EuroPHit

# D5.1.13_low invasive apartment refurbishment with radiator ventilators

*Source: Myhren 2011*

**INTELLIGENT ENERGY – EUROPE II**

Energy efficiency and renewable energy in buildings

IEE/12/070

**EuroPHit**

[Improving the energy performance of step-by-step refurbishment and integration of renewable energies]

Contract N°: SI2.645928

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## Technical References

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# 1 Ventilation radiators combined with heat pump system

- Placement: ventilation radiators on facade, connected to existing heating system, centralised heat pump on roof or in basement
- Type of building: Residential large
- Climatic conditions: Cold, warm

## 1.1 Description

A decentralised ventilation system with local supply air units (ventilator radiators) replacing radiators on outside wall, heating the incoming air via existing hydraulic system. The existing ventilation installation from bath and kitchen is used to extract air to the roof where heat is recovered by a heat pump (HP). Air and/or solar panel based HP solution for hot water should be included in the concept. Renewable energy sources on roof can be used to generate the necessary energy for ventilators and partly for the heat pump. The system should take into account the overall efficiency for heating and hot water for large residential buildings. The efficiency loss for ventilation heat recovery needs to be compensated for by increased hot water efficiency.

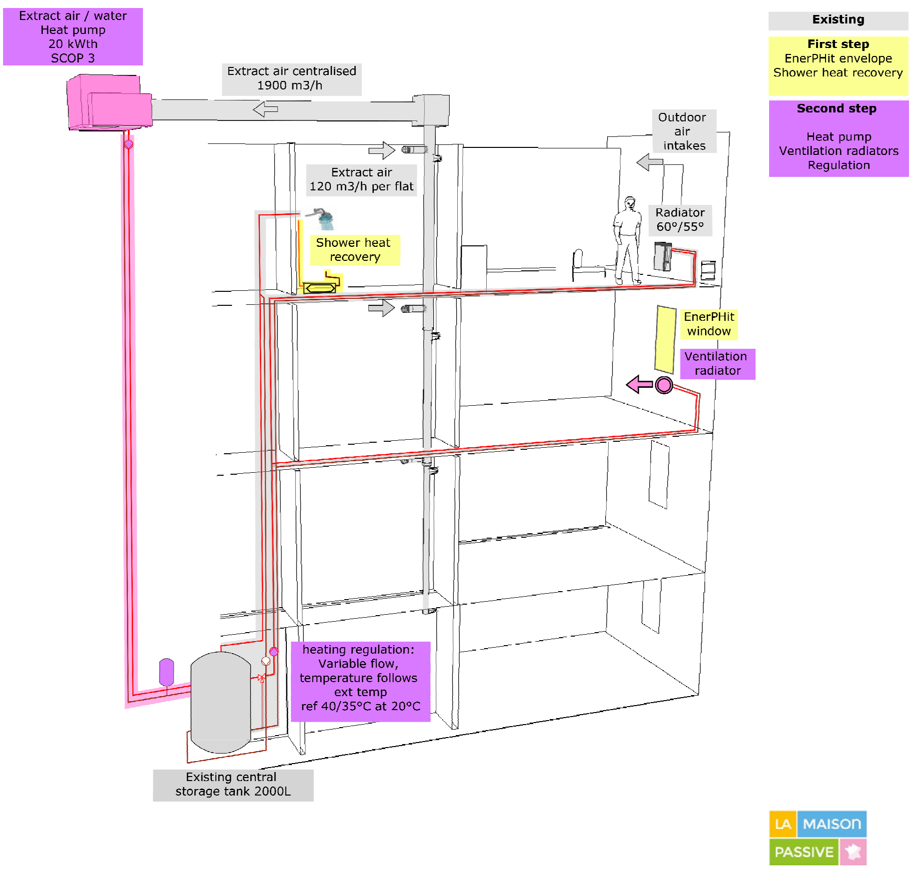


**Figure 1: System integration in a 4 storey apartment building, step by step retrofit**

Figure 2: Schematic diagram of a ventilation radiator
(Source: Myhren 2011)

