Renovation of ventilation in apartment buildings – Estonian experience

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Introduction

This study discusses Estonian experiences in renovating the ventilation systems of old apartment buildings. Most commonly used ventilation renovation measures have been single room ventilation units (SERU), ventilation radiators with exhaust heat pump (EAHP) and central heat recovery ventilation (CHR) with ductwork installation on the façade. The paper is based on the ventilation performance analyses of long-term field studies during two different grant schemes. The technical conditions of the support grant and the correct ventilation renovation measures to guarantee necessary air change rate are presented.

Old apartment buildings in Estonia were originally built without mechanical ventilation systems. Ventilation shafts were used for extract air. Lower apartment buildings (up to 5–6 floors) had a separate ventilation shaft for every apartment. Higher apartment buildings (more than 9 floors) had a separate ventilation shaft only for apartments in the two upper floors. Supply air intake was designed from air leakages, mostly through the windows.

The systematic research and renovation of apartment buildings started at the beginning on 1990s. Several typical renovation solutions were developed and pilot renovations were conducted. Renovation of apartment buildings during 1990 – 2000's was based mainly on end-user's cost efficiency principle. Insulation of end-walls, changing of windows, balancing of heating systems were the first typical renovation measures. In many cases, the renovation of ventilation was left undone, which resulted in worsened indoor climate. Soon it was realized that financial support for renovation works will be required to make the inhabitants understand the importance of a better indoor climate and make the decision to install a proper ventilation system even though it might seem costly at first sight.

Typical solutions for additional insulation of building envelop and renovation of ventilation have been developed for different types of buildings (Kalamees et al., 2016). Estonian requirements set by renovation grant schemes and cross-sectional measurements were used in the study. This study also analyses how requirements on ventilation influences achievement of ventilation airflow after renovation. Lessons learned from Estonian experiences can be used to make decisions in building renovation strategies and funding programs in other countries.

Requirements, support and practice of renovation of apartment buildings in Estonia

During the period of 2010 – 2014, a total of 663 apartment buildings underwent renovation work in Estonia under the umbrella of a financial support handled by Fund KredEx and during 2014 – 2017, a total of 460 additional apartment buildings followed (Kuusk and Kalamees, 2016). Renovation support depended on achieved energy performance class (EPC) based on primary energy (PE) use (**Table 1**). Pikas et al. (2015) showed that renovation support was useful to Estonian economy as 17 jobs per 1 M€ of investment in renovation were generated per year and direct tax revenue was between 32 – 33%, depending on the renovation project.

Requirements on ventilation have been varied. Before state financial support there were no specific requirements on renovation of ventilation. Fresh air inlets were installed into new windows or in the external walls in some cases. With the creation of financial support, the state also set requirements on renovation solution's indoor climate and performance of ventilation, **Table 1**. During the first grant period (2010 – 2014), there was a requirement to ensure the airflows according to the standard EN-15251 (2007) ICC II requirements. In second grand period the air change rates in apartments had been calculated according to the principles shown in **Table 1**. There were also some additional requirements, see **Table 1**.

After the renovation, ventilation airflow was measured with anemometer and by tracer gas (human CO_2 production) in at least 3 – 4 apartments of selected buildings (altogether 120 apartments). Indoor air CO_2 concentrations, temperature, relative humidity, supply air temperatures and sound pressure levels were also measured.

Experience with installed ventilation systems

These are the main four types of ventilation systems that have been installed during renovation of Estonian apartment buildings (**Table 2**):

- Centralized balanced ventilation with ventilation heat recovery (CHR);
- Exhaust ventilation with heat pump (EAHP);
- Renovating the old natural ventilation systems (without heat recovery) (NV);
- Room based supply/exhaust room units with ventilation heat recovery (SERU).

