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Smart Ventilation for buildings

PROCEEDINGS

In cooperation with:

Energy performance of demand controlled mechanical extract ventilation systems vs mechanical ventilation systems with heat recovery in operational conditions : Results of 12 months in situ-measurements at Kortrijk ECO-Life community

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ABSTRACT

In a recently built zero-carbon neighborhood, demand controlled exhaust ventilation systems (DCMEV) and mechanical ventilation systems with heat recovery (MVHR) are compared under operational conditions, with focus on the energy performance of both systems. The analysis is based on automatically gathered monitoring data, complementary in situ measurements and occupants surveys.
This paper comments on both ventilation systems and their energy saving potential according to literature. In this case study, demand controlled ventilation the electricity use of the system proved to be lower, heating demand proves to be comparable and the IAQ seems to be comparable.
When taking into account the electricity and heating prices, the total cost or net present value of the DCMEV system is nearly a third lower than that of the MVHR system, partly due to a higher investment and maintenance cost of the latter.
Further research should focus on the carbon footprint of ventilation systems, reliability and lifetime of sensors and the impact of regular filter cleaning/replacement in case of MVHR.

KEYWORDS

Demand controlled ventilation, heat recovery ventilation, energy performance

1 INTRODUCTION

Due to climate change and an increasing environmental awareness, regulations concerning energy consumption have become stricter. Improving the airtightness and level of insulation of residential buildings is a priority in order to reduce the energy demand.
In these well insulated airtight buildings, ventilation is crucial to guarantee a healthy indoor climate (Savin and Jardinier, 2009). As heat losses through the building shell are small, mechanical ventilation losses are of relatively higher importance in the building's heating demand. Moreover, mechanical ventilation can increase the total electricity use of households up to 50% (without domestic appliances) (Manz and Huber, 2000).

Ventilation can represent up to 30% to 60% of the total buildings' energy demand. Therefore reducing the ventilation's energy use is a key parameter to further reduce the buildings' energy demand (Liu et al., 2010) while at least maintaining a good indoor air quality. In Belgium, mechanical ventilation systems with heat recovery (MVHR) are often used in today's high performance buildings, as their use is implicitly prescribed by the passive house standards. However, demand controlled exhaust ventilation systems (DCMEV) with natural air supply through vents can be a worthy alternative to these MVHR systems (Laverge, 2010).

In the context of the European CONCERTO ECO-Life project, the existing social housing neighborhood 'Venning' in Kortrijk is transformed into a zero-carbon neighborhood (Himpe et al., 2015).

The ECO-Life project in Belgium is a residential community consisting of 274 dwellings, grouped into six clusters based on their location, typology, construction approach and timing. Three clusters are located in the Venning neighborhood and three others at the sites of Pottenbakkershoek, Gutenberg and Drie-Hofsteden (see Fig. 1). In Venning phase 1, Pottenbakkershoek and Gutenberg in total 6 multi-family buildings were newly constructed. In Venning phase 2 and 3 single-family houses that are grouped into 20 housing blocks were newly built and refurbished respectively.

Figure 1: Overview of the demonstration sites in Kortrijk

Table 1: Demonstration buildings overview and time schedule of monitoring

Demonstration Buildings	Gross floor area	Number of Dwellings	Start Occupancy	Start monitoring Manual	Start monitoring Auto Heat	Start monitoring Auto Elec	Stop Monitoring	Time (months)
Venning Phase1	7545	82	13/jul	13/sep	14/feb	15/jan	16/may	35
Venning Phase 2	7842	64	15/feb	15/feb	15/feb	15/feb	16/may	16
Venning Phase 3	7241	50	15/mar	15/mar	15/mar	15/mar	16/may	15
Pottenbakkershoek	2073	24	14/jul	15/jan	15/jan	15/jan	16/may	17
Gutenberg	1869	21	15/nov	15/nov			17/mar	17
Drie Hofsteden	2937	33	16/apr	16/apr			17/mar	12

2 MONITORING OF THE DEMONSTRATION BUILDINGS

Without going further into detail, three levels of metering were installed: general metering in all dwellings, detailed metering in a sample of dwellings and additional metering in a small sample for in-depth studies, such as end-user comfort evaluations and performance assessment of the ventilation systems.

