Monovalent and Hybrid Air-source Heat Pump Concepts for Existing Multifamily Buildings. Energy Performance and CO_2 Savings

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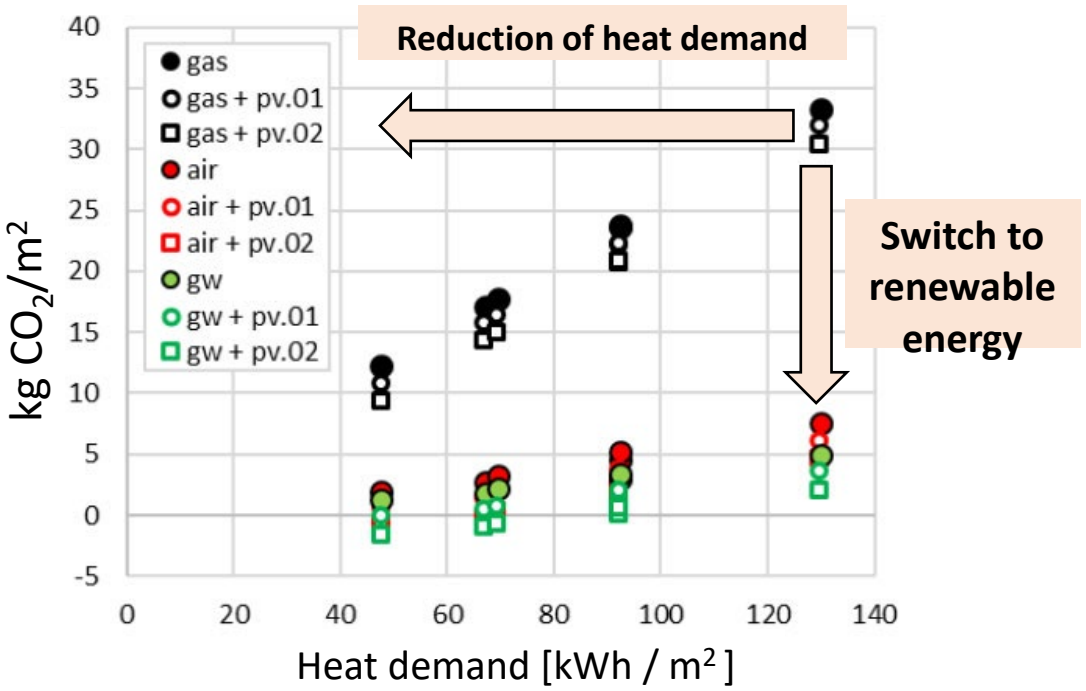
Overall challenge



Area related CO_{2eq} emissions for various multifamily buildings vs heat production with gas boiler, air source HP or groundwater source HP (with and without PV), *Romano et al., 2020*

Reduction of CO2 emissions :

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

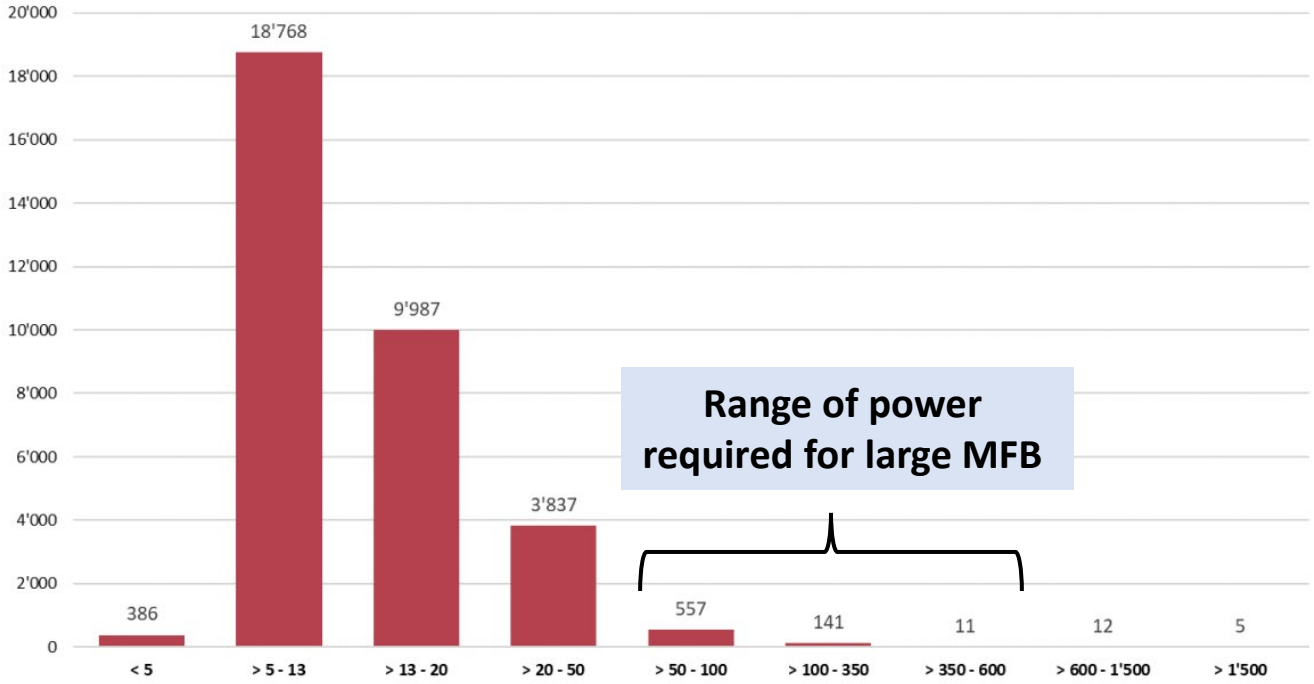
Outside air is often the **only source for HP in urban areas**

Air-water HP are rarely installed in large existing MFB (not or partially renovated)

