



Simulation-assisted development of a mini-split heat pump for space heating in minimal invasive renovations

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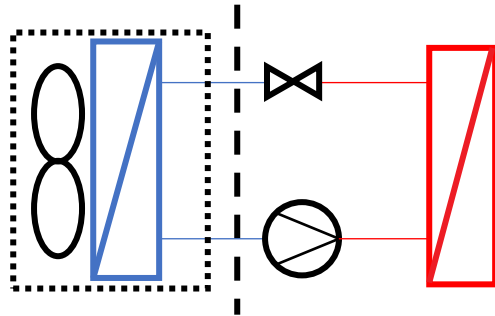
# Challenges in renovated multiple family buildings

- » Flats in multiple family buildings (MFBs) are traditionally heated decentral-wise with gas-fired boiler.
- » A complete modernisation of the heating system and/or a switch to a centralised heating system is often for technical, economical or social reasons not possible:
  - High investment cost;
  - High degree of invasiveness in the flat;
  - Missing space for the installation of a centralised HP;
  - Source accessibility;
  - Sound emissions.
- » Typical flat size in Austria in MFBs: 55-65 m<sup>2</sup> with no central technical room available.



Foto: baustoffwissen.de

# Renovation of multiple-family buildings with heat pumps



Source: [www.resi.co.uk](http://www.resi.co.uk)



# HP façade-integration in serial renovation

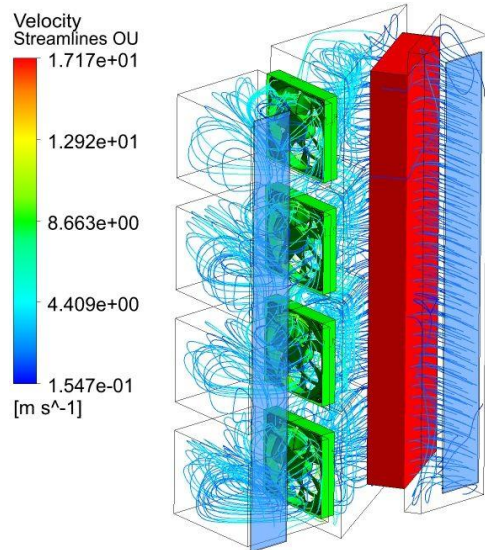


- » HP Façade-integration can boost through prefabrication the renovation process and increase cost-effectiveness;
- » Accessibility for maintenance and pleasant architectonic appearance;
- » Flow condition must be accurately investigated (efficiency, sound emissions) and a standardized overall development approach must be defined.
- » Macro research goal: develop an alternative to decentral gas boilers for space heating and domestic hot water preparation in MFBs through:
  - Compact design of the indoor unit for space saving;
  - Silent compact facade-integrated outdoor unit;
  - Improved architectonic appearance of the façade.

-> Split decentral air-to-water heat pump

# Modular, compact and silent split heat pump concept

Common outdoor unit design



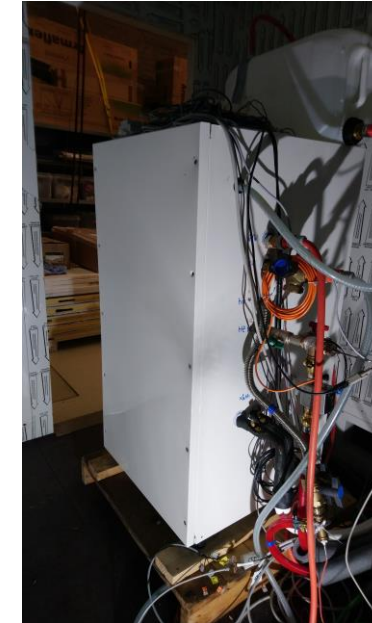
- » Four parallel axial fans
- » Lower power consumption and lower sound emissions compared to radial fans
- » Thermal capacity = 1.5 kW (A7W50)
- » Resulting sound power level of 39 dB(A) at 350 m<sup>3</sup>/h

Mock-up of outdoor unit



Ochs, Fabian; Monteleone, William; Dermentzis, Georgios; Siegele, Dietmar; Speer, Christoph; Compact Decentral Façade-Integrated Air-to-Air Heat Pumps for Serial Renovation of Multi-Apartment Buildings; Energies 15 (13), 4679