2.1 Venning demonstration buildings

The building design in all 3 phases was guided by the passive house standards aiming at a net space heating energy demand of 15 kWh/m²/year, leading to building envelope U-values below 0.15 W/m²K and an airtightness n_{50} of maximum 0.6 h^{-1}. Living rooms are oriented as much as possible to the south, while both fixed and movable shading elements were applied to reduce the overheating risk. The case-study is used to investigate the real energy performance of the ventilation systems, as well as to compare MVHR and DCMEV ventilation systems under operational conditions. This is done based on the available automatically gathered monitoring data.
One phase of the project consists of 64 new single-family dwellings. Half of the dwellings is provided with a MVHR (system D) and the other half is provided with a DCMEV (system C+) (see Fig. 2). Furthermore, the two groups of dwellings are similar in terms of typology, architecture, building construction and orientation.

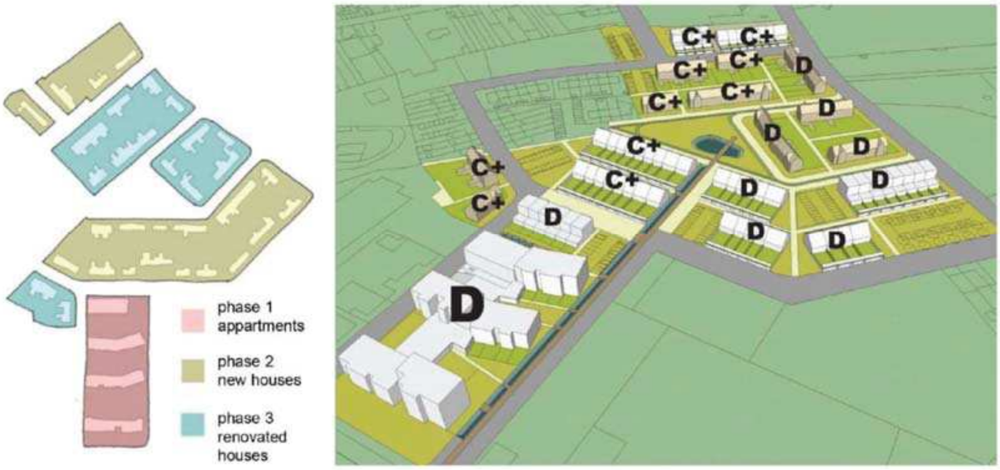

Figure 2: Overview of the demonstration sites in Kortrijk

The dwellings equipped with a demand-controlled ventilation system typically have a higher predicted net space heating demand compared to the passive house standard, up to 25 kWh/m²/year, but a lower use of auxiliaries. The real performance is investigated in this study.
The Venning district heating network supplies heat to the dwelling substations for space heating and domestic hot water production. The heating system consists of radiators in the main rooms and, in case of houses with balanced mechanical ventilation, a heating coil to preheat the supply air if necessary. Grid-connected photovoltaic systems are provided on the rooftops of all buildings.

2.2 Characteristics demand controlled mechanical extract ventilation systems

Various researches have already shown a high energy saving potential for demand controlled ventilation compared to constant air flow rate systems. Control strategies that interact with only one component provide energy saving potentials around 25%. The strategy that manipulates independently most of the buildings zones has an energy saving potential of up to 60%.
In both phase 2 and phase 3, a Healthbox EVO II of the manufacturer Renson is installed, in combination with supply vents above the windows of the type Invisivent EVO from the same manufacturer. The Healthbox included a 84W (max. capacity) fan.