Table 1. *Overview of financial support and requirements on energy performance, indoor climate and ventilation of renovating Estonian apartment buildings using the state support.*

Time period		Requirements on energy performance
2010 – 2014	**Financial support:** 15%, 25%, 35% depending on renovation solution **Requirements on indoor climate and ventilation:** Indoor climate according to EN-15251 (2007) ICC II requirements	**Requirements on energy performance:** • 15% support: heating energy reduction ≥ 20% (<2000 m²) and ≥ 30% (>2000 m²), PE ≤ 250 kWh/(m²·a); • 25% support: heating energy reduction ≥ 40%, PE ≤ 200 kWh/(m²·a); • 35% support: heating energy reduction ≥ 50%, PE ≤ 150 kWh/(m²·a). **Typical ventilation renovation measure:** • Fresh air inlets to natural ventilation • Single room supply-exhaust ventilation units • Exhaust ventilation with/without exhaust air heat pump • Central heat recovery ventilation
2014 – 2018	**Financial support:** 15%, 25%, 40% depending on renovation solution **Requirements on indoor climate and ventilation:** Indoor climate according to EN-15251 (2007) ICC II requirements	**Requirements on energy performance:** • 15% support: PE ≤ 220 kWh/(m²·a); • 25% support: PE ≤ 180 kWh/(m²·a); • 40% support: PE ≤ 150 kWh/(m²·a). **Typical ventilation renovation measure:** • Ventilation radiators with exhaust air heat pump • Central heat recovery ventilation with ductwork installation on the facade

Performance analyses have shown that the best ventilation renovation measure for old apartment buildings is CHR with ductwork installation on the façade. Ventilation unit of this system is put on the roof or in the attic, see **Figure 1a**. Flat or round shaped supply ducts are installed inside the additional insulation of external walls (**Figure 2**) and roof (**Figure 1b**). Old ventilation shafts are used to extract the air from apartments. As the air tightness of old ventilation shafts is often low, new ventilation ducts should always be installed inside the old shafts. The fresh supply air is given to the living rooms and bedrooms and polluted air is extracted from

Table 2. *Ventilation airflow rate calculation according to the II grant requirements, 2014 – 2018.*

Apartment type	Floor area	Extract airflow rate, l/s				Supply airflow rate, l/s					Air change
	m^2	WC	Bathr.	Kitch.	Total	Living	Bed1	Bed2	Bed3	Total	h^{-1}
Single room	35	-	10	6	16	10	-	-	-	10	0.63
1 bedrooms	55	-	15	8	23	10	10	-	-	20	0.58
2 bedrooms	70	10	15	8	33	10	10	10	-	30	0.65
3 bedrooms	80	10	15	8	33	10	10	10	10	40	0.69

