A method to analyse the performance of residential ventilation systems

The article describes the concept of recommendations of ventilation systems for residential buildings developed by Polish National Energy Conservation Agency and Warsaw University of Technology. The evaluations are based on computer simulations.


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The system of recommendations uses two types of virtual reference buildings: 8 story multi-family building and 2 story single family building. Reference buildings are equipped with 2 reference ventilation systems: natural (passive stack ventilation) and mechanical extract ventilation (central fan). The reference primary energy use is an average value for two reference ventilation systems. Investigated ventilation systems, depending on percentage of reference primary energy use, get an energy class from A1 to D. Recommended system has to provide at least 30% of energy savings and at the same time has to ensure that during occupation required ventilation rate is supplied.

The Concept of Ventilation Systems Assessment

The National Energy Conservation Agency (NAPE) and Warsaw University of Technology (WUT) developed system of recommendations of ventilation systems based on evaluation of annual primary energy use (including auxiliary energy use) and air quality (with ventilation rates as a investigated parameter). The system is based on results of computer simulations performed for virtual reference building in reference weather conditions. The concept can be applied for different types of buildings, however - at the moment – the scheme presents sufficient maturity only for residential buildings.

NAPE scheme uses two types of residential reference buildings: multi apartment building and single family house. The plans were prepared as a compilation of most typical solutions observed in buildings designed or modernized during last 20 years with technical support of NAPE.

NAPE recommendation scheme for residential buildings is based on a comparison of the annual primary energy consumption (heating and auxiliary energy associated with ventilation) and the air volume (minimal, maximal and average value for outdoor air temperatures below +12 °C) for three scenarios (**Figure 1**):

- reference building with reference passive stacked ventilation,
- reference building with reference mechanical extract ventilation,
- reference building with analysed ventilation system.

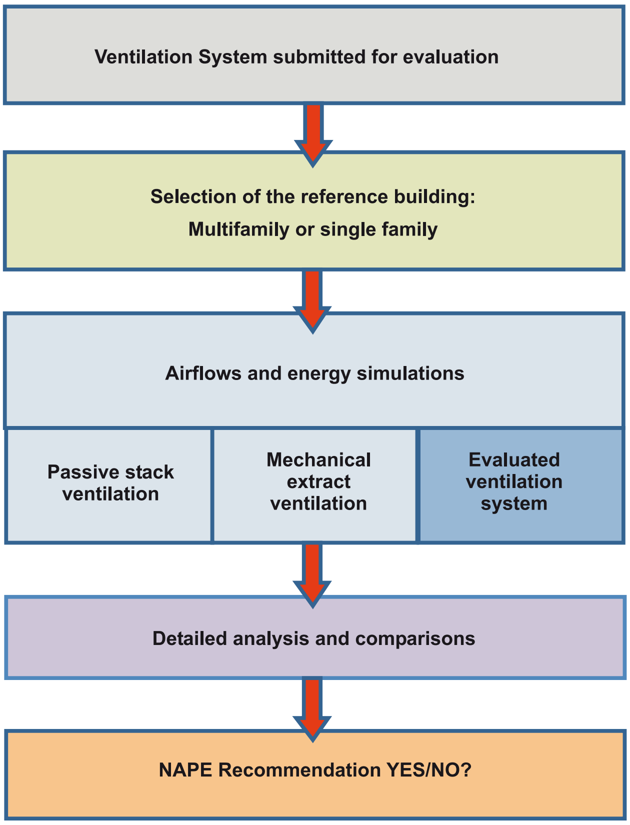

Figure 1. Schematic view of the NAPE recommendation scheme.

The reference primary energy use is an average value for two reference ventilation systems. Investigated ventilation systems, depending on percentage of reference primary energy use, get an energy class from A1 to D:

A1	0–30%
A2	30–50%
B1	50–70%
B2	70–90%
C	90–110%
D	>110%

Recommended system has to provide at least 30% of energy savings and at the same time has to ensure that during occupation required ventilation rate is supplied.

The multi-family NAPE reference building has the total volume of V_e = 5865 m³, surface of envelope A_e=2028.5 m² (shape ratio A_e/V_e = 0.35) and usable area A_f = 1634 m². Heat is supplied from town district heating network.