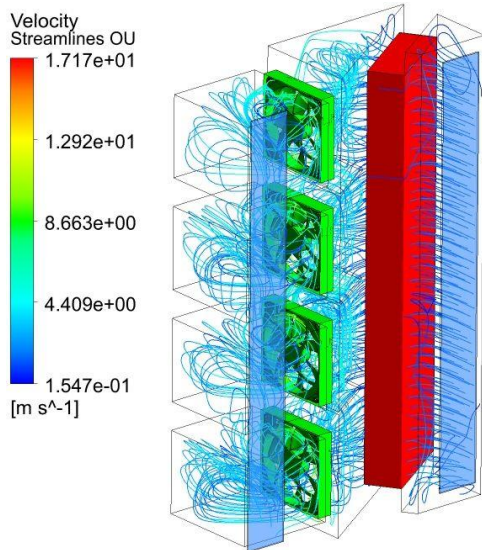
Prototype of indoor unit



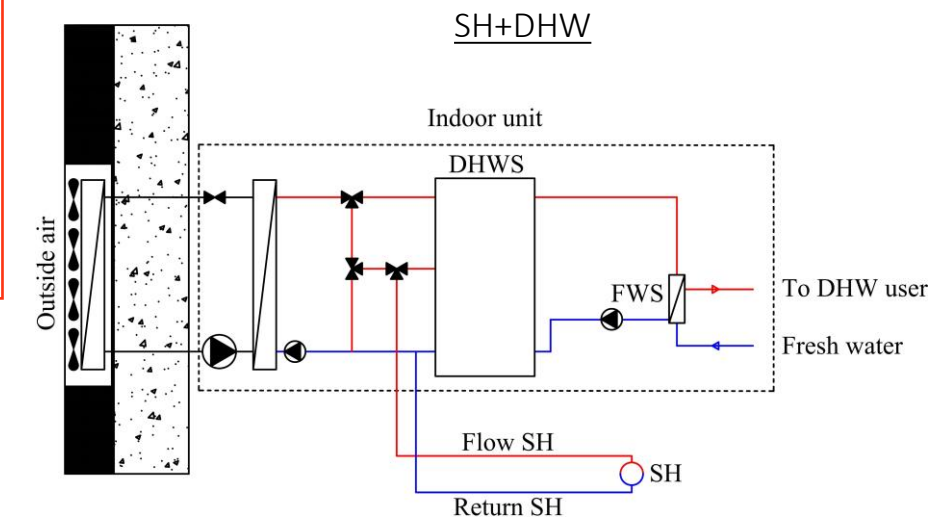
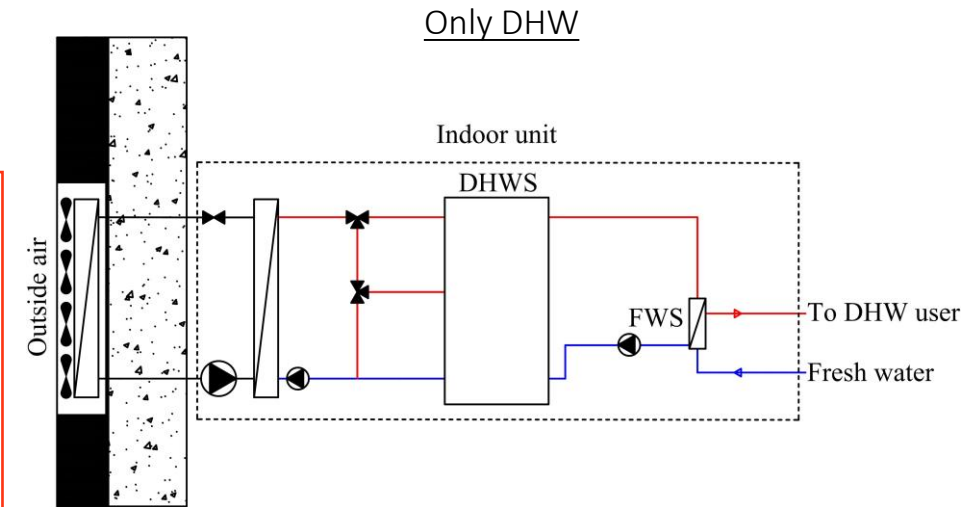
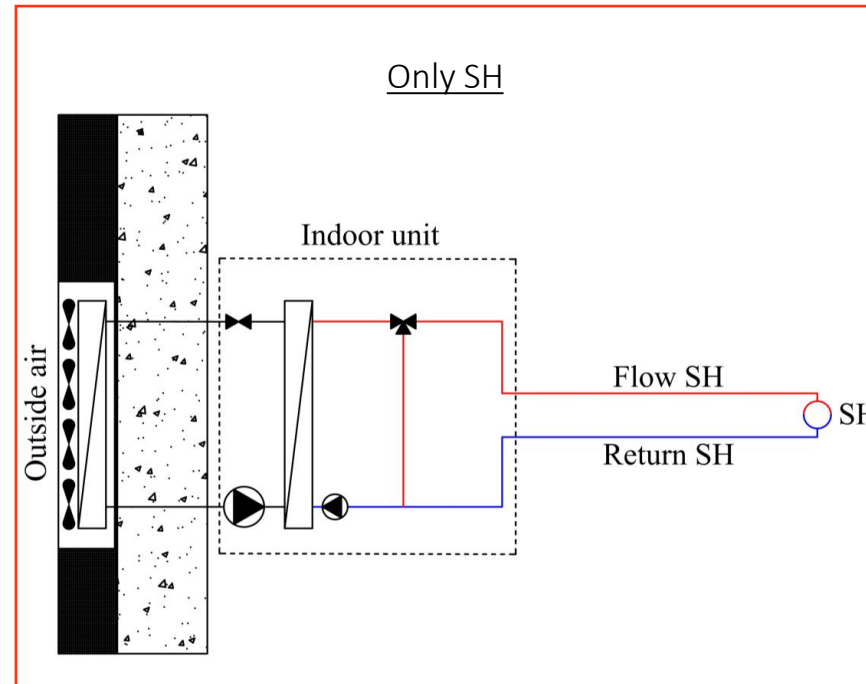
Monteleone, W.; Ochs, F.; Drexel, C.; Rothbacher, M.; Modular split-type heat pump with compact and silent façade-integrated outdoor unit, REHVA Cold Climate HVAC and Energy Conference 2021 Tallinn, E3S Web of Conferences 246, 06008

