Ventilation requirements and results in renovation of Estonian apartment buildings with KredEx scheme

JAREK KURNITSKI
Tallinn University of Technology
jarek.kurnitski@taltech.ee

ALO MIKOLA
Tallinn University of Technology

Renovation grants for deep renovation of apartment buildings have been available in Estonia since 2010. Lessons learnt from the first years helped to develop ventilation requirements and solutions which have led to common application of heat recovery ventilation so that required airflows have been achieved both in commissioning and in operation.

Keywords: Ventilation requirements, deep renovation, renovation grants, apartment buildings, air flow rates, commissioning, heat recovery ventilation, ventilation radiator

When Estonia implemented the first renovation grant scheme 2010-2014 many mistakes have also been made making this experience valuable. It is not a surprise that the lack of ventilation was a major problem at the beginning because the renovation of building fabric stops natural ventilation. It was required in the technical conditions of the renovation grant that EN 16798-1 (EN 15251:2007 at that time) indoor climate category II had to be followed, but ventilation rates were not specified. Commissioning requirement to measure airflow rates was not specified either. This led to the use of a wide variety of ventilation solutions including natural ventilation, single room ventilation units and heat recovery ventilation.

HRV ventilation unit on the roof

Measured air change rates in renovated apartment buildings illustrate the problems at that time, **Figure 1**.

Single room ventilation units (SRVU) and natural ventilation (NV) provided so low air change rate that it may pose a health risk for occupants, and is insufficient for humidity removal and may lead to mould problems. With exhaust heat pump (EAHP) and centralised balanced heat recovery ventilation (HRV) systems, the situation was more complicated. Airflow rate measurement reports available from most of buildings showed that in the commissioning phase these ventilation systems met the design airflow rates. Measurements conducted about one year later show that the airflow rates were reduced in operation that may be due to cold draught or energy saving considerations.

New ventilation requirements from 2015

To ensure adequate ventilation in renovated dwellings, KredEx renovation grant technical conditions require since 2015 that ventilation systems should either be sized according to EN 16798-1:2019 indoor climate category II or with room-based supply and extract air flow rate design values shown in **Table 1**. Supply air flow rate design value is 10 ℓ/s in living rooms and bedrooms. Extract air flow rate design values are 10 ℓ/s in WC, 15 ℓ/s in bathrooms (10 ℓ/s in small apartments) and 8 ℓ/s in kitchens (6 ℓ/s in small apartments). To balance the air flows, supply airflow rates in small apartments and extract airflow rates in large apartments are to be increased, which is marked with "+" in **Table 1**. In kitchens, only general ventilation was required. Additional boost from cooker hoods has not been required, because it might need ducting and remodelling of existing kitchens furniture that is not wanted by occupants.

