Performance of automated demand controlled mechanical extract ventilation systems for dwellings in Europe

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Introduction and methodology

On continent Europe, demand controlled ventilation (DCV) is considered today as a particularly relevant alternative to other mechanical extract ventilation systems (MEV) and especially for mechanical ventilation systems with heat recovery (MVHR). For the moderate climate zone of Western Europe, with about 2500–3000 heating degree days, the payback time for investments in heat recovery ventilation is long, especially in buildings with relatively low air change rates such as dwellings. Due to its competitive price setting as well as due to reports in popular media and scientific literature about possible health risks associated with heat recovery systems, simple central MEV dominates the residential ventilation market in this region. The great variability of a dwelling occupancy in time and place, enhances the potential of DCV. By applying DCV, heating energy related to ventilation is reduced by 20 to 50%, while electricity consumption is similarly reduced.

In Belgium an equivalence approach based on a Contam model[1] is used to rate the performance of demand controlled ventilation systems. Average cumulative CO_2-concentration (kppm.h) above Δ600 ppm is used as IAQ indicator, next to the risk on condensation and the exposure to odours.

In France the assessment of DCV systems is done by CSTB based on the Siren model[1] resulting in a so-called "Avis Technique". In the calculation also IAQ restrictions must be fulfilled.

In Germany the energy performance of a DCV system was investigated by the Fraunhofer institute based on the WUFI-Plus model[2]. In contrast to Belgium and France, however, this methodology is not officially accepted by authorities, to take into account in the German energy performance calculation (EnEv). Using DCV only leads to a fixed 10% reduction compared to MEV systems.

In the UK, there is no recognition of advanced systems either under Part F of the Building Regulation or under Appendix Q of the Standard Assessment Procedure (SAP). Therefore the Belgian approach is used to calculate the impact on IAQ and energy consumption of demand controlled systems.

The aim of this article is to assess theoretically the energy saving potential of DCV and the indoor air quality (IAQ) to which the occupants of the dwelling are exposed, compared to normative (design flow rates according to national standard) ventilation systems. Two different demand controlled mechanical extract ventilation (DCV) systems (DCV1 and DCV2) in comparison with passive stack ventilation PSV, MEV and MVHR were investigated.

Characteristics demand controlled systems

In this study, two automated demand controlled mechanical extract ventilation systems of Renson based on natural supply via trickle vents in the habitable rooms and mechanical extraction in the wet rooms (such as kitchen, bathroom, sanitary accommodation (toilet) and laundry (utility)) (DCV1) or even the bedrooms (DCV2) were analysed (**Figure 1**).

1 Savin, J-L., Laverge, J. (2011). Demand-controlled Ventilation: an outline of assessment methods and simulations tools. AIVC-tightvent conference 32.

2 Lengsfeld, K., Holm, A. Entwicklung und Validierung einer hygrothermischen Raumklima-Simulationssoftware WUFI-Plus. Bauphysik 29 (2007), Heft 3, Seite 178-186. Ernst & Sohn Verlag Berlin.