# Modular, compact and silent split heat pump concept

Common outdoor unit design



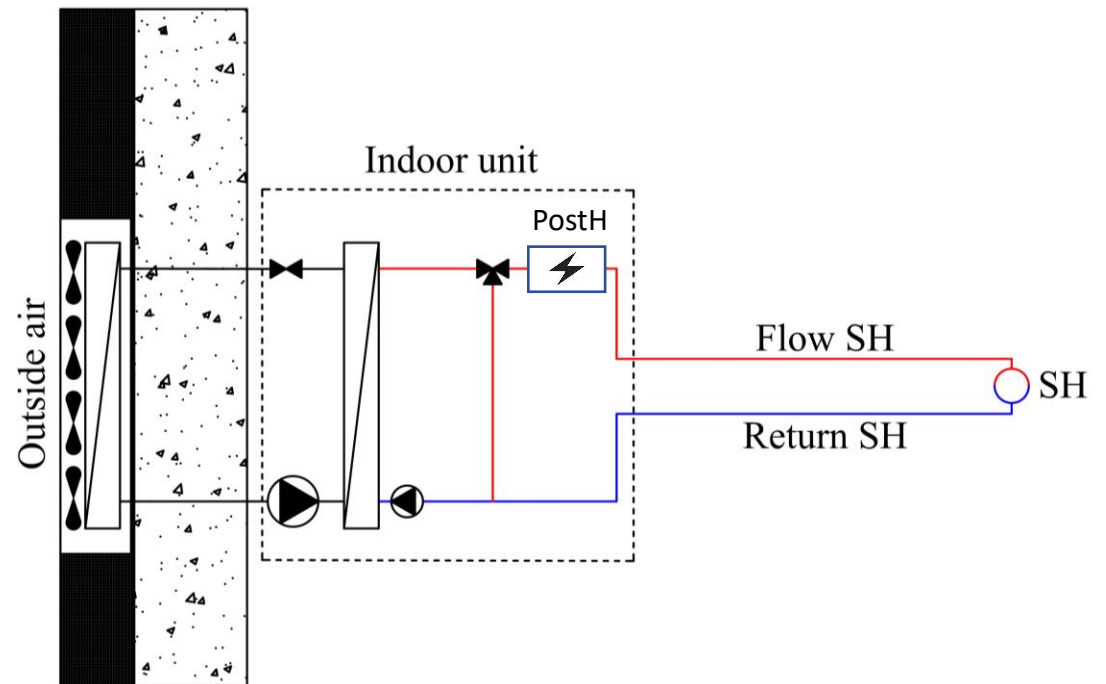
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# Modular, compact and silent split heat pump concept