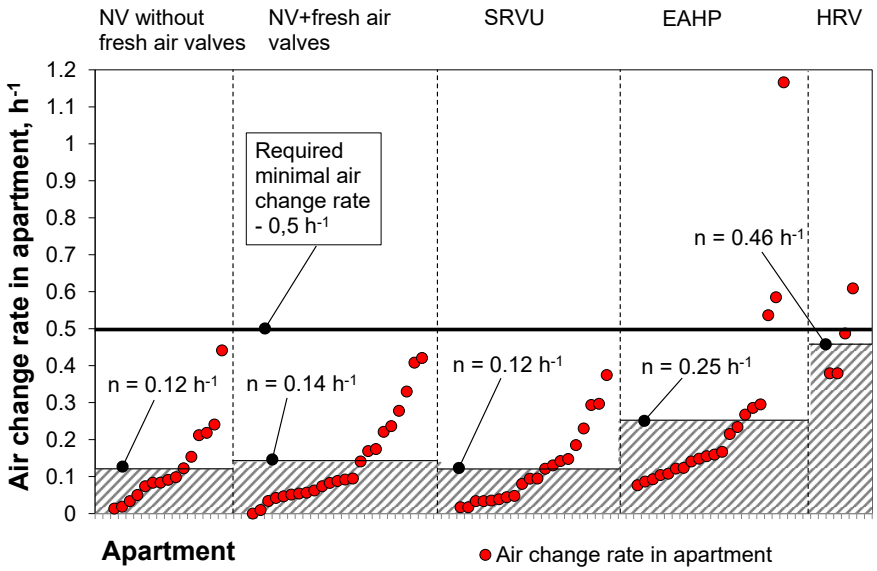

Figure 1. Air change rates measured in apartments renovated 2010-2014. Measurements made after operation for about one year after handing over (Mikola et al. 2022).

Table 1. *Ventilation supply and extract airflow rate requirements applied for ventilation sizing in model dwellings. ACR is the air change rate of the whole dwelling.*

Apartment type	Floor area, m^2	Extract airflow rate, ℓ/s				Supply airflow rate, ℓ/s					ACR
		WC	Bathroom	Kitchen	Total	Living	Bed1	Bed2	Bed3	Total	h^{-1}
Single room	35	-	10	6	**16**	10+6[1]	-	-	-	**16**	0.63
1 bedroom	55	-	15	8	**23**	10+2[1]	10+1[1]	-	-	**23**	0.58
2 bedrooms	70	10	15	8	**33**	10+2[1]	10+1[1]	10	-	**33**	0.65
3 bedrooms	80	10+2[1]	15+1[1]	8+4[1]	**40**	10	10	10	10	**40**	0.69

[1] values marked with "+" indicate the addition to balance airflows

These new ventilation requirements made it impossible to use natural ventilation and single room ventilation units (SRVU), so these ventilation solutions were practically banned and have not been used after 2015 with KredEx renovation grants. Airflow measurement reports were made mandatory and this together with new ventilation requirements changed the situation radically. Ventilation rates measured in buildings renovated after 2015 are shown in **Figure 2**. In centralized balanced heat recovery ventilation (HRV) in most of the buildings ventilation rates have not been reduced during operation and meet the requirements. In mechanical exhaust ventilation, the airflow rates were achieved in the commissioning according to airflow rate measurement reports, but still have been slightly reduced during operation. It is suspected that this is due to energy saving considerations as housing associations do not understand the operating principle of EAHP where airflow reduction will also reduce the heat source.

Room based ventilation rates were reasonably well met with HRV ventilation where extract airflow rates mostly met the requirements in operation and supply air flow rates were close to the requirement, **Figure 3**.

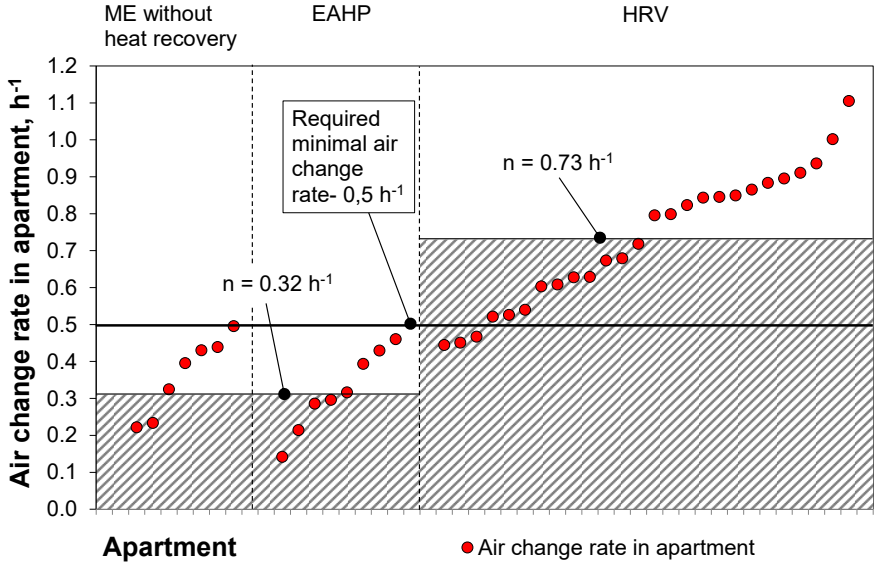

Figure 2. Air change rates measured in apartments renovated after 2015, with new ventilation requirements, in operation about one year after handing over.