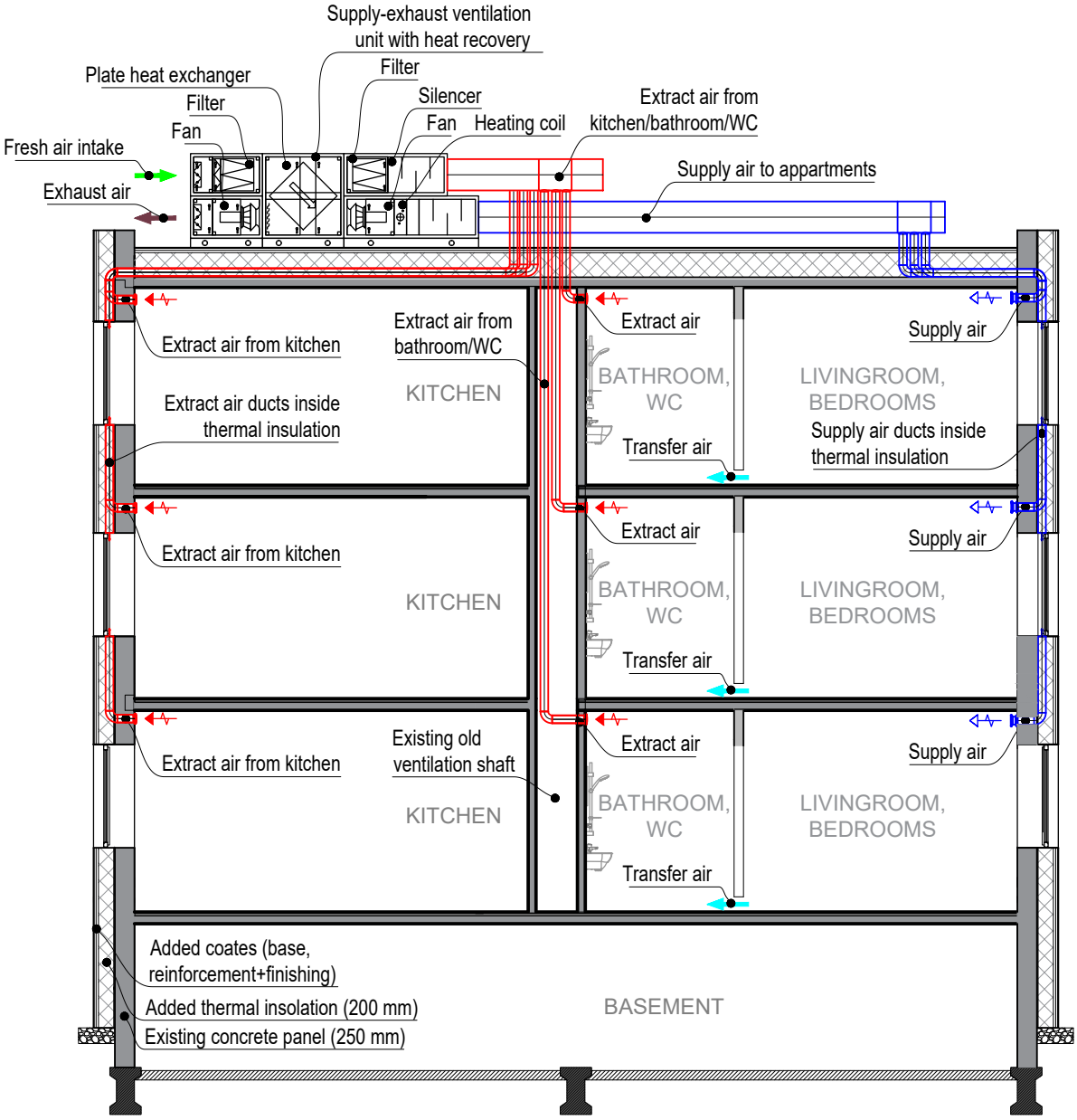

Figure 1a. Working principle of centralized balanced ventilation with heat recovery system (CHR).

toilets, bathrooms and kitchens. Installing ventilation ducts inside the additional insulation layer helps to avoid the visible ducts inside the apartments. The supply air grilles are installed on the external wall of the living room and bedroom and extract air valves are on the wall near the ventilation shafts. This technical solution means that the volume of the ventilation work inside the apartment is minimal and it does not disturb people much.

Ventilation ducts on the roof should be installed inside the insulation layer of roof or should be covered with a separate insulation layer. To ensure high heat recovery efficiency and avoid spreading of odours, the counter flow plate heat exchanger is commonly used. According to the requirements of the support grant, a water-based heating coil should be used to reheat the supply air. The detailed working principle of the CHR with ductwork installation on the façade is shown in **Figures 1a**, **1b** and **2**.

Exhaust ventilation with heat pump heat recovery and ventilation radiators has also been actively used

Figure 2. Supply ventilation ducts in additional insulation of external wall.

