Results of the evaluation study DeAL
Decentralized facade integrated ventilation systems

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ABSTRACT
Most office buildings in Germany have either no mechanical ventilation system or a centralized ventilation system with fresh and exhaust air supply. Within the last 10 years some projects using decentralized ventilation systems (DVS) came up. Common for this type of decentralised systems is that they take fresh air directly from outside through the facade via the DVS into the room. Within the DVS-component air conditioning (at least heating) takes place.

Since the year 2000 more than six companies provide this type of ventilation systems for office buildings and about 50 buildings have been realized in Western Europe. Within a two year research project the evaluation study DeAL investigated 10 of these buildings in respect of:

- how do the DVS operate in reality (reliability, energy consumption, noise etc.)?
- are the users and operational staff satisfied with DVS?
- are there advantages that can be quantified within the evaluation buildings?
- what is the thermal comfort in these buildings?
- is maintenance a problem with decentralized systems?
- does the necessary "wholes" in the facade influence the building performance (wind, sound protection, water tightness...)?

The investigation included detailed monitoring of the DVS for a period of at least one year. The study was finished by August 2008.

INTRODUCTION

The research project DeAL investigates office buildings with decentralized ventilation systems which are integrated in the facade. Within a two-year research project 10 buildings in full operation were investigated in respect of comfort, satisfaction of user and operators and energy efficiency. The project was led by Steinbeis. Project partners were the company TransSolar Energy Technology GmbH and the Institute for building and solar technology (IGS) of the Technical University of Braunschweig.

About 50 office buildings with decentralized ventilation systems were built in the last 5 years in central Europe. This concept will become more important in comparison to traditional air conditioning systems, because of the demand for flexible, space-saving technology in office buildings. These decentralized ventilation systems, which are integrated in the facade, meet following criteria (Figure 2) according to "VDMA-Einheitsblatt" 24390 [2]:

- The air supply takes place decentralized in the room, through openings in the facade. Some of the models discharge the air through the facade as well
- The air treatment (heating, cooling, heat recovery, ...) is done decentralized in the DVS.

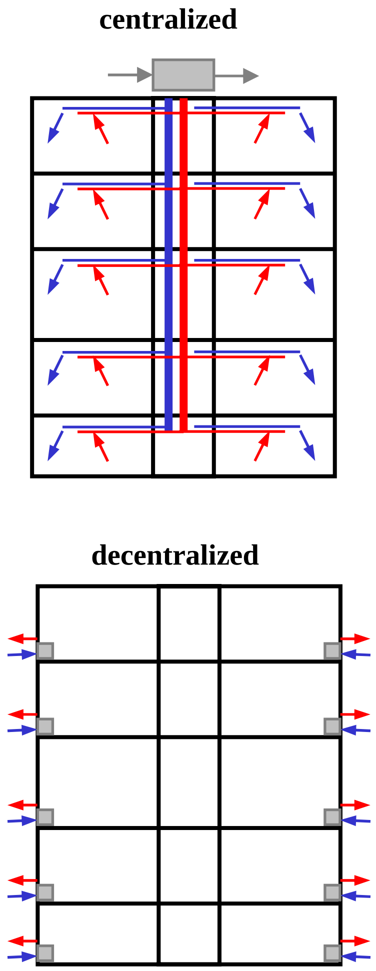


Figure 2. Comparison of central and decentralized ventilation system

Table 1. Advantages and disadvantages of decentralized ventilation system

Advantages	Disadvantages
• reduced floor heights, because no need for ventilation ducts and suspended floors • smaller room for ventilation devices • lower energy costs • flexible use of space • operation only if individual users are present in the room • user influence on the room climate possible	• variety of devices causes higher maintenance costs in the medium term • maintenance carried out in the (rented) spaces • humidifying and dehumidification is difficult • wind pressure and temperatures on the facade might influence the DVS-systems

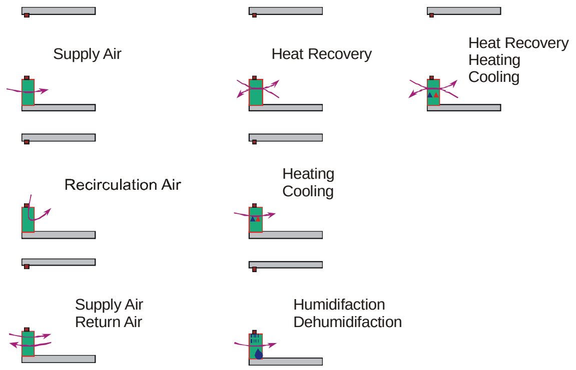


Figure 3. Types of decentralised ventilation devices.

The ventilation systems can be installed in the area of the balustrade, as sub-floor units, in the area of the ceiling, of the lintel or of the wall. The range of functions vary from pure heating and cooling mode via heat recovery up to humidification and dehumidification of the air. The manufacturers have now developed a series of basic components and modules, which can be combined with a number of devices. Very often an individual type of device will be designed out of these parts during the design stage of a building

APPROACH

Initially a market survey was carried out and the basic experience of the operators of buildings with DVS devices was interrogated via questionnaires and interviews. Secondly 10 buildings were investigated more exactly. Short-term and long-term (for one year) measurements were conducted, plan views and energy consumption were analysed and interviews of users were hold.