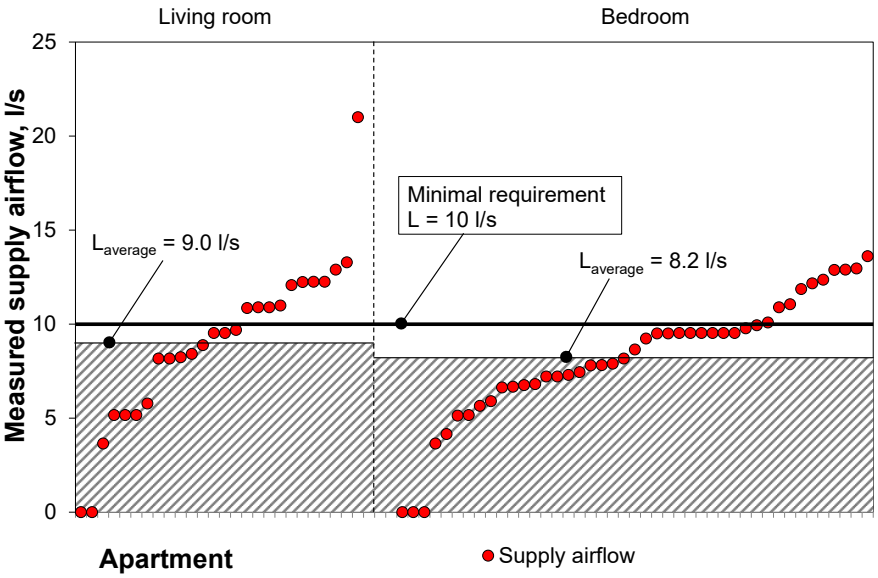

Figure 3. Supply air flow rates measured in bedrooms and living rooms in operation. In five apartments, supply terminals were almost closed or sealed with tape by occupants.

Ventilation systems used from 2015

There are two ventilation solutions that fulfil KredEx requirements for airflow rates and heat recovery and are widely used in practice:

- centralized mechanical supply and exhaust ventilation (balanced ventilation) with heat recovery (HRV);
- mechanical exhaust ventilation with exhaust air heat pump (EAHP) and ventilation radiators.

In HRV, additional insulation of 200 mm allows to install new supply air ductwork on the façade. Heat recovery efficiency is typically ≥ 80% and air handling unit SFP < 1.8 kW/m³/s. Sound attenuation is easy in centralized HRV and there is practically no draught because of heated supply air. The ventilation unit of this system is installed on the roof or in the attic as shown in **Figures 4-5**.

Flat plastic or round-shaped metal sheet supply ducts are installed inside the additional insulation of the external walls and roof. Old ventilation stacks are used to extract air from apartments. Because the air tightness of the stacks is often low, new ventilation ducts are recommended to be installed inside the old stacks. In some cases, exhaust air ductwork has been installed on the façade in a similar fashion to that of the supply air ductwork. The supply air is ducted to the living rooms, and the bedrooms and extracts are from toilets, bathrooms, and kitchens. Installing ventilation ducts inside the additional insulation layer helps to avoid visible ducts inside the apartments. The supply air diffusers are installed on the external wall of the living room and bedroom, and the extract air valves are placed in kitchen, bathroom and toilet. The volume of ventilation installation work inside the apartment