- Propane (R290) mini-split air-to-water HP
- 1 kW (electric) centralised post-heater
- Post-heater (PostH) is activated only if the measured temperature in the room is 1 K lower than the setpoint;
- Performance factor (PF) defined as:

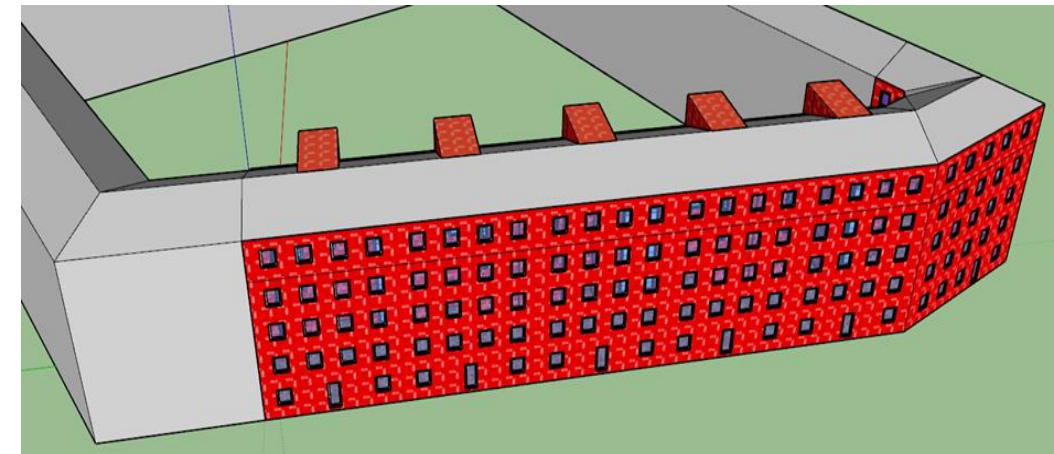
$$PF_{HP+PostH} = \frac{Q_{HP,th}}{Q_{HP,el} + Q_{PostH,el}}$$



## Demo-case: Rechenwegblock (existing)

- Multi-family house
- Innsbruck (AT)
- Year: 1939
  
- Mostly: small-size apartments (37 - 49 m<sup>2</sup>)
  
- Treated floor area: 2807 m<sup>2</sup>
- Space heating demand: 115 kWh/(m<sup>2</sup>a)
- Space heat load: 62 W/m<sup>2</sup>

according to PHPP (Passive House Planning Package)