The single-family NAPE reference building has the total volume of V_e = 550.5 m³, surface of envelope A_e=432.7m² (shape ratio A_e/V_e = 0.79) and usable area A_f = 149.8 m². Heat is generated in combi gas boiler (efficiency 90%).

In both buildings two variants of the reference ventilation are considered:

- passive stack ventilation (windows with air vents and ventilation ducts located in kitchens, toilets, bathrooms and lockers etc.)
- mechanical extract ventilation with constant air volume (location of air supply and exhaust as above).

The calculations of the energy consumption and the ventilation rates are performed using hourly weather data for Warsaw.

Simulations of Airflows in Buildings

Calculations of airflows are carried out with application of a quasi-dynamic multi-zone model (CONTAM 3.0 [1]). Opportunities of CONTAM version 3 and higher are quite broad, so the software can be used to model many types of natural, hybrid and mechanical ventilation including demand controlled systems.

Changes of total air flow obtained for a multi-family building with 2 reference ventilation systems are shown in the **Figure 2**.

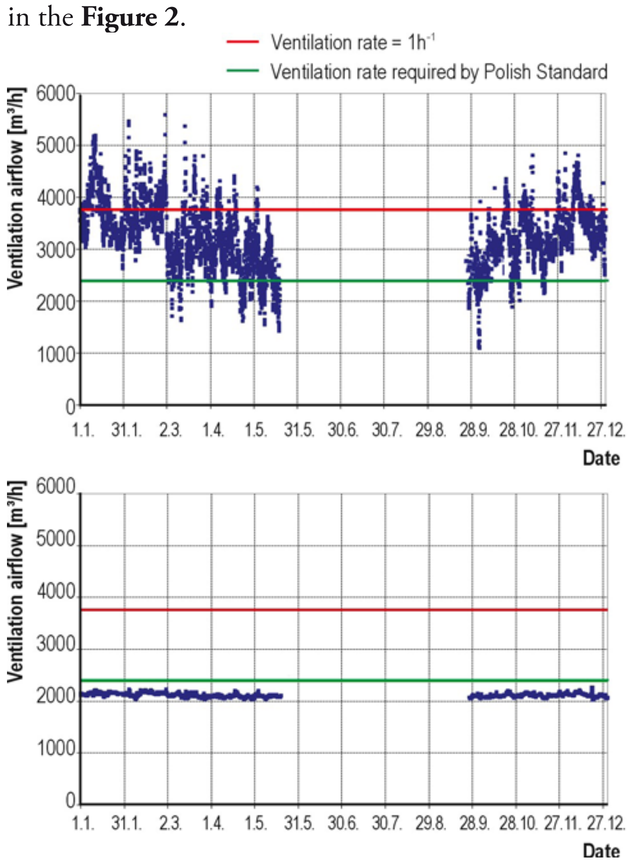

Figure 2. Changes of total air flow obtained for a multi-family building equipped with reference ventilation systems: passive stack ventilation (top) and mechanical extract (down)

Simulations of Annual Energy Use

For energy analysis of whole buildings, the recommendation scheme uses model 6R1C+AHU [3], which is modified version of simple hourly method 5R1C described in EN ISO-FDIS 13790 [2]. Total consumption of heat and electricity is converted into primary energy using energy waging factors and for NAPE reference buildings the following results were obtained: multi-family building 132 889 kWh/year (81.31 kWh/(m²year)) in case of passive stack ventilation and 106 681 kWh/year (65.27 kWh/(m²year)) in case of mechanical extract ventilation. Without any ventilation the reference building would hypothetically use ~48 000 kWh/year (29.37 kWh/(m²year)). The results of the primary energy use and ventilation intensity plotted on a two dimensional graph creates a background which is the basis for the assessment of other ventilation systems.

