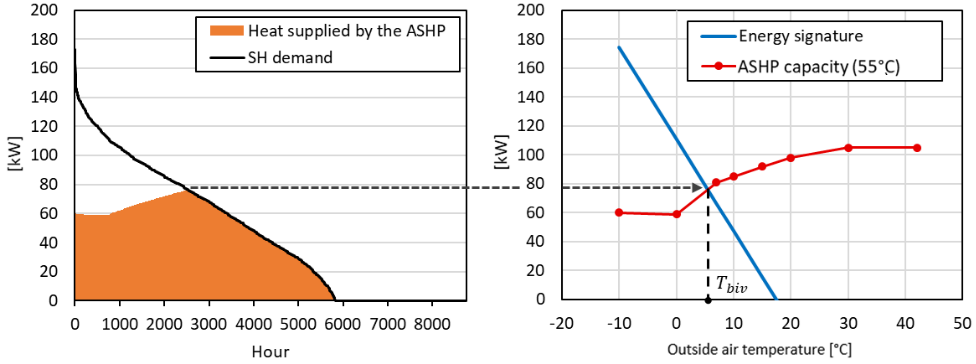
Power for DHW
@ 7°C/45°C

Installed capacity
@ 7°C/45°C
MAX $(P_{HP,SH}, P_{HP,DHW})$

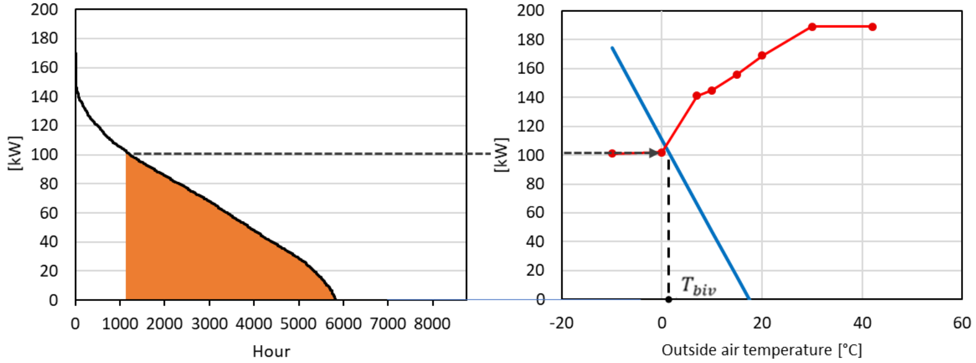
Systems sizing

Système	Variant*	#	HP capacity* for SH (@7°C/45°C) [kW_{th}]	HP capacity* for DHW (@7°C/45°C) [kW_{th}]	HP capacity** retained (@7°C/45°C) [kW_{th}]	Boiler capacity [kW_{th}]	T_{biv} [°C]	Volume tank SH [m^3]	Volume tank DHW [m^3]
Monovalent	Reference	A0	250	(84)	274	-	-	2.2	1.9
	Low DHW	A1	250	(84)	274	-	-	2.2	1.9
	High DHW	A2	250	(84)	274	-	-	2.2	1.9
	Low SH	A3	189	(84)	208	-	-	2.2	1.9
	High SH	A4	322	(84)	350	-	-	2.8	1.9
Parallel / modulating boiler	Reference	B0	(78)	84	88	95	4.5	2.9	1.9
	Low DHW	B1	(78)	84	88	95	4.5	2.9	1.9
	High DHW	B2	(78)	84	88	95	4.5	2.9	1.9
	Low SH	B3	(60)	84	88	72	2	2.9	1.9
	High SH	B4	104	(84)	104	122	5	2.2	1.9
	Low capacity	B5	(53)	84	88	95	4.5	2.9	1.9
	High capacity	B6	201	(84)	208	95	-8	2.2	1.9
Parallel / non-modulating boiler	Reference	C0	(78)	84	88	95	4.5	2.9	1.9
	Low DHW	C1	(78)	84	88	95	4.5	2.9	1.9
	High DHW	C2	(78)	84	88	95	4.5	2.9	1.9
	Low SH	C3	(60)	84	88	72	2	2.9	1.9
	High SH	C4	104	(84)	104	122	5	2.2	1.9
	Low capacity	C5	(53)	84	88	95	4.5	2.9	1.9
	High capacity	C6	201	(84)	208	95	-8	2.2	1.9
Alternative / non-modulating boiler	Reference	D0	137	(84)	137	189	0.5	2.2	1.9
	Low DHW	D1	137	(84)	137	189	0.5	2.2	1.9
	High DHW	D2	137	(84)	137	189	0.5	2.2	1.9
	Low SH	D3	104	(84)	104	143	0.5	2.2	1.9
	High SH	D4	175	(84)	175	243	0.5	2.8	1.9
	Low capacity	D5	(53)	84	88	189	4.5	2.9	1.9
	High capacity	D6	201	(84)	208	189	-8	2.2	1.9