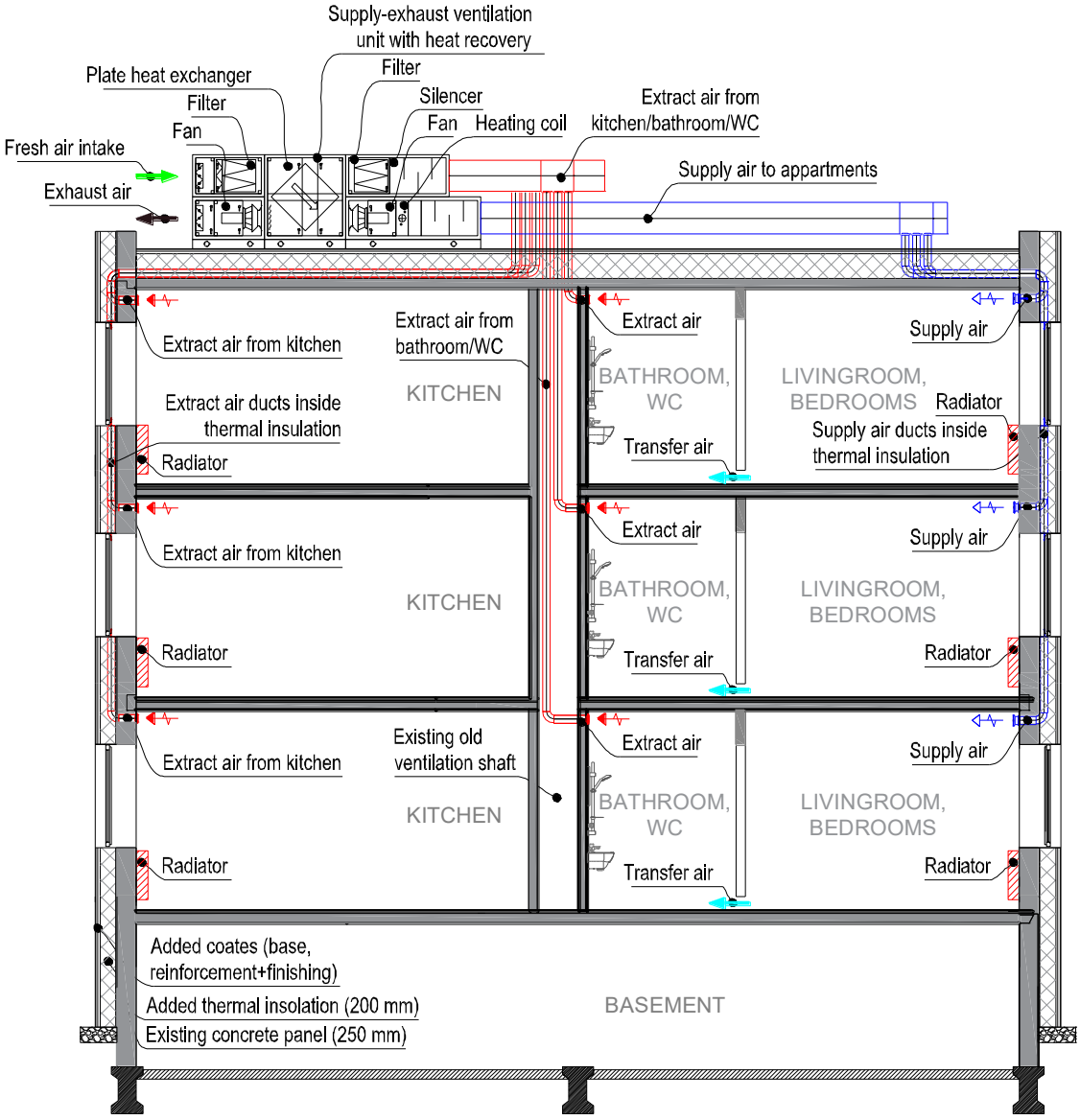

Figure 4. Working principle of centralized HRV renovation solution.

is minimal and does not disturb occupants if properly organised. In AHU, water-based reheating coil after heat recovery to reheat the supply air are used. Frost protection is an important issue, for which preheating coils are not allowed but sectional defrosting with adequate controls is typically used.