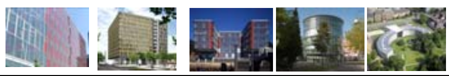
DESCRIPTION OF THE OBJECTS

In the year 2007, 30-40 building with DVS devices, which were built after the year 2000, were in operation and in planning, Figure 4.

Figure 4. buildings with DVS systems

Out of the detailed investigated buildings with one exception, all buildings are office-buildings (Figure 5). The relevant heated net floor area is between 2.060 square meters and 23.264 square metres in this project. The number of DVS devices ranges between 60 and 815 units per building.

Location:	Zürich	Zürich	Berlin	Neckarsulm	Stuttgart
Area:	7.741 m²	6.317 m²	9.027 m²	6.114 m²	3.454 m²
Occupied since:	2004	2002	2003	2007	2002
Number of DVS:	313	200	166	200	272
Function:	- Supply air (activ) - Heating - Cooling	- Supply air (passiv) - Heating - Cooling	- Supply/ Recirculation/ Return Air (activ) - heating - cooling - Humidi-fication	- Supply Air (activ) - Heating - Cooling - Humidification	- Supply/Return Air (activ) - Heating - Cooling
Integration:	Floor	Parapet	Parapet	Floor	Parapet



Location:	Düsseldorf	München	Hamburg	Freiburg	Leverkusen
Area:	43.000 m²	20.900 m²	10.142 m²	2.110 m²	23.100 m²
Occupied since:	2005	2007	2002	2006	2002
Number of DVS:	815	800		65	800
Function:	- Supply Air / Return Air (activ) - Heating - Cooling	- Supply Air / Return Air (activ) - Heating - Cooling	- Supply Air (passiv) - Heating - Cooling	- Supply Air (activ) - Heating - Cooling - Recirculation Air	- Supply Air (passiv) - Heating - Cooling
Integration:	Facade	Parapet	Floor	Floor	Floor

Figure 5. Characteristics of the 10 buildings investigated in detail

Looking at the energy concepts of the buildings, it becomes apparent that decentralised ventilation devices are often in buildings with "lean" climate and energy supply technology. Commonly used is the combination of the thermal "agile" decentralized ventilation technology with the "dull" concrete core tempering. The ventilation heat losses through the ventilation system and the relatively good U-values of the facades allow a concrete core tempering with low area-related heating and cooling capacity to cover the demand on heating and cooling. The concrete core tempering is operated at temperatures around room temperature which allows the use of "environmental energy". This energy is taken by energy pile installations, geothermal probes, use of well water or free cooling at night.

RESULT

Operators survey

An operators survey was carried out for 17 buildings 2005 and 2006. The aim of the survey was to collect data of the buildings and their energy concepts in which DVS are in use.

Figure 6 provides information about the total satisfaction of the operators with the equipment. The overall satisfaction of the operators with the decentralised ventilation devices is high. Twelve of sixteen operators assessed the equipment as very good and are very comfortable with it respectively. Only two operators are uncomfortable with the operation of the devices. One operator considers decentralised ventilation devices which are integrated in the building as a wrong decision.

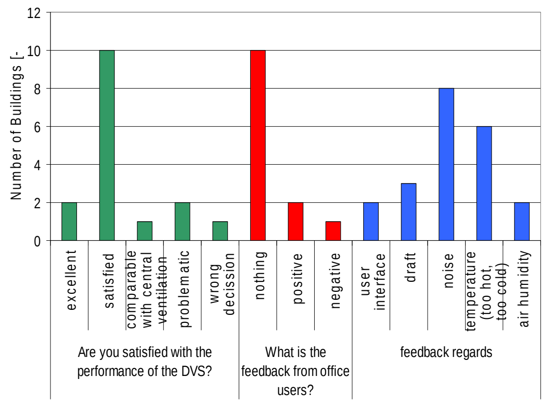


Figure 6. Satisfaction with the devices.

In general, there is few or no feedback from the office users to the operators. Complaints occurred regarding mainly an excessive noise emitted by the devices and the air temperature, (too hot or too cold).

Energy Efficiency

Final Energy - Heat

Figure 7 shows the annual heat consumption of the buildings with decentralised ventilation technology related to the net floor area and the results of various research projects (EVA 2006 [1], Schweiz 1999 [3], Frankfurt 2002 [4], enerkenn [5]).

The office buildings with the minimum heat consumption investigated in the studies demonstrate values between 25 and 70 kWh / (m² NGFa) (bottom of the bars). The buildings with the maximum heat consumption (top of the bars) need 167 to 245 kWh / (m² NGFa) heat. The average thermal heat consumption of the buildings (centre line) is 97 to 140 kWh / (m² NGFa). Good comparable to this study is the result of the EVA study, as the type of buildings, age and methodology is similar (good reference value is the average value of the EVA study with 97 kWh / (m² NGFa)).