Requested HP capacity : > 50 kW

Contraints of large air-water HP in existing MFB

HP sales in Switzerland according to power capacity (kW)
2021



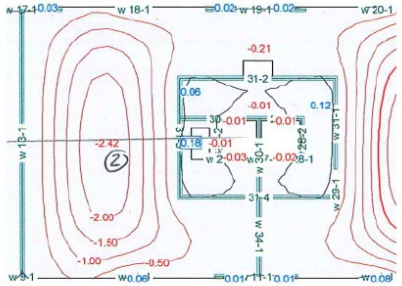
Groupement professionnel Suisse pour les pompes à chaleur (GSP). Statistiques 2021

Contraints of air water HP in existing MFB :

- HP > 50 kW_{th} not designed for the residential sector
- Noise emissions
- High investment cost
- …
- **Lack of standardized hydronic concepts :**
  - → Only hydronic concepts up to about 15 kW_{th}
  - → Design and operation literature mainly on single family house
  - → Constraints in the context of the existing buildings

Air-warter HP integration in existing MFB

HP weight in the roof



Demand change over time

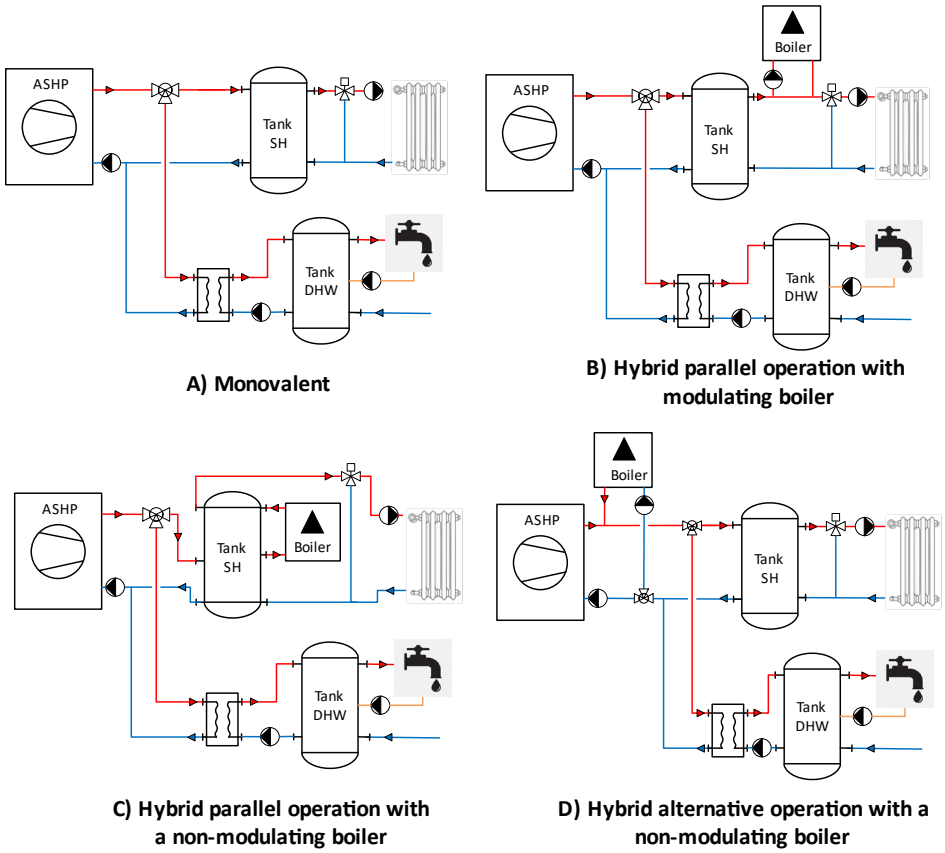
non-renovated → renovated

Limited space in the boiler room

Keep existing equipment (boilers, tanks, etc.)

Fuel-switch scenarios (TRNSYS simulation)

4 centralized air-water HP systems for the whole building



A) Monovalent

B) Hybrid parallel operation with modulating boiler

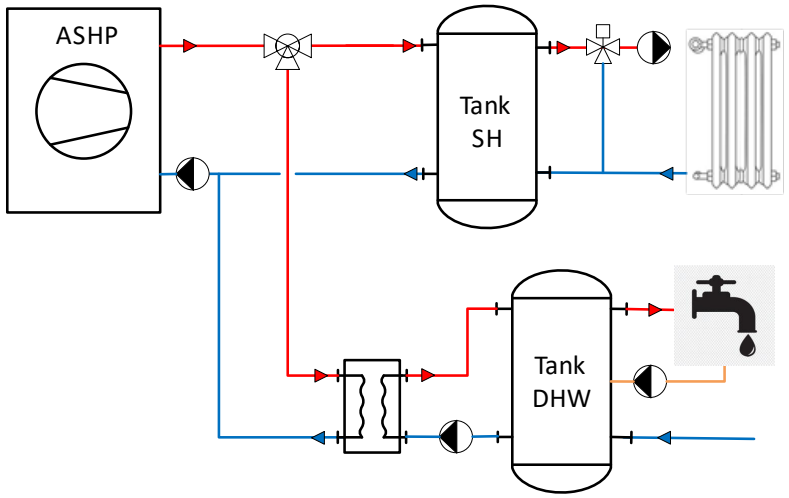
C) Hybrid parallel operation with a non-modulating boiler

D) Hybrid alternative operation with a non-modulating boiler

- **Fuel-switch scenarios based on :**
  - Discussions with experts in the field
  - Long-term in-situ monitoring of pilot projects (Montero, O., 2022)
- **Model validation with in-situ monitoring (TRNSYS)**
- **Normalization to reference conditions**
  - Climate, space heating and DHW demand
- **Sensitivity analysis**
  - Levels of heat demand and heat pump capacity
- **Conclusion and recommendations**

Monovalent heat pump operation

- HP to cover 100% of the demand (SH and DHW)
- **Easier to control**, but requires measures of noise reduction, rooftop static and extra height construction limits
- Cost → More HP capacity than hybrid systems