## 1.2 Suitability for step-by-step retrofits

This solution aims at residential buildings for which:

- A centralised extract ventilation system is in place and functioning
- A centralised generation system provides heating and DHW, distributes heating by a hydraulic system
- Implementation of ventilation with heat recovery (either centralised or decentralised) is complex and costly

Approach for step by step retrofits using this solution:

- Step 1: improvement of thermal envelope to EnerPHit levels (partial or on all opaque components), measures to insure sufficient air quality with existing ventilation system.
- Step 2: If existing windows integrated fresh air inlets, installation of new airtight EnerPHit windows will be coupled with replacement of existing hydraulic radiators by ventilation radiators. If not, ventilation radiators can be installed when the heating system reaches the end of its service life time.

This solution uses as much as possible the residual value of existing ventilation and heating systems, and combines ventilation and heating into a semi-centralised system. It should therefore offer an attractive investment cost for apartment buildings.

## 1.3 Innovative content

Existing heat pump solutions (for new build and retrofit) do not offer the same services as the solution developed in this brief, for instance:

- Renson's E+ combined heat pump (heating&DHW) on extract air is meant to be an auxiliary individual generator to a central heating system. Fresh air intakes are not ventilation radiators but nozzles integrating accumulators placed in window frames. (http://www.renson.be/fr/documentation-systeme-e+.html)

- France Air's Soraya is a centralised heat pump on extract air that produces DHW only and is combined with a central boiler. (http://www.france-air.com/)

## 1.4 Demands

- Air exchange : 30m3/person, air intake regulated manually or by air quality sensors, balance with centralised extraction
- Efficient ventilators <0,20 Wh/m3 for ventilation radiators
- Efficient filtering of outdoor air F7
- Annual Coefficient of Performance of combined Heat Pump > 3 for heating and DHW
- Thermal bridge free installation
- Airtight installation, special care when going through wall insulation
- Homogenous air exchange inside
- Frost protection (cold climates)
- Sound protection: max. 35db in technical room and 25db in living areas
- Frsi25> 0,7 (building physics criteria)

## 1.5 Advantages

- Good step by step functionality - stepwise upgrade
- Use of existing heating system
- Possible to use same system for active/passive cooling
- Central extract air to water heat pump installation
- Decentralized/centralized solution with minimized ducting
- RES integration easily possible on roof
- Possibility to combine with heat pipe system
- Thermal comfort: combination of convective and radiant heating for homogeneous temperatures

## 1.6 Risks

- Thermal loss in distribution, especially cold return flow
- Noise from ventilators
- Costs for filter replacement (high if many filters per dwelling unit)
- Costs for heat pump maintenance (connection to existing hydraulic distribution)
- Balanced air flow
- Low efficiency
- Higher heating demand than solutions with passive heat recovery

## 1.7 New products

- Ventilation radiator
- Roof top integrated HP/solar/PV solution

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# 2 Application to a typical apartment building

This section aims at quantifying costs and gains of the solution. Numbers come from PHPP9 simulations in a cool-temperate climate (degree hours 71 kKh/a).

## 2.1 Reference scenario: ventilation with heat recovery

An apartment building of 16 flats climate gets its envelope refurbished and ventilation upgraded with an average heat recovery rate of 80%. The heating demand after retrofit is 15 kWh/(m².a) thanks to efficient components and favourable form heat loss factor.

A combined heat pump delivers heating at low temperatures (40°C) as well as domestic hot water, with outdoor air as cold source, at 20 kW thermal output.

Considering 2000 m3/h nominal ventilation airflow, and 25 L60°C/Person.day, the final energy consumption for heating, DHW, ventilation and auxiliary is 15 kWh/(m².a), at an annual performance factor of heat pump of 2.5.

