MONITORING RESULTS AND OPTIMIZATION OF A FAÇADE INTEGRATED VENTILATION CONCEPT FOR BUILDING RETROFIT

Fabien Coydon, Maxime Duran, Arnulf Dinkel, Sebastian Herkel

Fraunhofer Institute for Solar Energy Systems ISE
Heidenhofstrasse 2
79110 Freiburg, Germany
fabien.coydon@ise.fraunhofer.de

ABSTRACT

An office building of the Fraunhofer Institute for Solar Energy systems (Fraunhofer ISE) in Freiburg was retrofitted in 2012 with an innovative concept based on technology integration in the façade. Prefabricated window modules integrating air inlets and outlets, façade integrated air ducts and a heat and moisture recovery ventilation device were implemented. A long term monitoring was set up including energy, temperature, CO_2 and humidity measurements. The results of this monitoring and an analysis of the system are presented, focussing on the influence of façade integrated air ducts on the energy performance of the whole system and on the thermal comfort.

A specific definition of the global energy efficiency of façade integrated ventilation systems is proposed and used to evaluate the performance of the system.

On the basis of the monitoring results, a simulation model could be defined and used to optimize the integration concept by testing different geometries and materials. The last developments of the integration system are presented such as the next step of this work: the implementation of the system on the façade of a multifamily home in Frankfurt.

KEYWORDS

Central ventilation, Façade integration, Heat recovery, Building retrofit, Energy efficiency

1 INNOVATIVE FAÇADE RETROFIT WITH INTEGRATED AIR DUCTS

1.1 Advantages and risks of façade integration

In order to reach the goals for the reduction of CO2 emissions set by the European Union, the rate of energy retrofit has to be multiplied by 2 or 3. The main difficulties are the costs which are often high because of the multiplicity of tasks to be realized. Walls, roof and floor must be insulated, windows and heating device must be replaced and a ventilation system must be installed. The dwellings are mostly unfit for habitation during a few weeks, a few months or sometimes for the whole duration of the retrofit. In some European countries, the installation of ventilation is mandatory in retrofitted buildings, as for example in Germany where the DIN norm 1946-6 (DIN 2009) imposes since 2009 to install a ventilation system as soon as a third of the windows are replaced.

Integrating the ventilation system in the façade can represent a good solution (Coydon, Dinkel et al. 2013) since it avoids cumbersome air ducts inside the dwellings, simplifies the retrofit work by avoiding core holes and allows to let the tenants inside the dwellings during the work.

The main risk of integrating air ducts into an external wall is the heat loss leading to a reduction of the heat recovery potential which was already investigated by the Fraunhofer IBP for a similar integration concept (Ziegler, Krause et al. 2012). This study presents an analysis of this risk.

1.2 Demonstration building and its retrofit concept

A new façade concept was tested in 2012 for the energy retrofit of an office building belonging to the Fraunhofer ISE (Figure 1):

Figure 1 Retrofitted façade of the demonstration building and retrofit concept

This retrofit concept is based on insulation boards (standard EPS material) in which air ducts can easily be clipped-in. These insulation boards are fixed on the façade after what the air ducts can be installed and covered by a second layer of insulation boards. Thanks to these systems, air ducts are integrated in a structured manner allowing fast and replicable work. This layer allows clipping-in the pipes horizontally or vertically into the prepared channels.

Prefabricated window modules are including roller shutters and air inlets so that the windows openings can be directly used for penetrating into the building and no core hole is necessary.

The panels cover the wall of 6 offices situated on the second floor (see Figure 2). In that case, the air handling unit is placed outside on a separate roof in a container.