In phase 2, air is extracted in all wet areas such as kitchen, bathroom, toilet and laundry room (see Fig. 3 left). Every wet room has a separate extraction point to the ventilation device, where a valve regulates the flow through at the end of each duct. The valve is activated by a stepper motor that is controlled by a sensor located at the valve and a control algorithm.
Following sensors are used to control the extraction of the different rooms:

- Bathroom — Humidity sensor (Relative Humidity RH)
- Toilet — Volatile Organic Compound sensor (VOC)
- Bathroom with toilet — RH and VOC sensor
- Kitchen — CO_2 sensor
- Laundry room — Moisture sensor (RH)

In phase 3, a so-called 'smart zone' configuration is used where air is supplementary extracted in the bedrooms, in addtion to the wet rooms (see Fig. 3 right). The airflow control of the bedrooms is done on the basis of a CO_2 sensor. With a 4-position switch the demand control can also be switched off to (temporarily) ventilate with an increased or decreased airflow.

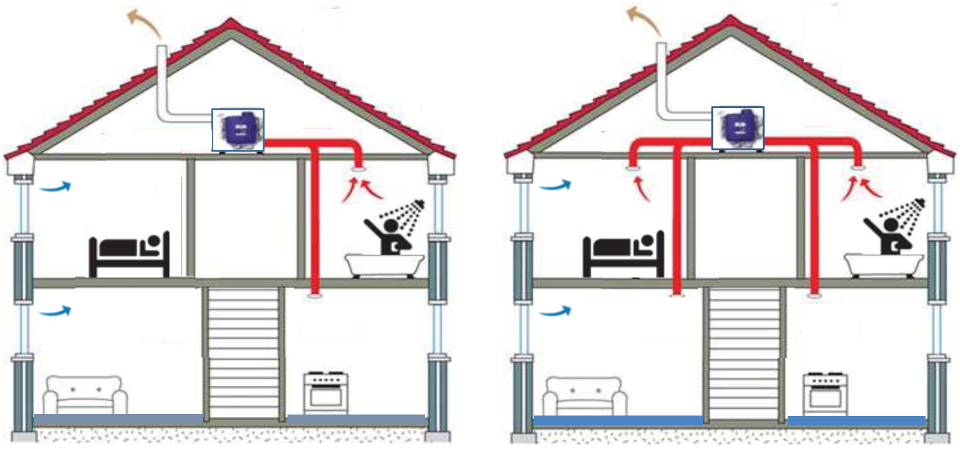

Figure 3: Demand controlled mechanical extraction ventilation without (left) or with (right) 'Smartzone'

2.3 Characteristics mechanical ventilation systems with heat recovery

The MVHR system installed in the case study is the Swegon CASA R120 (see Fig. 4). The ventilation system uses the RECOnomic rotary heat exchanger, of which the rotor has an aluminum foil structure which consists of a multitude of narrow passages. The temperature effectiveness of the heat exchanger is specified as approximately 80% under steady laboratory conditions. There are two fans of 120 W in the device.
The supply air goes through a heating battery before entering the rooms, to ensure a supply temperature of 19°C. Besides, the system is equipped with an automatic summer bypass.
By default, the device is set to 'home' (intermediate setting on a 3 position switch). Unfortunately, the control panel is often located in a hard-to-reach place, making it difficult to change settings.

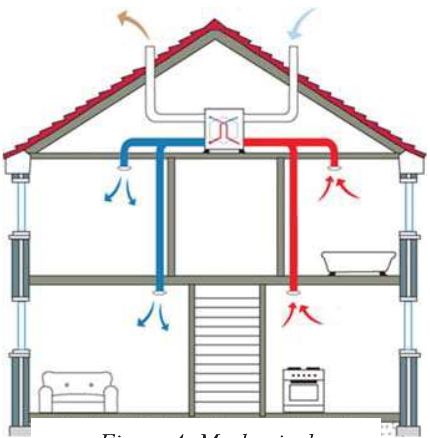

Figure 4: Mechanical ventilation with heat recovery

3 RESULTS

3.1 Ventilation heat losses

The total heat use is monitored for all dwellings of the Venning neighbourhood. In dwellings monitored in detail, the domestic hot water use is monitored as well. In most cases, the heat use for space heating is not measured, but can be derived by subtracting the domestic hot water use from the total heat use. The use of domestic hot water stays rather constant throughout the year. Heating on the other hand will not be turned on during summer, so the total daily heat use in that period will only be due to the use of domestic hot water. This average daily hot water use can then be subtracted from the total heat use to get an approximated energy use for space heating.
In dwellings with demand controlled extract ventilation, the fresh air enters the dwelling without pre-treatment, which can have an influence on the additional heating needs. It is expected that due to this inlet of cold air, the heating demand of dwellings with demand controlled extract ventilation is larger than for dwellings with heat recovery ventilation.