**Table 1. Total amount of investment and maintenance costs for reference scenario:**

| Measure | Investment Cost<br><br>[k€/dwelling] | Maintenance Cost<br><br>[k€/dwelling], 20 years |
|---|---|---|
| Envelope | 24 | |
| Ventilation | 7 | 0.85 (filters, regulation) |
| Heating&DHW | 7 | 1.7 (hydraulic maintenance) |
| Total | 38 | 2.55 |

## 2.2 Alternative solution with ventilation radiators

Now considering a heat pump on extract air feeding ventilation radiators through existing hydraulic distribution, the heating demand of the building is 21 kWh/(m².a) (no passive heat recovery on exhaust air). The heating demand uptake is low because:

- envelope is airtight, n50 = 1 h-1
- infiltration air change rate is lower when building is in depression compared to balanced flows
- cool-temperate climate (71 kKh/a).

Heat recovery on drain hot water brings the heat demand for DHW down to 16 kWh/(m².a) (specific hot water consumption of 17 L60°C/Person.day).

The heat pump, 20 kW thermal installed capacity, works at higher COP due to higher temperature source (extract air: 17-25°C), enabling an annual performance factor of 3 for heating and DHW.

The final energy consumption for heating, DHW, ventilation and auxiliary is 12.3 kWh/(m².a), due to heat recovery on DHW and higher efficiency of the heat pump

The estimated costs for are:

- 0.7 k€ per ventilation radiator, including installation. 3 ventilation radiators needed per flat.
- 7 k€/dwelling for the heat pump on extract air, including connection to existing heating system
- 1 k€/dwelling for heat exchanger installation of grey hot water, recovered heat sent to tap

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**Table 2. Estimated investment and maintenance costs**

| Measure | Investment Cost<br><br>[k€/dwelling] | Maintenance Cost<br><br>[k€/dwelling], 20 years |
|---|---|---|
| Envelope | 24 | |
| Ventilation | 2.1 (ventilation radiators) | 1.2 (filters, regulation) |
| Heating&DHW | 8 | 2 (hydraulic maintenance) |
| Total | 34.1 | 3.2 |

The alternative solution can present a lower total cost, if price of ventilation radiators+separate windows is lower than price of windows integrating heat recovery. Maintenance costs will increase if outdoor air filters are not grouped.

### 2.2.1 Regulation

For an efficient heat emission, the forward temperature for heating distribution could be varying in function of outdoor and representative core indoor temperature.

### 2.2.2 Integration of Renewable Energy Sources

A solar thermal unit on the roof could provide a base for heating and DHW, if connections to storage tank are feasible (see energy diagram below). A high/low schedule for the thermal output of the heat pump could be implemented to maximize solar fraction:

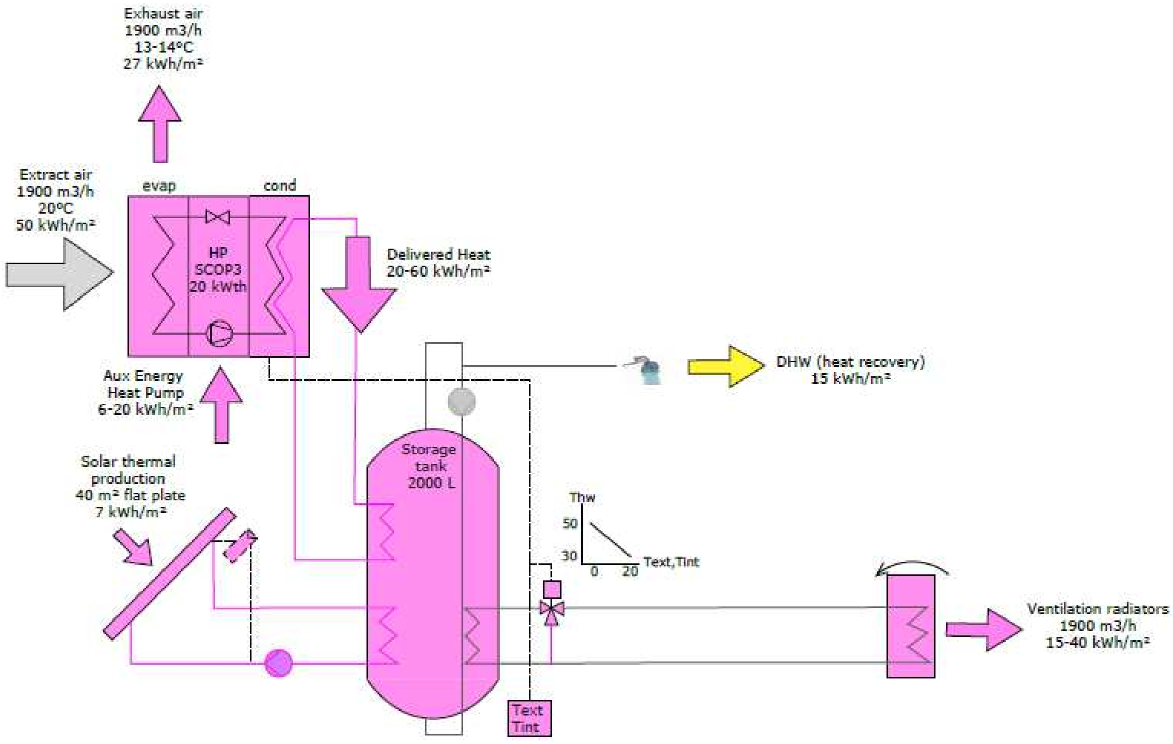


**Figure 3: Energy diagram of solution integrating solar thermal panels**

A schedule regulating the heat pump thermal output could improve the overall system efficiency, for instance a simple dual schedule:

- high thermal output: 0h-4h to prepare DHW consumption in the morning, and 11h-15h to combine heat from heat pump and solar thermal
- low thermal output: rest of the day, sufficient output to cover heating load

## 2.3 Possible system layout

If the technical room hosting storage tanks is in the cellar, the primary loop connecting the heat pump to storage should pass through existing vertical service shafts if any.

Another approach is to connect the heat pump directly to the circulation hot water loop, which requires a careful upgrade of existing pumps and study of additional expansion tank. This might reduce the investment for heat pump connection.

The installed heating capacity of the ventilation radiators is 500 W/radiator, 1500 W/dwelling.