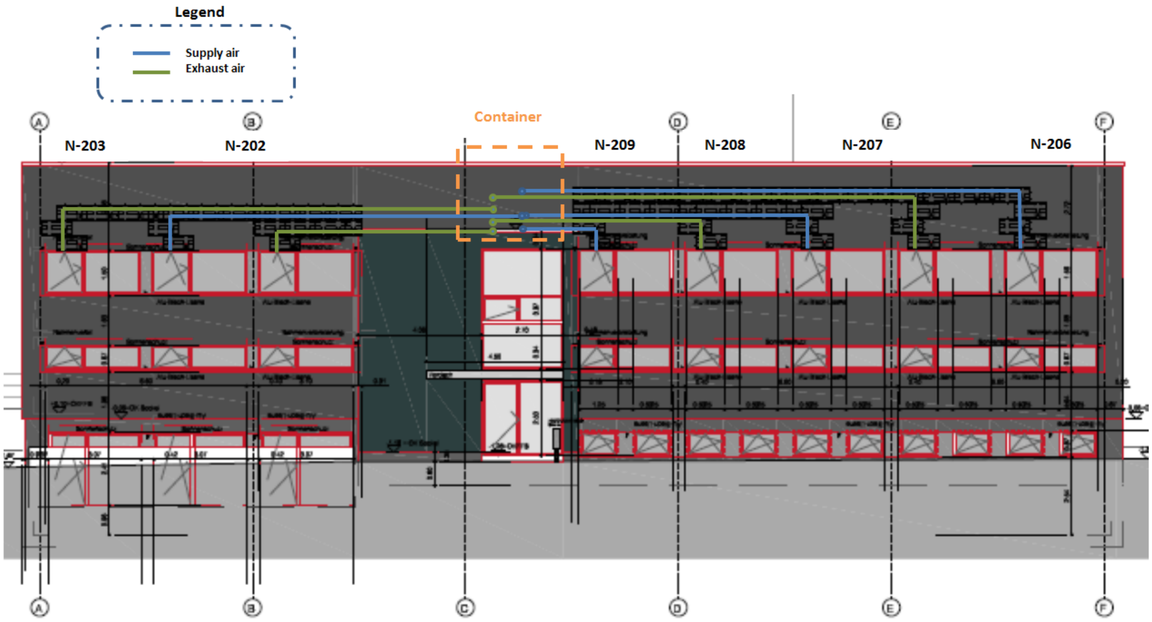

Figure 2 Renovated façade with air ducts paths

2 ANALYSIS OF THE SYSTEM

2.1 Monitoring concept

The measurements include temperature and humidity sensors at each strategic point of the system (inlets and outlets of the ventilation device and of each air duct) but also sensors for airflows and electrical consumptions (Figure 3).

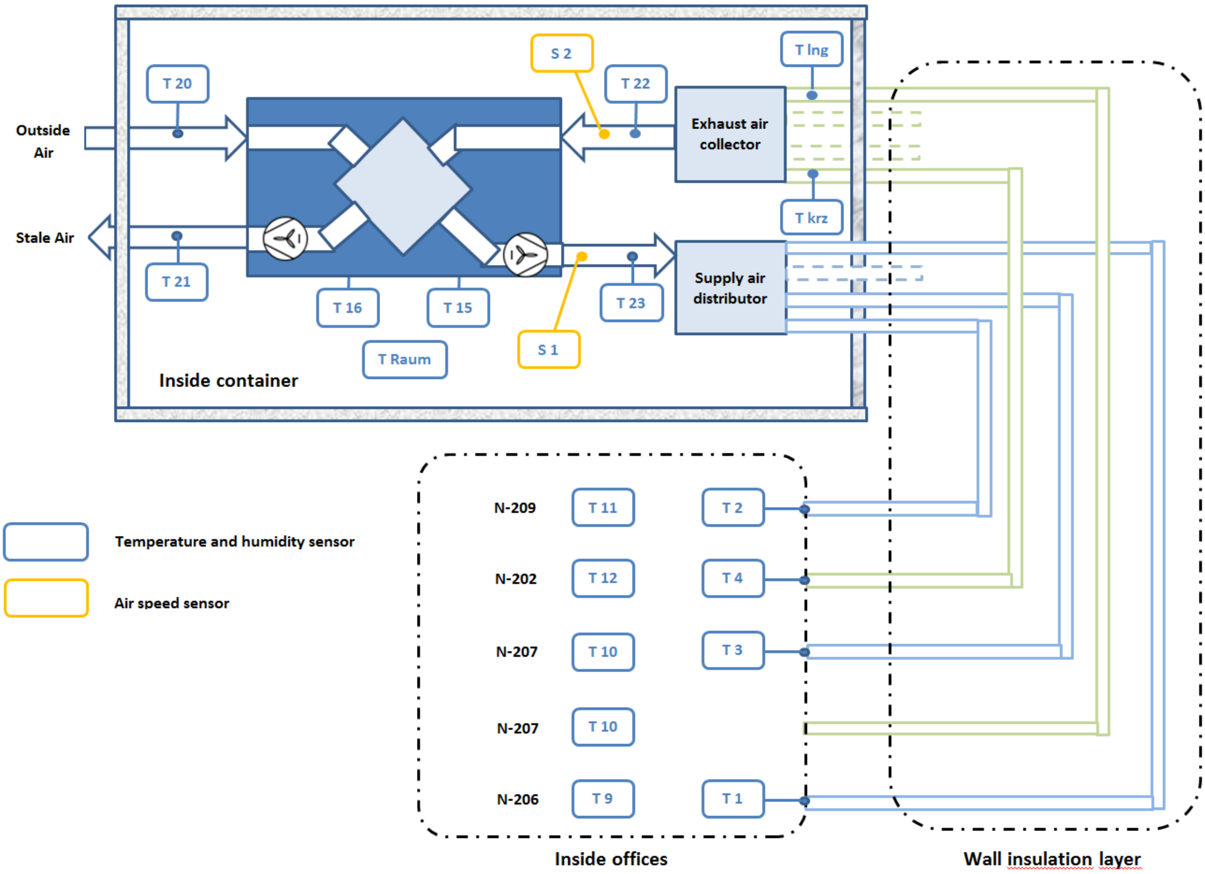

Figure 3 Setup of the monitoring concept

2.2 Energy efficiency of the ventilation system: definitions

The norm DIN EN308 (DIN 1997) defines the heat recovery rate of a ventilation system with a simple ratio of temperature differences. This definition is based on the comparison between a ventilation device and a theoretical reference case which is a ventilation system without heat recovery providing the same airflow. The temperatures taken into account are directly measured at the inlets and outlets of the ventilation device:

$$\eta_{EN308} = \frac{T_{supply-1} - T_{outside}}{T_{exhaust-1} - T_{outside}} \quad (1)$$

In order to describe the energy performance of the system, the electrical power of the fans must be taken into account. For the theoretical reference case, the electrical power is supposed to be equal to zero:

$$\eta_{device} = \frac{\dot{m}.Cp.(T_{supply-1} - T_{outside}) - P_{elec}}{\dot{m}.Cp.\ (T_{exhaust-1} - T_{outside})} \quad (2)$$

The main issue of façade integrated air ducts is their heat losses. Therefore, we used the supply and exhaust temperatures inside the rooms instead of the temperatures at the interface between façade integrated ducts and device:

$$\eta_{with\ ducts} = \frac{\dot{m}.Cp.(T_{supply-2} - T_{outside}) - P_{elec}}{\dot{m}.Cp.\ (T_{exhaust-2} - T_{outside})} \quad (3)$$

In order to respect the heat balance with the new boundaries, we had to take the influence of the air ducts on the building envelope insulation into account:

$$\eta_{with\ wall} = \frac{\dot{m}.Cp.(T_{supply-2} - T_{outside}) - P_{elec} + HL - HL'}{\dot{m}.Cp.\ (T_{exhaust-2} - T_{outside})} \quad (4)$$

With:

HL: Heat Losses through the wall of the reference case

HL': Heat Loss through the wall with façade integrated air ducts

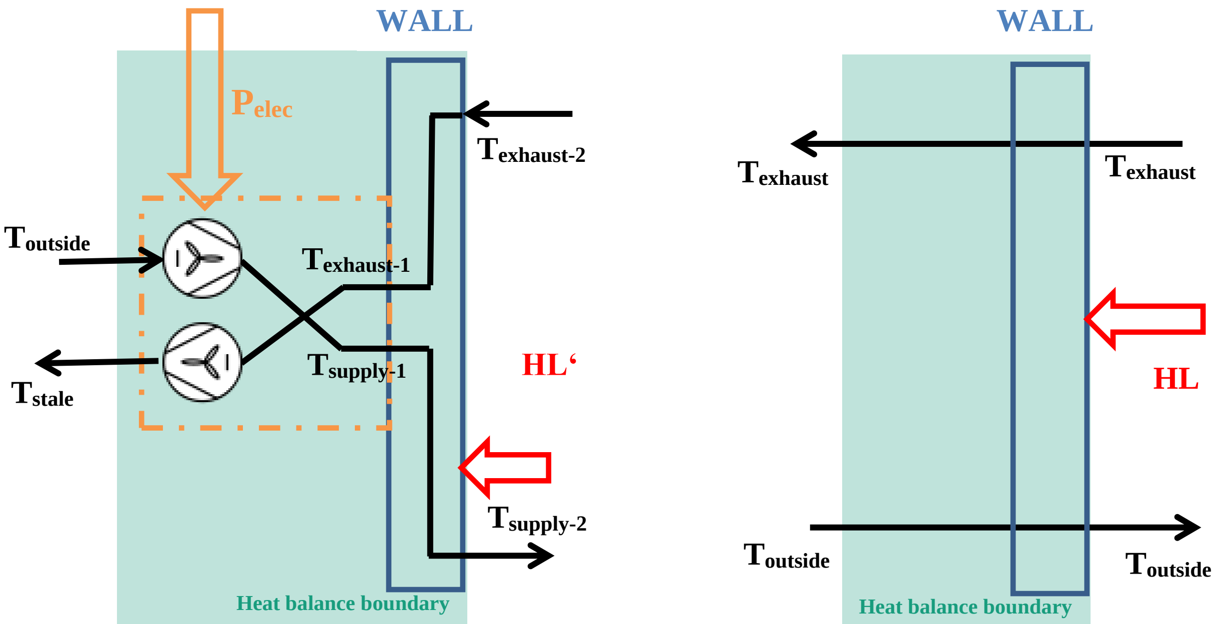

Figure 4 Thermal balances of the analysed system (left) and reference case (right)

2.3 Energy efficiency of the ventilation system: results

In order to distinguish the influence of heat losses of the air ducts and of the external wall, we compared the results obtained by equations (2), (3) and (4) and represented the results on Figure 5.

As the boundary of the heat balance is set on the inner surface of the wall, the presence of air ducts in the façade is reducing the heat losses coming from the inside air. In the relevant domain (T_{ext} < 14°C), the efficiency of the device itself, taking the electrical power into account is around 85 %.

This efficiency is reduced to around 65 % by the heat losses in the air ducts but a part of these heat losses is regained by the reduction of losses through the wall. Thus the global efficiency of the system is around 75 %.

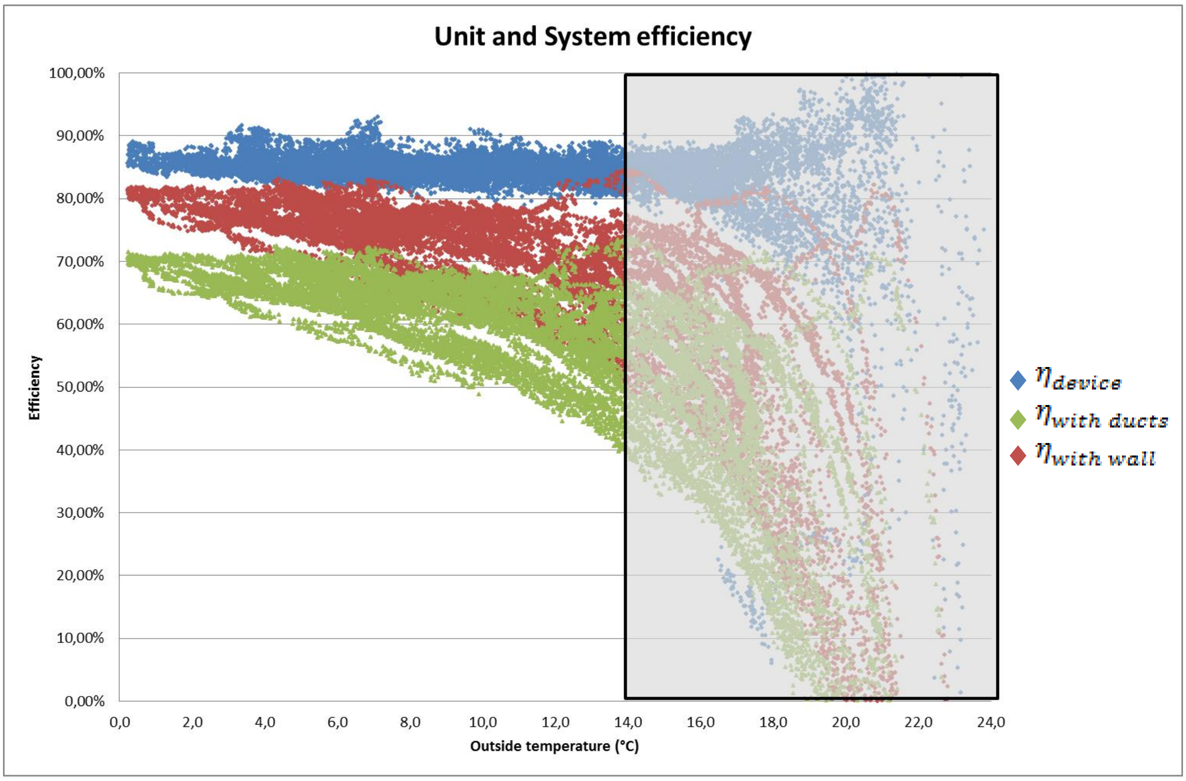

Figure 5 Energy efficiency of the ventilation system according to 3 different definitions

In order to improve this result and reduce the influence of the heat losses in the ducts, a numerical model was developed at the Fraunhofer ISE, so that modifications in the system could be simulated.

3 NUMERICAL MODEL

3.1 Description of the model

The model aims to optimize the panels by calculating the heat losses of the air ducts and through the wall according to several contexts.

The mesh size for the model is 5 mm x 5mm in a vertical section of the wall and around 1 m for the dimension parallel to the air ducts. The model allows a combination of exhaust and supply airs and can only analyse steady states.

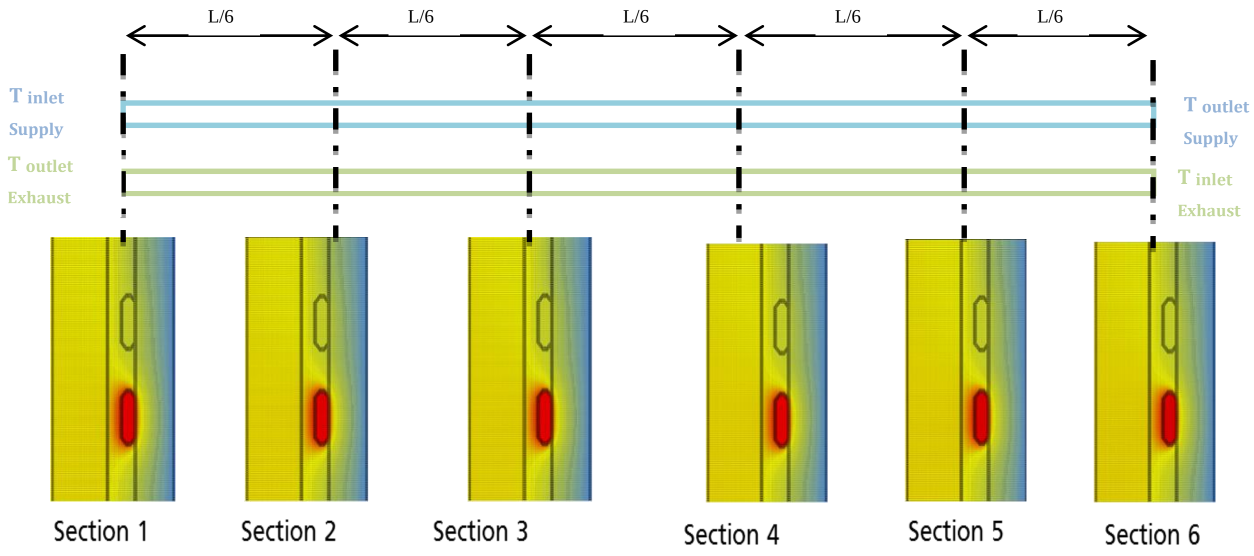

Figure 6 Description of the numerical model

1.1 Validation of the model

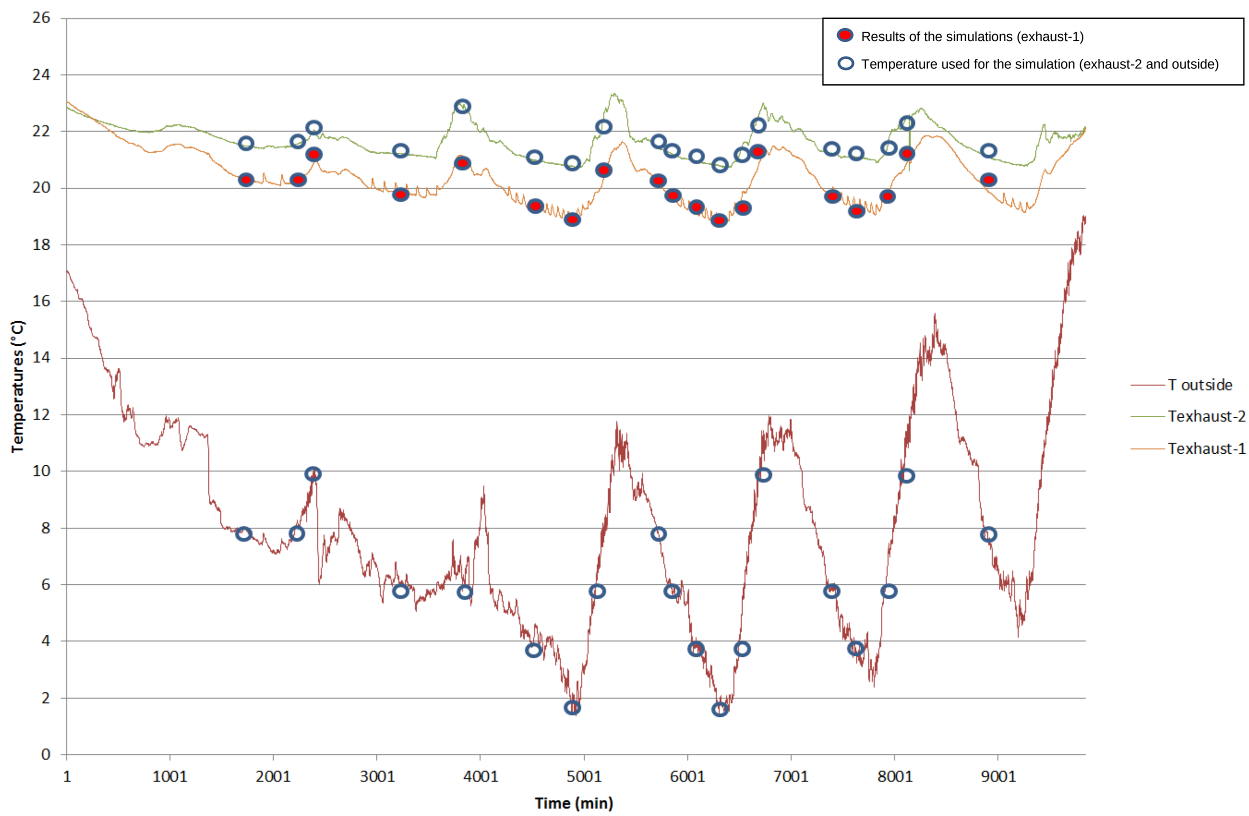

Figure 7 Results difference between the model and measurements

Figure 7 presents the results of the validation tests for the longest exhaust air duct (duct where the heat losses are the highest). Only the heat losses of the air ducts could be validated whereas the model is also calculating the heat losses of the wall but this point seems to be less critical.

The same validation tests were done for the other air ducts and for different airflows and gave all acceptable results.

4 OPTIMISATION OF THE INTEGRATION SYSTEM

4.1 Context of the work

Within a European project (Retrokit) focusing on prefabrication for building retrofit, a demonstration building will be renovated in 2015 in Frankfurt (Germany) with façade integrated HVAC networks. This demonstration building is a multifamily home (20 dwellings) where the external walls will be insulated, the windows and the heating system will be replaced and a new façade integrated ventilation system will be installed.

Figure 8 shows the design phase on one façade of the building with air ducts and heating pipes. Figure 9 shows the foreseen integration concept.

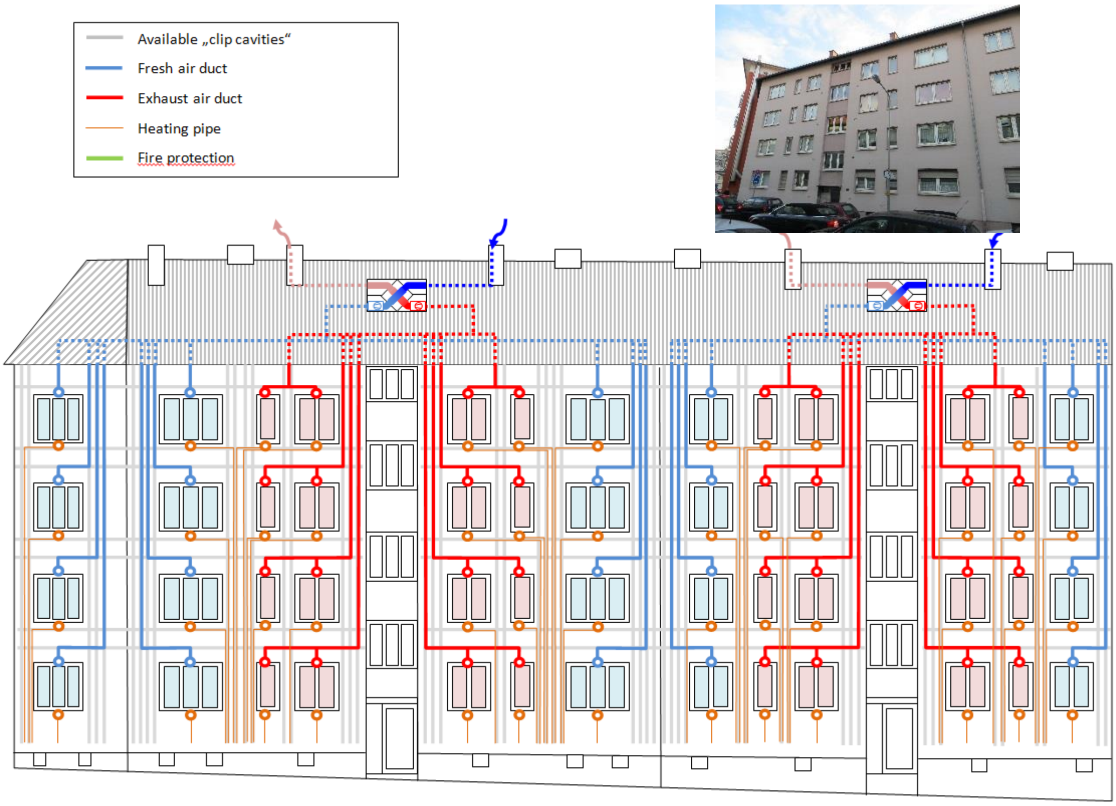

Figure 8 Networks layout on one of the façades

As the new developments are done for a multifamily home, a special focus had to be set on the fire protection. This issue had a strong influence on the choice of the materials:

- the insulation boards will be made of mineral wool,
- the air ducts will be either PVC or Aluminium ducts.

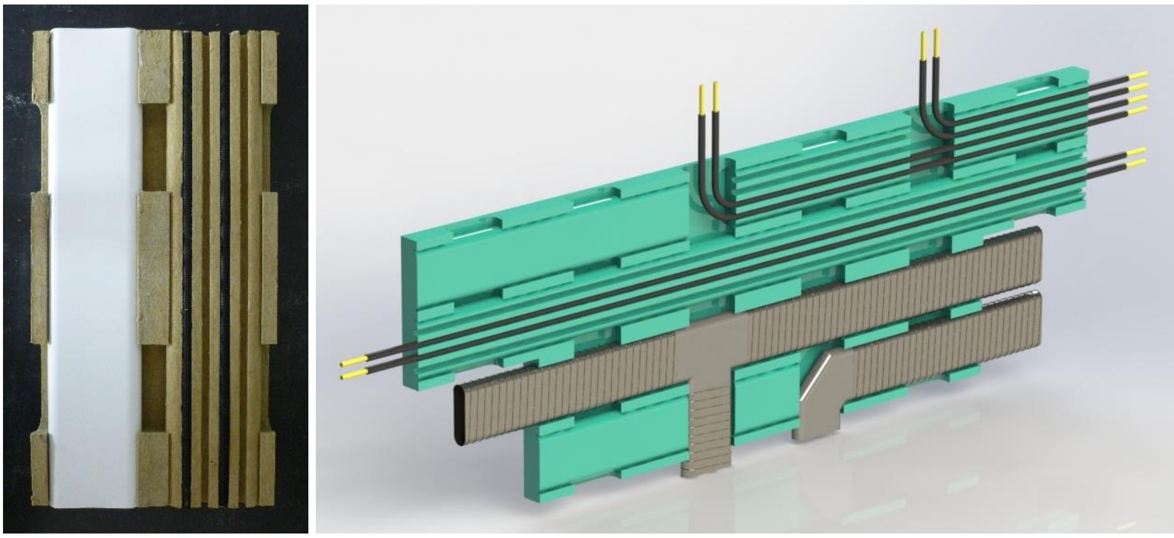

Figure 9 Picture and 3D view of the new foreseen integration concept

4.2 Optimisation

The main parameter used for the optimization was the thickness of both insulation layers (Figure 10). The total thickness of the insulation is 160 mm (fixed by the building owner). The energy point of view is playing a key role in the choice of these thicknesses but the stability of the insulation boards (which has to resist to the working conditions of construction sites) is also an important point. Different geometries of air ducts were also investigated regarding their heat losses but also other issues like their simplicity to be cleaned.