Another popular ventilation solution is based on exhaust air heat pump (EAHP) that can be added to any centralized mechanical exhaust ventilation system. Energy analyses conducted with German, Italian and Estonian climate (Kuusk et al. 2020) have shown that EAHP has superior heat recovery performance over HRV in Central European and warmer climates. In this system, it is important to pay attention to adequate intake air solution, because simple air inlets are sensitive to outdoor noise, generate cold draught and have typically poor filtration. KredEx requires to use hydronic ventilation radiators for intake air, which are like common radiators, but have an air intake section with filter (typically ePM1 60% (F7) efficiency) and heat up intake air practically to room temperature. Ventilation radiators are not sensitive to freezing, even if thermostats are closed, that has been demonstrated by laboratory experiments and by wide use in cold climates. Extract air is collected on the roof to an air to brine heat exchanger of the ventilation exhaust unit, where the heat is transferred through a brine loop, to a brine to water heat pump. The heat pump provides heat to space heating and to domestic hot water. The seasonal coefficient of performance (SCOP) is 3.0 – 4.0 depending on the connection scheme and heating curve. The main problem of this renovation solution has been using old natural ventilation stacks without inserting new ducts inside the old stacks. Low airtightness of old stacks may lead to unbalanced air flow rates and noise problems. The main principle of EAHP system is shown in **Figure 6**.