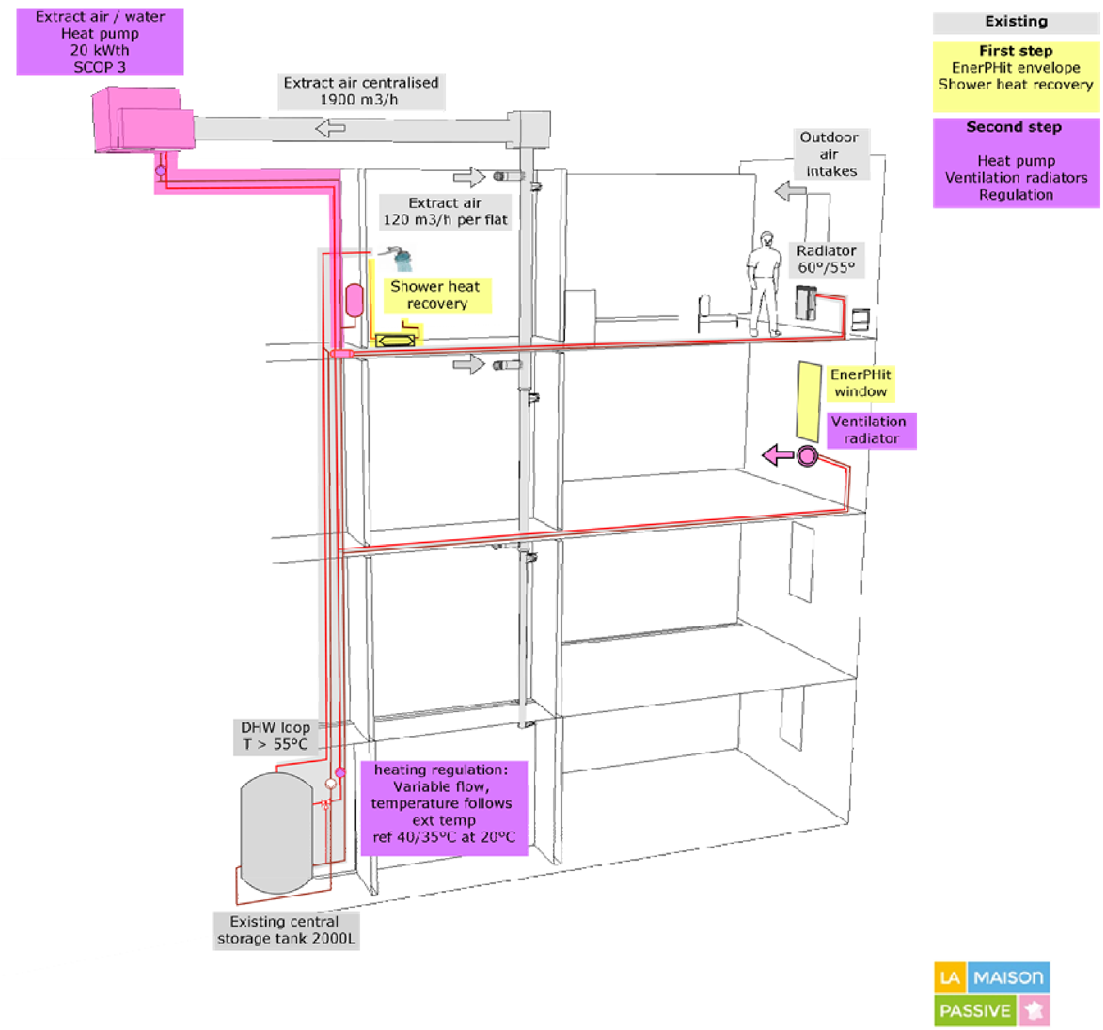


**Figure 4: Connection of heat pump to existing circulation hot water loop**

# 3 Conclusion

A heat pump on extract air feeding ventilation radiators can be a cost-effective solution for low invasive retrofits.

Ventilation radiators offer promising comfort properties, as they mix convective and radiant heating and have a quick response. Main challenges are to provide suitable ventilation and heating regulation at affordable cost, and group filtering in order to reduce maintenance cost.

Heat Pump on exhaust air present high COP, so that the lower energy efficiency is compensated in the final energy balance. Gas absorber heat pumps could be attractive as a replacement of existing gas boilers as switching from gas to electricity can be costly.

This solution is based on higher heating demand levels than usual EnerPHit solutions, so it should be implemented preferably in cold-temperate or temperate climates.

# 4 References


- Potential of Ventilation Radiators: Performance assessment by numerical, analytical and experimental investigations, Jonn Are Myhren, KTH, 2011

- Analysis and design of solar based systems for heating and cooling of buildings, Igor Shesho, NTNU, 2014

- Plaquette Commerciale France Air Soraya, 2014


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# 5 Annex: transient simulation on an apartment building

This simulation aims at studying parameters for winter comfort with ventilation radiators of an heating capacity of 20W/m² max, and capability of a centralized heat pump assisted by solar thermal to provide sufficient heat for heating and DHW in winter.

