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Review Article

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Heat Recovery in a Passive House – A Technical Study

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ABSTRACT
This presentation highlights the energy efficiency of buildings known as "Passive Houses," comparing the energy performance of a conventionally built house with that of a house constructed according to the standards set by the Passive House Institute.

This study details the energy and functional analysis of a heat recovery ventilation (HRV) system in a passive house located in Găeşti, Dâmboviţa County. The performance of the HRV system was evaluated under real usage conditions, focusing on heat loss, energy consumption, and indoor air quality.

In the final part of the article, using graphs and technical diagrams, we demonstrate how the implementation of a high- performance HRV system in a passive house significantly reduces energy losses and contributes to a healthy indoor climate. This study confirms the benefits of using HRV systems in the temperate climate of the Găeşti region, supporting the broader adoption of these solutions in energy-efficient homes.

Keywords: Passive House, Energy Efficiency, Carbon Footprint, Case Study, HRV System, Heat Recovery

Introduction

Nowadays the most debated topic is the one related to the high energy consumption that affects biodiversity and accelerates climate change in an alarming way, the energy crisis that has hit the world lately has made people who were planning to build a house think even more, in the last decade temperatures have increased, recording temperature records in all areas of the world and weather phenomena have become more unpredictable. Old buildings do not comply with the new standards, and the way in which construction is carried out needed new regulations, so new regulations were born to regulate how construction is carried out, in the E.U. measures were taken through the normative "NO. 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL" so the member states of the European Union have introduced provisions, requirements, regarding the safety of buildings and other constructions, health, sustainability, energy efficiency, environmental protection, economic aspects and other aspects that are important in the public interest.

The thermal efficiency of single-family houses built until 1989 (and many years after that) is extremely low. The walls of the houses were generally made of GVP bricks (with vertical voids) with thicknesses of up to 37.5 cm and rarely with BCA, at the same time the walls were uninsulated. The slabs of the houses, above ground, at elevation 0.00, and from the last level, under the attic, were uninsulated. At that time, in Romania, polystyrene was not used, being still a material that was not known to

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everyone, just like mineral or basalt wool, cellulose insulation, etc. The joinery was made of solid wood, with two sashes, with a 4 mm glass sheet each, fixed with putty. Thermal bridges and the lack of tightness of the houses were present almost everywhere, so the energy efficiency of the houses was poor.

Figure 1: Measures to prevent heat loss

Loss As a result of such a construction we have:

- 300 kWh per square meter per year – heat.
- 45,000 kWh per year for a house of aboutstudio to a 110 m2 2-room apartment (Figure 4b). Another example – Casa Buhnici, in Corbeanca, Ilfov (Figure 4c).
- 150 square meters.
- Energy class E. And thermal bridges are not taken into account; the result could be even more tragic.

For all these reasons, the concept of "PASSIVE HOUSES" was arrived at, a passive house is a building with extremely low energy consumption, designed and built to maintain a comfortable indoor climate with a minimum amount of energy, without requiring a conventional heating source. The basic concepts involve superior thermal insulation, air tightness, energy efficient windows, a ventilation system with heat recovery and the use of renewable energy resources [1].

Figure 2: Modern passive house

The largest number of certified passive houses in Europe is in Germany, which is the birthplace of passive houses. The world's first passive house was built here in 1988 in Kranichstein – Darmstadt, Germany, and has been operating at the same design parameters ever since [2].

Figure 3: The first passive house built in Germany

In Romania, the "Passive House" standard is quite difficult to achieve, the cost of implementation being significantly higher than for a conventional house. However, there are completed projects, and some are ongoing. The first passive house construction in Romania was in Burlusi – Arges (Figure 4a), but the first certified passive house is "EvoHouse" with 4 apartments, from a 45 m2 [3].