Example of Recommendation

The example presents the analysis of performance of humidity based demand controlled hybrid ventilation [4]. Air vents used in that system has variable characteristics influenced by relative humidity. For given pressure drop air flow is proportional to relative humidity (in range 30...70%). Characteristics of exhaust grills also depend on relative humidity. Additionally exhaust grills mounted in bathrooms and toilets are equipped with presence sensors that force opening of a control damper when users are in a space (delay for switching off is 20 min). Exhaust fans mounted on a roof above collecting ducts are equipped with pressure sensors and can reduce fan speed when needed.

In CONTAM environment the building together with analysed ventilation system has been idealized as 127 zones and 884 flow paths. Additionally in case of humidity based demand controlled hybrid ventilation systems the model takes into account controls (in analysed case humidity influences characteristics of air vents, exhaust grills and exhaust fans).

Figure 3 presents ventilation rate for whole building during the heating period in case of humidity based demand controlled hybrid ventilation. Average air volume is ~40% of maximum value that is approximately equal required ventilation rate. This indicates that analysed system is capable to provide required ventilation rates on demand.

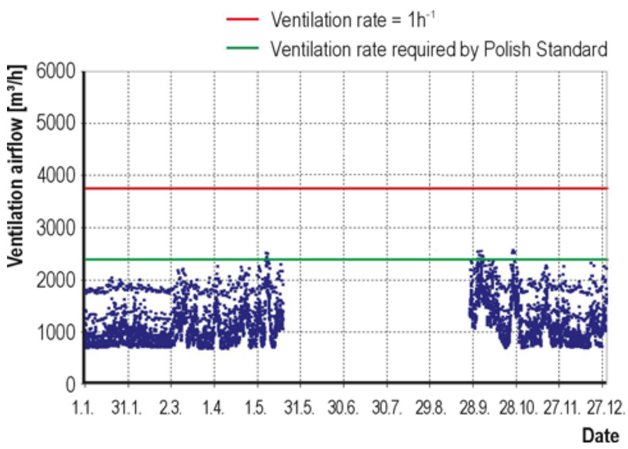

Figure 3. Ventilation rate for whole building during the heating period for humidity based demand controlled hybrid ventilation.

Some ventilation systems (e.g. passive stack ventilation) work with huge differences in ventilation rates not only over time but also between similar flats located at different floors. Therefore before recommendation detailed analysis of airflows is performed. **Table 1** presents comparison of air ventilation rates for small studio M2 (66.5 m²) for 8 floor and ground floor. Simulation indicated that humidity based DCV hybrid system works with substantial differences in ventilation rate over time but without important differences between floors.

The comparison of primary energy use for reference multi-family building equipped with three different ventilation systems (two reference and one under evaluation) proved that utilization of humidity based DCV hybrid system leads to substantial energy savings. Reference energy consumption for comparisons is an average obtained for two reference ventilation systems 119 785 kWh/year (73.29 kWh/(m²year)). Primary energy use of reference building with analysed ventilation system is 79 712 kWh/year (48.78 kWh/(m²year)). This indicates the savings of ~33%. Taking into account just the energy for ventilation savings are much higher

Table 1. Summary of airflows analysis for humidity based demand controlled ventilation.

Ventilation rate, m³/h	M2 8 floor			M2 ground floor		
	Humidity based hybrid ventilation	Mechanical Ventilation (ref)	Passive stack ventilation (ref)	Humidity based hybrid ventilation	Mechanical Ventilation (ref)	Passive stack ventilation (ref)
Average	36	68	88	37	75	167
Min	21	65	28	22	68	41
Max	90	78	289	90	86	270
Stnd. Dev.	14.7	1.6	36.1	14.9	2.7	30.3