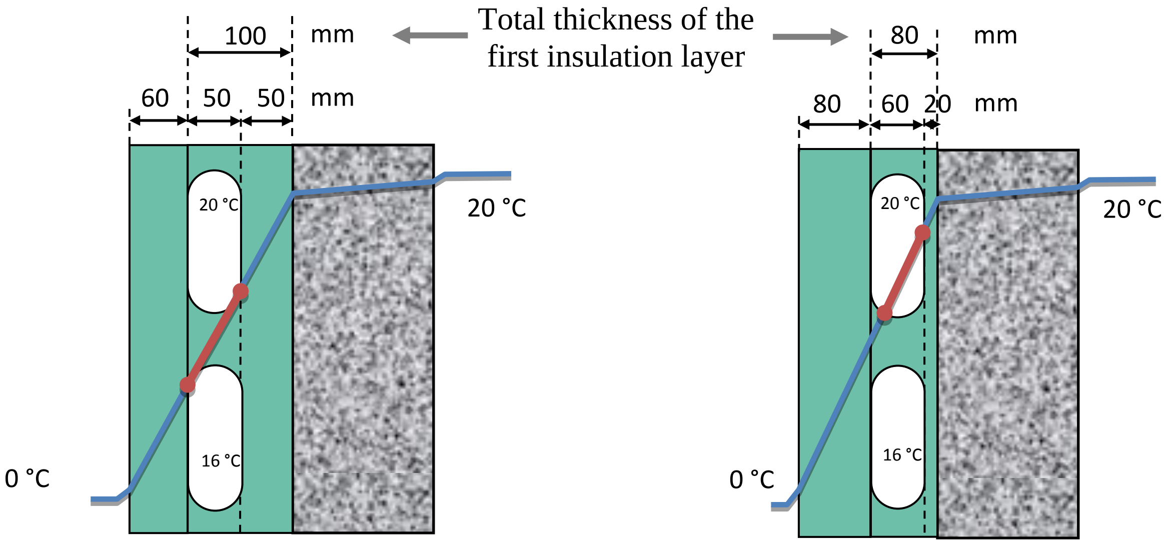

Figure 10 Two different configurations of the insulation layers thickness

Figure 11 is showing the temperature difference between inlet and outlet of the longest air duct planned for the demonstration building presented in 4.1.

The results presented here are corresponding to the following conditions:

- External dimensions of Tube 1: 205 mm x 55 mm
- External dimensions of Tube 2: 205 mm x 40 mm
- Inside temperature (= inlet of the exhaust pipe): 22°C
- Outside temperature: -20°C
- Temperature at the inlet of the supply air duct: 17°C
- Airflow set on its minimal value: 23 m³/h

The thickness indicated on Figure 11 for each case is the thickness of the first insulation layer.

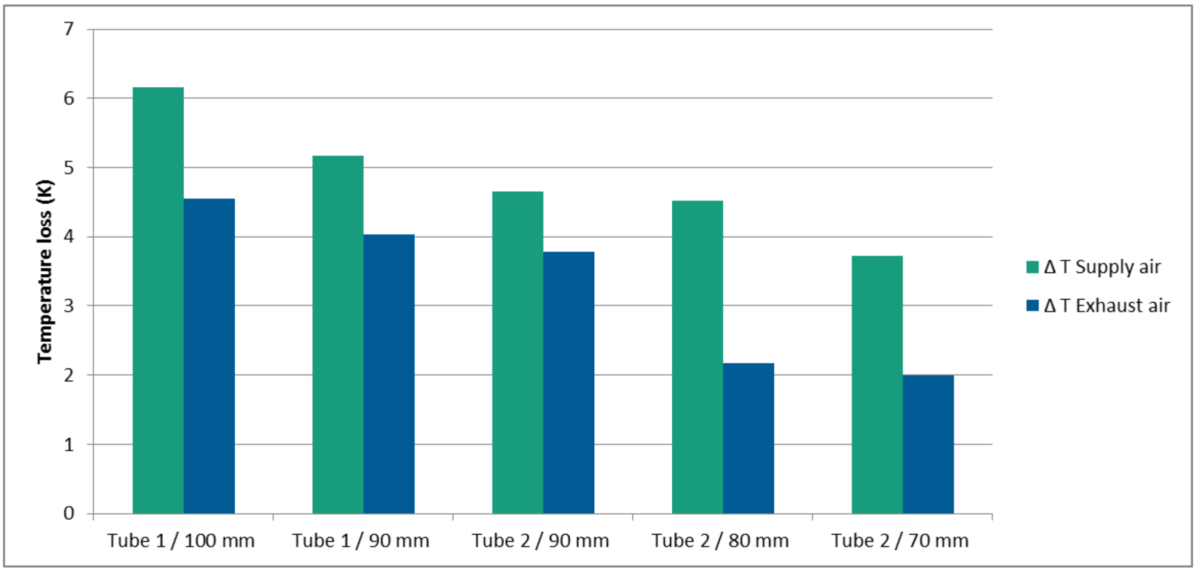

Figure 11 Temperature differences between inlet and outlet simulated for a 15m long duct

Thanks to the reduction of the thickness of the first insulation layer, the air ducts are positioned in a warmer domain and the heat losses of the air ducts can be reduced.

As presented in 2.3, the former integration system has led to a reduction of the energy efficiency of 10 %. With the last developments, we are aiming at keeping this reduction under 4 %.

5 CONCLUSION

Integrating ventilation ductworks in the façade of retrofitted building is a promising solution to make renovations easier, cheaper and more comfortable for the building tenants. It is possible to install air ducts in the insulation layer of an external wall without risking high heat losses with a standard insulation thickness of 16 cm.

The next steps of this study will be to confirm the simulation results by comparing them to the measurements which will be implemented after retrofit on the demonstration building in Frankfurt.

The integration of heating pipes is currently investigated and will be the subject of future publications.

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