Figure 4a: Burlusi – Arges

Figure 4b: EvoHouse

Passive houses are defined, among other things, by an energy requirement for heating below 15 kWh/m²/year and high air tightness. To maintain a healthy indoor climate in a very airtight space, it is essential to introduce a controlled ventilation system. Heat recovery ventilation (HRV) allows air exchange with high energy efficiency, which prevents the accumulation of moisture, the formation of mold, the achievement of high CO_2 concentrations and thermal discomfort. Without an HRV system, a passive house would require frequent opening of windows, which would compromise the energy performance of the building. The study presents the behavior of a centralized HRV system in continuous operation [4].

Figure 4c: Casa Buhnici

In designing an efficient HRV system, the optimal positioning of the inlet and outlet grilles is essential: inlets should be placed in living rooms and bedrooms, and extractions in bathrooms, kitchens and wet areas. The system should be balanced so that the flow of air supplied is equal to that extracted, ensuring neutral pressure inside. The use of high-efficiency filters (minimum F7 for inlet) is recommended to prevent the ingress of external pollutants. The noise level should be kept low (e.g. below 30 dB(A) in resting areas), which requires increased attention to sound insulation and the quality of the fans used [5].

We Propose a Technical Case Study

This study details the energy and functional analysis of a heat recovery ventilation (HRV) system in a passive house located in Găești, Dâmbovița County. The performance of the HRV system was evaluated under real-world conditions of use, in relation to heat losses, energy consumption and indoor air quality.

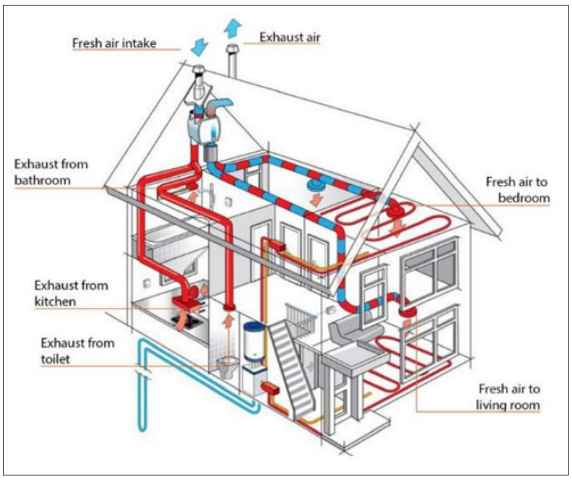


Figure 5: Circuit of a distributed HRV system

Construction Description

- **Usable Area of the Conditioned Space:** 260 m² (130 m²/level)
- **Height Regime:** Ground floor + First floor
- **Structure Type:** Reinforced concrete frame with brick filling
- **Insulation:** EPS 100 mm foundation, basalt wool 200 mm external walls, 300 mm ceiling
- **Windows:** triple-pane PVC, Uw = 0.85 W/m²K.

