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# INVESTIGATION OF THE REAL EFFICIENCY OF A DECENTRALIZED HEAT RECOVERY VENTILATION SYSTEM

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**Abstract**

The paper presents the measurement method and values of the temperatures of the incoming and outgoing air obtained as a result of the connection and automation of 4 decentralized heat recovery ventilation units into one system, and the measured results of the thermal efficiency of the entire system. The built system consists of four single-room heat recovery devices, which are integrated into an automated system. The built-in sensors can be used to measure the average temperature of the ventilated rooms or the current temperature and relative humidity of the air flowing through the ventilation units, as well as the carbon dioxide level of the rooms. The units received automation that complements the original individual control elements, which is capable of complex control tasks from any computing device, graphic interface and Wi-Fi connection. The units' sensors, which can be moved into the air stream, are suitable for the momentary measurement of the parameters of the flowing air, thereby estimating the thermal efficiency of the entire system.

**Keywords***: decentralized heat recovery ventilation, automation, real thermic efficiency* .

## 1. Introduction

Decentralized heat recovery ventilation equipment is an air-technical device whose purpose is to improve indoor air quality and minimize heat loss during ventilation. The decentralized indicator indicates that these systems operate at a local level, i.e. they are used in one room or a smaller area.

These devices usually perform two main functions:

- Circulation and renewal of air: De-centralized ventilators introduce fresh air into the building and simultaneously remove used, polluted air. This improves indoor air quality, reduces humidity, and helps get rid of odors and harmful gases that accumulate in the air.
- Heat recovery: The essence of the heat recovery function is to transfer the heat of the warm air leaving the building to the cold fresh air entering the building. In this way, the amount of energy used by the heating or cooling system can be minimized, as the system recovers and returns the heat to the environment.

Decentralized heat recovery ventilation systems can be extremely efficient in smaller buildings or in rooms where it is not feasible to build a central ventilation system. In addition, through their energy efficiency, they contribute to the sustainability of the building and to the reduction of heating/cooling costs.

Decentralized heat recovery ventilation equipment can operate on the basis of two main heat recovery principles: the principle of heat exchange (recuperative) and the principle of heat storage and heat release (regenerative).

Among these, the regenerative version is the most common, and the subject of this thesis is the examination of the thermal efficiency of a system built with this type of ventilation.

The principle of regenerative heat exchange: the equipment has a heat storage unit (usually a ceramic insert). The machine has a single fan with variable rotation direction, which blows the internal warm air out of the apartment for a given period of time (usually 70 seconds), so that it heats up the heat storage pad. After the given time, the fan changes direction and blows fresh, cold air from outside through the heat storage insert, heating it up, so that the fresh air is heated and enters the living space. The ceramic insert can absorb and release a part of the steam, so the drying effect of the fresh, preheated air is less pronounced than with the heat exchange solution.

Regenerative units must be installed in pairs to ensure efficient air exchange and to avoid alternating overpressure and depression in the ventilated living area.

The structure of such a ventilation unit is depicted in **Fig. 1.** In principle, it consists of a brushless fan enclosed in a plastic tube, a regenerative ceramic insert, a supply unit and a control unit that changes the direction and speed of the air flow, as well as a filter for removing dust and other impurities.

Such equipment can be installed even after the buildings are completed; their disadvantage compared to centralized heat recovery ventilation equipment is the almost complete lack of centralized automation. The advantage is the much lower purchase price, even in the case of installation of several units **[1, 2, 3]**.

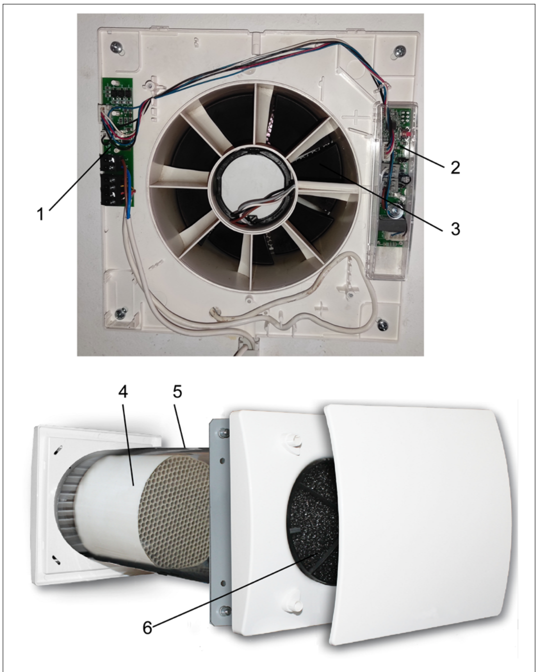



**Fig. 1.** *Decentralized heat recovery ventilation equipment: 1 – power supply; 2 – individual control unit; 3 – fan with a brushless motor; 4 – heat-absorbing ceramic insert; 5 – ABS housing; 6 - dust filter.*

## 2. The built ventilation system

The tested system was built with 4 Aerauliqa HR150 **[4]** type units, which provides the ventilation of a one-story house with an approximatively 100 m$^2$ livable surface 250 m$^3$ air space, which has 50 cm thick external walls (**Fig. 2** and **Fig. 3**).