First of all it is noted that the general metering results in phase 2 show a space heating demand much lower for demand controlled extract ventilation (system C) than expected by EPB calculations (national energy performance calculation software), as illustrated in Fig. 5. Even when these expected values are scaled, taken into account the smaller amount of heating degree days of the considered year (May 2015 – April 2016), the monitored space heating demand deviates much from the expected energy use.

A first reason for this can be that the heating demand in the EPB calculation is overestimated for dwellings with the DCMEV system. For these dwellings the ventilation losses represent half of the total heat losses. The demand control is taken into account in the EPB calculation through a reduction factor for the intended ventilation rate, that is used for calculating the ventilation losses. For the ventilation unit and configuration installed in this case study, the reduction factor is 0.65. This actually means that 65% of the design airflow rate is taken into account for the calculation of the ventilation losses. If the actual average ventilation rate is lower than 65% of the design airflow rate, ventilation losses will be lower and the space heating demand is reduced. Another potential explanation is the reduced temperature in non heated spaces.

For dwellings with mechanical ventilation with heat recovery (system D), the monitored heating demand is close to the scaled values expected from the EPB file (Fig. 5). The monitoring data follow the trend of the expected heating demand, larger dwellings have higher heating demands.

The monitoring results also indicated there were no significant differences between the space heating energy needs in both types of dwellings with different ventilation system (Fig. 6). This can be explained by the low airflow rates due to the demand control, reducing the ventilation heat losses and thereby reducing the heating demand. Additionally, the heat recovery of the MVHR system is affected by the 'use factor' introduced by Laverge et al. (2017).

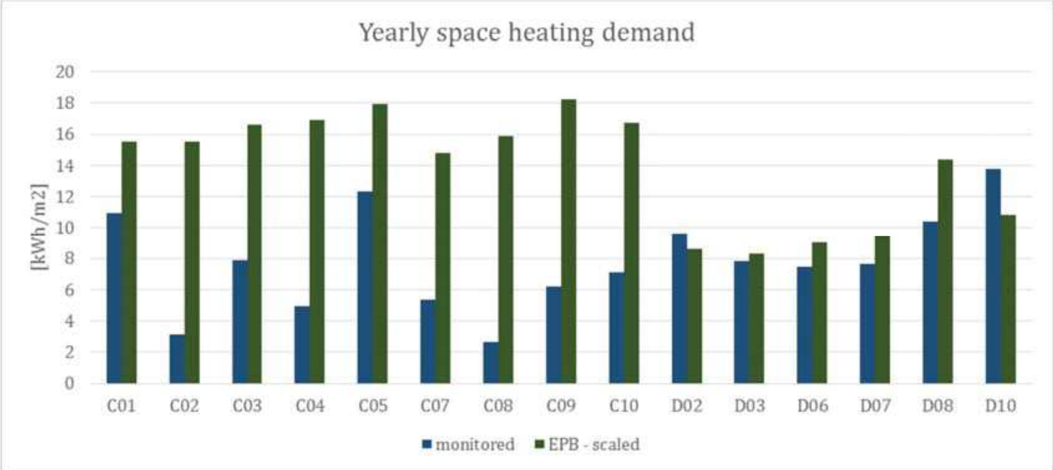

Figure 5: Phase 1 - Yearly space heating demand according to EPB calculations and monitoring in several buildings in phase 2, in case of DCMEV (C) and MVHR (D)

