Evaluation of supply temperature set-points and airflow imbalance using smart ventilation data

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1 BACKGROUND

The installation of central mechanical ventilation with heat recovery (MVHR) in renovated apartment buildings presents considerable challenges, primarily due to insufficient space for ductwork. Consequently, many renovation projects are installing decentralised MVHR units, catering to individual apartments. Many of these devices offer the option of communicating with their controllers via Modbus, BACnet, KNX, or internet APIs, provided the necessary resources are available for the connection. Unlike central MVHR units, which offer the opportunity for centralised commissioning and maintenance, these decentralised units are frequently located in suspended ceilings or cabinets in refurbished apartments. This placement makes them challenging to access without a coordinated effort. Therefore, monitoring these decentralised MVHR units via available communication links – a concept commonly referred to as 'smart ventilation' - proves to be more convenient and less labour-intensive. Most MVHR units come with standard data sets, which typically include supply and exhaust fan signals and temperature sensors located before and after the heat exchanger for both the supply and exhaust airflows. The controller uses these temperature measurements, as depicted in Figure 1, to adjust the bypass damper's opening position, thereby modulating heat recovery. This adjustment aims not only to achieve the specified supply temperature set-point but also to prevent frost accumulation by raising the exhaust temperature when necessary. During the commissioning phase, the installer seeks to balance the supply and exhaust airflows to maximise heat recovery and minimise infiltration or exfiltration. However, reaching the specified airflows for each zone proves difficult. Even when achieved, this balance could degrade over time due to dust accumulation on components or occupants' interference with the valves. 'Smart ventilation' data can be used to optimise heat recovery by ensuring balanced supply and exhaust airflows. By performing an energy balance, 'virtual sensors' can be created to indicate the airflow balance. In this study, we utilized 'smart ventilation' data from 100 apartments in Frederikshavn, Denmark, to assess the supply temperature set-points and airflow balance.

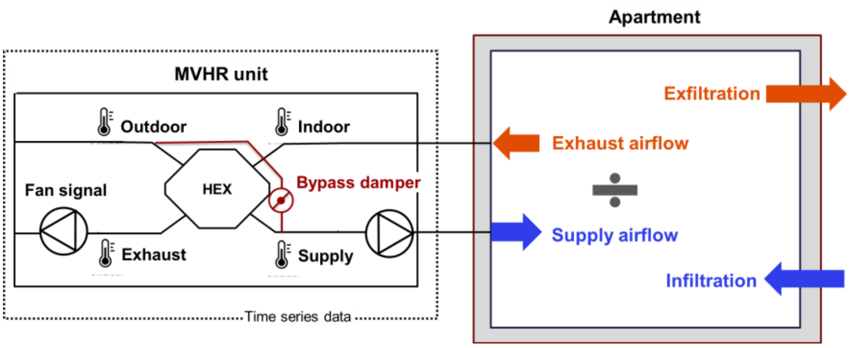

Figure 1. Common data from a residential AHU with a plate heat exchanger.

2 METHODS

We aimed to create a simple indicator assessing heat recovery. We started with the energy balance for heat transfer in the exchanger, where $Q_{supply} = \dot{m}_{supply}\, c_p \left(T_{supply} - T_{outdoor}\right)$ was set equal to $Q_{exhaust} = \dot{m}_{exhaust}\, c_p \left(T_{indoor} - T_{exhaust}\right)$. The validity of this equivalence depends on four key assumptions: (1) All mechanically driven supply and exhaust airflow pass through the heat exchanger. (2) The temperature changes are large enough to offset measurement errors. (3) The ratio of volume flows remains constant. (4) There is no condensation inside the heat exchanger. As such, we only consider data satisfying the corresponding conditions: (1) The bypass damper is fully closed. (2) The outdoor temperature is less than 10°C. (3) The exhaust fan signal remains un-boosted. (4) The exhaust temperature is above the dewpoint temperature of the indoor air. Ventilation heat exchangers have high nominal efficiencies, so the temperature difference between airflows is small longitudinally. Therefore, we assume the supply and exhaust airflows have roughly similar specific heat capacities (c_p) and air densities (ρ). This led to Equation 1 – the flow ratio (Fr) of supply and exhaust airflows.

$$Flow\ ratio, Fr = \frac{\dot{m}_{supply}}{\dot{m}_{exhaust}} = \frac{\cancel{\rho_{supply}}}{\cancel{\rho_{exhaust}}} \cdot \frac{\dot{\boldsymbol{V}}_{\boldsymbol{supply}}}{\dot{\boldsymbol{V}}_{\boldsymbol{exhaust}}} = \frac{\left(T_{supply} - T_{outdoor}\right)}{\left(T_{indoor} - T_{exhaust}\right)} \tag{1}$$

In the Danish temperate climate, the outdoor temperatures rarely rise above freezing, suggesting that the bypass damper should remain closed for nearly the entire heating season. If the bypass damper is open excessively, it could indicate that the supply temperature setpoint is too low, triggering unnecessary bypass of heat recovery (or an undetected sensor fault). We aimed to create a bar plot wherein the magnitude of each bar shows the balance of airflows while each bar's colour indicates whether the applied filters removed most (red) or very little (green)of the data. A red bar indicates an excessive opening of the bypass damper, potentially due to low supply temperature set-points or other errors. It also suggests a high degree of uncertainty, arising from the invalidity of the previously stated assumptions.

3 MAIN RESULTS AND CONCLUSIONS

Figure 1 shows the constructed indicators for all 100 'smart ventilation' units in an apartment building. It indicates that the ventilation is poorly balanced in most units. Several apartments had most of their data filtered out (red), possibly due to low supply temperature setpoints or other faults. The next step involves manually investigating these problematic apartments.

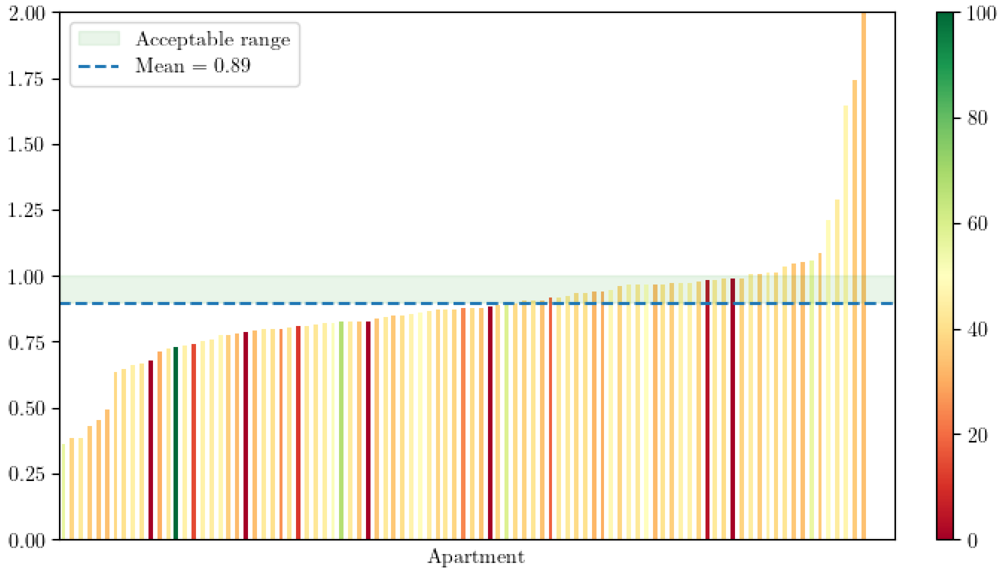

Figure 1. Flow ratios for 100 'smart ventilation' units.