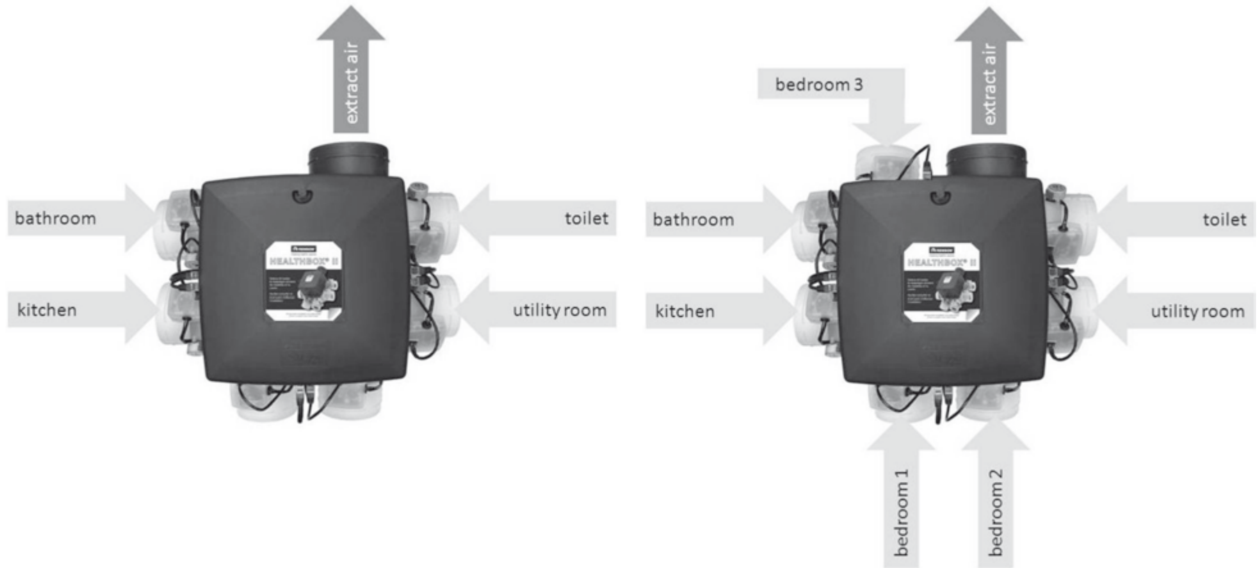


Figure 1. Configuration of DCV 1 (left side) and DCV 2 (right side). The fan is situated in the central box, the valves which contain the IAQ sensors (RH, CO_2, VOC) are connected to the central box.

The basis of the DCV system constitutes a constant pressure fan which has self-regulating extract valves connected to the fan at the end of the extract ducts. In that way, the air flow rate is controlled on pollutant concentration at room level (multi-zone-control). An automatic calibration procedure is integrated in the system to make sure that in each extract duct the design air flow rate can be effectively reached.

Each self-regulating extract valve can contain up to two sensors, to control and monitor the extract air flow rate. A relative humidity sensor (RH), an odour (VOC) sensor and/or a CO_2 sensor can be applied. Based on the measured values of the sensors, the flow rate through the duct is adjusted between a minimum (15% of the design flow rate) and the design flow rate. The minimal room air flow rate is never lower than 0.1 l/s/m² as specified in EN 15251.

Results

Belgium

For DCV1 and DCV2 the ventilation heat losses and cumulative CO_2-concentration are shown in **Figure 2** compared to the reference systems which are indicated by the red line. As can be seen in **Figure 2**, the IAQ of PSV and MEV is always worse with respect to that of MVHR. Due to variable wind and thermal forces on the building, air flow rates are less controlled and cross ventilation can occur, especially in case of PSV, which causes higher CO_2-concentrations especially in the bedrooms.

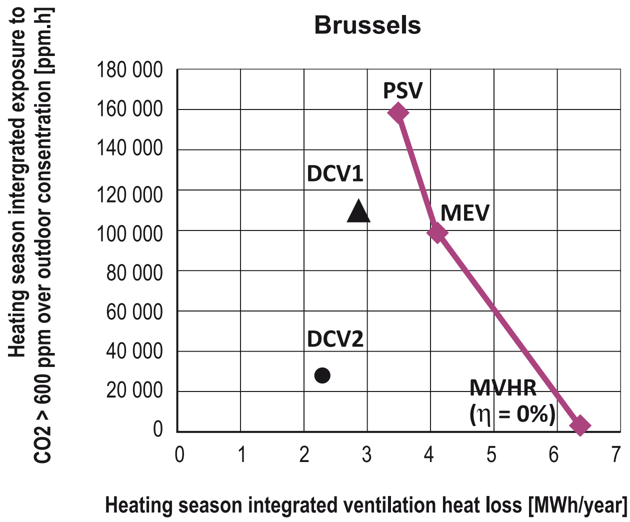


Figure 2. Average cumulative CO_2-concentrations (kppm.h) above Δ600 ppm against ventilation heat loss (MWh/year) for the reference (red line) and the DCV1 and DCV2 ventilation systems according to current Belgian standard.