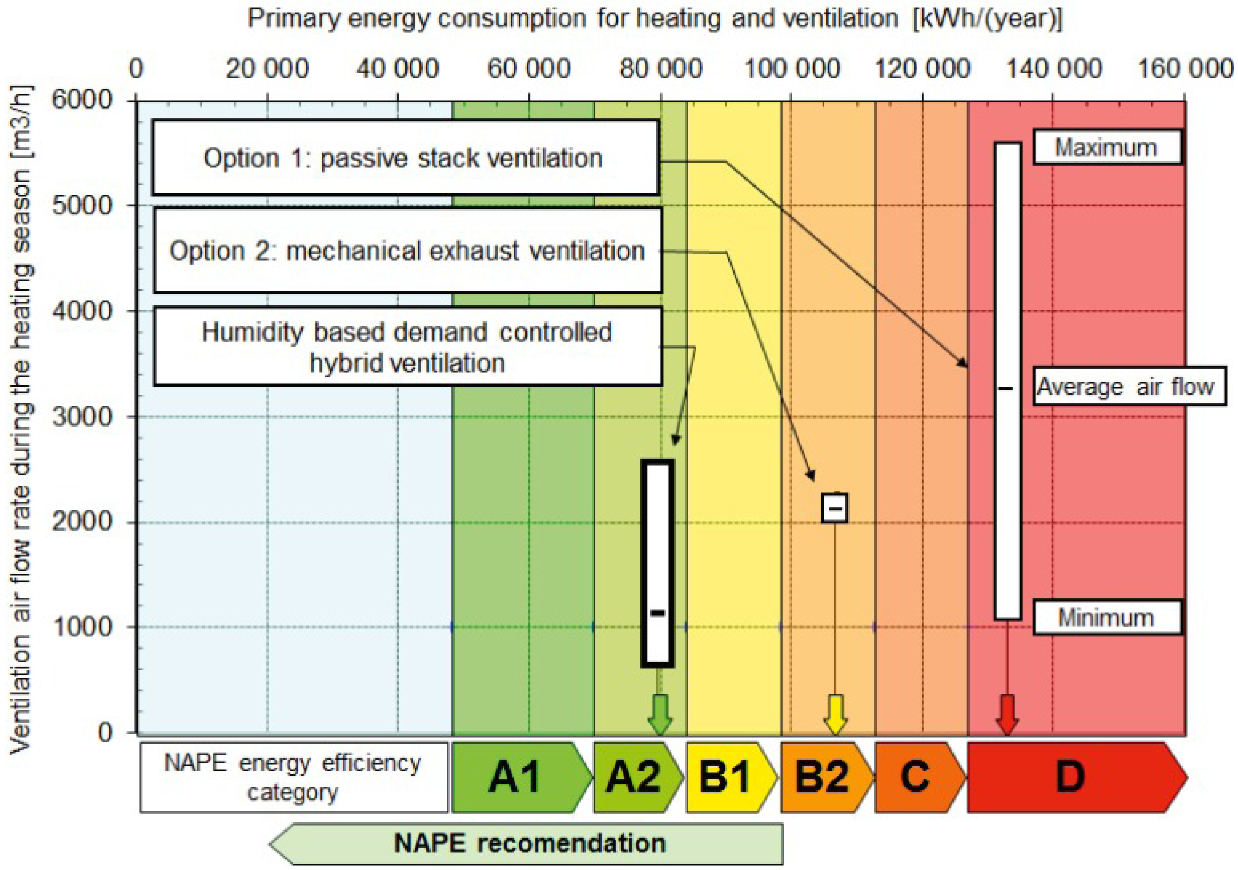

Figure 4. Reference levels of primary energy use and reference air flows with the recommended direction of modernization.

and reach ~55%. As the result of presented analysis the system got energy class A2 (**Figure 4**).

Conclusions

The described method for determining the energy efficiency of ventilation systems for residential buildings is characterized by the simplicity of the calculation, while allowing for consideration:

- auxiliary electricity consumption for fans and pumps,
- airflow changes due to temperature and wind speed fluctuations,
- airflow changes resulting from the control of ventilation components,
- reduction of heat consumption due to use of heat recovery (including the necessary reduction of heat recovery efficiency in case of frost built-up in heat exchanger or during transition periods),
- indoor air quality level created by evaluated ventilation systems. ■

References

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[2] ISO-FDIS 13790:2007 Energy performance of buildings - Calculation of energy use for space heating and cooling.

[3] P. Narowski, M. Mijakowski, A.D. Panek, J. Rucińska and J. Sowa, Integrated 6R1C Energy Simulation Method – Principles, Verification And Application, Proceedings of the 10th REHVA World Congress "Sustainable Energy Use in Buildings" CLIMA 2010, May 9-12 2010, Antalya, Turkey

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