(40%) in renovation of apartment buildings. During the first grant period, the fresh air inlets were used for supply air, but due to people complaining about the cold draught, the requirement to preheat the supply air was added in the conditions of the second grant. To preheat the air, ventilation radiator system is used. The supply air enters through ventilation radiators where it is filtered and heated at the same time. Extract air moves through ventilation shafts to air to water heat exchanger of ventilation unit where the heat is transferred through a brine loop to water to water heat pump. The heat pump provides heat to the domestic hot water and space heating system. The annual average coefficient of performance (SCOP) is 3.0 – 3.5. The main problem of this renovation solution is using old natural ventilation shafts without inserting new ducts inside the old shafts. The air tightness of old shafts is too low and therefore, the ventilation systems are often unbalanced and very noisy. That, in turn, means that the air flow

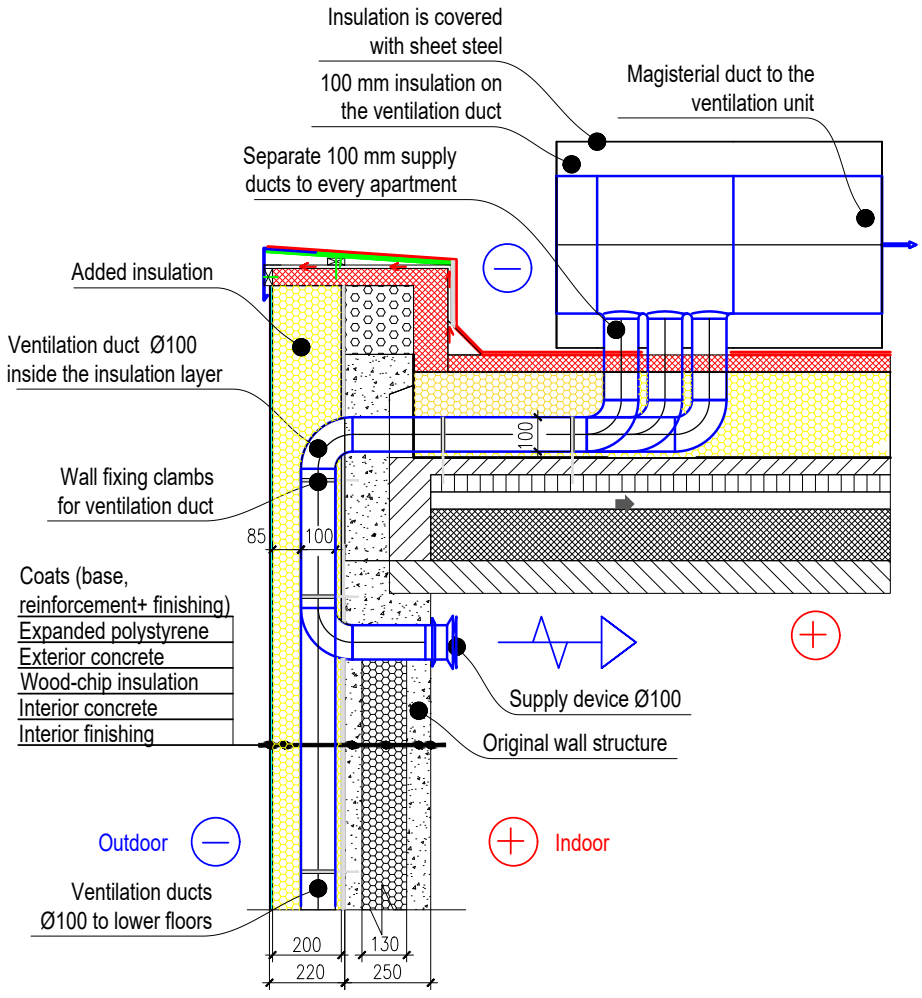

Figure 1b. A section of CHR system with ventilation ducts inside the building façade.

rates are reduced. The main principle of EAHP system is described in **Figure 3**.