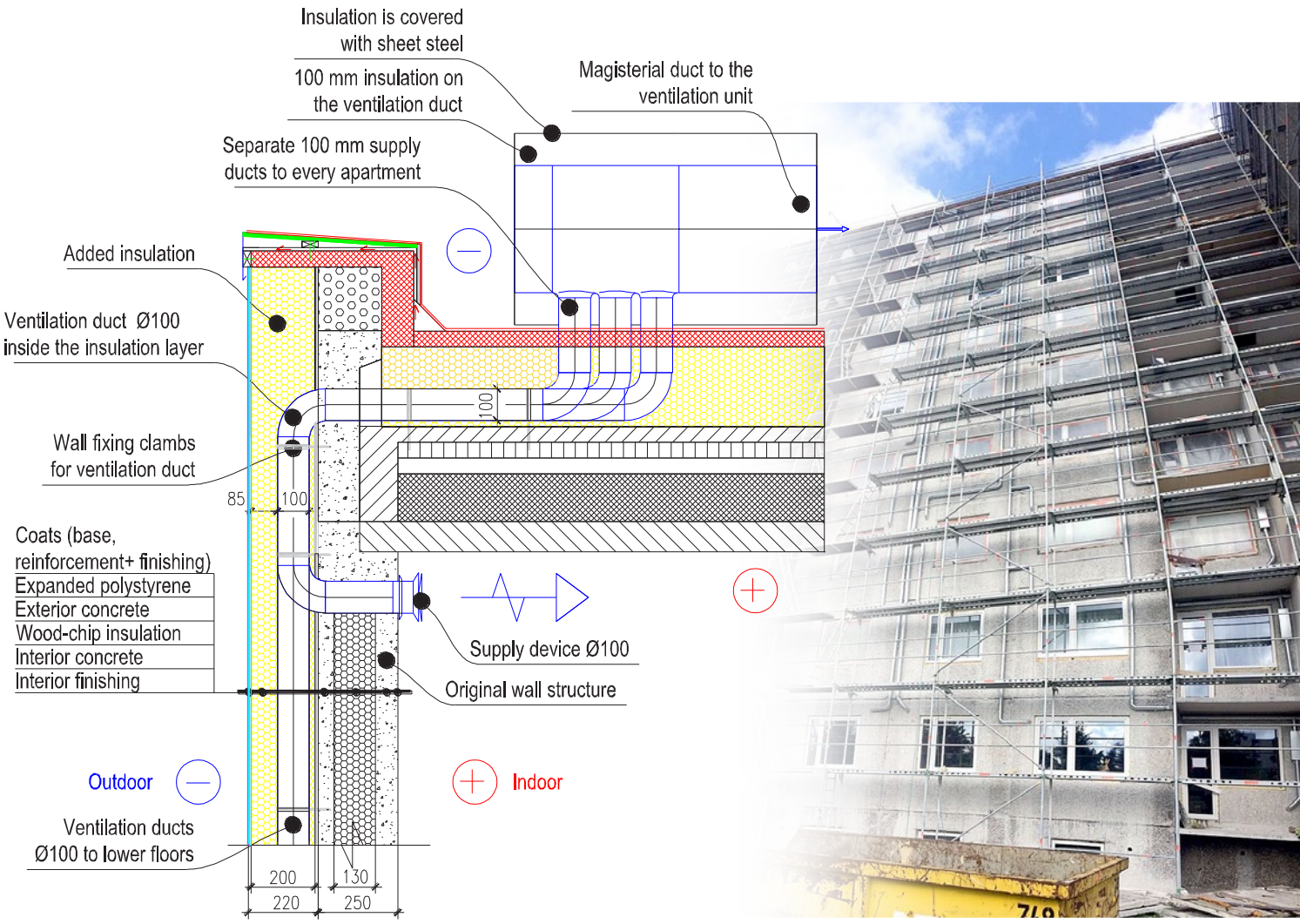

Figure 5. Ventilation ductwork installation on the wall.

There are many possible connection schemes for EAHP; operation with space heating priority has been preferred to maximise the cooling of district heating return. A schematic connection is shown in **Figure** 7.

Conclusions

Estonian renovation experience shows that it is possible to achieve heating energy savings up to 70% together with good indoor climate while adequate heat recovery ventilation solutions are used. In renovation the extent of the installation work needed inside apartments has been critical. Strict ventilation requirements with room-based airflow rates were necessary to mainstream heat recovery ventilation solutions in practice. Both centralized mechanical supply and exhaust ventilation and mechanical exhaust ventilation with exhaust air heat pump and ventilation radiators have been used as standard solutions since 2015. It was also necessary to develop model design drawings and to make ventilation airflow measurement reports mandatory to push towards following the new requirements.

Economic analyses have shown that the grants given by the government are budget neutral, because of average tax return of 32% from renovation projects (Pikas et al. 2015). Renovation has a positive reputation and is seen