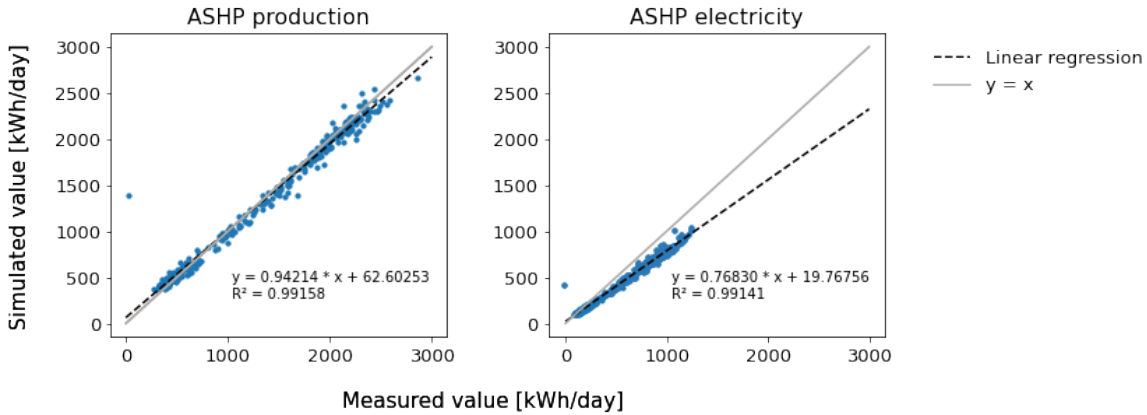


a) Monovalent concept

Monitoring campaign of pilot project installed in Geneva

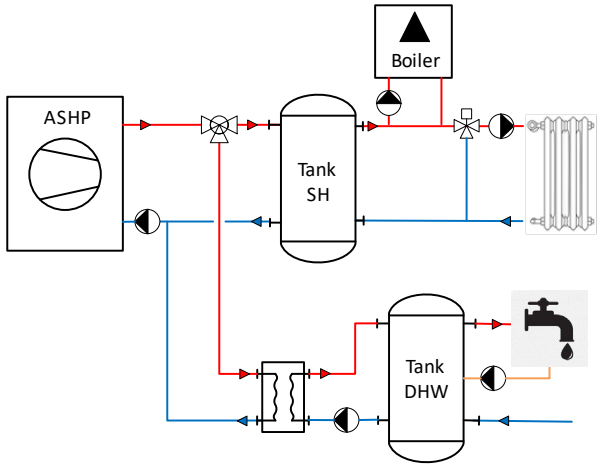
Montero, O. ; https://doi.org/10.3390/en15145033

Validation of the system model

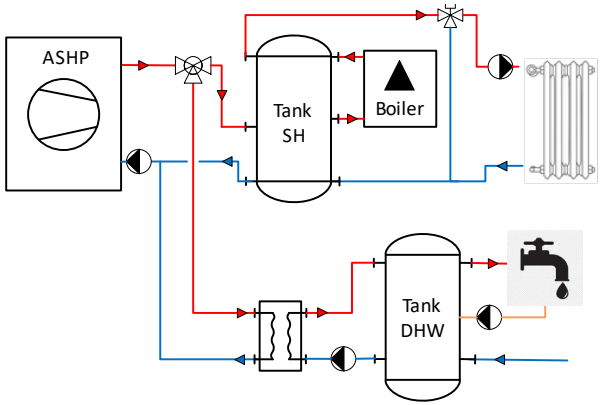


Hybrid parallel operation

- **Economic choice** to keep a part non-renewable (HP cover 80% of the demand)
- **Transitional solution**, while awaiting an envelope renovation
- **More complex** (hydraulic and control) than a monovalent system
- HP supplies 100% of the DHW production



b) System with modulating boiler



c) System with non-modulating boiler

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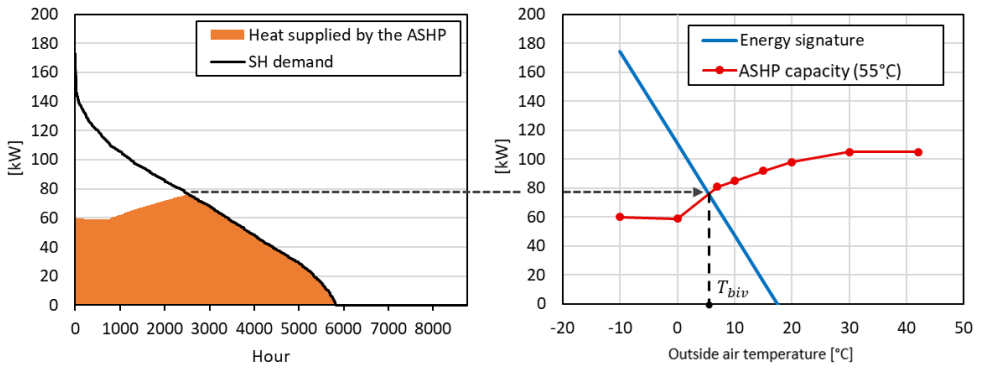
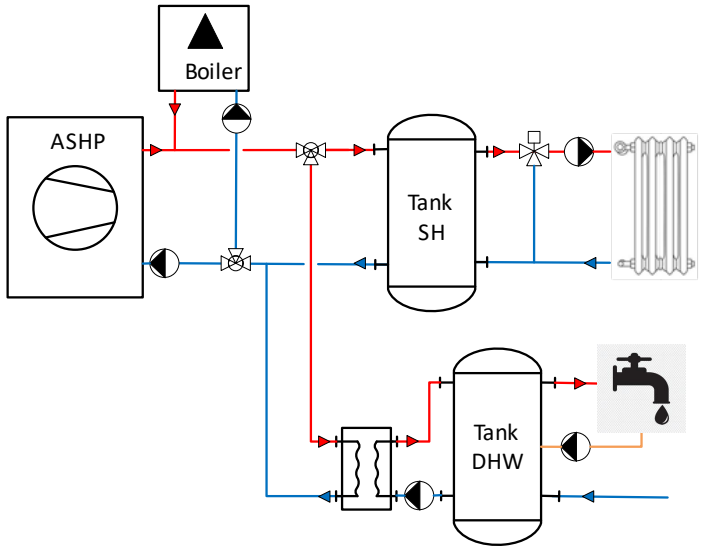
Parallel operation