Single room-based supply/exhaust room units with ventilation heat recovery (see **Figure 4** left) have also been used for ventilation renovation during first grant period. Mainly the SERU with regenerative ceramic heat exchanger was used. The single-fan-based units work in cycles, switching between supply and exhaust mode in every 60 – 70 seconds. During the exhaust

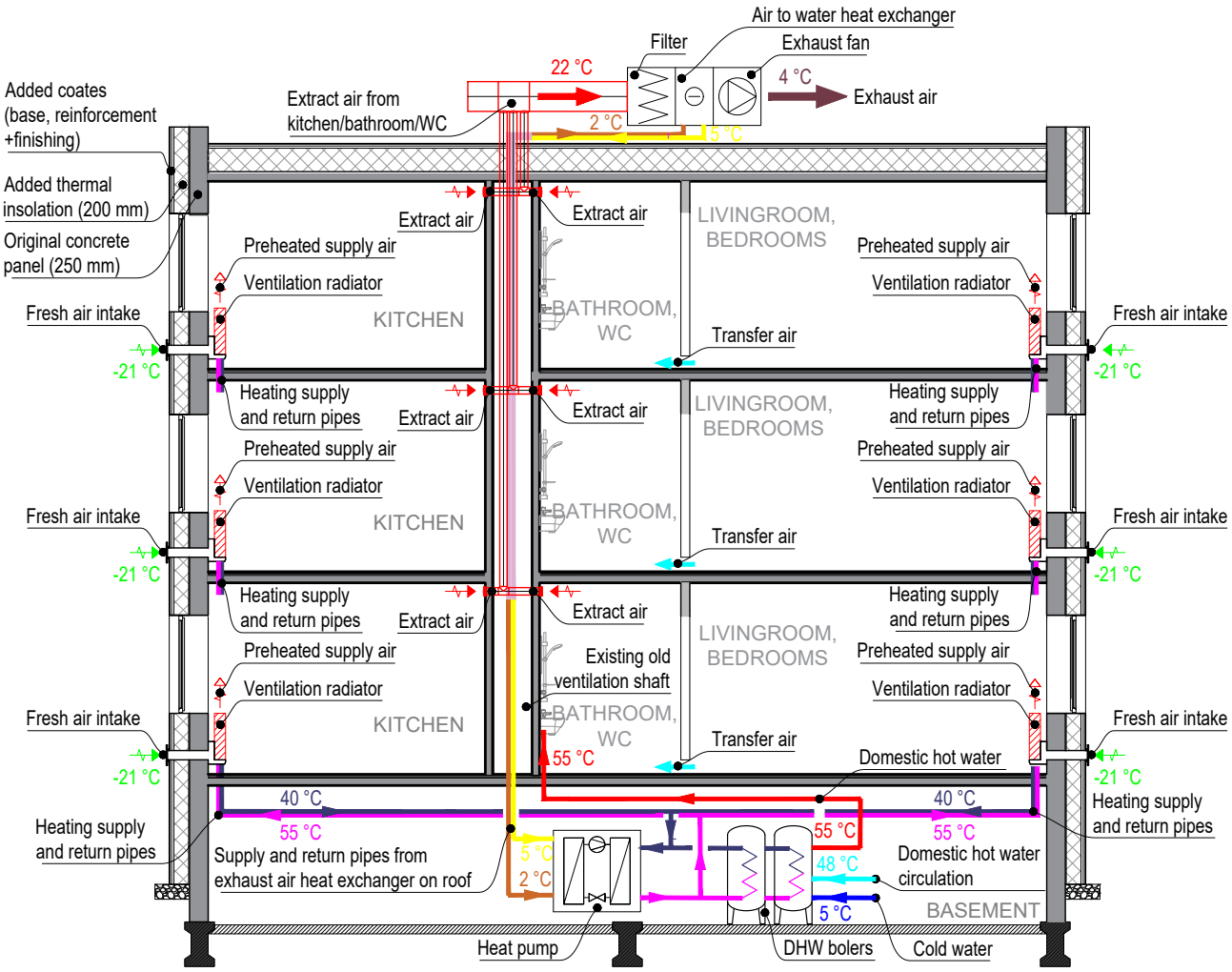

Figure 3. Ventilation radiators with exhaust heat pump heat recovery.