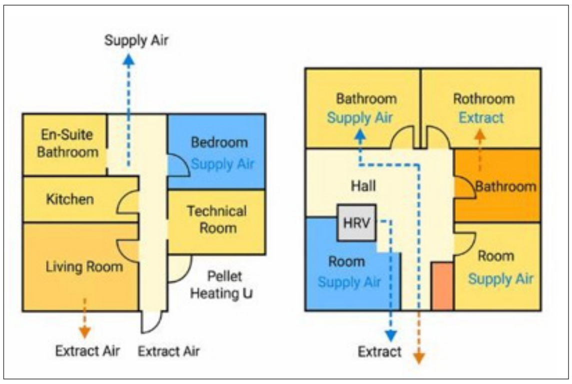


Figure 6: Horizontal distribution of air intake/exhaust

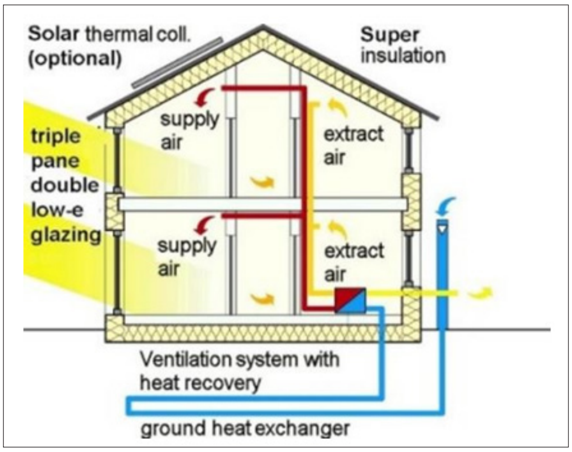


Figure 7: Vertical distribution of air intake/exhaust

Hrv System Configuration

- **Type:** Centralized system, with unit located in the technical room
- **Maximum flow:** 350 m³/h
- **Recuperator:** countercurrent, certified efficiency90%
- **Distribution:** insulated flexible pipes, mounted in the floor
- **Ventilated Areas:** kitchen, bathrooms, bedrooms, living room.

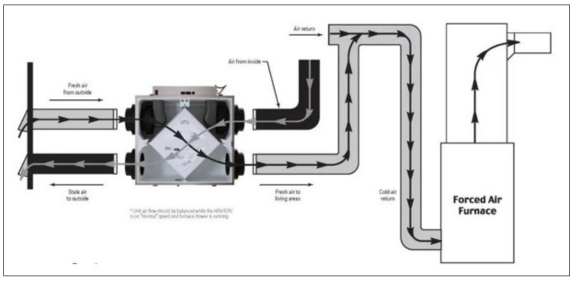


Figure 8: Simplified diagram of the HRV system

Figure 9: Heat recovery ventilation system Photo source: INCD URBAN-INCERC

Photo source: https://device.report/manual/15545380

Evaluation Methodology

- Energy Modeling: PHPP 9
- Dynamic Simulations: DesignBuilder + EnergyPlus
- Monitoring: CO_2 data (ppm), temperature (°C), relative humidity (%)
- Analysis Period: 12 months (January–December)

Calculation Formulas

1. Calculation of HRV System Efficiency

η = (T_ie - T_ei / (T_ii - T_ei) × 100 where:

T_ie = supply air temperature (°C) T_ee = exhaust air temperature (°C) T_ii = indoor air temperature (°C) T_ei = outdoor air temperature (°C).

2. Calculation of Ventilation Air Requirement

V_a = V_c × ACH where:

V_a = required air flow rate (m³/h) V_c = room volume (m³)

ACH = air changes per hour (usually between 0.5 and 1 for residential rooms).

3. Calculation of ventilation Heat Loss

Q = V × ρ × c_p × (T_i - T_e) where:

Q = ventilation heat loss (W) V = air flow rate (m³/s)

ρ = air density (approx. 1.2 kg/m³)

c_p = heat capacity of air (approx. 1005 J/kg·K)

T_i = indoor temperature (°C) T_e = outdoor temperature (°C).

Thermal Efficiency Results

- Average Heat Recovery: 88.5% throughout the year.
- Heat Loss Reduction: 80% compared to natural ventilation.

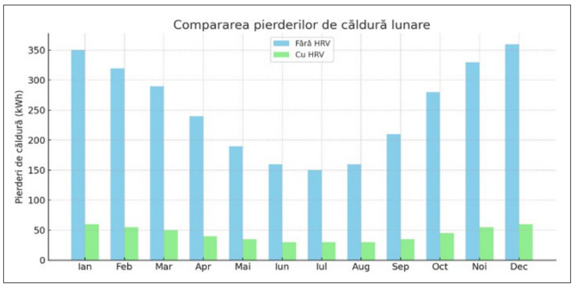


Figure 10: Comparison of monthly heat losses

Indoor Air Quality Results

- CO_2 concentration maintained below 950 ppm in all rooms (simulated values)
- Average indoor temperatures: 20.5°C in winter, 24.3°C in summer (simulated values).