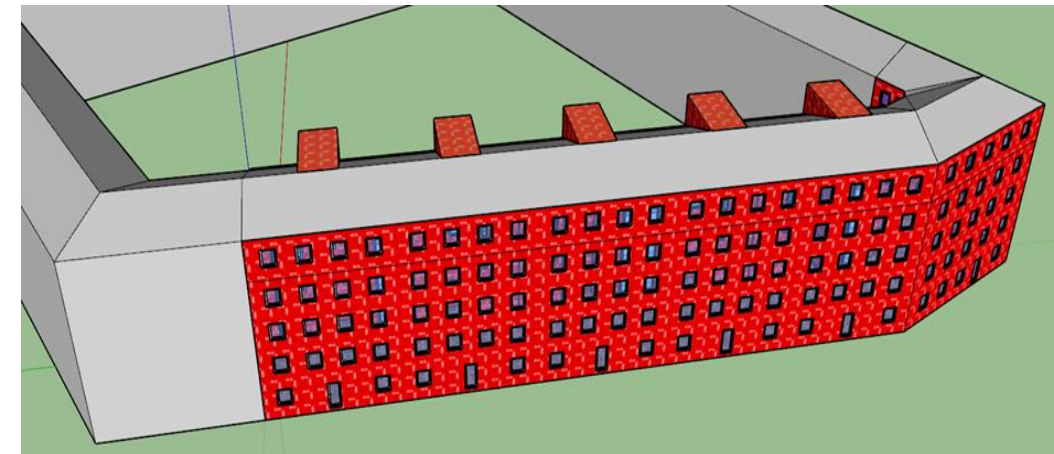


# Rechenwegblock: existing and renovated



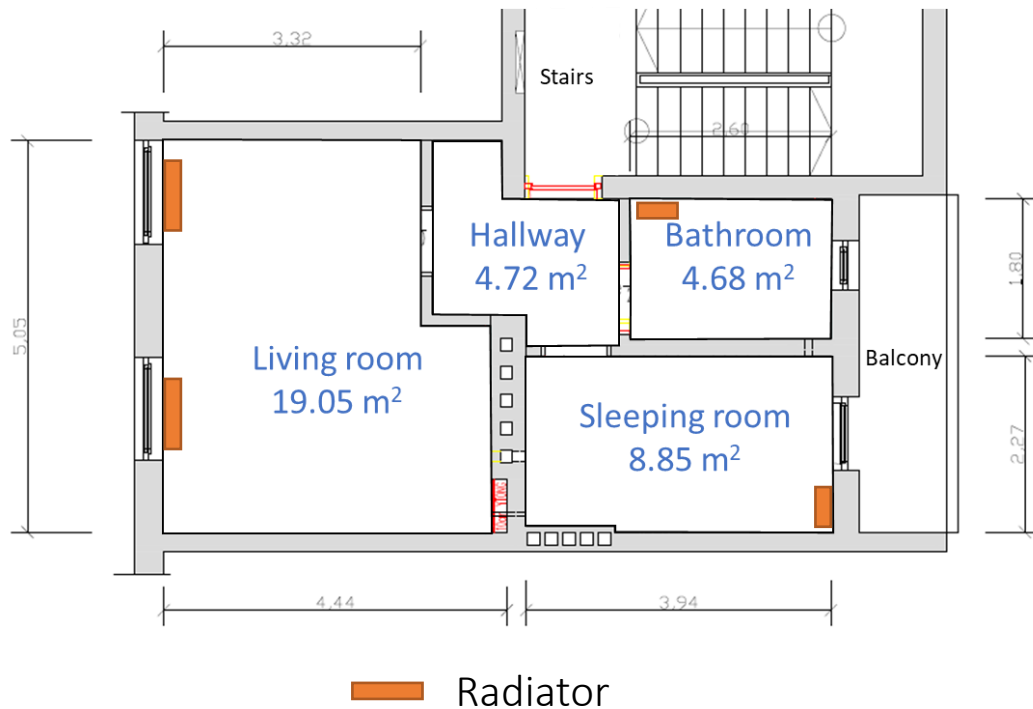
- Thermal envelope:
  - Insulation in external walls, roof, basement roof
  - New windows
- Mechanical ventilation with heat recovery

	Existing	Partial renovation	EnerPHit renovation
Average U-value [W/(m <sup>2</sup> K)]	0.812	0.362	0.272
Efficiency MVHR	-	-	75%
Heating Demand [kWh/(m <sup>2</sup> a)]	115	56	25
Heat Load [W/m <sup>2</sup> ]	62	33	21