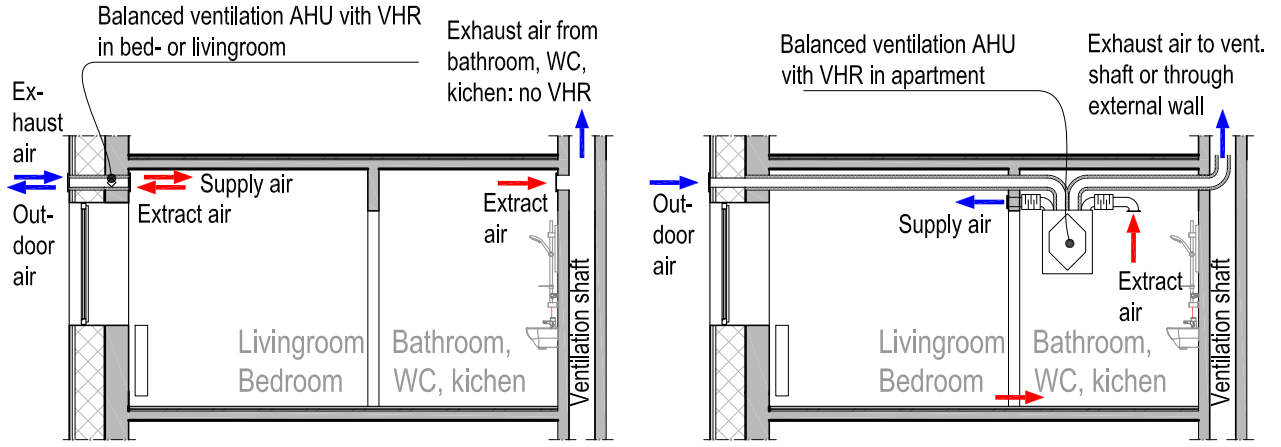

Figure 4. Room based supply/exhaust room units with ventilation heat recovery (left) and apartment based balanced ventilation with ventilation heat recovery (right).

cycle heat from the warm exhaust air is accumulated in the ceramic comb-like heat exchanger and is then used to heat up cold outdoor air during the supply cycle. The field measurements have shown that this system does not ensure sufficient air change rate and efficient heat recovery (Mikola et al., 2016, 2019). The main problem is related to the large negative pressure in the lower floor apartments. The fans used in SERUs are not capable of working in typical pressure conditions occurring in multi-story buildings in cold periods (Mikola et al., 2019). Since the results of using SERUs as a ventilation renovation measure were disappointing, this solution is no longer being used.

Apartment based balanced ventilation with ventilation heat recovery has also been used (see **Figure 4** right). The ventilation unit of this system is installed to staircases, corridors or sanitary rooms, under the ceiling or on the wall. Plate or rotary heat exchanger is used in ventilation unit. The air is extracted from kitchen hoods, toilets and bathrooms. Supply air devices are installed in living rooms and bedrooms. Since installing this system to apartment requires space and construction work in apartment, it is used very rarely (≈ 1%). The use of apartment based balanced ventilation is still so small, that it is not possible to make any conclusions about its use in renovation of apartment buildings. Still, this solution is actively used in renovation of detached houses in Estonia.

The air flow has been measured before renovations and during both grant periods (see **Figure 5**). The average air change rate before renovations was 0.24 h^{-1} (Mikola et al., 2017). During the first grant period, the average air change rate was 0.16 h^{-1} for renovated natural ventilation (NV), 0.18 h^{-1} for single room ventilation units (SERU), 0.20 h^{-1} for mechanical exhaust ventilation with exhaust air heat pump heat recovery (EAHP) and 0.57 h^{-1} for centralized balanced ventilation with heat recovery (CHR). During the second grant period the average air change rate of mechanical exhaust ventilation with and without exhaust air heat pump heat recovery (EAHP) was 0.32 h^{-1} and for centralized balanced ventilation with heat recovery (CHR) 0.73 h^{-1}.

