

## Diseminare rezultate proiect RetroKit

### „Toolboxes for systemic retrofitting”

Lucrare

### „Ventilation systems with complex monitoring and control”

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**Ventilation systems with complex monitoring and control**

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1) Executive Summary (one page):

Indoor air quality (IAQ) is a term which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. One of the most important factors in determining the IAQ is the proper ventilation of the buildings.

This paper is focused on the monitoring and control solution for IAQ. The work was developed in the frame EU Fp7 program for the Retrokit project. For this it was used a demo building placed in Frankfurt where different kind of ventilation systems were installed. One of them is based on air extraction from the dwellings and the other one also extracts the air, but preheats the outside fresh air supply.

One of the Icpe tasks was to develop the monitoring and control system for the ventilation, facade ETICS and coating solutions for this demo building. So Icpe designed a dedicated system composed of the following components: Ventilation units, temperature sensors, PLC controller, Modbus transmitters of PT100 temperature sensors, flow meters, power network meters that will give information about different indoor air parameters. All information is monitored by means of a 3G data logger that collects all the data from sensors placed in different parts of the Ventilation system and then transmit them to a data server. All the monitored data can be observed and download online.

Keywords (3-5 keywords):

Building energy management system, energy efficiency, energy management, control optimization, energy performance, commissioning

## 1) Introduction

Indoor air quality (IAQ) is a term which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. One of the most important factors in determining the IAQ is the proper ventilation of the buildings.

This paper is focused on the monitoring and control solution presentation for IAQ. The work was developed in the frame EU Fp7 program for the Retrokit project. For this it was used a demo building placed in Frankfurt where different kind of ventilation systems were installed. One of them is based on air extraction from the dwellings and the other one also extracts the air, but preheats the outside fresh air supply.

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The Demo building was built in 1954 having owner ABG FRANKFURT HOLDING, and is placed in Frankfurt Germany, Nauheimer Straße 1-3. There are 20 apartments in the building, 12 in Site 1 and 8 in Site 2. There are 4 floors, basement and attic. The basement and the attic are not heated. The building is presented in figure 1 – see below

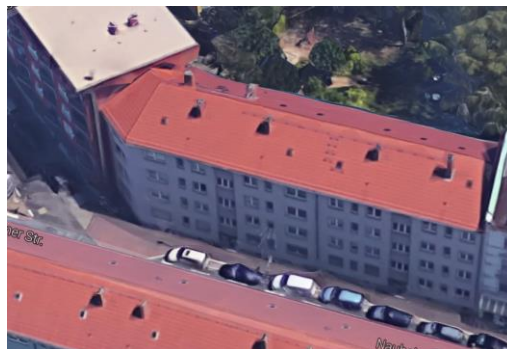


Fig. 1 Demo Building

## 2) Objectives and demo Sites presentation

To carry out the tasks of the projects, Icpe together with other partners involved in the project for the Frankfurt demo Site designed and realised a dedicated monitoring and control system of the indoor air parameters, of parameters inside the ventilation systems and the temperature values on the building façade and to correlate them.

The concept used for this work is based on the monitoring and control system developed by Icpe and its partners to the project.

The objective is to measure, record and control the ventilation systems and monitor the temperature values in the ETICS of the building facade.

Together with the monitoring sensor systems, the following RetroKit technologies were implemented in the Demo building in Frankfurt:

- Multifunctional insulation board

- Multifunctional paintings
- Multifunctional façade channel
- Two types of ventilation systems: with heat recovery for Site 3 and without heat recovery for Site 1

Next we will present the installed systems in demo Sites.

### 2.1) Demo Site 1 Presentation (IBP-System):

The demo building is split up in two demo Sites. In this way two different ventilation systems could be installed and tested. The first Site, as shown in figure 2 corresponds with the part of the building where there are 3 dwellings per floor while the second corresponds with the part of the building where they are 2 dwellings per floor.

The ventilation system in demo Site 1 has a simple decentralised structure and works by extracting air from the dwellings. The supply of air streams is made through air inlets in the window frame while the outlets for the exhaust are positioned in kitchens and bathrooms. The air ducts that lead to the attic are integrated in the insulation layer.

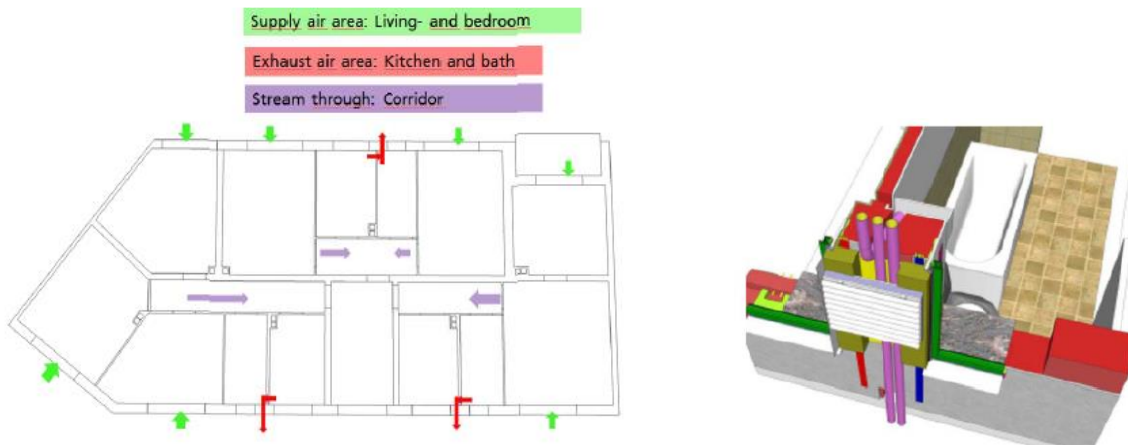


Fig. 2 Positioning of the ventilation ducts

The exhaust fans for the 12 apartments are positioned in the attic, so the maintenance is independent from the tenants. The area between the installation channels is filled with Styrofoam insulation and fire bolts between the 2nd and 3rd floor.

The air flow requirements for proper air quality are between 35 and 110 m<sup>3</sup>/h for both types of dwellings (2 and 3 bedroom). Table 1 summarizes the airflow requirements

	Airflow for the fan, 3-steps	Air exchange
2 bedroom apartment	35/65/110 m <sup>3</sup> /h	0,25/0,45/0,75 h <sup>-1</sup>
3 bedroom apartment	35/65/110 m <sup>3</sup> /h	0,20/0,37/0,63 h <sup>-1</sup>

Table 1: Airflow requirements

In order to achieve the desired control of the air flow rate, the ventilators have 3 levels of power and work as follows:

- Level 1 is always running to ensure the basic ventilation for moisture protection

- Level 2 and 3 are used depending of the control system installed in the dwellings:
- 6 apartments are equipped with a manual switch for level 2 and 3
- 3 apartments are equipped with automatic humidity control (measurement in the exhaust air in the attic) that switches the power levels according to the humidity in the exhaust.
- 3 apartments are equipped with automatic VOC or CO<sub>2</sub> control (measurement in the exhaust air in the attic) that switches the power levels.

## 2.2) Demo Site 2 Presentation (ISE- System):

For demo Site 2 (the part of the building with two dwellings on each floor) there were installed 8 mechanical supplies and exhaust air system with heat recovery. Heat exchangers were installed in the attic of the building in order to recuperate a part of the heat from the exhaust air and heat the fresh air that is brought in the dwellings. The ducts for the supply and exhaust air are installed in the façade insulation. The isolation has special patterns for housing the ducts. There are two insulation layers. The first layer is mounted on the old faced. The ducts are mounted on the special patterns made in this layer. The patterns that are not needed are filled with insulation wool. A second layer comes on top of the first to finish the facade insulation. Figure 6 presents the insulation system. The insulation system is presented in figure 3

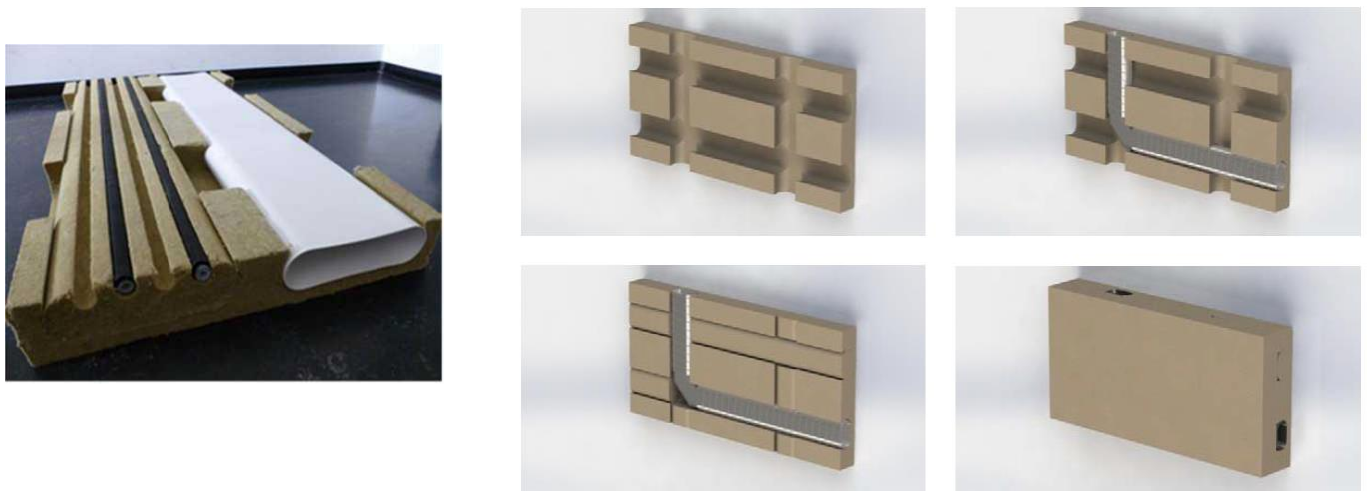


Fig. 3 Insulation system and ducts for site 2

Every dwelling has its own ventilation system. So in the attic there are a total of 8 ventilation units with heat exchangers. The control of each ventilation unit is made by its own RH/CO<sub>2</sub> sensor.



Fig. 4 Positioning of ventilation ducts for Site 2

#### Additional measurements

##### 2.3) Demo building Façade presentation:

In addition to the ventilation systems the building was coated with special types of paint with the following properties: Self-cleaning, IR absorbing, IR reflecting, Colour Stability Sel. In order to assess the impact of the coating on the buildings energy performance, measurements of temperature had to be performed. For this Pt100 temperature sensors were installed between the layers of the insulation and the coatings.

The next table describes the coating type and colour for both sites

Paints Colour Man. number	Functionality
White Sto 16287	<b>Self-cleaning</b>
Grey Sto 16283	<b>IR absorbing</b>
Anthracite Sto 16279	<b>IR reflecting</b>
Red Sto 32440	<b>Colour stability</b>

Table 2 : Building coatings.

### 3) The monitoring system requirements

In order to assess the retrofitting measures and the air quality, Icpe together with the partners developed a complex monitoring and control system that is able to gather and record all the needed measurements. These measurements include temperature, relative humidity, airflow, CO2 levels measurements and also measurements of electrical parameters.

The following table centralizes all the types of measurements that are required for both demo Sites.

<i>Frankfurt Retrofit solutions monitoring system</i>		
Location	Parameter monitored	Monitored points
Ventilation Ducts	Temperature	31
Ventilation Ducts	Relative Humidity	31
Ventilation Ducts	Air flow	4
Ventilation Ducts	CO2	4
Facade	Temperature	22
Power input cable of the ventilation units	Current	5
Power input cable of the ventilation units	Power	5
Power input cable of the ventilation units	Energy	5
Control Switch	Switch position	3
Total		110

Table 3 Monitoring points

#### Demo building Frankfurt – Nauheimer str. Site 1

In Site 1 there are monitored a total of 3 ventilation devices. The temperature and humidity is measured in 7 points positioned on the ventilation ducts. All ventilations devices are equipped with power network analysers to measure the electrical parameters, and have status relays mounted on the control circuit in order to record the operation state of each unit.

#### Demo building Frankfurt – Nauheimer str. Site 2

For Site 2 there are monitored two of the ventilation units (one device from a dwelling on the ground floor and one device from a dwelling at the second floor) in Site 2:

- electrical consumption
- supply airflow
- exhaust airflow

- 14 temperature + humidity sensors

The positioning of the sensors on the ventilation ducts is shown in figure 5



Fig. 5 T/RH sensor positioning on front and back facade for Site 2

#### Facade insulation and coating monitoring

For assessing the coating and the insulation of the building PT100 temperature sensors were installed in several positions. These positions are highlighted in figures 6 and 7. The red dots represent Pt100 in plaster near the surface, the blue dots are Pt100 sensors mounted directly on the exhaust air channel, and the green dots are Pt100 sensors mounted directly on the old facade.



Fig. 6 – Pt 100 sensor positioning front of the building



Fig. 7 – Pt 100 sensor positioning back side of the building

#### 4) Results

##### 4.1) the ventilation monitoring system

In order to monitor and record the ventilation system parameters presented at chapter 3, Icpe proposed and then installed the following equipment:

No.	Equipment	Specification	Qty.	OBS
1	P18D Lumel	T/RH sensor with RS485 - Modbus	31	for monitoring T/RH in ventilation ducts - 7 for Site 1, 24 for Site 2
2	SM61 Lumel	Data concentrator for Modbus network	1	
3	N27P Lumel	Power network analyser 5 A	5	form measuring the ventilation units - 3 in Site 1, 2 in Site 2
4	PLC 1762 L32BXB Allen-Bradley	12 D0/20 DI/1 RS485/1 Ethernet/1 RS232	1	Used for data gathering and computation
5	DI ADD ON for PLC	4 Analog input	1	used to monitor the flow speed
6	Relay	Relay with coil voltage the same as the ventilator	9	used to monitor the switch positioning from the ventilation units
7	RS485 4 Wire cable	For RS485 network	1	Used for data transition
8	Cable	2*1 Liycy	1	Used for powering the sensors
9	Power supply	10 A/24 V Power supply	1	Power supply for the sensors/PLC etc.
10	Accessories	Accessories (DIN rail, terminals, cabinet etc.)	1	
11	CO2-D-TH-RS Temco	T, RH, CO2 (0-3000 ppm )	4	for monitoring CO2/T/RH in ventilation ducts – Site2 in the attic

12	Flow meter	Air speed	4	for monitoring flow rate in ventilation ducts - Site 2
13	PT100 sensors	Temperature sensor	22	used for measuring the façade and the channel temperature in Site 1
14	T3-PT10 Temco	T3-PT10 - 10 Pt 100 inputs Rs485 output	4	used to collect the signal from the PT 100 sensors mounted in the facade

Table 4 Measurement sensors and equipment used the monitoring system

Because of the large number of Modbus devices, it was decided to use 2 separate Modbus networks. The first network gathers data from all T/RH, Power network meters and two of the CO2 sensors. Data is collected with the help of a data concentrator and sent to the 3g Analytics Data logger for processing and transmission to the storage server.

The second Modbus network connects the other two CO2 sensors and the T3-PT10 PT100 temperature transmitters to the PLC. Also the PLC reads the analogic signal of the flow meters and the status of the control units (CO2 detector, manual switch or RH detector). In order to read the position of the switches we have installed 9 240 V ac relays, 3 for each monitored ventilation unit.

The architecture of the monitoring and control system is presented in figure 8.

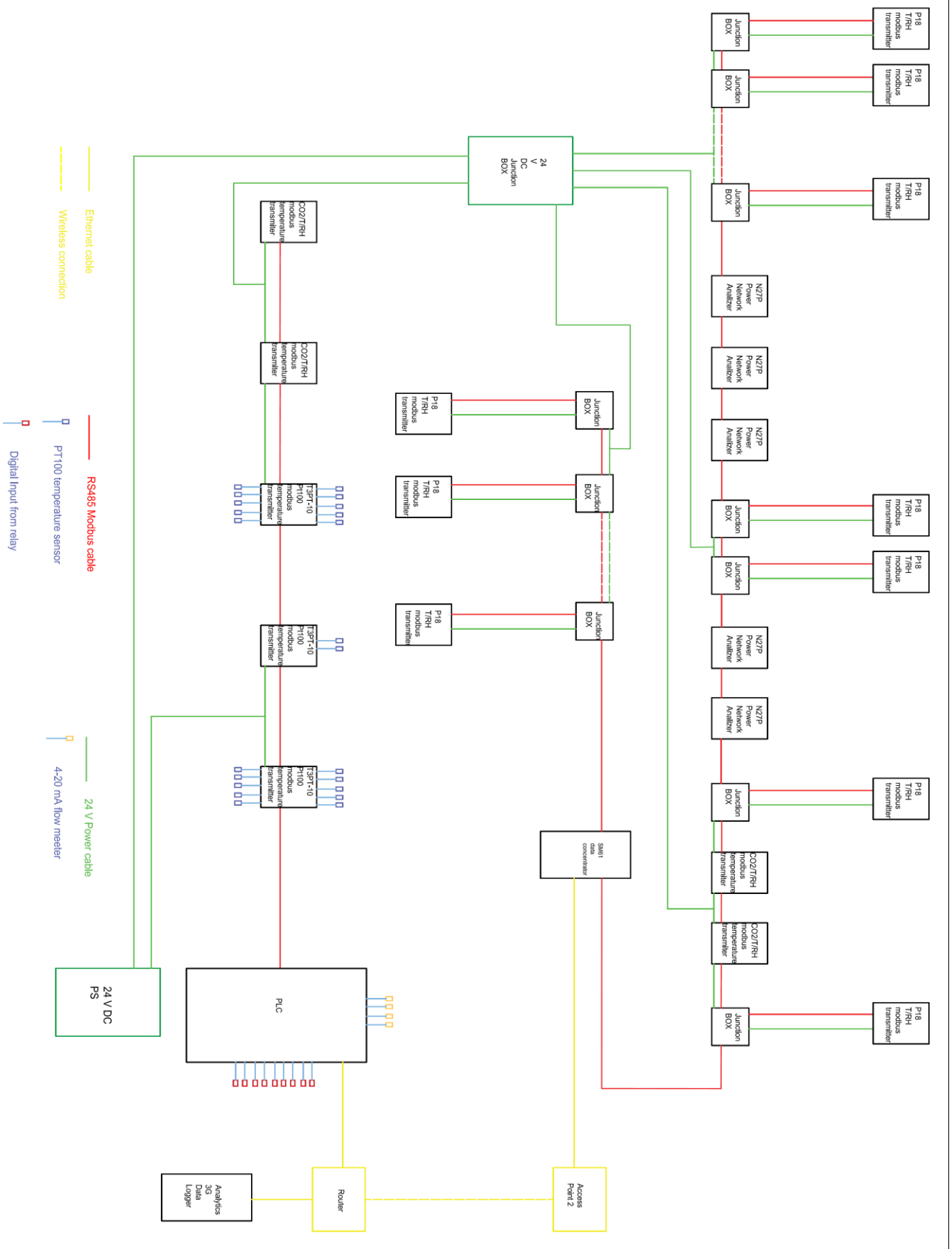


Fig. 8 The architecture of the ventilation monitoring and control system

The Power network meters (figure 9) were installed on the feeding electric circuit of each of the 5 monitored ventilation units: 3 on Site 1 on the ventilator units of dwelling Ground Right, dwelling Ground Left and dwelling 3 Right and 2 on Site 2 on the heat exchanger unit of dwellings 2 G and EG. At the time of the installation, only the Power network meters mounted on Site 2 were powered on. The ventilators from Site 1 were connected straight to the electrical circuit of the building, with no control units being connected to them. We prepared the 3 Power network meters so that the control units will be powered through them. The devices are powered from the electrical circuits of the heat exchangers/ ventilator units.



Fig. 9 From left to right Power network meter: heat exchanger EG Site 2, ventilator 3 right Site 1, ventilator EG right Site 1

The 4 CO<sub>2</sub>/T/Rh sensors (fig. 10 and 11) were mounted in Site 2 on the heat exchangers of 2 Left and Ground Right. 2 of the sensors were mounted on the inlet of fresh air from the heat exchangers and 2 on the outlet of vitiated air from the heat exchangers. They are powered from the 24 V dc power supply mounted in the cabinet with the PLC unit.



Fig. 10 CO<sub>2</sub> sensors for heat exchanger 2G



Fig. 11 CO<sub>2</sub> sensors for heat exchanger EG

4 of the T/Rh combined sensors were mounted on the inlet and outlet of vitiated/fresh air of the heat exchangers from Site 2 and one sensor was mounted on Site 1 on the ventilation unit of 3 right dwelling. They are powered from the 24 V dc power supply mounted in the cabinet with the PLC unit.

For measuring the flow rate of the air in the ducts in Site 2 on the measured heat exchangers, there were mounted 4 air speed meters. 2 were mounted on the return pipes from the heat exchanger units and two were mounted on the outgoing pipes of the ventilation units. They are powered from the 24 V dc power supply mounted in the cabinet with the PLC unit. We first measure the air speed and from the air speed we can calculate the flow rate.



Fig. 12 The 4 air speed meters installed

The T3-PT10 (figure 13) devices are used to read the PT100 sensors installed between the layers of the façade. The measured temperatures are sent to the PLC from the T3-PT10 on RS485 Modbus network. Each device can read a maximum of 10 PT100 temperature sensors. On Site 1 there have been mounted 2 T3-PT10 Units (for a total of 12 PT 100 sensors) and one on Site 2 (for Site 2). There were sent to Frankfurt 4 T3-PT10 device, but at the time of the installation we found only 1 device. Another 2 devices will be sent to Frankfurt to replace the missing ones.



Fig. 13 Installed 3T-Pt10 Pt 100 transmitter

The PLC cabinet contains the 24 V DC power supply, the PLC unit with the analogic and digital inputs and the relays that convert 230 V AC signal to 24 V DC signal. It was mounted in Site 1 in the attic next to the cabinet with the Analytics 3G gateway. The PLC is used to read and compute data from the flow meters, 2 CO<sub>2</sub>/T/RH combined sensors, the T3-PT10 devices and the state of the ventilation devices mounted in Site 1.



Fig. 19 PLC cabinet

SM61 Data concentrator was installed to collect the data from the T/RH sensors installed on the ventilation system and from the Power network meters.



Fig. 20 SM61 enclosure montage in Site 2

All sensors and devices except the flow meters which transmit 4-20 mA signals have RS485 Modbus RTU capability. Besides the 3 bus cables that have been installed by ABG NOVA, Icp team had to install the following data and power circuits:

2 RS485 Modbus RTU networks

4 circuits with power and signal for flow meters

1 24 V DC power circuit for sensors

2230 V AC power circuits for PLC cabinet and SM61 Data concentrator

Data analysis platform

All data is recorded with an integration step of 15 minutes and transmitted to a data server via a 3g internet connection.

To access the data there has been developed a web platform secured with a username and a password.

All recorded data can be seen on the platform, graphics can be generated, and comparisons can be made. Also data can be downloaded in spread sheet format for a more complex analysis.

## **5) Conclusion**

The developed system achieves the requirements in order to measure and control not only the IAQ, but also in order to assess the impact of the coating and the insulation materials in the buildings energy efficiency.

## **Acknowledgement**

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