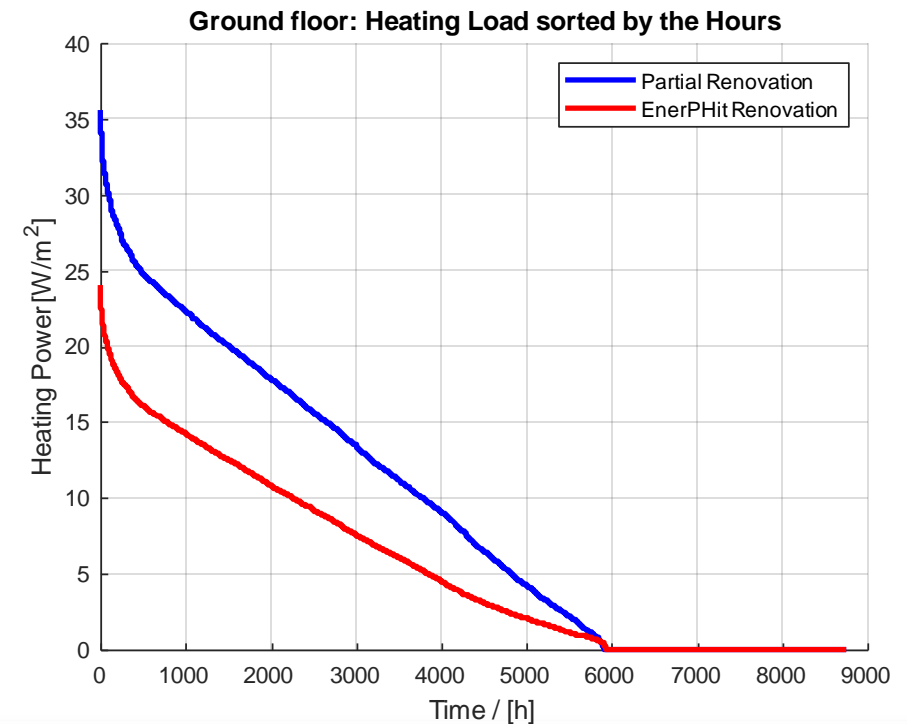
# Studio apartment

- Floor area: 37.3 m<sup>2</sup>



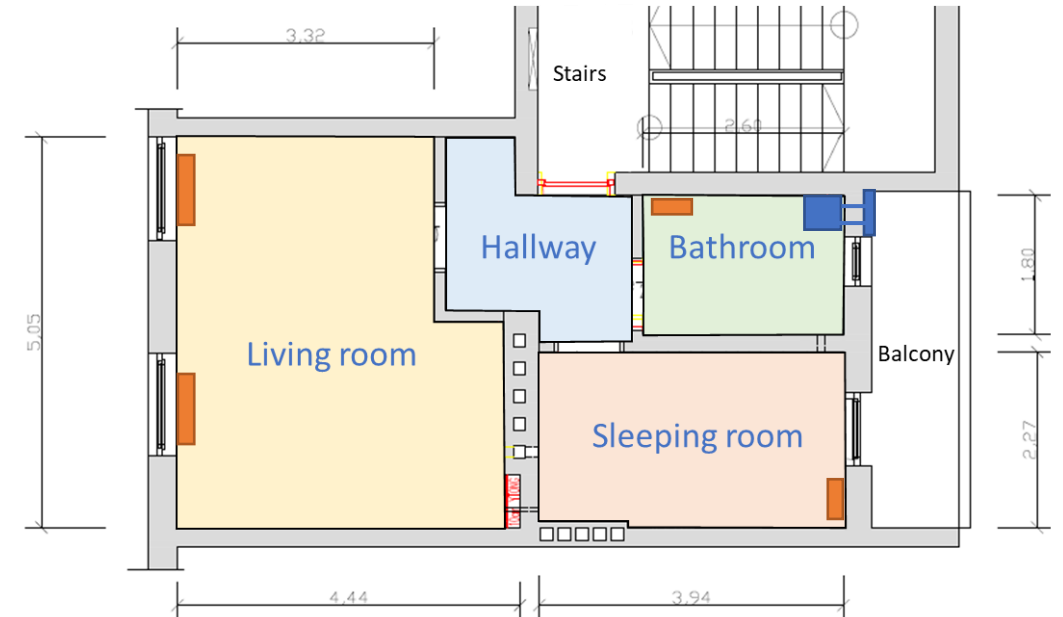
## Space Heating Demand [kWh/(m<sup>2</sup>a)]

	Partial renovation	EnerPHit renovation
Ground Floor	81	49
2 <sup>nd</sup> Floor	58	27
4 <sup>th</sup> Floor	80	48



# Multizone dynamic simulations

- Simulink, CARNOT + CarnotUIBK
- Setpoint temperature during heating season: 22.5°C
- Control on the living room temperature
- Implementation of a heating curve based on the outdoor air temperature
- Summer: night ventilation and shadings



## Envelope + MVHR

		Partial renovation	EnerPHit renovation
Radiators	New (T↓)	Technically challenging	Technically feasible
	Existing (T↑)	Technically critical	Technically challenging