Comparing the performance of different ventilation renovation measures during two grant periods, we can see that the air change rate of EAHP and CHR systems have significantly improved. The main reasons for better performance of these measures were more strict requirements for air flows and sound levels, quality survey for design documentation and mandatory airflow measurement report. Renovating natural ventilation and using single rooms units did not ensure sufficient air change rate and were exclude from second grant support measures.

Conclusions

The centralized balanced ventilation with ventilation heat recovery ensured the necessary air change rate in renovated apartment buildings. This is the most widely used solution in renovation of up to five-storey apartment buildings in Estonia today.

Although the average air change rate of mechanical exhaust ventilation with heat pump heat recovery was lower than in the requirements, in some cases (mostly for tall buildings) this solution can be the only possible technical solution to provide the extract air heat recovery. We recommend this solution for buildings were the CHR cannot be technically used or where it is economically not viable.

The renovation of old, natural ventilation systems or using single room ventilation units cannot guarantee sufficient air change rate and acoustical quality, therefore, these ventilation renovation measures are not suitable.

Achievement of sound pressure levels ≤ 25 dB(A) was not a problem, when that target was considered already during design process.

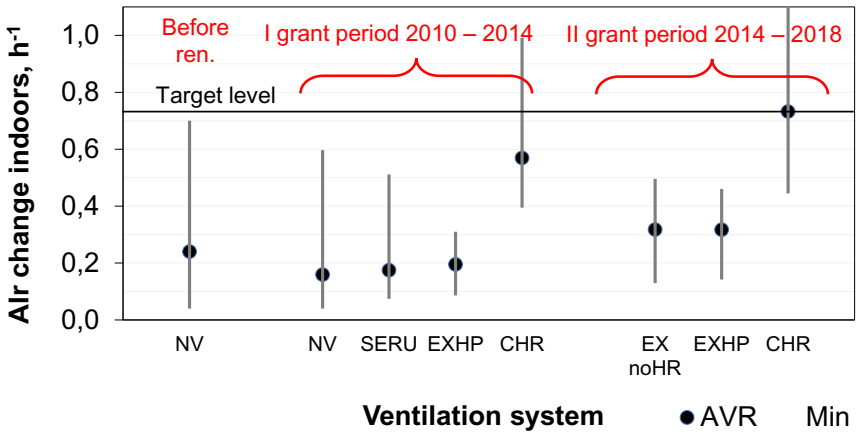

Figure 5. Average ventilation airflow in Estonian apartments before renovation (left) and after renovation during the two renovation grant period.

Only the general requirement to ensure indoor climate category II does not guarantee compliance. As a result, since the 2014, the requirements have been clarified and made more specific. A significantly better solution is:

- **to specify** the calculation methods of airflow rates and ventilation noise levels in the regulations,
- **to ensure** the project undergoes an expert review to verify that the design solution meets the conditions,
- **to require** the airflows to be measured at the end of the renovation.

It is important to have clear and unambiguous requirements and to require control and verification of the result achieved. ■

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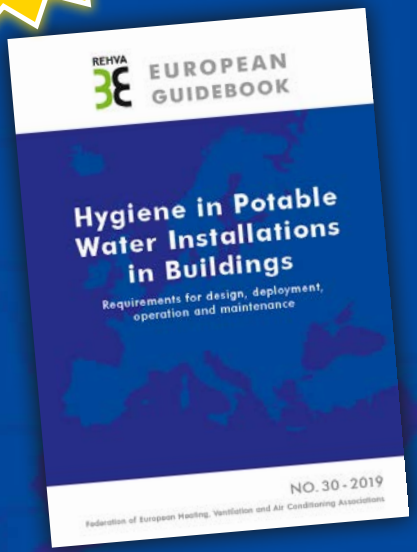

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