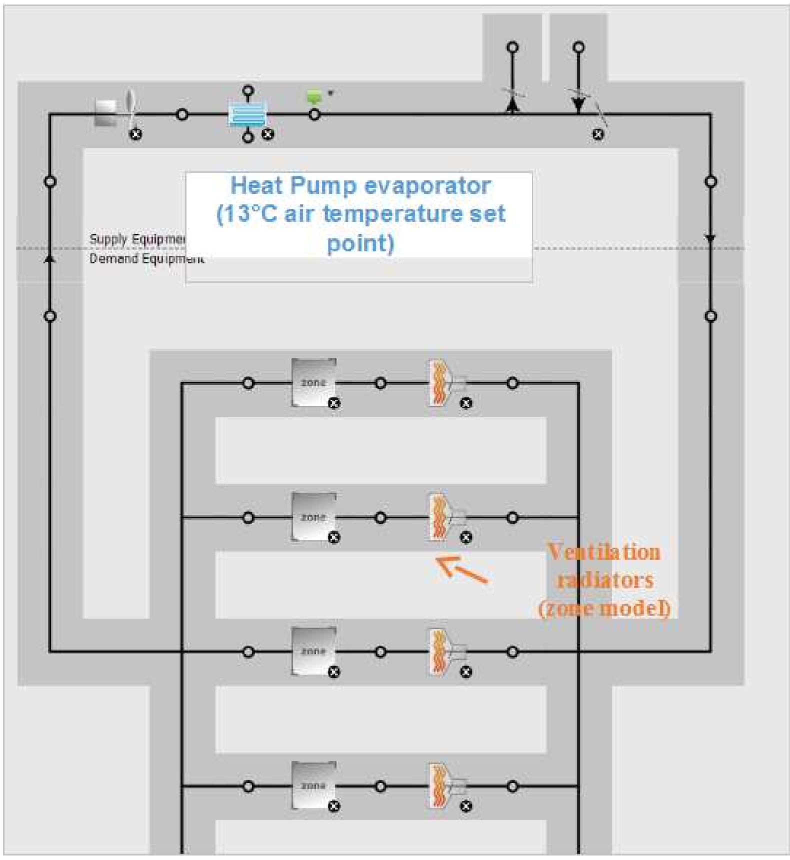
## 5.1 Assumptions

- 4 storey building, 16 flats
- Climate dataset: Paris
- Envelope : retrofit to EnerPHit standard, airtightness improved to average infiltration air change rate of 0.16 h-1
- Ventilation : 1900 m3/h extract
- Gas absorber heat pump on extract air on the roof, 17 kW thermal output, temperature set point for extract air leaving evaporator = 13°C
- Ventilation radiators heating capacity up to 20 W/m² for air change rate of 0.5 h-1
- 2000 L Hot water storage tank in cellar
- 80 m² solar thermal panels, flat plate, horizontal
- Waste water heat recovery per dwelling