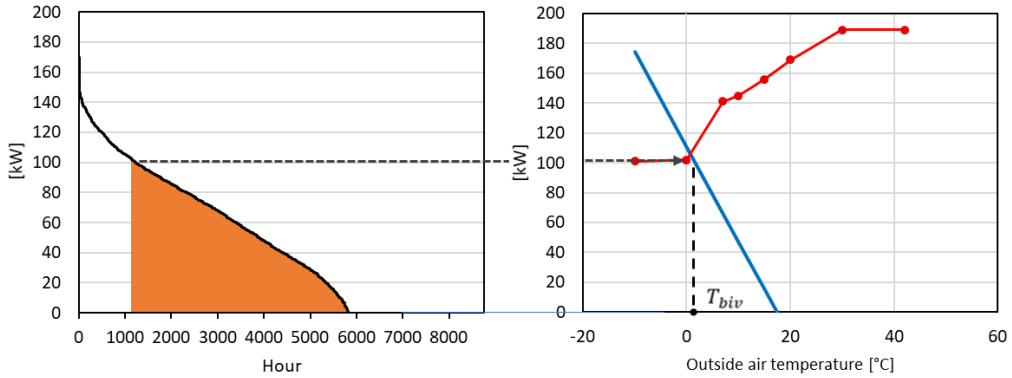
Hybrid alternative operation

- **Existing boiler will be disconnected** (eg. old boiler with a low modulation)
- **Boiler removal with minor hydronic modifications**
- HP supply 100% of the DHW production

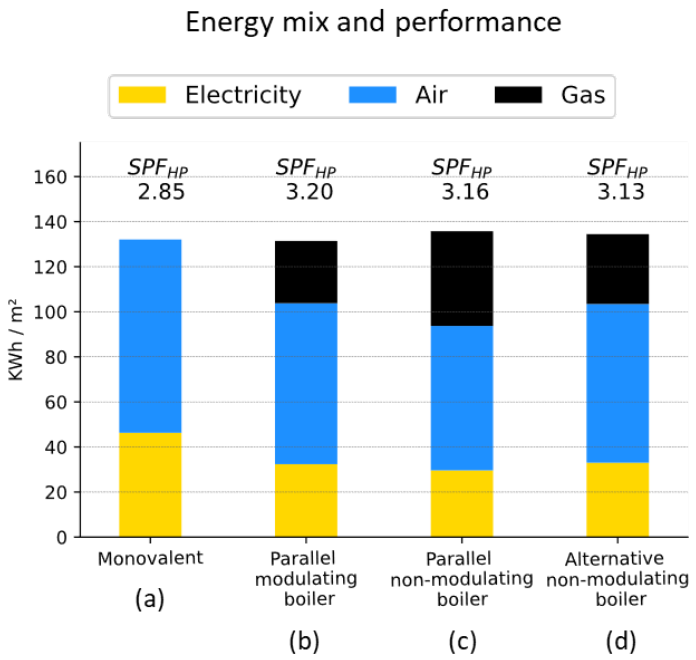


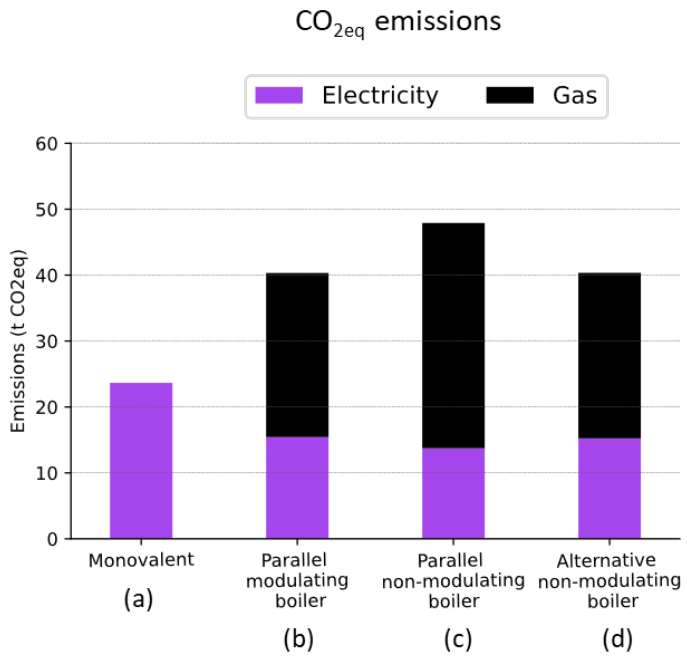
d) System with non-modulating boiler

Alternative operation



Results for reference systems





*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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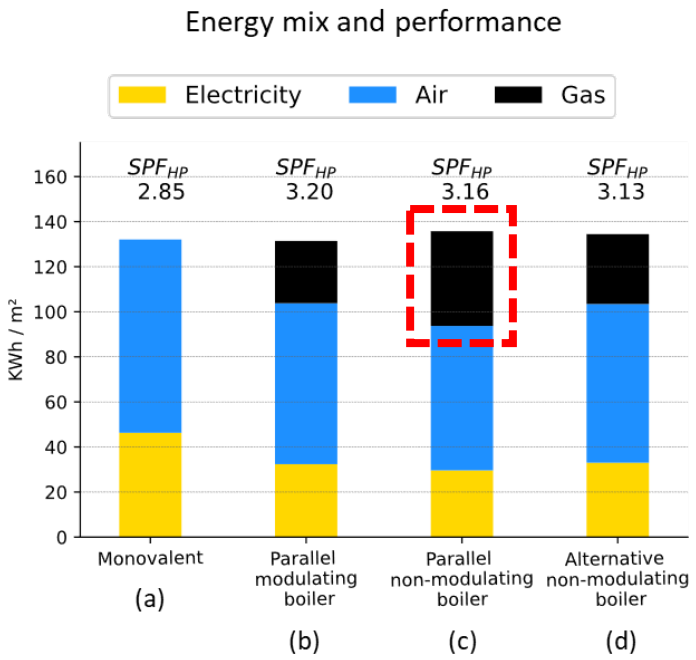