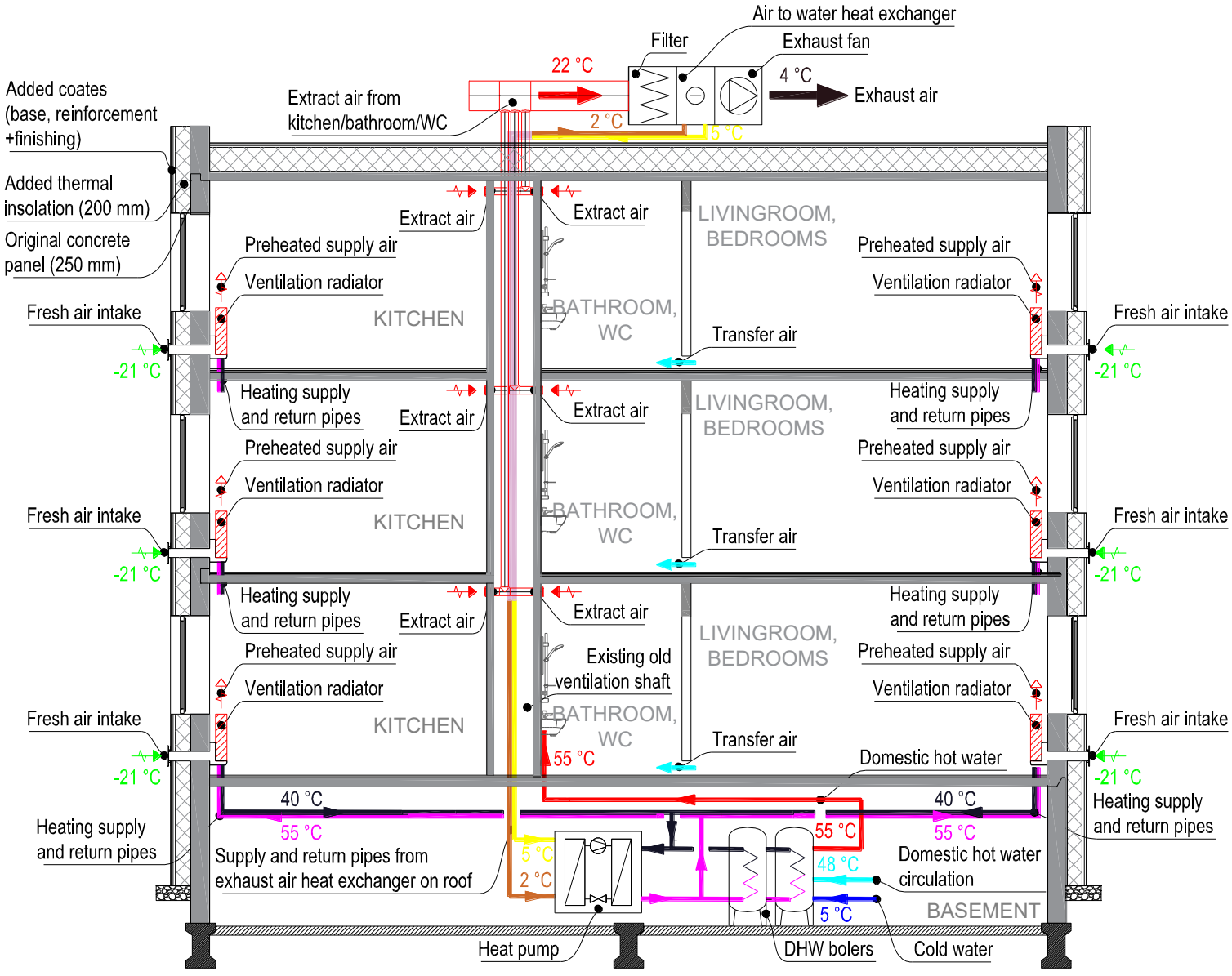

Figure 6. Ventilation radiators with exhaust heat pump heat recovery.