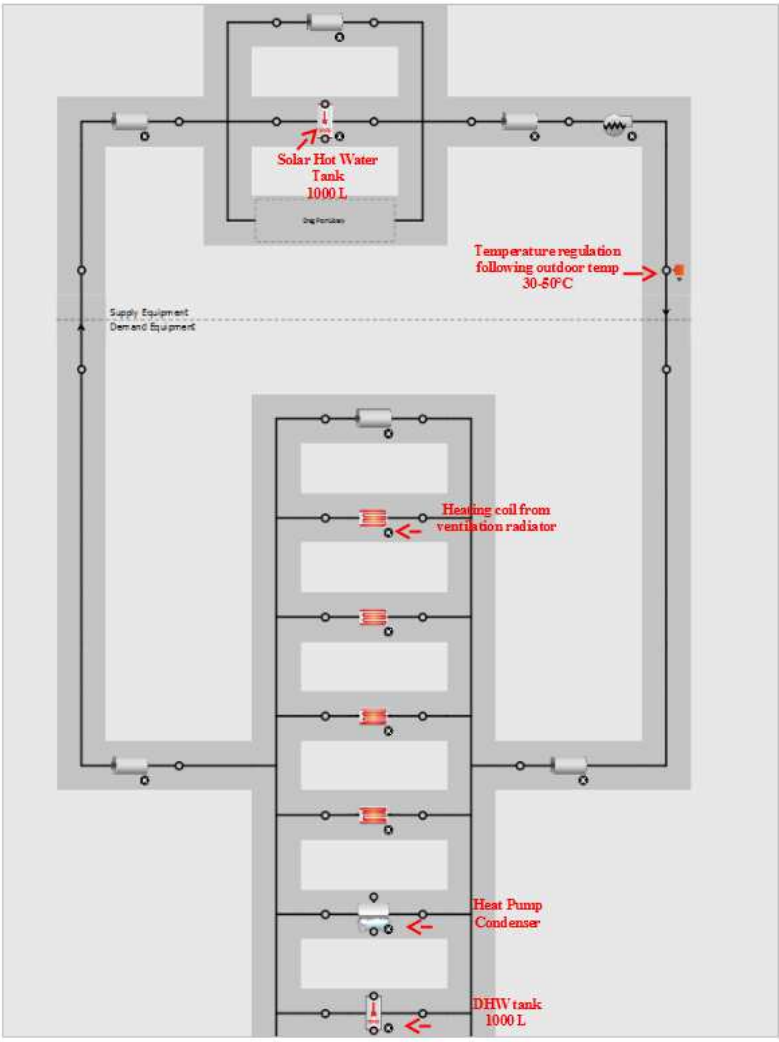
## 5.2 Model

Software used: OpenStudio 1.9 / EnergyPlus 8.3

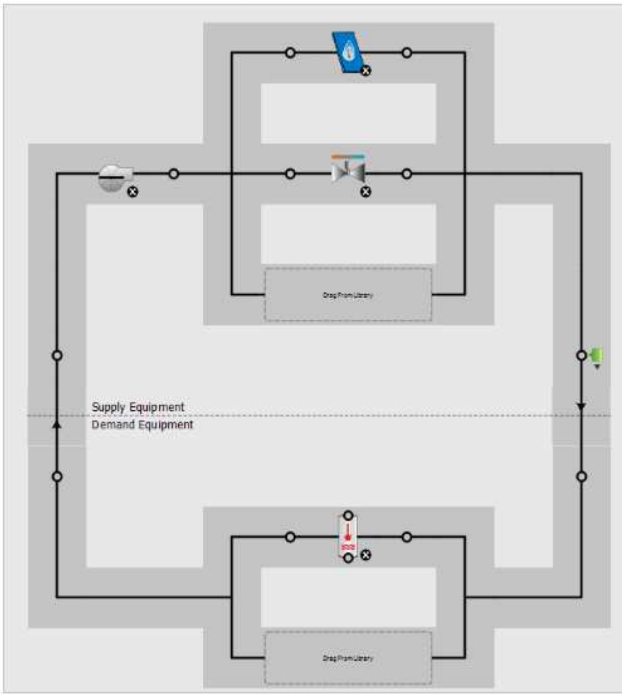
Model for ventilation loop:



Model for hot water loop:

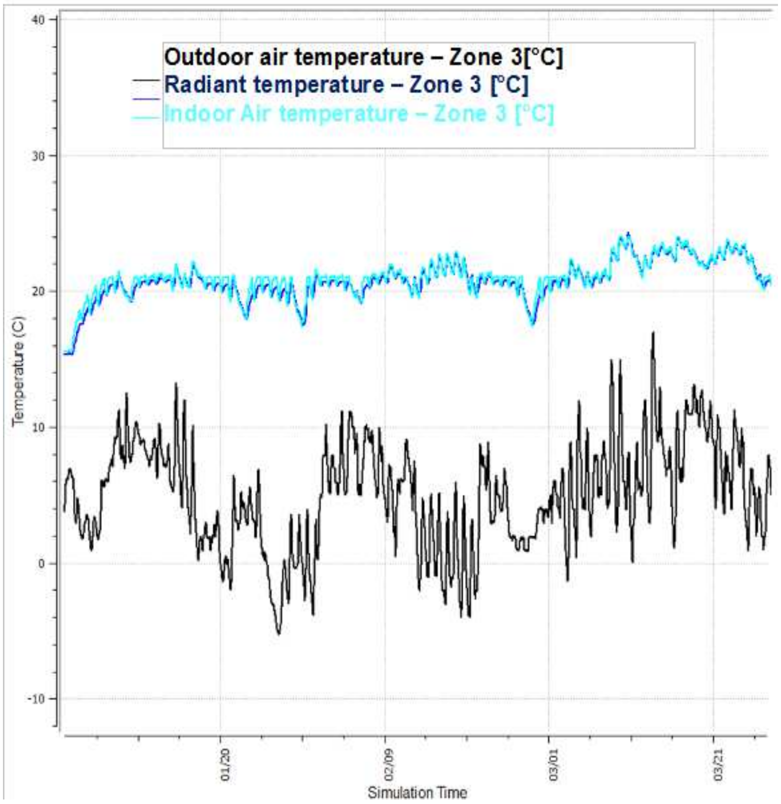


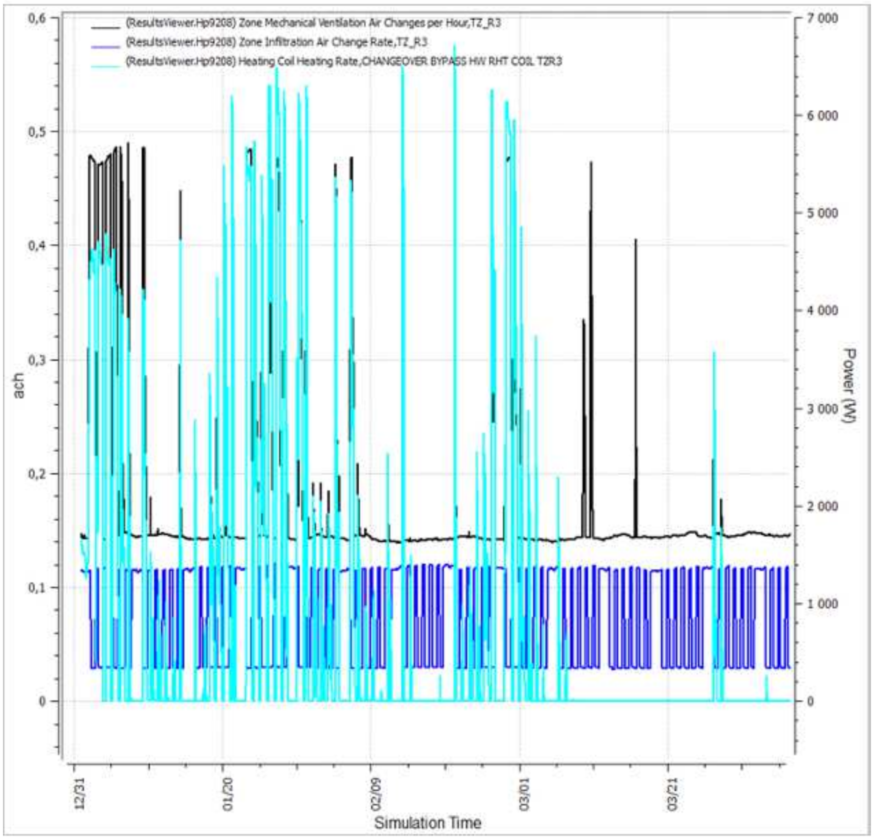

Model for solar water loop:



## 5.3 Results

Ventilation radiators deliver good comfort in flats with operative temperature between 20 and 23°C during the day and 18-20°C during the night (see January temperatures below). Simulations show that airflow regulation is essential to reach good compromise between temperature and air quality. These results are obtained following an occupation schedule for heating operation, a regulation following CO2 sensors could be more resilient.






The absorber heat pump works with a seasonal COP of 1.8 on the period January-March: