Deep energy renovation, the effect of airtightness and heat recovery in renovation projects

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Introduction

Both discussions and published articles often talk about the need to improve a building's thermal insulation. It is often thought that thermal insulation, new windows and exterior doors are key to the energy efficiency solution of renovation construction. However, it is not that simple. Improving the U-values of the building envelope is only one part in the pursuit of energy efficiency. Something that is not given enough attention is the building's airtightness and heat recovery. It has significant impact on both energy efficiency and the functionality of the building.

Making technical improvements, such as choosing the right heat generation, hydraulic balancing of the heating network, resizing the radiators to new low system temperature conditions and selecting proper control devices are other key measures. On-site electricity production is also easy to install. Many buildings need cooling, but this is often not considered in renovation. In addition to these, a well-functioning ventilation system is essential, both for the residents' health and the condition of the building. Therefore, energy-efficient renovation package is technically demanding and must be planned and implemented professionally. All areas must function as planned. There are too many failed renovated apartment and single-family buildings, where goals have not been achieved and sometimes a mouldy, "sick building" has resulted in exchange for high costs.

Energy balance of building

The following pictures show the energy flows of a Nordic residential apartment building as an example. The example building, **Figure 1**, is relatively energy efficient in an European scale for an old building and has good air tightness, EP value 160 kWh/(m²a), while the European average lies around 200 – 250 kWh/(m²a). The heating energy input of the sample building consists of space heating 40%, domestic hot water 20% and heat gain 40% including use of electric appliances, sun radiation and occupants. Heat losses mainly consist of ventilation exhaust air 30%, windows and doors 22%, sewage water 20%, walls 17%, roof 6% and soil 5%.

When the outer shell of the building in question is renovated, the windows are renewed and thermal insulation is added to the outer walls including under the roof and the building's energy flow ratios change, as shown in **Figure 2**. Despite the significantly improved U values, the building's EP value only improves by 28% to 115 kWh/(m^{2}a).

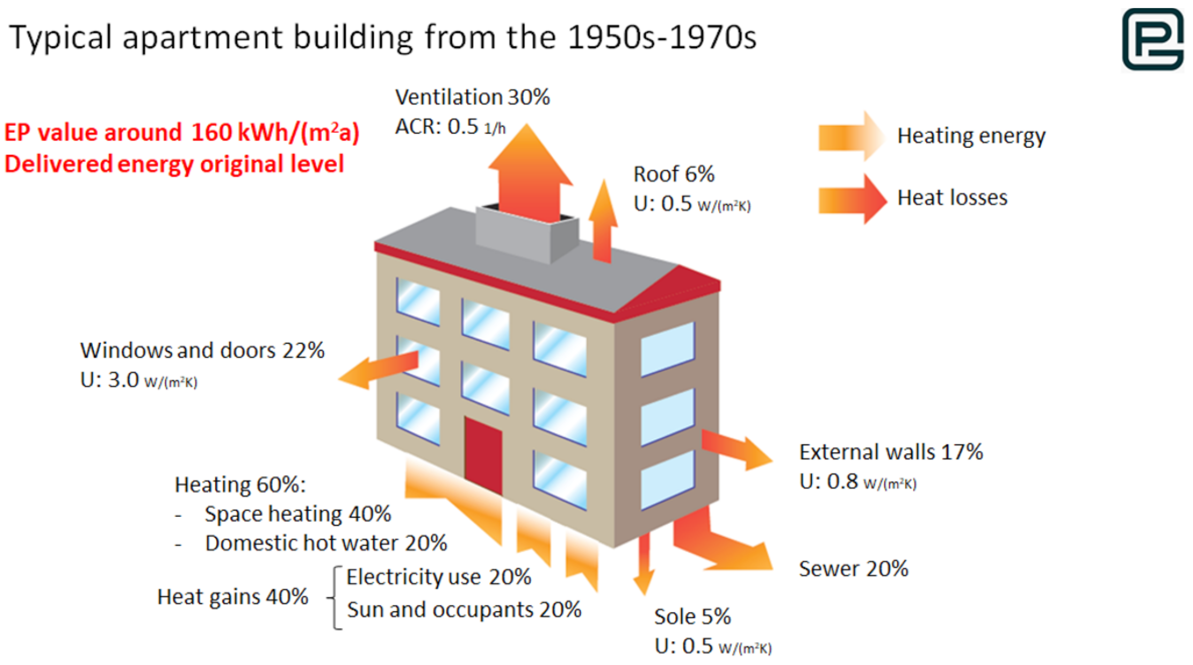

Figure 1. Example of energy balance of an apartment building before the renovation.

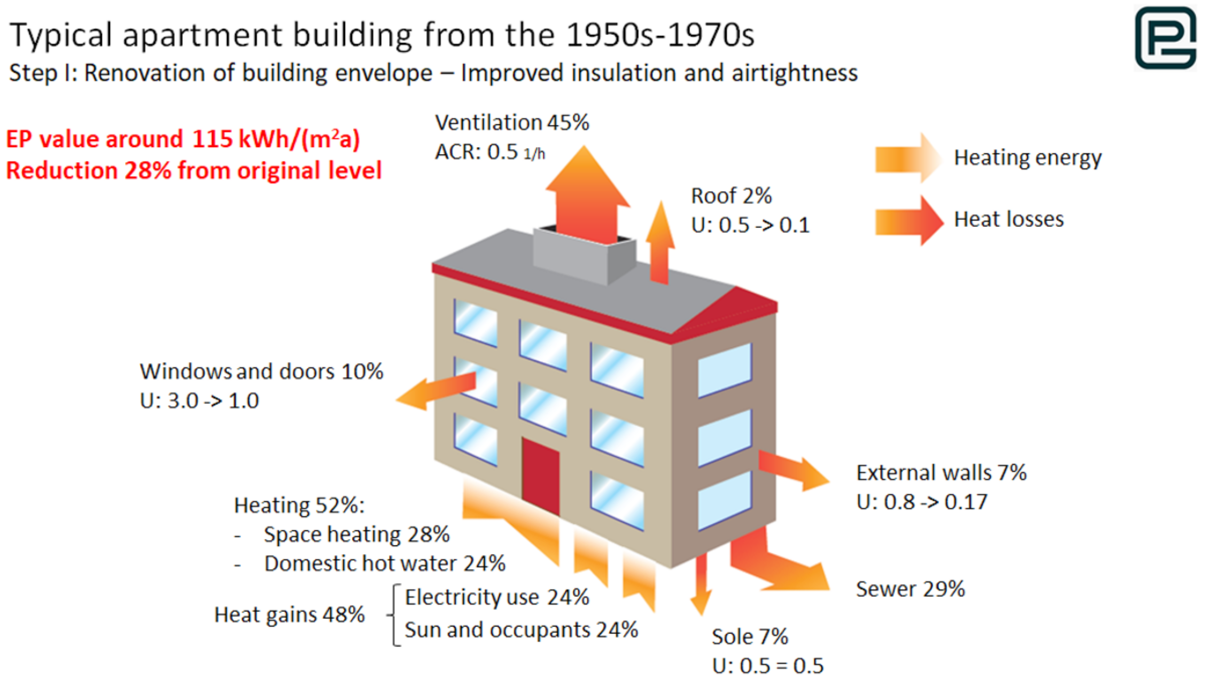

Figure 2. Improving the U values of the building's outer shell, windows, doors, walls and roof reduces heating energy consumption by only 28%.

These repairs are typically the most expensive part of a deep energy renovation and the benefit achieved is not sufficient. Observations indicate that in order to improve the energy efficiency at least by 50%, heat recovery is typically required from the ventilation exhaust air that forms the largest part of losses at 45%. Another important potential for heat recovery is sewage water which account for losses of 29%. Since the building in question was already airtight under the original conditions and underpressurized with mechanical exhaust ventilation, renovating the outer shell did not bring any additional benefits in infiltration/air leakage losses.

Airtightness

Often, the poor airtightness in old buildings and especially in single-family houses is a problem in more ways than one. In a Finnish building airtightness study, a wide dispersion came to the fore.

> *Air permeability q_{50} = How many cubic meters of air (m^3) flow through one square of the outer shell (m^2) per hour when the pressure difference is 50 pascals. The air permeability of a building is measured by the fan pressurization method, Blower door method. Infiltration airflow rate in m^3/h can be calculated as $q_{50} \cdot A/20$ where A is the building envelope area in m^2 including external floor.*

Air permeability q_{50} values in old detached houses, **Figure 3**, ranged from 0.5 to 12, with an average of 3.7 m^3/m^2h.