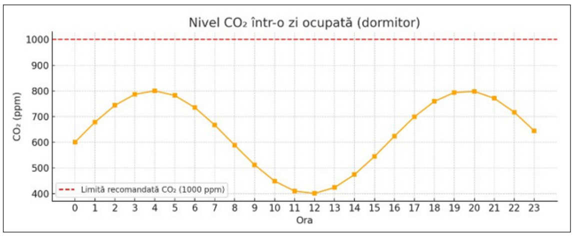


Figure 11: CO_2 level on a busy day (bedroom).

Results Regardin the Economic Analyse

- Estimated savings: 3,000 kWh/year
- HRV system payback: 6.5 years (installation cost ~5,000 EUR).

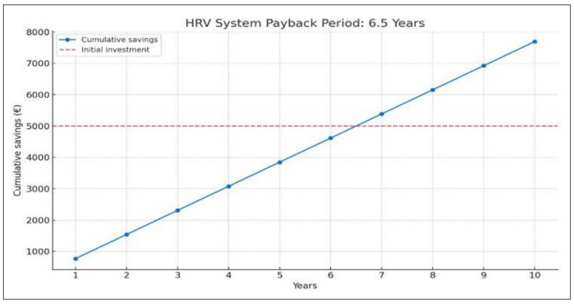
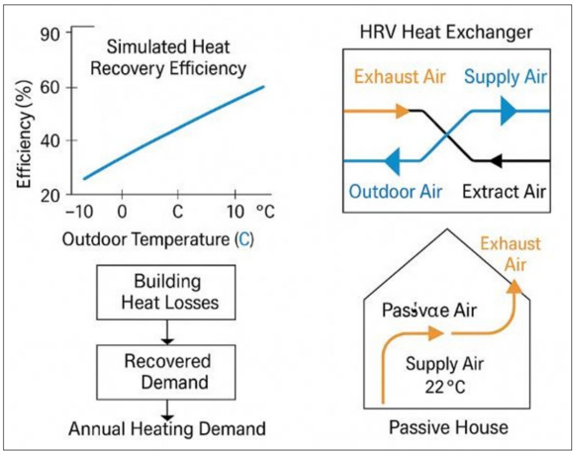


Figure 12: Amortization of costs

Conclusions for Implementing the Hrv System

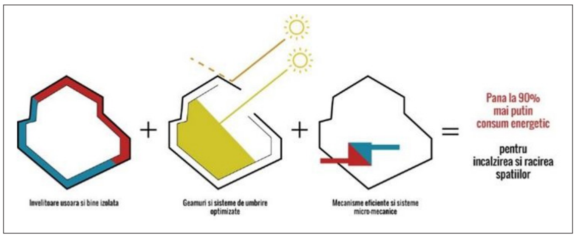
Implementing a high-performance HRV system in a passive house significantly reduces energy needs and contributes to a healthy indoor climate. This study confirms the benefits of using HRV in the temperate climate of the Găești region, supporting the expansion of these solutions in energy-efficient homes.



Current Trends

At the moment, the main effort regarding the implementation of renewable energy sources is focused on improving technologies, in order to lower their costs.

The main goal is to increase the performance of equipment and reduce the energy consumed in operation, but also to judiciously choose the processes, depending on the geographical conditions and the habits of future users.



Classification and Certification of Passive Houses

- Classic Passive House (this type of house is the classic one)
- Passive House Plus (this type of house produces the energy it needs through unconventional sources)

- Premium Passive House (this type of house produces more energy than it consumes, so what is produced in excess enters the network, the owner becoming a prosumer).
- Passive House is a certification standard that is based on measurements carried out on a building by an accredited institution.

Passive House requires compliance with 5 criteria, these being insulation, sealing, avoiding thermal bridges as much as possible, a ventilation system with heat recovery, the window system and the building's exposure.

Passive House is a certification that only takes into account energy efficiency.

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