DCV1 realises a similar IAQ compared to MEV, while the CO_2-concentration exceeds of DCV2 are very small. This means that DCV2 approaches closely the IAQ of MVHR. DCV1 and DCV2 reduces the ventilation heating energy with approximately 35 and 50%, respectively, compared to MEV. When expressed compared to MVHR (no heat recovery, $\eta = 0\%$), a heating energy reduction of about 55 to 65%, respectively, is found. Common residential MVHR realise a heat recovery efficiency of 70 to 85%, if well designed and maintained.

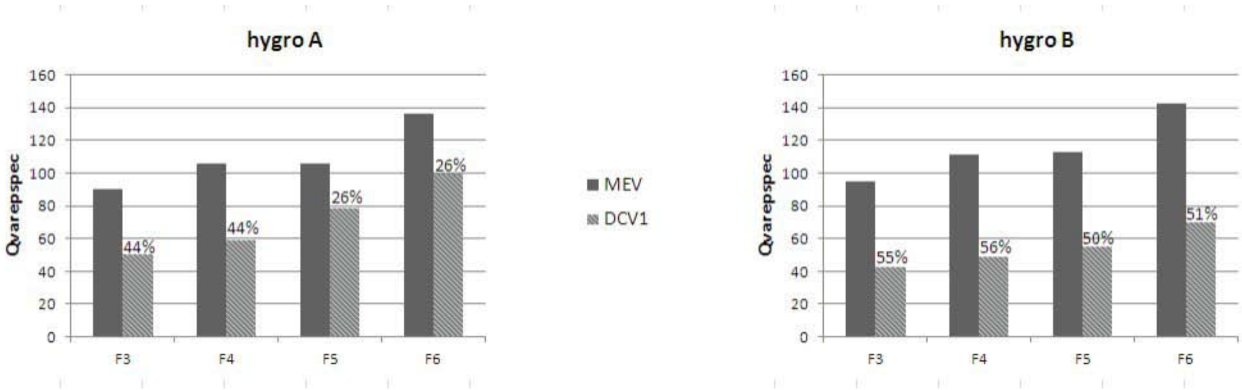
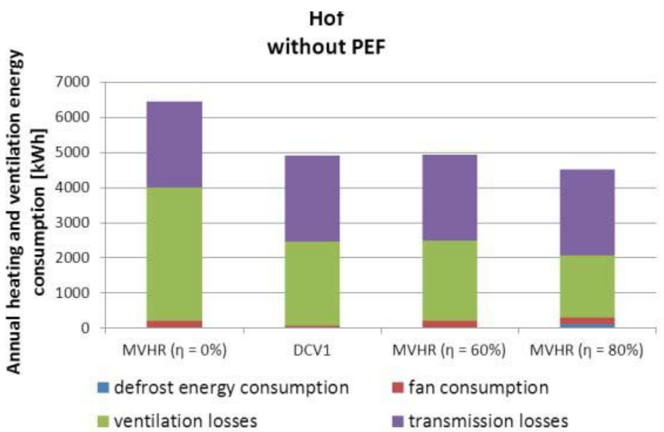


Figure 3. Average reduction for the reference and DCV1 ventilation systems according to current French law and "Avis Technique" for hygro A (left) and hygro B (right) systems.

France

In the French calculation procedure DCV systems are only compered to MEV systems. When IAQ criteria are fulfilled, a so-called air flow rate reduction factor "$Q_{varepspec}$" is calculated. Since extract from bedrooms is not allowed according to the law of 24 march 1982, there are no results for DCV2. The mean results for classic DCV1 systems now available on the French market are shown on **Figure 3** for the most current building types (F3 – F6) and for both hygro A and hygro B systems. Hygro B meaning not only the extract is adapted according to RH in the room but also supply is controlled on RH in the dry room. **Figure 3** shows how for the hygro A systems DCV1 results in a reduction from 26 to 44% in comparison with MEV systems without demand control. In combination with a RH controlled supply, an even greater reduction can be achieved with a DCV1 system of approximately 53%.