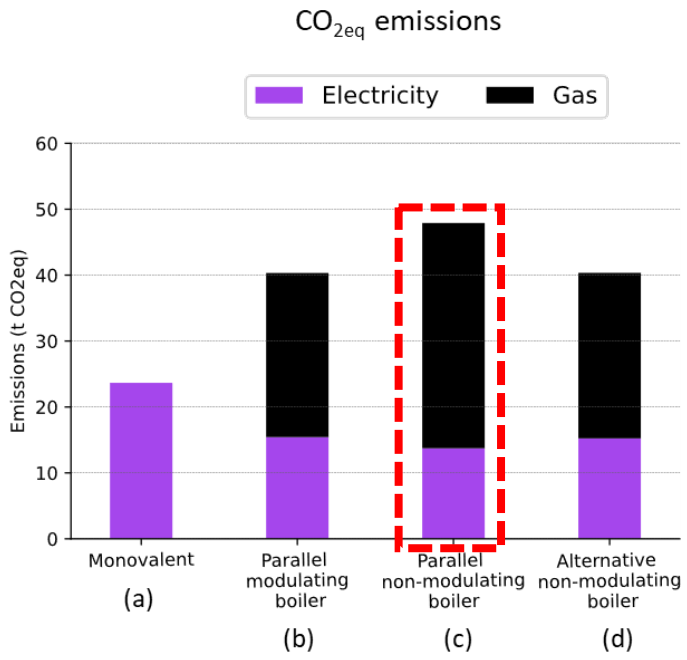

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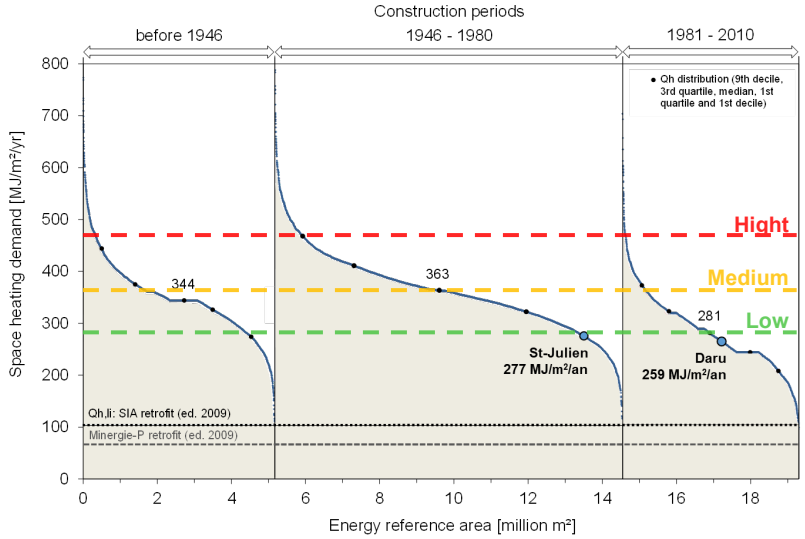
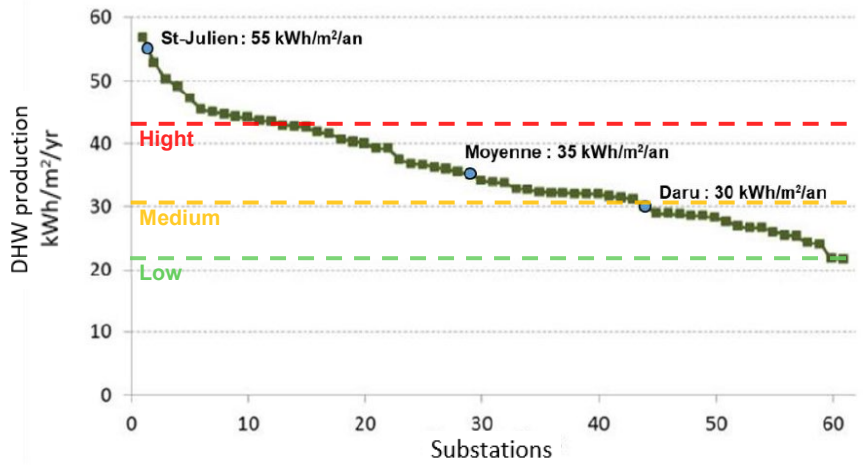
Sensitivity analysis

→ 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.