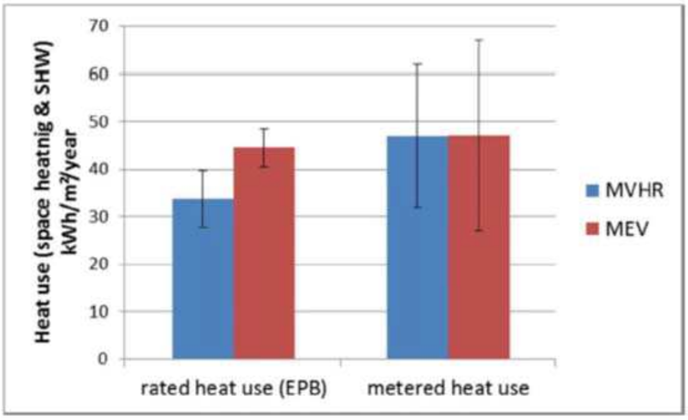

Figure 6: Phase 1 – Average yearly space heating demand according to EPB calculations and monitoring in phase 2, in case of DCMEV and MVHR

For the dwellings in Venning **phase 2** and **phase 3 combined**, usable detailed data was available for 22 dwellings.

On average for phase 2 and 3, the dwellings with a DCMEV show a slightly higher energy use for space heating than those equipped with a MVHR (10-15%), although the large uncertainty intervals show that this difference is not significant (Fig. 7). Energy use in phase 3 is a little higher than in phase 2 for both systems.

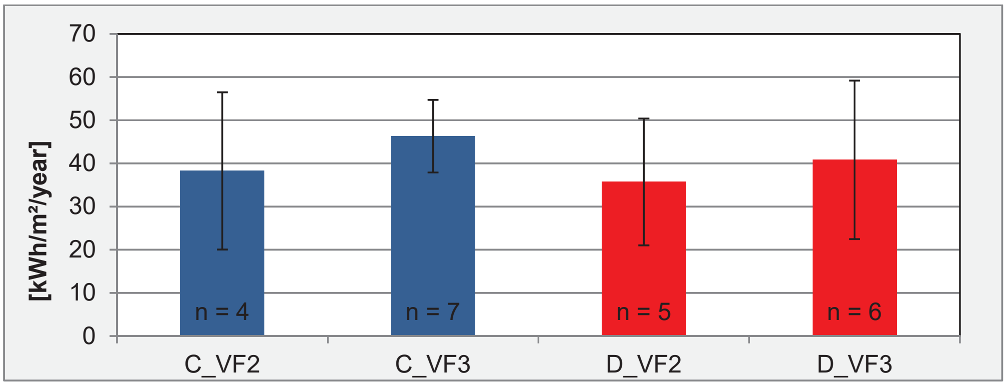

Figure 7: Phase 2 & 3 – Average yearly space heating demand according to monitoring, in case of DCMEV (C) and MVHR (D)

3.2 Fan consumption

Mechanical supply and extract ventilation has a higher electricity use than simple exhaust ventilation due to the additional electricity use of the supply fan. Heat recovery ventilation has an even higher energy use: due to the protective filters and the narrow passages of the heat exchanger, an increased pressure drop is induced, which in turn causes a higher fan electricity consumption.

Demand control reduces the actual electricity use of the ventilation system to one third of the expected electricity use, as lower fan speeds resulting from the demand control were not taken into account when determining the expected values.
The ventilation fan electricity use based on the Belgian energy performance calculations methodology, is compared to monitoring results in the dwellings in the Venning neighborhood.

According to the Belgian methodology, the results are expressed per volume of the dwelling. For DCMEV, an energy use of 0,74 kWh/m³/year is assumed, when no demand-controlled ventilation is taken into account. However, monitoring results in phase 2 showed a three times lower energy use resulting in 0,25 kWh/m³/year, mainly due to demand control (See Fig. 9).

For a MVHR, an electricity use of 1,31 kWh/m³/year is assumed in the Belgian methodology. According to the monitoring results, this is an underestimation as the real energy use was two times higher at 2,63 kWh/m³/year. A poorly designed ventilation system with a pressure drop larger than expected could be responsible for this high energy use, or an underestimation in the EPB calculation.