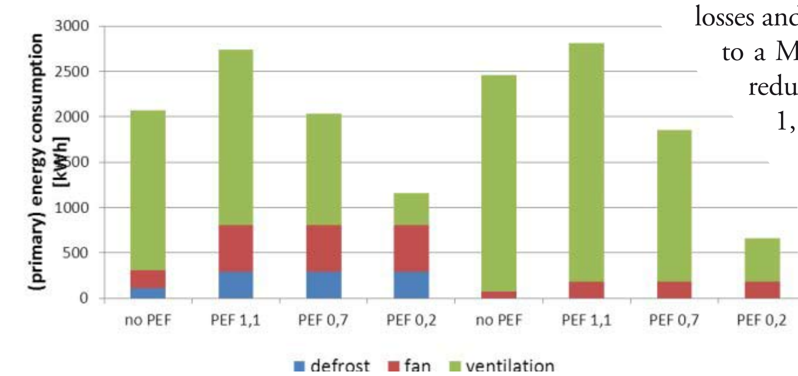


Figure 4. Energy loss (kWh) for the reference and DCV1 ventilation systems according to current German standard not taking into account primary energy factors (top) and taking into account primary energy factors for heating energy (bottom).

Germany

In Germany only DCV1 was calculated and compared to the MVHR systems as shown in **Figure 4**. On the left and right graph, respectively without and with taking into account different primary energy factors (PEF). Here also fan consumption and defrost energy consumption was calculated for the different systems. The difference in total annual energy consumption between DCV1 and MVHR (η = 80%) is only 633 kWh due to ventilation losses and 241 kWh less fan consumption. Compared to a MVHR (η = 60%) system, DCV1 achieves a reduction of 27 kWh. Furthermore, for PEF = 1,1 (a classic heating system with gas) DCV1 performs equal as MVHR (η = 80%). The smaller the PEF, the better DCV1 performs since the electrical part becomes more important. Thanks to the minimal electrical consumption of DCV1 it performs better than MVHR (η = 80%).

Looking at IAQ DCV1 performs well, only in the bedroom the threshold of 1200 ppmv was exceeded. With DCV2, extracting direct from the bedrooms, this would definitely not be the case.