The units are connected electronically (based on the manufacturer's guide): U1.1 on the ground floor with U2.1 on the upper floor and U2.1 on the ground floor, with U2.2 on the upper floor. These pairs are completely independently of each other, in the original installation it was possible to change the air flow rate (volume yield) of a pair with the help of a mechanical switch.

Our goal was to build an automation system, with the help of which the two independent systems can be connected into a single system, whose characteristic parameters, such as temperature, relative humidity and CO2, can be measured in all rooms, as well as inside the ventilators. The entire system must be controllable from a computer interface, manually or fully automated.

The system was built with a very cost-effective solution based on the operating principles shown in **Fig. 4** with a central microcontroller (ESP32) and four ESP8266 type HUB units, which are connected to each other via a WI-FI network **[5]**. The central unit runs automation and measurement algorithms and a web server. The HUBs supple-

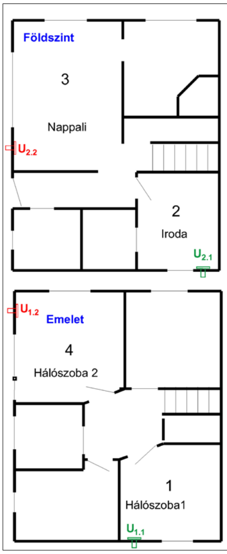



**Fig. 2.** *Placement of ventilation units in the house.*


**Fig. 3.** *The location of the ventilation unit's inlet on the wall of the building.*

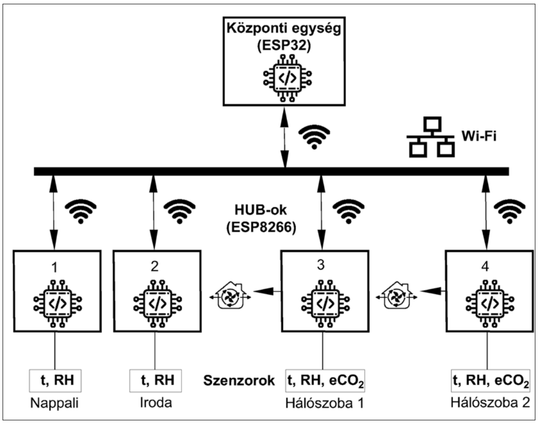



**Fig. 4.** *Control and measurement unit diagram of the ventilation system.*

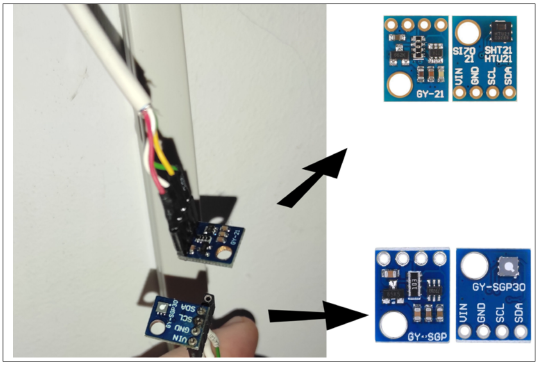



**Fig. 5.** *The SHT21 (temperature and relative humidity) and SGP30 (eCO2) sensors can be moved from the room into the air flow of the ventilation unit.*

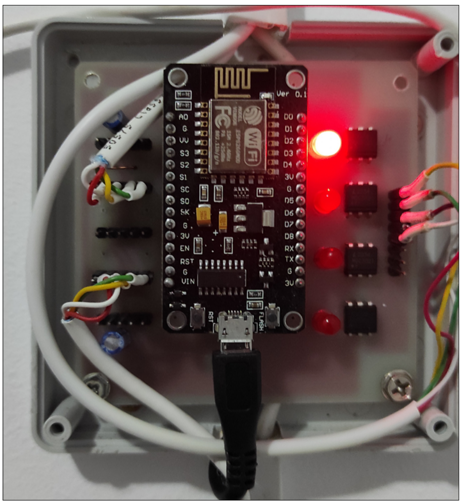


**Fig. 6.** *The custom-built control and meter HUB with ESP8266 in function.*

ment and connect the basic control tasks of the ventilation units, as well as perform the tasks of measuring the environmental parameters provided by the sensors.

The sensors providing the measurements: one SHT21 (temperature and relative humidity) at each ventilation unit, and a SGP30 eCO2 sensor in the two bedrooms (Fig. 5) [6, 7]. In normal operation, the sensors measure the air parameters of the rooms, but they can be moved inside the ventilation units in front of the dust filters.

Such a control-measuring unit in operation is depicted in Fig. 6. The construction and operation of the electronic system, automation algorithms, and communication are not the subject of the present article.

The parameters of the operating system are continuously monitored; the sampling parameters can be set according to the measurement task in a resolution of 3-99 seconds. They can be tracked in measured numbers (RH) or real-time graphs. To do this, you need to connect to the web interface running on the ESP32 via the Internet on a smartphone or personal computer. Fig. 7 shows a detail with the HMI user interface, where the real-time temperatures are visible (two sensors in the rooms and two inside the ventilation).

The measured data can be recorded in Google Cloud or in a Google Sheet via a script, upon request (it can be started with a button via the HMI

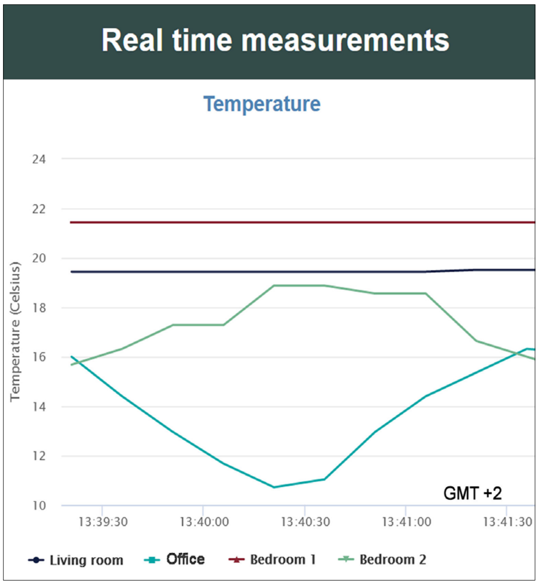



**Fig. 7.** *Detail of the user interface that can be run on computing devices - the display of temperatures in real time.*

interface). The schematic diagram of the data recording system is depicted in Fig. 8.

The data recorded in the Google sheet are available via the Internet until they are deleted, the data here can be processed at any time (Fig. 9).

The data found here can be saved in an Excel file and can even be displayed graphically (manually), as shown in Fig. 10.

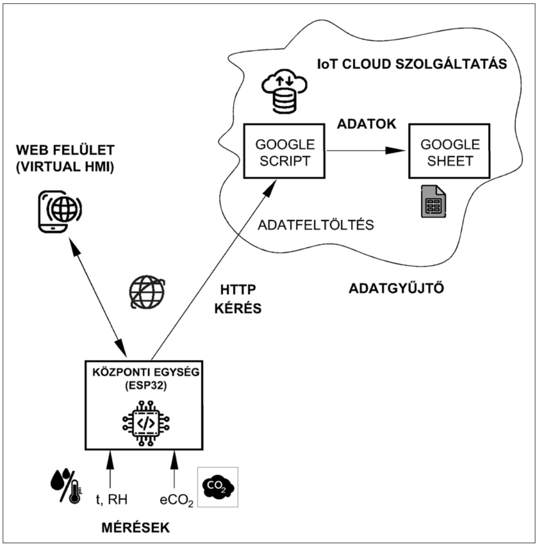
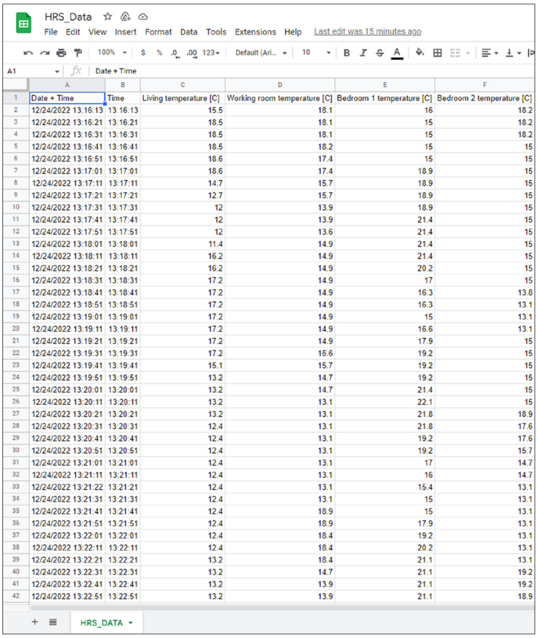



**Fig. 8.** *Uploading the measured environmental parameters to the IoT Cloud.*


HRS_Data

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A1 Date + Time

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Date + Time | Time | Living temperature [C] | Working room temperature [C] | Bedroom 1 temperature [C] | Bedroom 2 temperature [C] |
| 2 | 12/24/2022 13:16:13 | 13:16:13 | 15.5 | 18.1 | 16 | 18.2 |
| 3 | 12/24/2022 13:16:21 | 13:16:21 | 18.5 | 18.1 | 15 | 18.2 |
| 4 | 12/24/2022 13:16:31 | 13:16:31 | 18.5 | 18.1 | 15 | 18.2 |
| 5 | 12/24/2022 13:16:41 | 13:16:41 | 18.5 | 18.2 | 15 | 15 |
| 6 | 12/24/2022 13:16:51 | 13:16:51 | 18.6 | 17.4 | 15 | 15 |
| 7 | 12/24/2022 13:17:01 | 13:17:01 | 18.6 | 17.4 | 18.9 | 15 |
| 8 | 12/24/2022 13:17:11 | 13:17:11 | 14.7 | 15.7 | 18.9 | 15 |
| 9 | 12/24/2022 13:17:21 | 13:17:21 | 12.7 | 15.7 | 18.9 | 15 |
| 10 | 12/24/2022 13:17:31 | 13:17:31 | 12 | 13.9 | 18.9 | 15 |
| 11 | 12/24/2022 13:17:41 | 13:17:41 | 12 | 13.9 | 21.4 | 15 |
| 12 | 12/24/2022 13:17:51 | 13:17:51 | 12 | 13.6 | 21.4 | 15 |
| 13 | 12/24/2022 13:18:01 | 13:18:01 | 11.4 | 14.9 | 21.4 | 15 |
| 14 | 12/24/2022 13:18:11 | 13:18:11 | 16.2 | 14.9 | 21.4 | 15 |
| 15 | 12/24/2022 13:18:21 | 13:18:21 | 16.2 | 14.9 | 20.2 | 15 |
| 16 | 12/24/2022 13:18:31 | 13:18:31 | 17.2 | 14.9 | 17 | 15 |
| 17 | 12/24/2022 13:18:41 | 13:18:41 | 17.2 | 14.9 | 16.3 | 13.8 |
| 18 | 12/24/2022 13:18:51 | 13:18:51 | 17.2 | 14.9 | 16.3 | 13.1 |
| 19 | 12/24/2022 13:19:01 | 13:19:01 | 17.2 | 14.9 | 15 | 13.1 |
| 20 | 12/24/2022 13:19:11 | 13:19:11 | 17.2 | 14.9 | 16.6 | 13.1 |
| 21 | 12/24/2022 13:19:21 | 13:19:21 | 17.2 | 14.9 | 17.9 | 15 |
| 22 | 12/24/2022 13:19:31 | 13:19:31 | 17.2 | 16.6 | 19.2 | 15 |
| 23 | 12/24/2022 13:19:41 | 13:19:41 | 15.1 | 15.7 | 19.2 | 15 |
| 24 | 12/24/2022 13:19:51 | 13:19:51 | 13.2 | 14.7 | 19.2 | 15 |
| 25 | 12/24/2022 13:20:01 | 13:20:01 | 13.2 | 14.7 | 21.4 | 15 |
| 26 | 12/24/2022 13:20:11 | 13:20:11 | 13.2 | 13.1 | 22.1 | 15 |
| 27 | 12/24/2022 13:20:21 | 13:20:21 | 13.2 | 13.1 | 21.8 | 18.9 |
| 28 | 12/24/2022 13:20:31 | 13:20:31 | 12.4 | 13.1 | 21.8 | 17.6 |
| 29 | 12/24/2022 13:20:41 | 13:20:41 | 12.4 | 13.1 | 19.2 | 17.6 |
| 30 | 12/24/2022 13:20:51 | 13:20:51 | 12.4 | 13.1 | 19.2 | 15.7 |
| 31 | 12/24/2022 13:21:01 | 13:21:01 | 12.4 | 13.1 | 17 | 14.7 |
| 32 | 12/24/2022 13:21:11 | 13:21:11 | 12.4 | 13.1 | 16 | 14.7 |
| 33 | 12/24/2022 13:21:22 | 13:21:21 | 12.4 | 13.1 | 15.4 | 13.1 |
| 34 | 12/24/2022 13:21:31 | 13:21:31 | 12.4 | 13.1 | 15 | 13.1 |
| 35 | 12/24/2022 13:21:41 | 13:21:41 | 12.4 | 18.9 | 15 | 13.1 |
| 36 | 12/24/2022 13:21:51 | 13:21:51 | 12.4 | 18.9 | 17.9 | 13.1 |
| 37 | 12/24/2022 13:22:01 | 13:22:01 | 12.4 | 18.4 | 19.2 | 13.1 |
| 38 | 12/24/2022 13:22:11 | 13:22:11 | 12.4 | 18.4 | 20.2 | 13.1 |
| 39 | 12/24/2022 13:22:21 | 13:22:21 | 13.2 | 18.4 | 21.1 | 13.1 |
| 40 | 12/24/2022 13:22:31 | 13:22:31 | 13.2 | 14.7 | 21.1 | 19.2 |
| 41 | 12/24/2022 13:22:41 | 13:22:41 | 13.2 | 13.9 | 21.1 | 19.2 |
| 42 | 12/24/2022 13:22:51 | 13:22:51 | 13.2 | 13.9 | 21.1 | 18.9 |

HRS_DATA

**Fig. 9.** *Detail of the measurement data recorded in the Google sheet.*

## 3. Measurement results

Thanks to the automation, momentary temperatures can be measured inside the ventilation units. Using these data, the thermal efficiency of the entire system can be assessed.

The temperature of the air flowing in and out, thanks to the ceramic insert, changes continuously as shown in Fig. 10. This was recorded 2 times: at –12 and +4 ºC outside temperature, at all three ventilation speeds. The measured data were saved from the Google cloud to an Excel file, from the continuously changing temperature data (every 70 seconds) an average was calculated, and the thermal efficiency was calculated using the formulas from [8]. The results are shown in Table 1.

**Table 1.** *Comparison of the efficiencies calculated in the rooms and in the entire system with the efficiencies specified by the manufacturer for individual units*

| Outside temperature [ºC] | Ventilator speed | Thermal efficiency [%] Living room | Office | Bedroom 1 | Bedroom 2 | System | Manufacturer |
|---|---|---|---|---|---|---|---|
| –12 | 1 | 51 | 49 | 96 | 93 | 72.25 | 82 |
| –12 | 2 | 60 | 58 | 85 | 82 | 71.25 | 74 |
| –12 | 3 | 64 | 63 | 73 | 73 | 68.25 | 70 |
| +4 | 1 | 62 | 62 | 85 | 87 | 74 | 82 |
| +4 | 2 | 63 | 63 | 78 | 80 | 71 | 74 |
| +4 | 3 | 67 | 67 | 71 | 73 | 69.5 | 70 |

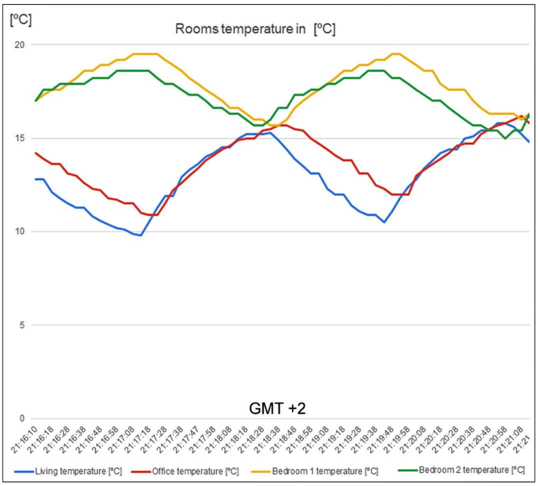


**Fig. 10.** *Visualization of saved data in Excel.*

## 4. Conclusions

The automation system is suitable for measuring the typical parameters of the ventilation provided by the custom made centralized single-room units.

Measuring air parameters and recording the data in an external data cloud enables subsequent analysis and processing of the data.

The measurement of the current temperature of the air flowing through the ventilation units makes it possible to determine the thermal efficiency of the individual units and the entire ventilation system.

The measured and calculated averages of the efficiencies are very little below the efficiency "promised" by the manufacturer. But the explanation for this is the formation of free air flow in the building due to the difference between the above, below and outside temperatures, which visibly increases the efficiency of the above units and reduces the efficiency of the lower units. However, the measured/calculated average efficiency of the system is only a maximum of 4.6% below the average efficiency of 74% stated on the manufacturer's website.

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