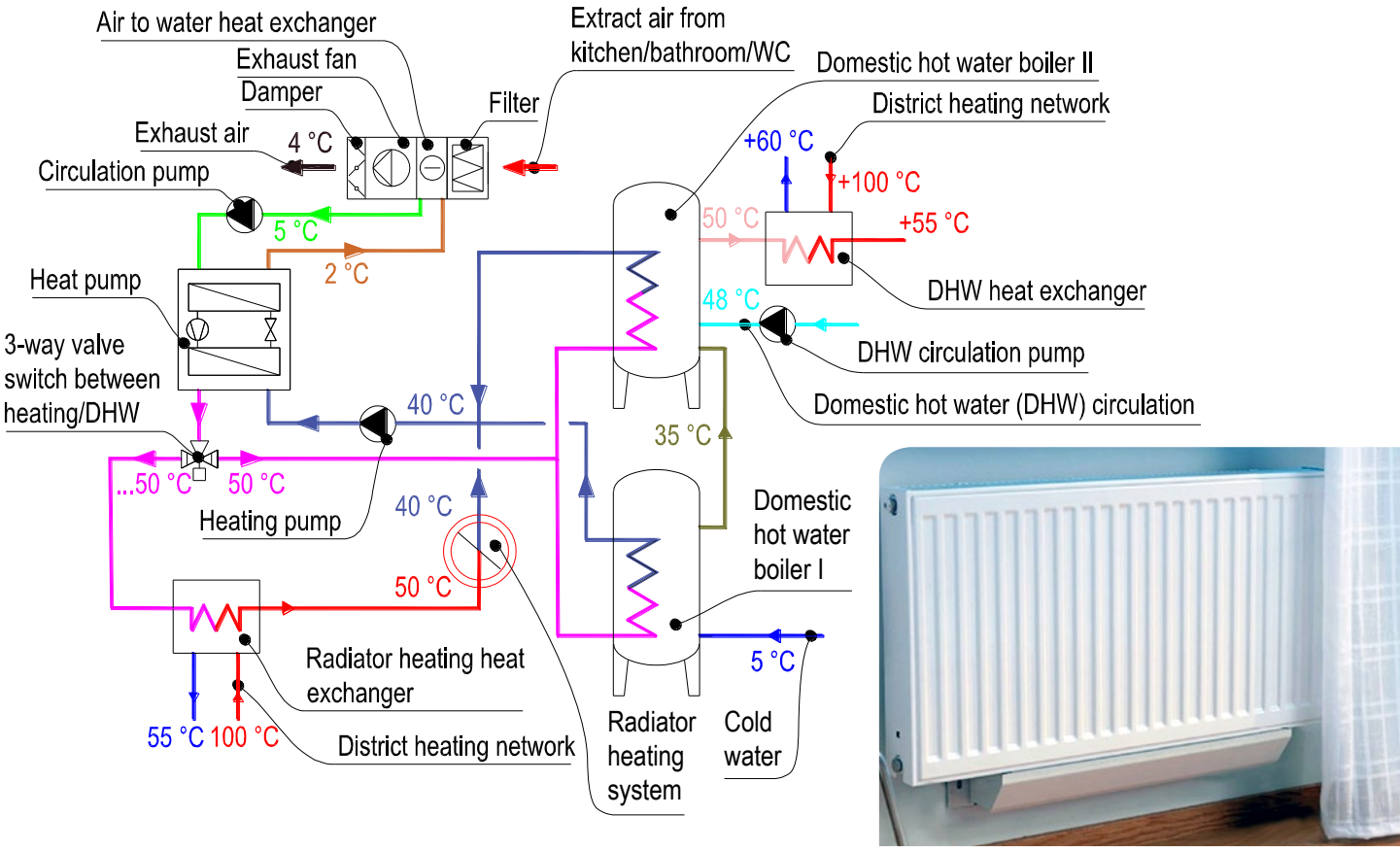

Figure 7. Exhaust air heat pump connection scheme and ventilation radiator.

beneficial for homeowners through improved indoor climate and general condition of the property, and increased real estate value. To date, about 3 000 apartment buildings are renovated, and it is planned to renovate all the rest of apartment buildings constructed before 2000, all together 14 000 buildings, by 2050 according to the Estonian long term renovation strategy. Typically, the renovation grant provides 30% financial support of the total renovation cost in large cities and 40-50% in periphery. ■

References

Mikola, A.; Hamburg, A.; Kuusk, K.; Kalamees, T.; Voll, H.; Kurnitski, J. The impact of the technical requirements of the renovation grant on the ventilation and indoor air quality in apartment buildings. Building and Environment, 2022, 210, #108698. https://doi.org/10.1016/j.buildenv.2021.108698.

EN 16798-1:2019 Energy performance of buildings - Ventilation for build-ings - Part 1: Indoor environmental input parameters for design and as-sessment of energy performance of buildings addressing indoor air quality, thermal environment, light. CEN 2019.

Kuusk, K.; Naumann, J.; Gritzki, A.; Felsmann, C.; De Carli, M.; Tonon, M.; Kurnitski, J. Nearly zero energy renovation concepts for apartment buildings. E3S Web of Conferences 172, 18009 (2020) https://doi.org/10.1051/e3sconf/202017218009.

Pikas, E.; Kurnitski, J.; Liias, R.; Thalfeldt, M. Quantification of economic benefits of renovation of apartment buildings as a basis for cost optimal 2030 energy efficiency strategies. Energy and Buildings 86 (2015) 151–160 https://doi.org/10.1016/j.enbuild.2014.10.004.