Parallel operation



Alternative operation



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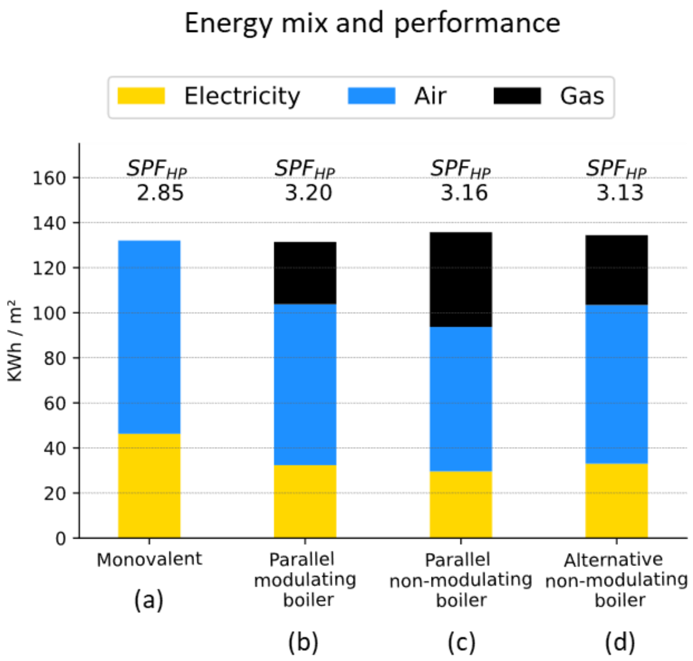
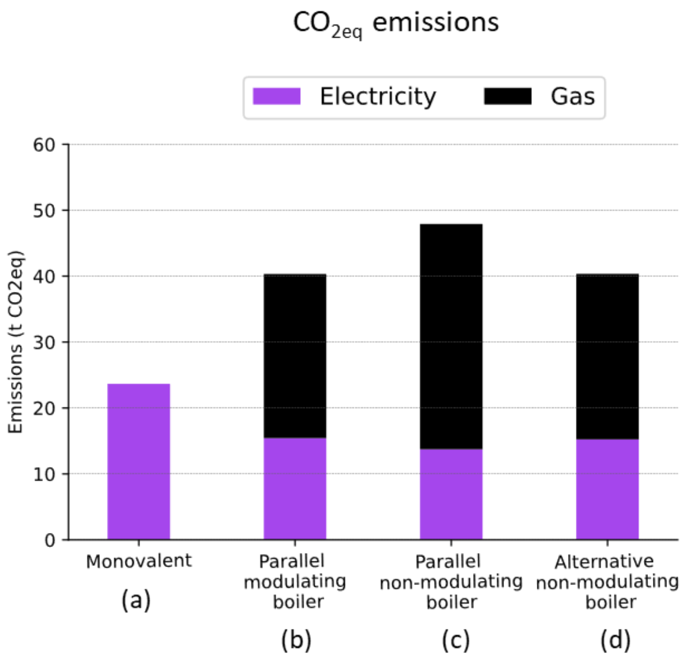
Results for reference systems





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