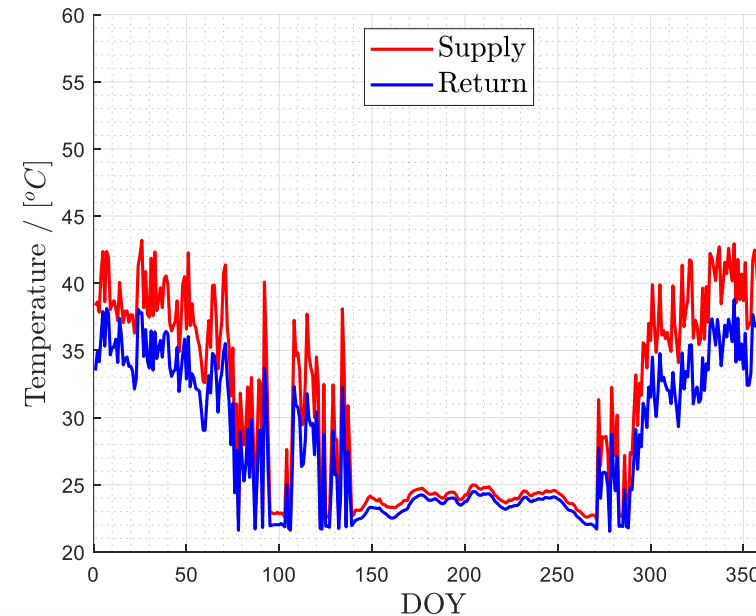
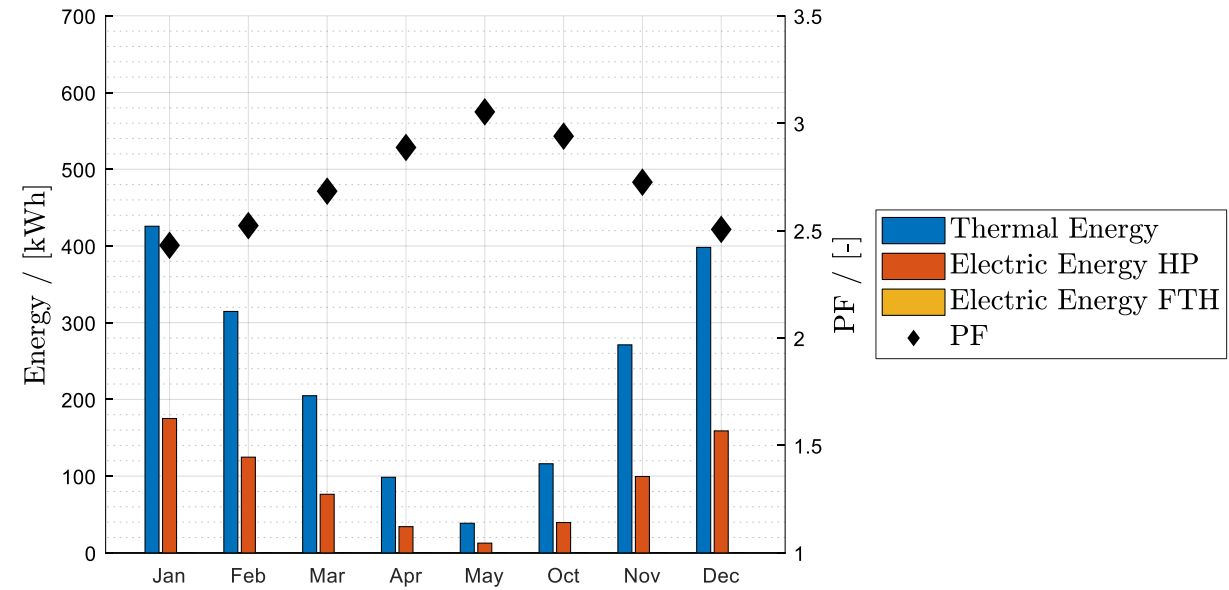
# Results (Ground Floor)

Average temperature in heating season [°C]

	Partial renovation + Existing radiators	EnerPHit renovation + New radiators
Living Room	22.5	22.6
Bathroom	22.4	22.2
Sleeping Room	21.5	22.3

Performance factor in the heating season (HP + PostH) [-]

	Partial renovation + Existing radiators	EnerPHit renovation + New radiators
Average	2.21	2.76
Min - Max	1.47 - 2.65	2.43 - 3.10