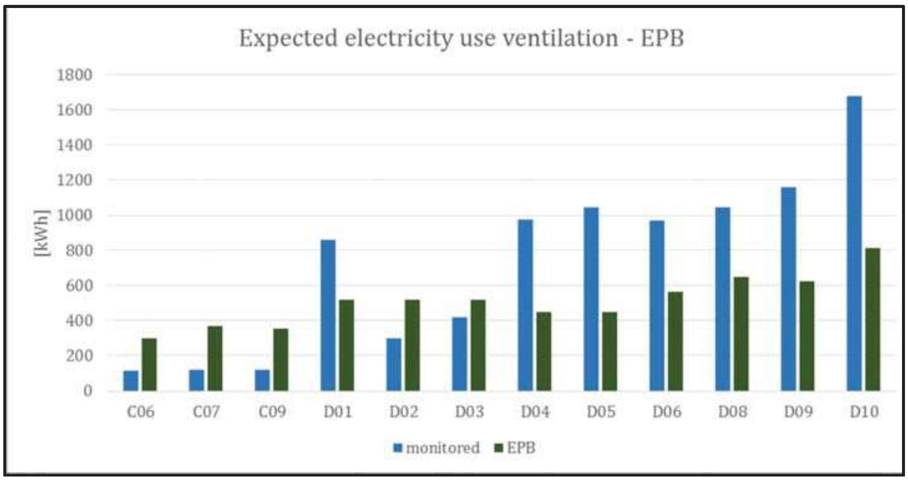

Figure 8: Phase 1 - Yearly fan consumption according to EPB calculations and monitoring in several buildings in phase 2, in case of DCMEV (C) and MVHR (D)

For phase 2 and 3 combined, after data filtering, 26 dwellings remained for which useful detailed data is available. Data are expressed as an average per dwelling. The fan consumption of DCMEV compared to MVHR was respectively 15 and 25%.

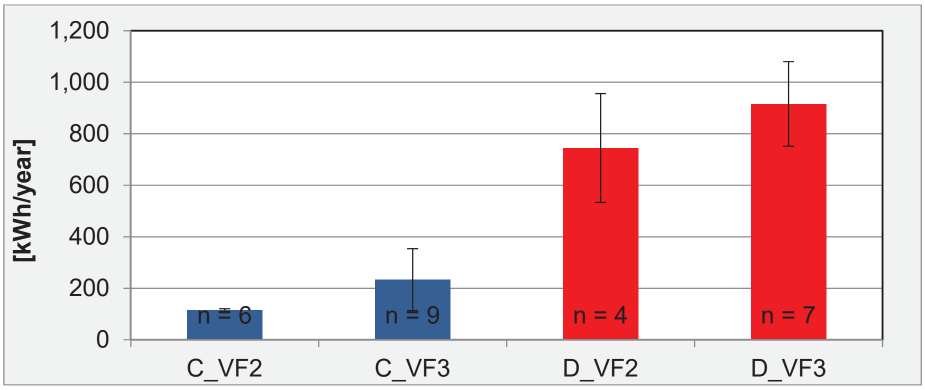

Figure 9: Phase 2 & 3 – Average yearly fan consumption according to monitoring, in case of DCMEV (C) and MVHR (D)

3.3 IAQ in-situ measurements

Reduction of ventilation losses may not lead to improper air quality. Ventilation should be designed to avoid a low indoor air quality (IAQ), corresponding to a relative CO_2 concentration higher than 1000 ppm (above outdoors) and preferably to obtain relative CO_2 concentrations is smaller than 600 ppm. In between these limits the IAQ is assumed to be moderate to medium. With the use of measurement data of the CO_2 concentrations during winter, the indoor air quality in the various dwellings can be assessed.

For both types of ventilation systems, there are dwellings with good IAQ and low IAQ; there is no ventilation system that provides a significantly better IAQ over the other ventilation system (Derycke, 2016).

For dwellings with DCMEV the position of the inlet grilles is of key importance. Closing the inlet grilles results in higher indoor CO_2 concentrations and therefore a lower IAQ. A minimum opening is recommended. For dwellings with MVHR the operation mode of the ventilation unit has a large influence, minimizing the airflow rates typically leads to a poor indoor air quality.