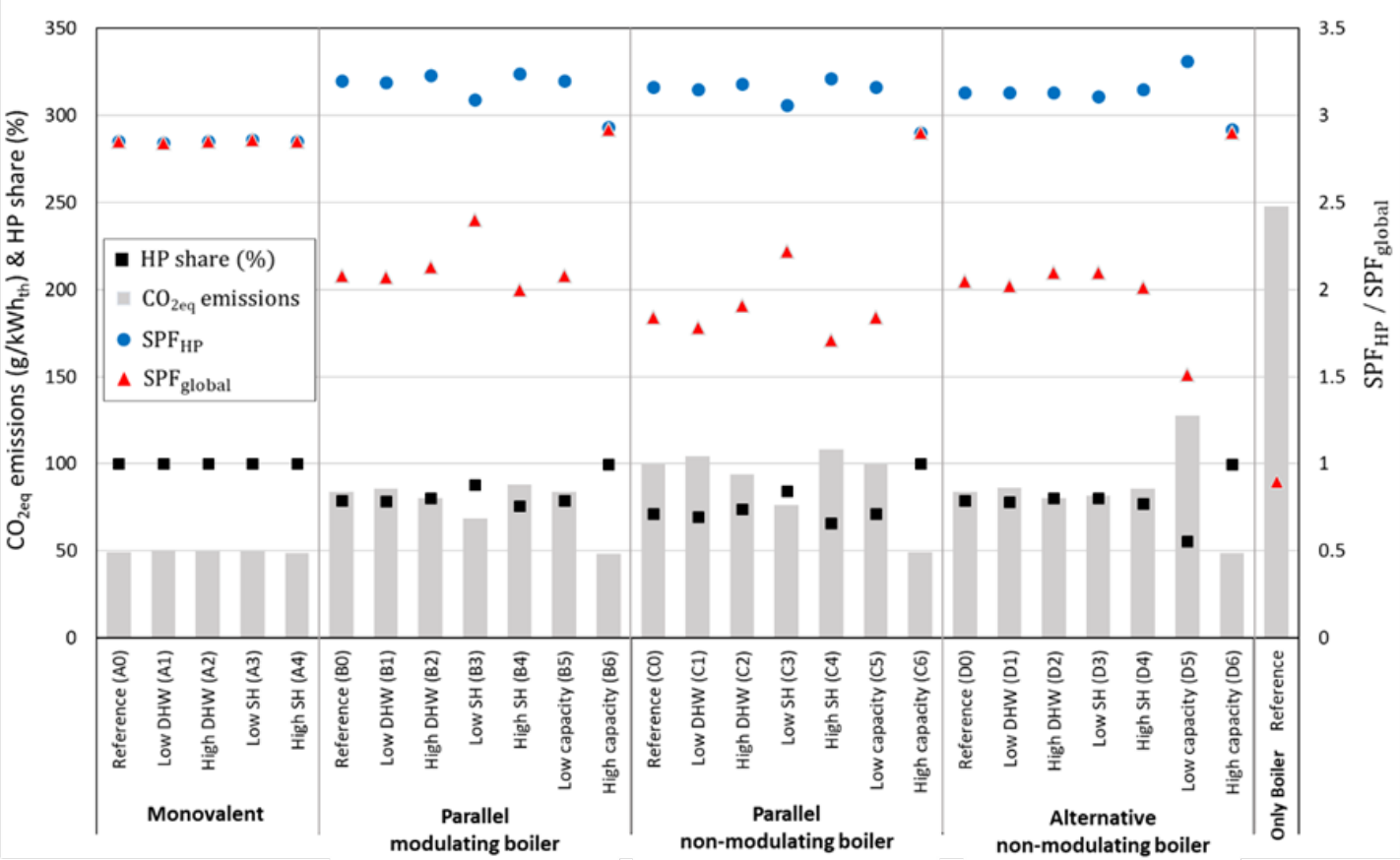


Distribution of the DHW demand of residential buildings (one million m2 of heated area). Quiquerez, Loic. 2017. https://archive-ouverte.unige.ch/unige:91218.

→ HP capacity: under or oversizing

Results

26 cases (4 reference cases + 22 variants)



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

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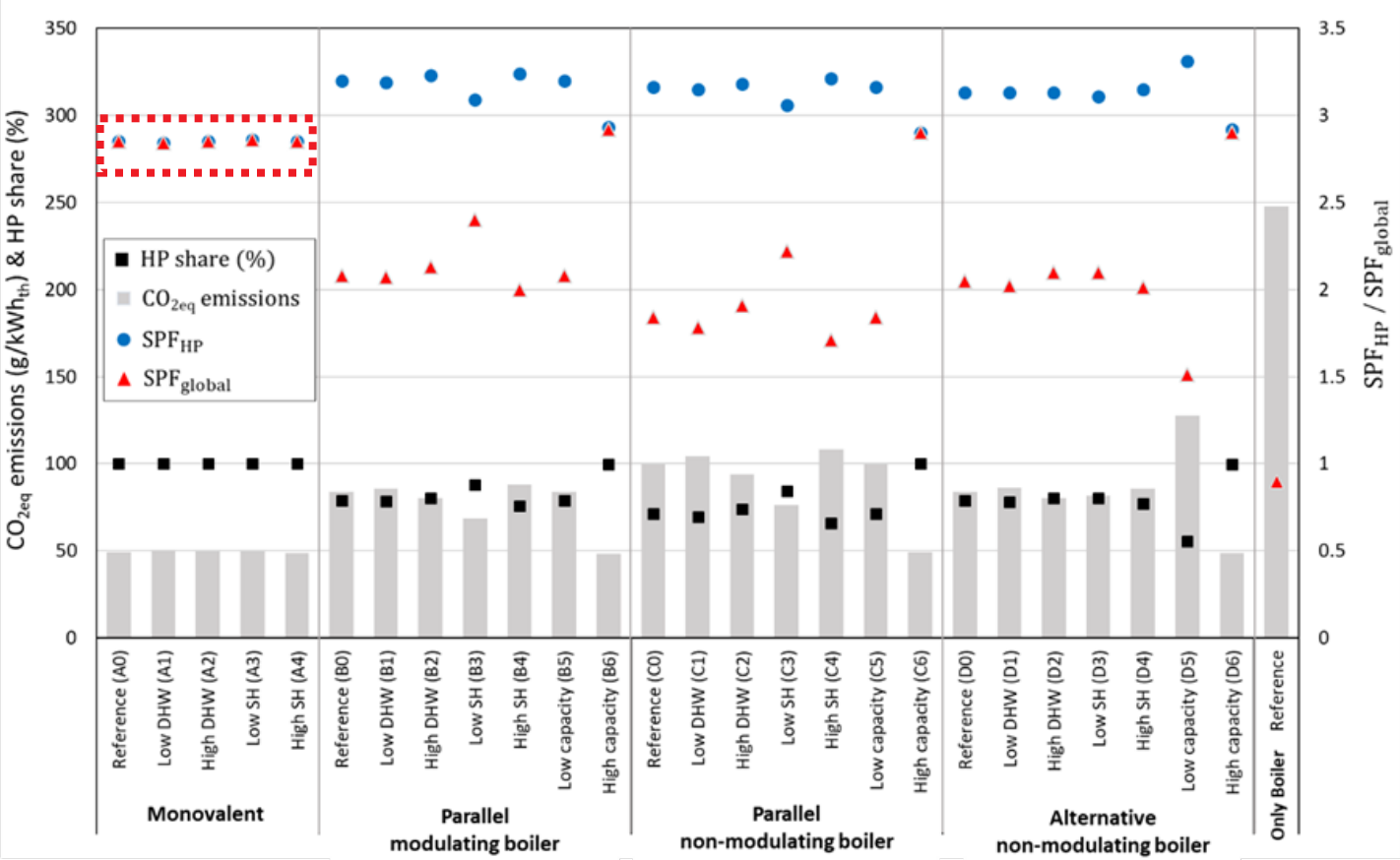