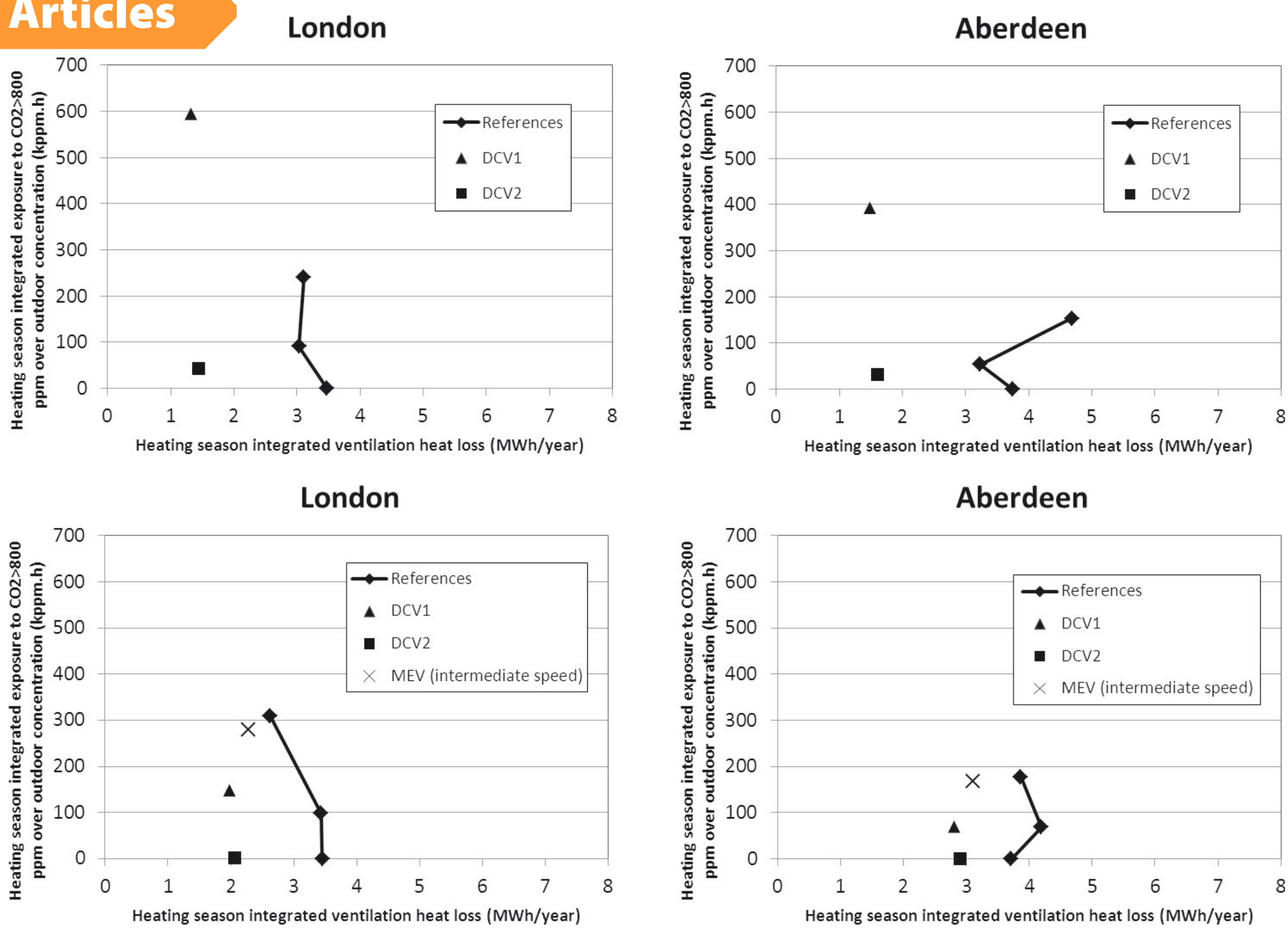


Figure 5. Average cumulative CO_2-concentrations (kppm.h) above 800 ppm over outdoor CO_2-concentration against ventilation heat loss (MWh/year) for the reference (red line) and the DCV1 and DCV2 ventilation systems with supply air flow rates according to current British standard (top) or equal to MVHR (bottom) for London and Aberdeen.

UK

Following approved document F and the Belgian assessment procedure, DCV1 and DCV2 were compared to the reference systems in **Figure 5** for the location of London and Aberdeen. The smaller air supply rates of all UK designed ventilation systems and the smaller extract rates of MVHR, explain the lower heat losses and the worse IAQ of UK designed systems when compared with **Figure 2**.

When looking to DCV1 and DCV2 in **Figure 5** for a given location, it is clear that both DCV systems have a similar impact on the ventilation heat losses, but huge differences are observed concerning exposed IAQ. Since DCV1 has an IAQ worse than the reference it is unacceptable according to the procedure. Increasing the design air flow rates for MEV to a similar level as those for MVHR, improves significantly the IAQ of DCV1 (**Figure 5**). For DCV2 the IAQ is acceptable and situated in the middle between that of MEV and MVHR. The heating energy reduction of DCV1 and DCV2 for the two locations is in the range of 50 to 60% when compared to MEV and MVHR (η = 0%).

With respect to ventilation heat losses for the location of London, the energy losses of DCV1 and DCV2 with higher air supply rates increase by about half. This means that heating energy reduction for DCV1 and DCV2 becomes about 35% compared to MEV and about 40% when compared to MVHR (η = 0%).

Conclusions

By means of different European equivalence procedures the significant effect of demand control on the performance of a MEV system was illustrated and discussed. Ventilation heat losses were reduced by 30 to 50% due to automated demand controlled systems. Fan consumption of demand controlled MEV systems is remarkably lower than MVHR systems. In that way, under Western European climate conditions, demand control can bring a standard MEV system to a similar level as MVHR when considering primary energy consumption. Besides, due to the automatic detection of the IAQ in the different rooms, the guarantee on good IAQ is higher when compared with a manually operated mechanical system without sensors, leading to similar IAQ levels as those obtained with MVHR. ■