Apartment buildings are clearly more airtight than detached houses. For example, q_{50} values of new apartment buildings, with an average of 0.6 m^3/m^2h. **Figure 4**.

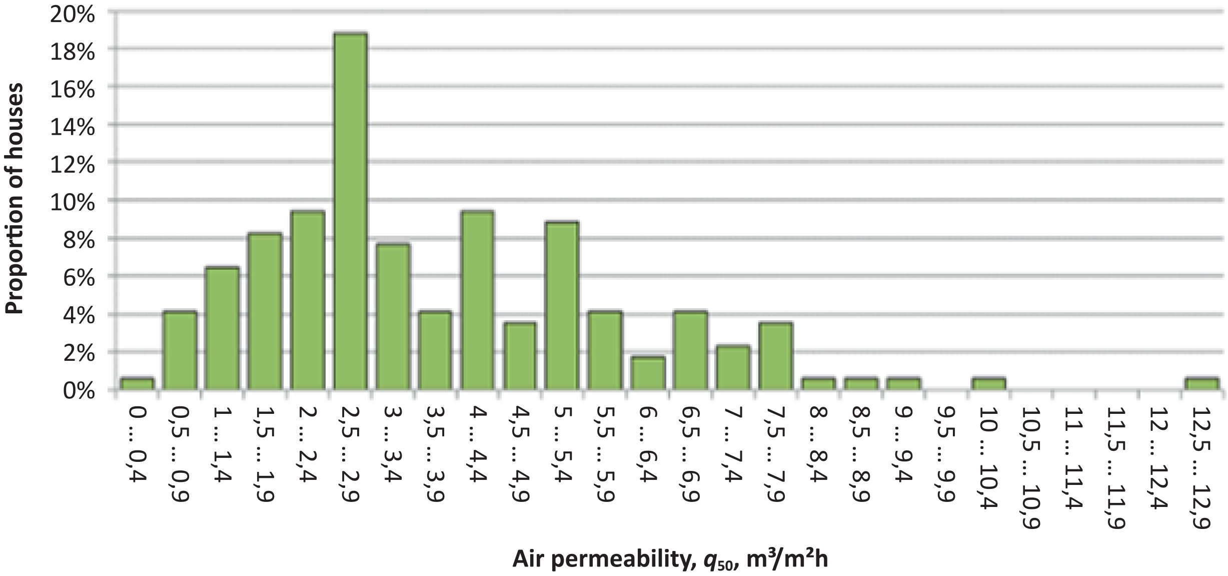

Figure 3. q_{50} values of old detached houses (1978-2006). (Vinha et al.)