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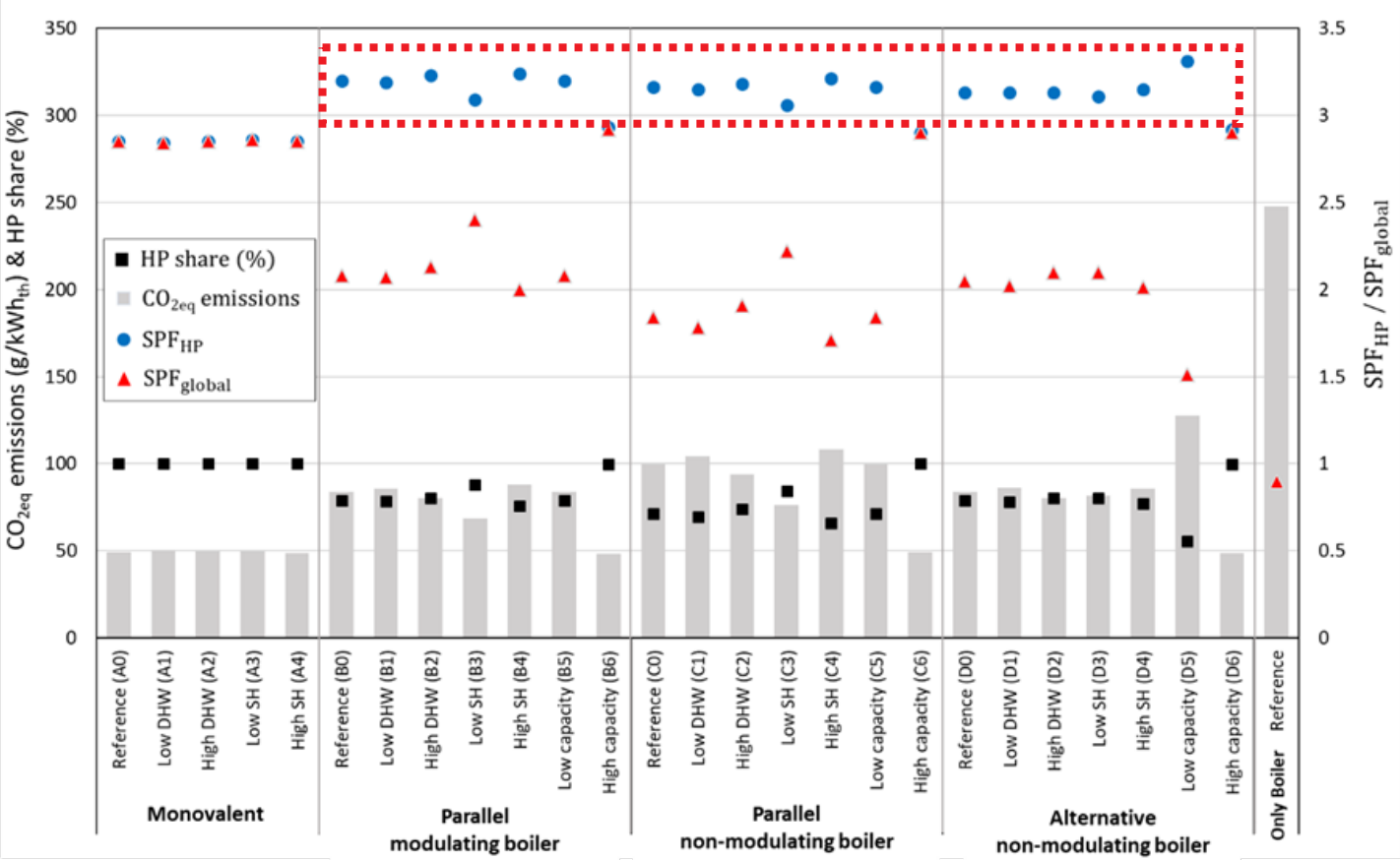

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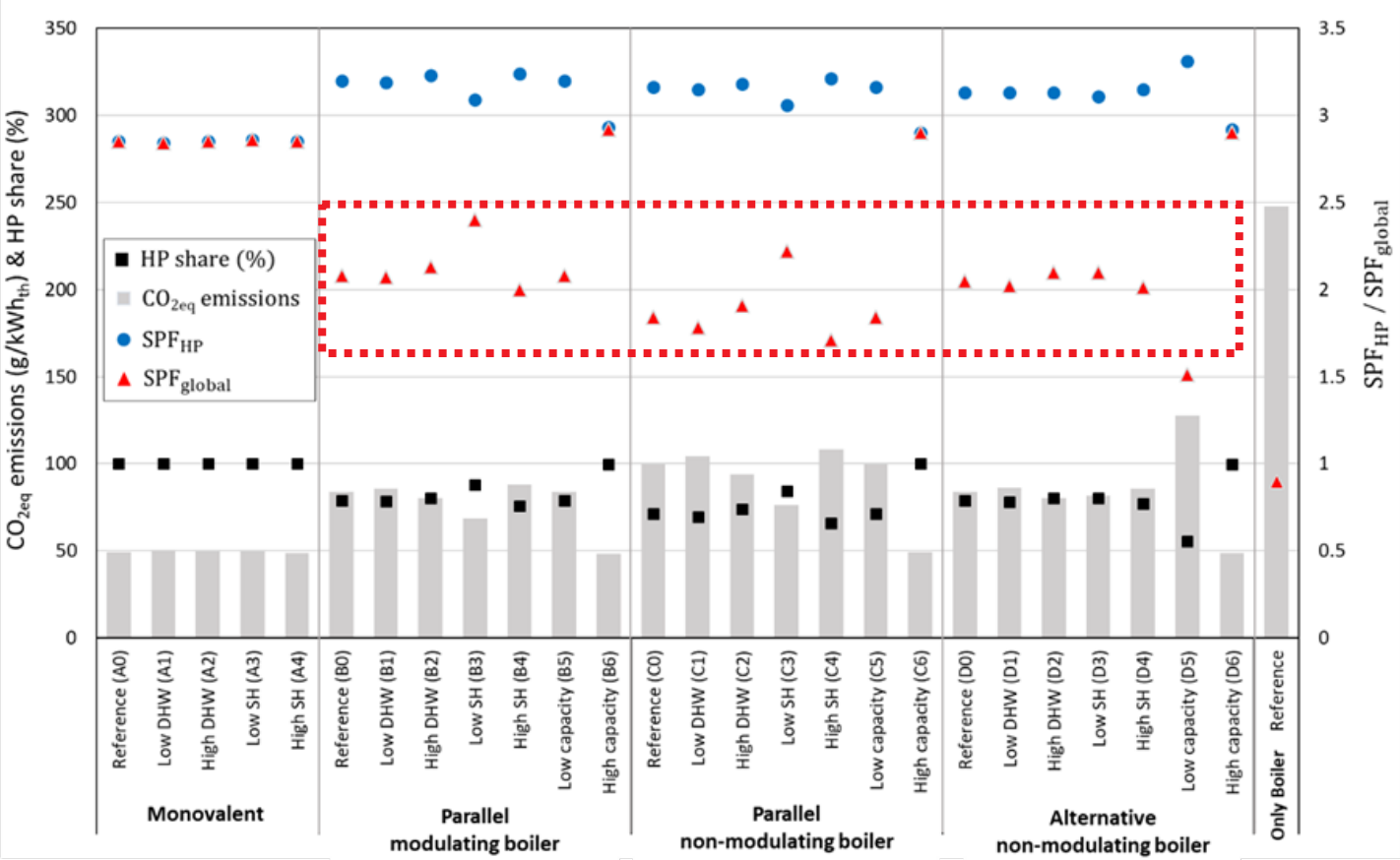

