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# Internal Insulation of Preservation Worthy Facades

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**Abstract.** With international awareness of the need to decrease greenhouse gas emissions, the Danish government set a target to be fossil fuel-free by 2050. To achieve that, existing buildings will need to be retrofitted with energy-saving technologies such as improved thermal insulation. In Denmark, a larger mass of the building stock from around 1850 to the 1940s is preservation worthy. The construction is typically solid brick walls with wooden beams on the floors. This creates a challenge for energy retrofitting since the external facades cannot be altered. The application of internal insulation can influence the temperature and moisture profile of the wall. Moisture builds up in the interface between the original brick wall, and the insulation layer can create an environment where mould can grow. Previous research also demonstrated a risk of moisture build-up at the beam-ends when internal insulation is applied. Saint-Gobain ISOVER has, together with DTU, spent five years developing a new system, ISOVER RetroWall System, which addresses these problems. The presented work will include a short introduction to the concept, results and conclusions from the field test and presentation of two sites with the finished system in use.

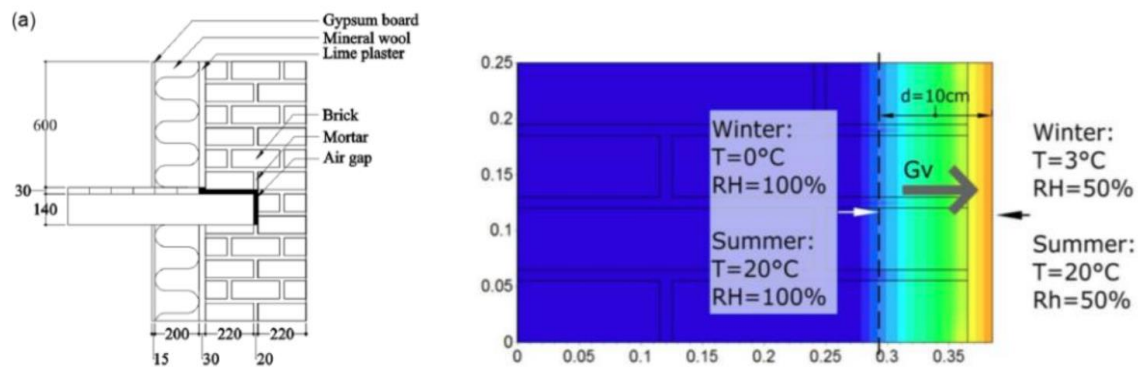
Keywords: Retrofit system; Internal Insulation; Moisture; Heritage Solutions

## 1. Introduction

### 1.1. Background

The Danish building stock ranging from the 1850s up to the 1940s has aesthetic value, and the facade needs to be preserved. To comply with government regulations for energy retrofitting, internal insulation is, therefore, the only option. Although it faces a technical problem, applying internal insulation and having the vapour barrier on the inside excludes the possibility of internal diffusion, and external drying by diffusion is the only option. Furthermore, the wooden beams lay within the brick wall. So longer periods with high relative humidity or condensation should be avoided in order to preserve its structural integrity. Previous studies done by Fosso [2] investigated the effect of wind-driven rain, capillary and added water content by diffusion into the air cavity Figure 1.

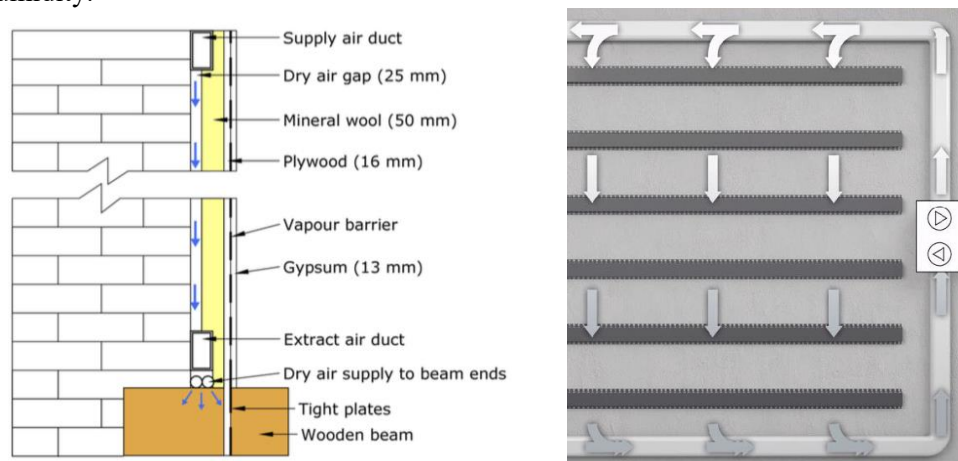




**Figure 1.** Cross section typical wall (left) and heat, air and mass conditions for summer/winter in the air cavity (right)

### 1.2. Internal Ventilated Insulation with Active Moisture Control

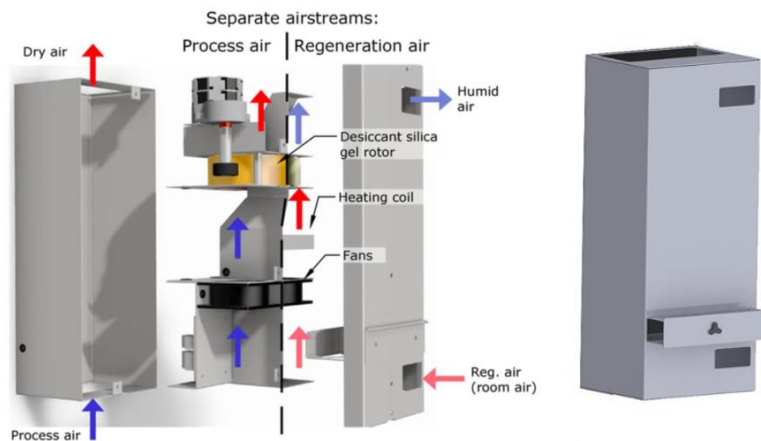
RetroWall is a new concept for internal insulation for heritage buildings. The system tackles the problem by having active moisture control within the air cavity, between the internal wall and the insulation, and supplies air into the floor structure. The heat, mass and air balance to achieve the required airflow was prior investigated by Lucchesi [5], taking into account internal, external temperature, local climate and relative humidity.



**Figure 2.** RetroWall Cross Section (left) and Airflow Layout (right)

The active dehumidification blows the air inside of a 25 mm air gap from the top of the wall. The air is collected on the bottom part of the wall and back to the dehumidifier. The system is composed of an air gap of 25 mm followed by 50 mm of insulation with mineral wool and a wall consisting of two 13 mm gypsum boards with a vapour barrier in between, as shown in Figure 2. The structure of the system is supported by horizontal steel brackets (25x110 mm), which have a 40% perforated area allowing the air to go through. The air supply and extraction are done on the top and bottom parts of the wall by steel ducts (54x100 mm).

The dehumidifier is responsible for moisture control. In order to prevent moisture-related problems such as mould growth and wood decay, it keeps the relative humidity under 75%. The air collected is heated 10 degrees Celsius before returning into the cavity. The unit is split into two sections, process and regeneration airflows. The airflow within the air cavity is the process airflow, while the regeneration process is the airflow that dries the desiccant wheel with indoor air, see Figure 3. The moisture content exchanged indoors is very low, 30g/day while regular activities are 10kg/day.



**Figure 3.** Dehumidifier unit design

The system is connected to sensors that measure the Relative humidity, temperature and moisture content. The measurements happen every two hours for 5 minutes with an airflow of  $16 \text{ m}^3/\text{h}$ . If the relative humidity is over 65%, the system switches on until moisture is removed and humidity gets lower than 55% [1]. The criteria state that the conditions that can promote the germination of fungi spores RH needs to be over 80%, and ASHRAE [4] compares that mould growth happens when relative humidity is over 80% and a temperature between 5 and 40 degrees Celsius, an average of 30 days running should be overcome.

### 1.3. Energy Saving and Dehumidifier energy consumption

Energy savings will depend on the thickness and thermal resistance of the insulation applied in the RetroWall. The system could generate a potential energy saving in heating per wall area of  $113 \text{ kW/m}^2$  given a previous U-Value of  $2,10 \text{ W/m}^2\text{K}$  is reduced to  $0,41 \text{ W/m}^2\text{K}$  and assuming the standard heating degree days. The Dehumidifier unit system is able to cover  $12 \text{ m}^2$  net wall area and its power consumption is 60W when operating. It typically runs 2 - 6 hours per day during winter months, and given a  $12 \text{ m}^2$  wall, the power consumption is  $5,5 \text{ kWh/m}^2$  per year. When insulating this wall with 50 to 100 mm of high performance insulation, the energy savings will be 10 - 20 times the energy spent.

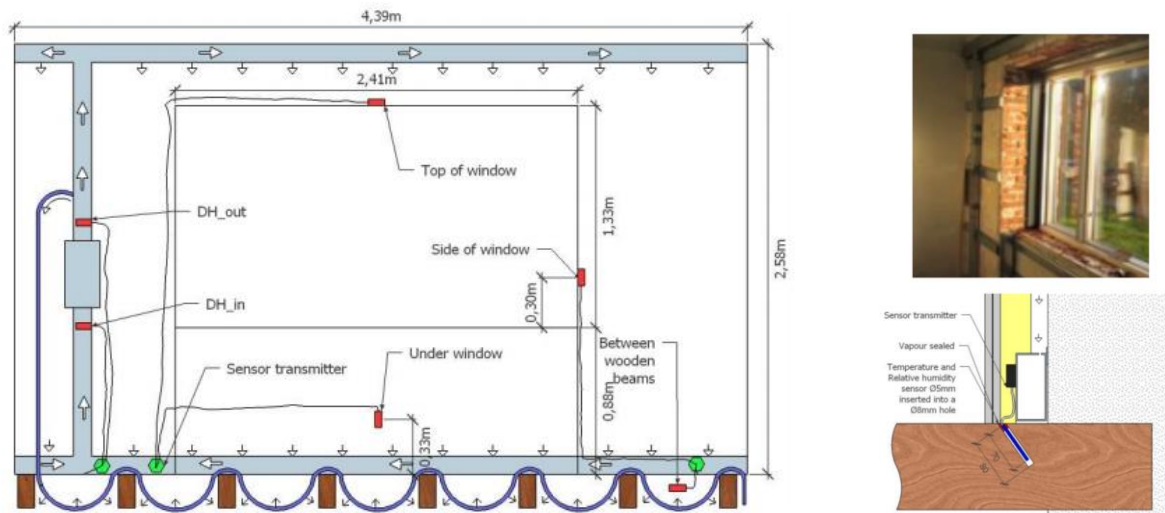
## 2. Method - Test Cases

ISOVER, with the collaboration of DTU, had several investigations on the system development and further on, the RetroWall system has been tested at real test locations by Anton [1]. Since 2016, data has been collected, and some adjustments have been made. Further descriptions and discussion related to the following places Ordrupvej (OD), Thomas Laubs Gade (TL) and Vejen Kommune (VK).

**Table 1. Test Cases - Construction details**

Building, year, orientation	Floor Structure	Interior Finishing of the Wall	Wall Material	Wall thickness and Under window
Ordrupvej, 1933 - West	Wooden Beam	Plaster with sawdust wallpaper	Red Brick	470 mm 360 mm
Thomas Laubs Gade, 1899 - East	Wooden Beam	Painted plaster	Yellow brick	280 mm 110 mm
Vejen Kommune, 1962 - North East	Concrete slab	Painted plaster	Yellow brick	360 mm 360 mm

For one of the test cases, Ordrupvej, before installing the system, the wallpaper and paint were removed. Several sensors were placed within the wall in order to collect data while the system operates, as shown in Figure 4. In addition, the wooden beams got a dedicated hose to bring the dried air to remove moisture from beam ends.



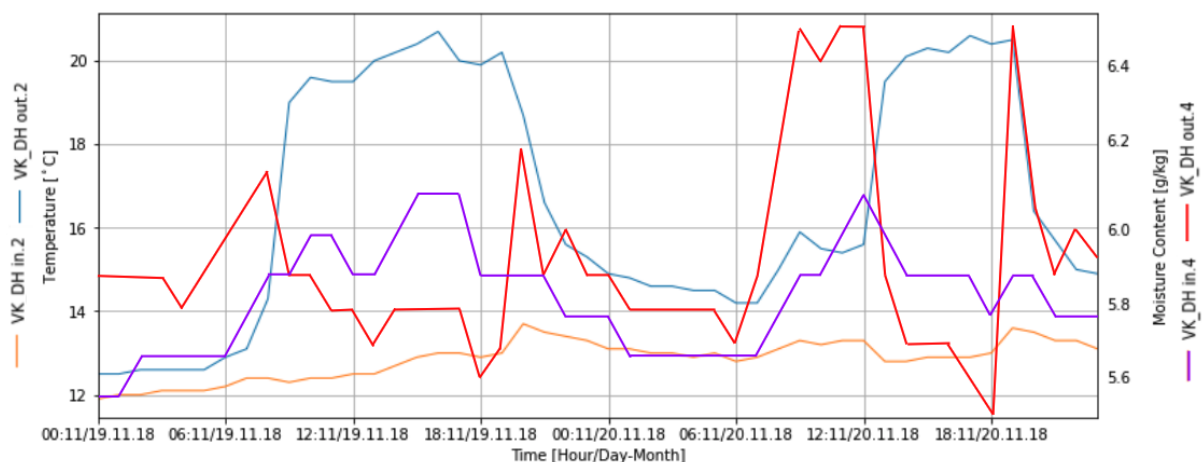
**Figure 4.** Retrofit layout, the sensors for temperature and relative humidity are in red colour (left), installation (top right) and sensor in the wooden beams (bottom right) [1]

### 3. Results

The critical areas usually are under the window due to the reduction in wall thickness and floor supporting structure. The following section will briefly describe a typical day of operation and all test sites.

#### 3.1. Dehumidifier Operation

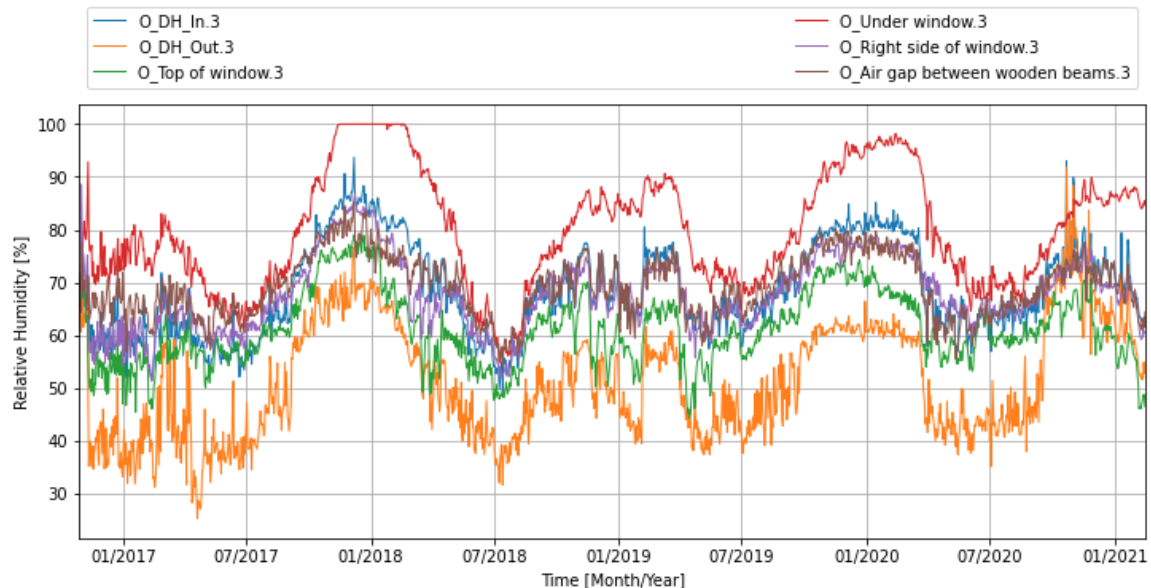
The Dehumidifier usually operates for 5 min every 2 hours to collect data on Relative Humidity. If RH is more than 65% it keeps running and we can capture the operations by the temperature difference from the inlet and outlet as in Figure 5. On the right, it can be seen that for the same period, Moisture Content in the outlet (DH Out) drops below the inlet (DH In) as soon as that operation starts, meaning it is drying the air.



**Figure 5.** VK - Dehumidifier DH inlet x DH outlet - Temperature (left) and Moisture content (right)

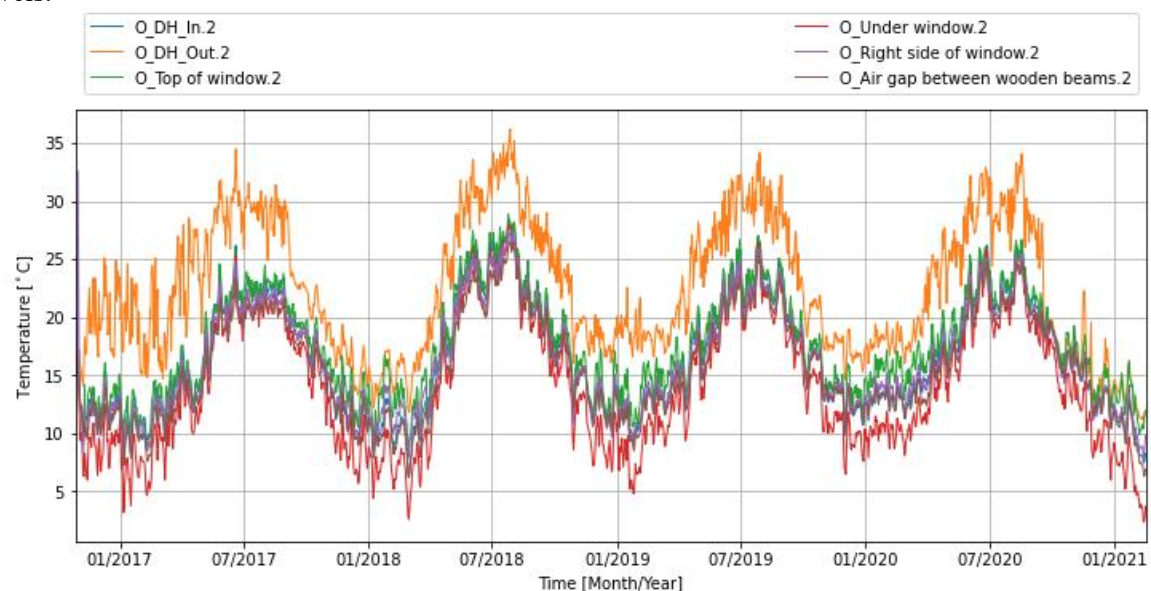
#### 3.2. Test Site - Ordrupvej

This site has a floor structure made over wooden beams that lay into the brick wall. This is a critical area as moisture can be driven by capillarity to the wood and start germination of mould and decay the element. For this reason, there is a hose supply airflow and sensors to capture the moisture, temperature and relative humidity. The RH was under 80% in this critical area during these five years, which proves the efficacy of the dedicated hose, see Figure 6. “Under window” is still the most critical due to the thickness of the wall and the difficulty to the airflow to get in that region.



**Figure 6.** OD - Relative Humidity - 2016-2021

In Figure 7, the average temperatures for all sensors are shown and as expected, “under window” has the lowest, which corresponds to higher levels of humidity. Meanwhile, the temperature in between wooden beams was also low, but due to the extra air supply, relative humidity was kept at acceptable levels.



**Figure 7.** OD - Temperature - 2016-2021

### 3.3. Test Site - Thomas Laubs Gade



During the start of the system, Thomas Laubs Gade location had measurements of Relative Humidity under the window over 90%. The system showed to be able to remove moisture when switched on, but the occupant of the apartment kept switching off due to some noise issues. Figure 8 shows the data from the past five years, in which overall, the sensors show relative humidity was kept under 75%. “Under window” has a wall thickness 20% smaller, being the critical area that during winter and rainy days had some spikes. Beams end mid-position had results under 70% all year long.

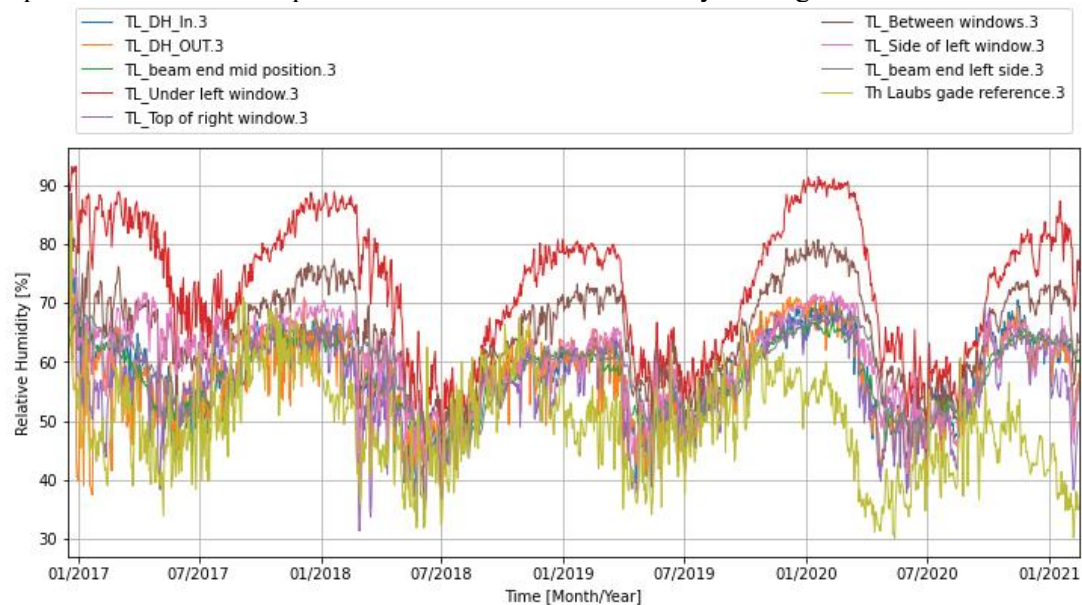


Figure 8. TL - Relative Humidity - 2016-2021

Figure 9 shows the temperatures for all sensors, and for the period in which it registered a higher relative humidity of 90%, the temperature was ranging down to 5 degrees Celsius. It would take at least 16 consecutive days to consider spore germination if temperature and humidity kept stable.

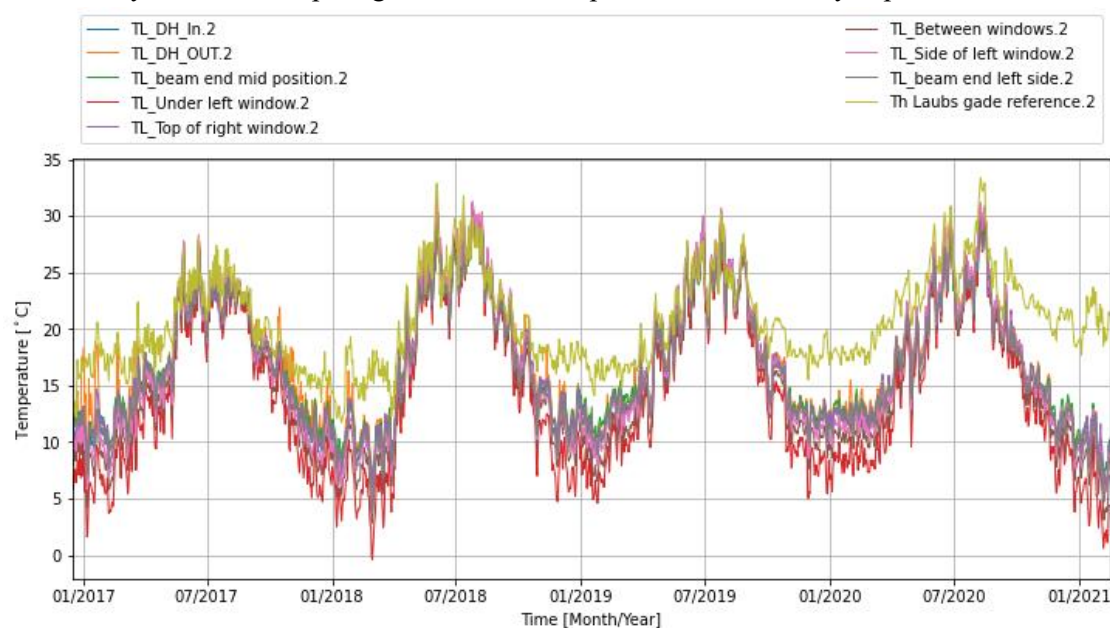


Figure 9. TL -Temperature - 2016-2021

As it could be seen in this test case, the only critical place is “under window”, which could have some extra hose to redirect airflow, as the wooden beams have it.

### 3.4. Test Site - Vejen Kommune

According to Figure 10, it can be seen the Relative Humidity was kept under 70% for all sensors with the exception of the Top Wall Left side, which is not expected. It could be the sensor got in contact with the wall, or there is a crack.

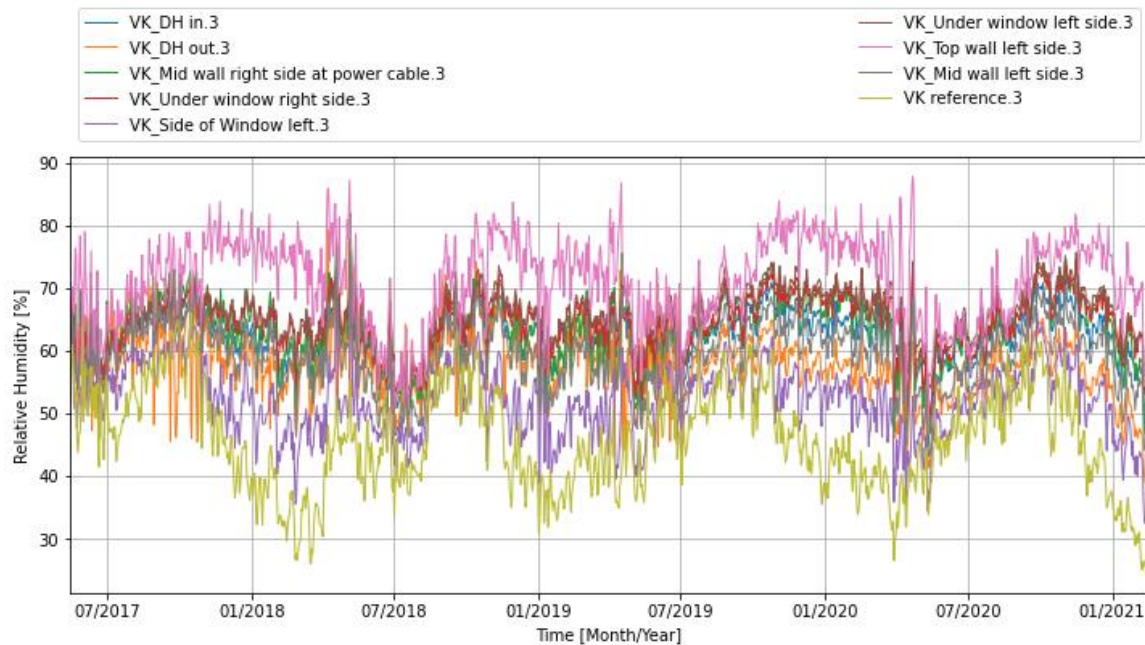


Figure 10. VK - Relative Humidity - 2016-2021

Given that the top of the wall sensor is close to the duct, which supplies heated air from the Dehumidifier is also not expected to get the lowest temperature, as shown in the plot in Figure 11.

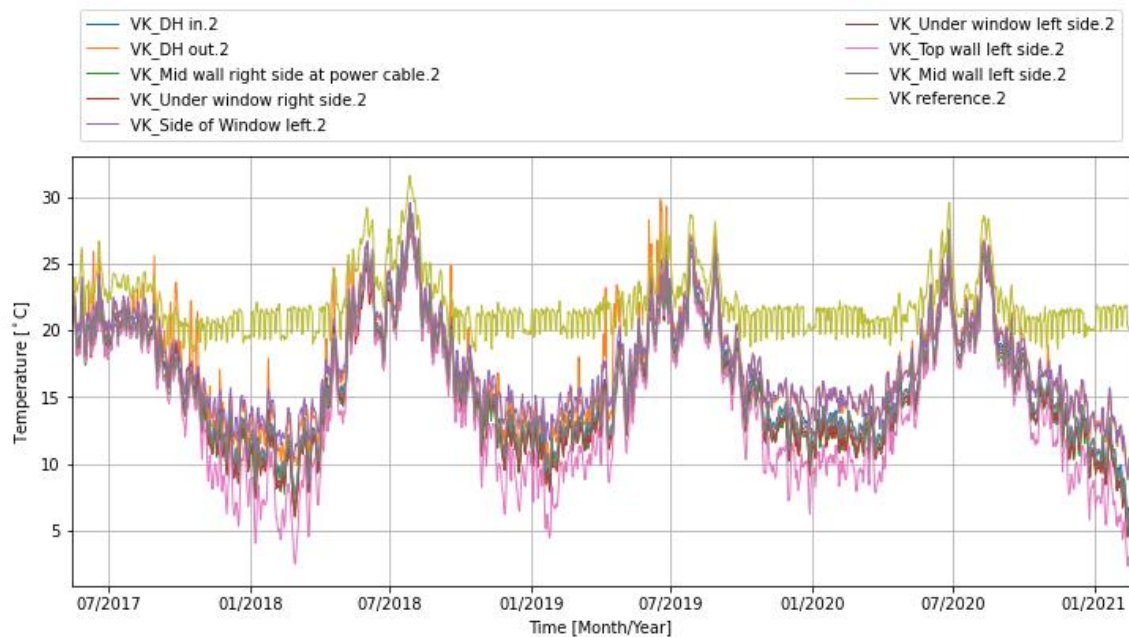


Figure 11. VK - Temperature - 2016-2021



#### 4. Conclusions

Previous reports from Ørbæk [1], Lucchesi [5], Fosso [2], Roca [3] and Hviid [6] investigated the installation and set points, heat, air and mass balance airflow and noise optimization of this new concept of internal retrofitting.

The current results over the last five years for the test cases show that the concept has the potential for removing moisture from the ventilated cavity while insulating apartments internally. The insulation increases indoor climate conditions for occupants while keeping them safe from moisture. Overall the results show that the system has been effective in keeping the relative humidity stable under 75% and providing real-time data on the conditions. Critical areas like beam-ends and “under window” require special attention, and one of the test cases had a dedicated hose to bring airflow to the area. With a more robust solution, airflow was more efficient, and relative humidity was kept under safe conditions. Furthermore, the concept was able to operate with different walls, floor and windows configurations, and various facing orientations. Heritage buildings are often built with a wooden structure, which requires a safe solution regarding moisture control, given it could lead to structural damage.

The solution gave a positive outlook on how to insulate heritage buildings and keep moisture safe. Furthermore, by removing the cold wall responsible for drafts and cold temperatures, the overall indoor climate was improved. RetroWall results showed it is a robust solution for the future for internal insulation.

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