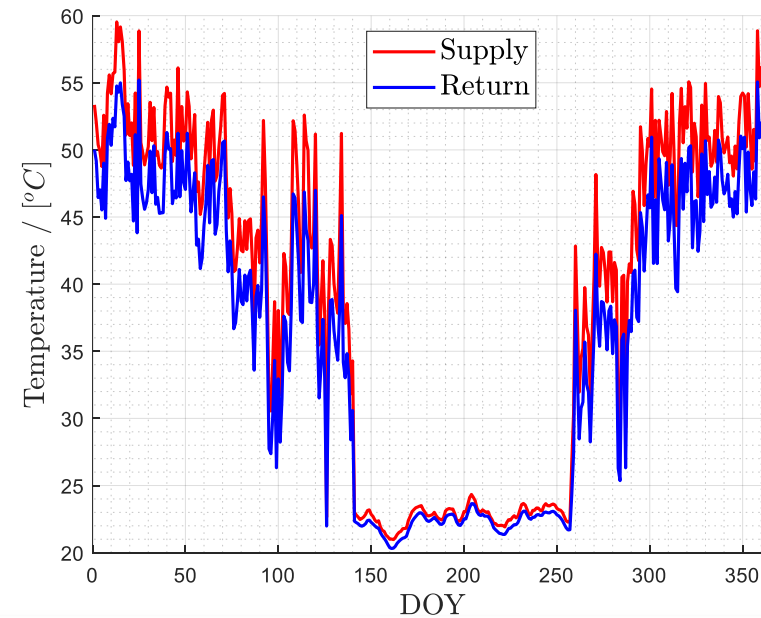
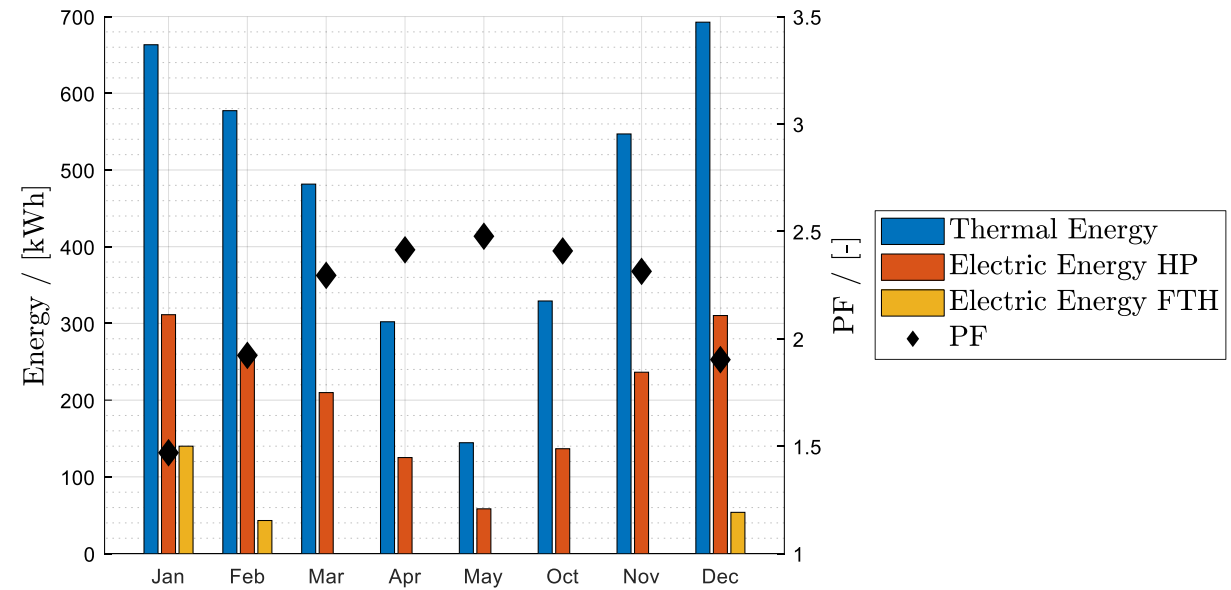
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# Results (Ground Floor)

## Electricity consumption (PostH %) [kWh<sub>el</sub>]

		Partial renovation	EnerPHit renovation
Radiators	New (T↓)	1855 (12%)	722 (0%)
	Existing (T↑)	1918 (12%)	960 (0%)

## Conclusions & Outlook

- » Decentral small-scale facade-integrated heat pumps can be a viable solution for the space heating in renovated flats even if not necessarily coupled with a floor heating system;
- » Compactness and reduced sound emissions need to be assured by means of an integrated design development;
- » For a small renovated flat (37 m<sup>2</sup>) and EnerPHit renovation quality the mini-split HP (with a design thermal capacity of 1.5 kW) is able to supply the SH demand;
- » It is technically possible to supply the SH demand with the split HP (with post-heater) in a partially renovated flat with old radiators, but not efficient enough;
- » Through monitoring, the performance of the split heat pump will be evaluated in a real demonstration case;
- » Further analysis will include the possibility of supplying the SH demand with convectors and investigate cooling operation for warmer climates.

# Acknowledgements

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