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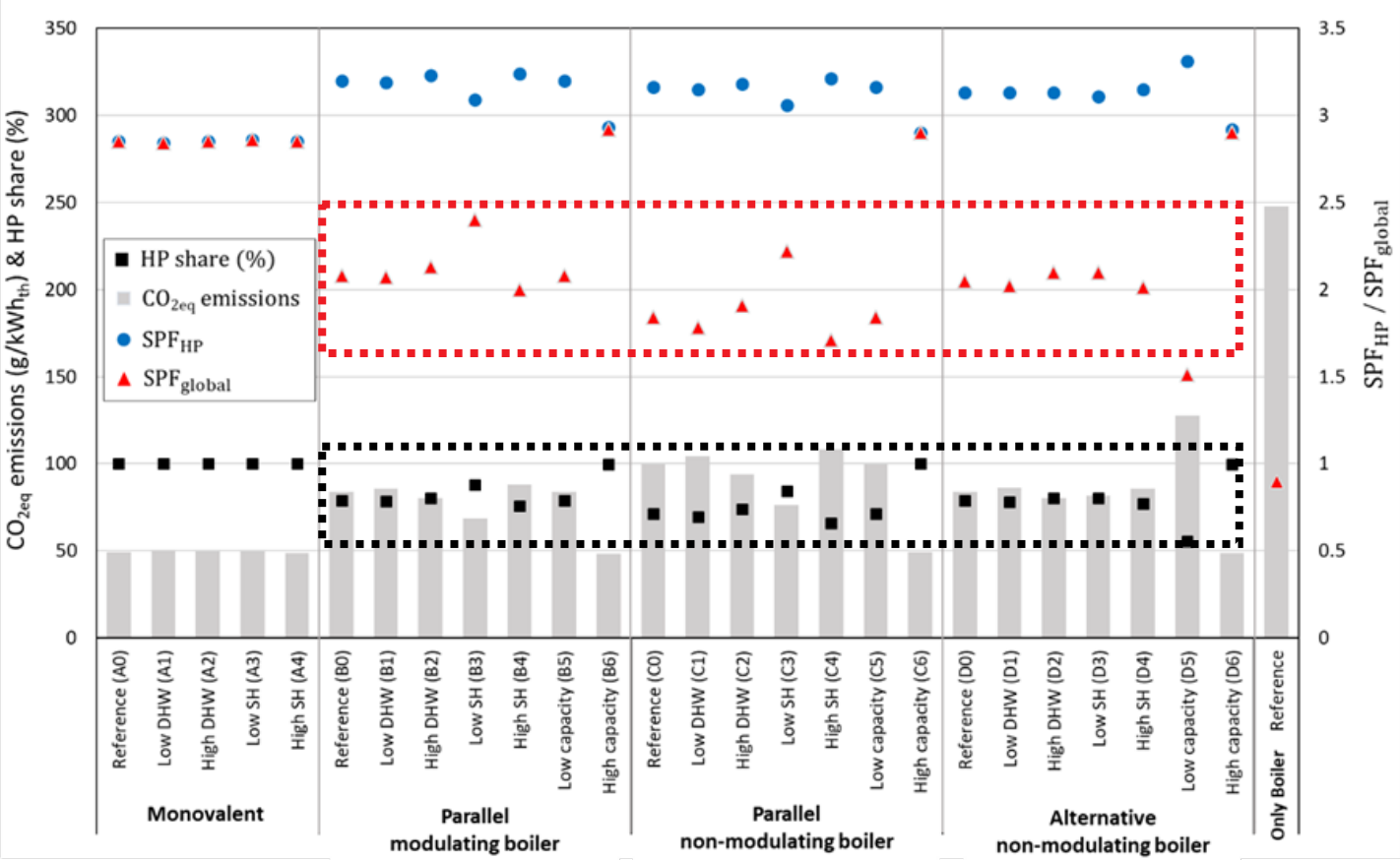

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Conclusions

- Focus on overall system performance (HP + boiler) rather than only HP performance
- **Monovalent systems**: Emissions 1.3 to 2.5 time lower than hybrid, but 2 - 3 times higher HP capacity
- **Hybrid systems**: Emissions 2.3 to 3.5 times lower than with fossil boiler

  → Transitional solution, while awaiting an envelope renovation

Further aspects :

- Economic analysis
- Electric heating rod as back-up
- Separate HP for each mode (DHW and SH)

Thank you for your attention!