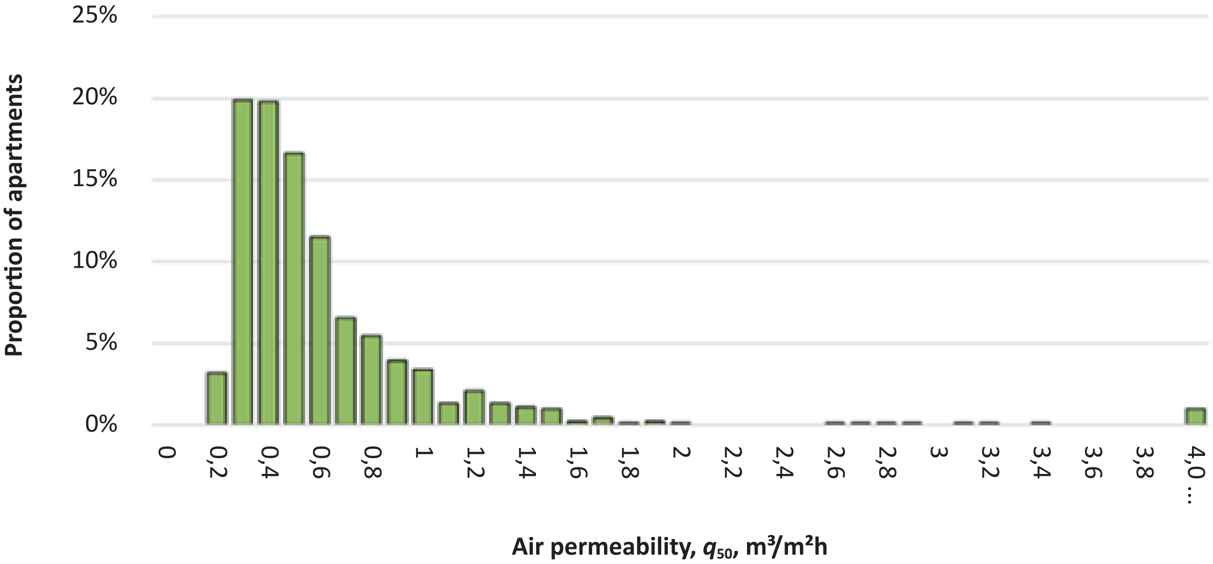

Figure 4. Airtightness values of new apartment buildings (2014-2018). (Vinha et al.)

Airtightness	Air permeability, q_{50}, m^3/m^2h	Infiltration losses, kWh/a	Cost per year, €, energy price 0.2 €/kWh	Costs in 20 years, €
Poor	8	5,200	1,040	20,800
Good	0.5	300	60	1,200

Figure 5. Airtightness has a significant impact on the energy costs of a typical detached house. Here, 0.20 €/kWh has been used as the price of heating energy. The difference can be up to €20,000 within 20 years.

If, for any reason, the thermal insulation of the exterior walls is not renewed during renovation, it is, for example, worthwhile improving the building's airtightness in any case. The energy benefits obtained in this way can be achieved at significantly lower costs. **Figure 5** compares the energy costs of two typical Finnish single-family houses due to infiltration losses.

Air leaks in buildings cause additional energy costs, moisture condensation in structures, draughts as well as dust, microbes and radon entering the indoor air. Leaks can be located by thermal imaging, probing by hand, air flow measurements, smoke testing, tracer-gas method or acoustic methods. For an energy-efficient house, the airtightness q_{50} target should be 1.0 m^3/m^2h or lower. This achieves an energy saving of about 20% compared to the airtightness q_{50} value of 4.0 m^3/m^2h. Typical leak points are insufficient seals on windows and doors, seams on windows and door frames, seams on exterior walls and roofs, wall penetrations for electrical cabling and ventilation duct penetrations in the walls and ceiling. Defects in the moisture barrier/foil also cause air leakage.

Condensation

A family of four produces 5–10 kilograms of water moisture in the air of the apartment. However, it does not all leave through ventilation, but tends to move through the structure in the direction of the outside air during winter. If the building envelope is not sufficiently air- and steam-tight (insulating film), the water humidity cools the insulating material and reaches the dew point temperature, whereupon the steam condenses into water. The wall structure must be after the moisture barrier breathable in the direction of the outside air so that the water can evaporate/dry out. This prevents the growth of mould in structures. In the summer, when the outdoor temperature and humidity are high and air conditioning is in use, the condensation phenomenon in question occurs in the structure towards the inside, **Figure 6** that brought a need for a moisture barrier allowing humidity transfer at high relative humidity. Especially in demanding warm and humid climates, building structures must be able to transfer water moisture both towards the outside and inside.

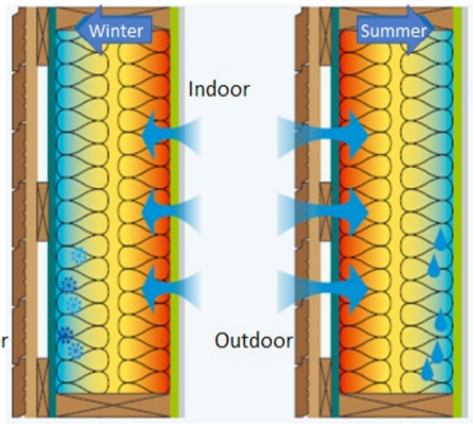

Figure 6. During winter, water vapor travels outwards in the cold direction in the structure. In summer, when indoor cooling is in use, water vapor travels inwards.

Conclusion

These examples demonstrate how important it is to improve air tightness and install heat recovery from exhaust air in deep renovations aiming at least to halve energy usage. ■