3.4 Overall comparison between ventilation systems

Combining the available data on the energy consumption for heating and auxiliary energy (electricity), allows to calculate the real performance in detail. Contrary to what is usually expected from existing simulations/calculations, the monitoring results demonstrate that the total energy consumption is very similar for both ventilation systems (Table 2).

Table 2: Yearly mean space heating and fan consumption in case of DCMEV and MVHR

	DCMEV	MVHR
Space heating consumption (kWh)	6592	5826
Fan consumption (kWh)	186	853
Total energy use (kWh)	6778	6679

Finally, the total energy cost (electricity and heating) of the ventilation systems was compared. Due to high electricity prices compared with natural gas per kWh (5 times higher in Belgium), DCMEV systems have about 30% lower yearly total energy costs (± 408€) when compared with MVHR (± 536€). These results confirm the conclusions made in earlier research papers (Krus et al., 2011).

Furthermore, Figure 10 illustrates that the energy cost to ventilate cannot be seen apart from the total cost of a system, including investment (product and installation cost) and maintenance cost (cleaning, sensors, filters). DCMEV systems show the lowest net present value after 15 year.

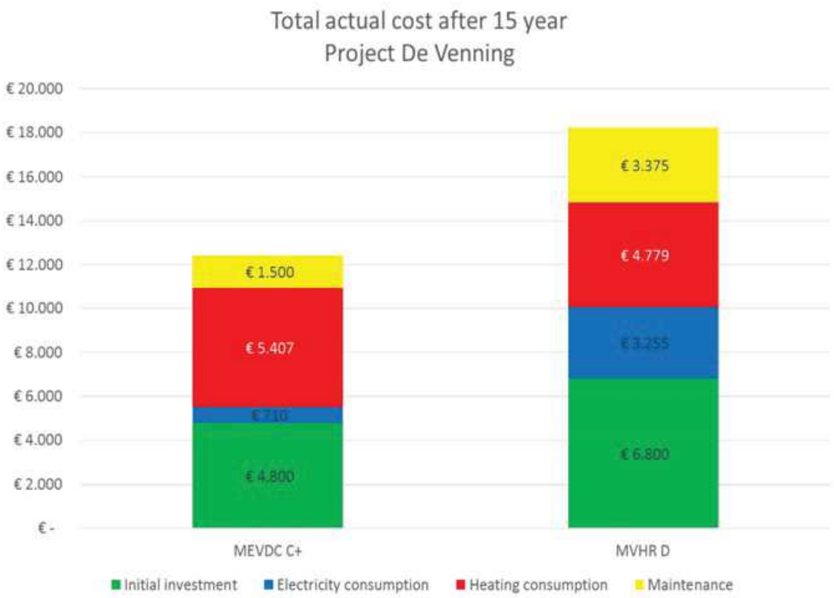

Figure 10: Comparison of total actual cost for DCMEV and MVHR after 15 year

4 CONCLUSIONS

In general, monitoring results revealed that dwellings with the demand controlled ventilation system show similar heating demand than those with heat recovery ventilation. Besides, the dwellings where a DCMEV was applied, use an average of 186 kWh auxiliary energy for ventilation on an annual basis, while the MVHR system used up to 853 kWh. This is a difference of at least 4 due to the presence of two fans, the higher airflow resistance of the system and a less demand controlled air flow rate. Space heating consumption cannot be seen apart from auxiliary consumption.

Therefore from an energetic viewpoint demand controlled ventilation system seems a good alternative for the heat recovery ventilation. Of course, a good air quality should be maintained. Dwellings with demand controlled ventilation showed no significant better or worse indoor air quality than dwellings with mechanical ventilation with heat recovery.

The total cost or net present value of qualitative DCMEV systems with or without demand control is nearly a third lower than that of a qualitative MVHR system, due to higher investment and maintenance cost of this latter.

Further research should focus on embedded carbon of the system, sensors lifetime and the impact of regular filter cleaning and replacement in case of MVHR, optimizing the DCMEV system with respect to design air flow rates and control algorithms.

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