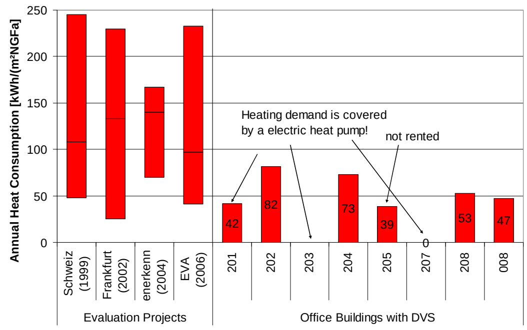


Figure 7. final energy consumption – heat demand of office buildings with DVS

All this makes apparent that the buildings with decentralized ventilating indicates a significantly low heat consumption, in comparison to the average office building with a central ventilation technology. The heat consumption of all buildings with decentralised ventilation technology is below the average consumption of EVA study. The heat consumption of four buildings is about 50% below the average of the EVA study. However, it should be noted that heat pumps are used in buildings 201, 203 and 205 to fulfil the demand, and they cover the heat consumption partly or as a whole with electricity. Furthermore, it should be noted that the building 205 wasn't rented and operated with lowered room temperature during the investigation.

Final Energy - Electricity

Figure 8 shows the electricity consumption of the buildings related to the net floor area (total current consumption including tenants' consumption). The average electricity consumption of the building stated in the studies is 83 to 160 kWh / (m² NGFa). The reference value which is drawn in comparison is the average value of the EVA study of 90 kWh / (m² NGFa).

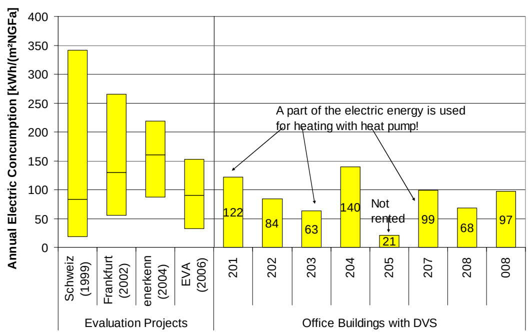


Figure 8. final energy consumption – electricity

Analysing the power consumption of the building with a decentralised ventilation technology a tendency towards low consumption can be reported. Three buildings spend more electricity than the "EVA"-average, four buildings spend less power. Although building 205 is not rented, there is a current consumption of 20.7 kWh / (m² NGFa). The building with the maximum electricity consumption is occupied by an insurance company and includes a computer centre with a high using-depending power consumption. In building 201, 203 and 205, a part of the electricity consumption is used for the operation of the heat pump, i.e. the power consumption contributes to the heating. This explains the relatively high electricity consumption of building 201, while the consumption of building 203 - despite of the heat pump - is surprisingly low.

Space efficiency

One theoretical advantage of the decentralized ventilation technology is the smaller space requirement (no central ventilation facility, no ventilation shafts, etc.). As part of this study it was analysed whether this theoretical advantage of the decentralized ventilation technology is actually implemented in the construction practice.

The space efficiency of the buildings is here shown by the ratio of the area used for technical compliances (FF) and the main usable area (HNF) to DIN 277. According to IFMA [6] and BKI [7] the area of efficiency in buildings with a medium technical equipment is 11.5% and 10.3%.

Figure 9 shows the area efficiency of buildings with decentralised ventilation technology in comparison to buildings with central ventilation technology.

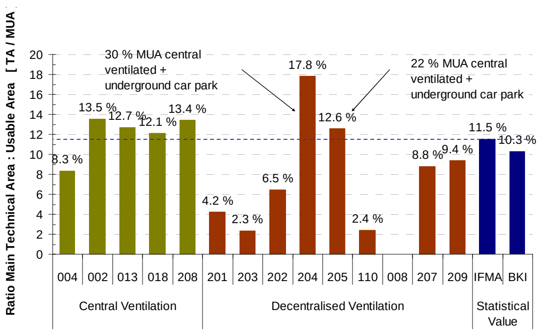


Figure 9. space efficiency of buildings with decentralised ventilation technology.

Within the framework of EVA investigated buildings with a central ventilation systems are comparable with the parameters for IFMA. The buildings with decentralised ventilation are significantly more space efficient except two buildings. Four of the buildings with decentralised ventilation require about 5-8% less functional area and show the potential for efficiency. The buildings 205 and 201 are comparable with centralized ventilated buildings, this is partly due to the fact that, besides decentralized ventilation devices in these two buildings there are also considerable parts centrally ventilated and some large ventilated garages.

Comparison of the height between floors

Regarding the height between floors, there could be expected a similar advantage of the decentralized ventilation technology: Air supply and exhaust system is not required, therefore lower heights between the floors are possible with the same room height due to a smaller suspended ceiling.

This benefit hasn't been implemented in the buildings, which were investigated for this study (see Figure 10). It is likely that the concept of decentralized ventilation has been belatedly added in the preliminary design, so that no adjustment has been carried out. Only the buildings 203 and 204 benefit from the lower height between the floors. The potential additional space, especially in high-rise buildings, is considerable: 30 cm lower effective floor height means an additional floor every 10 floors or 10% higher area efficiency!

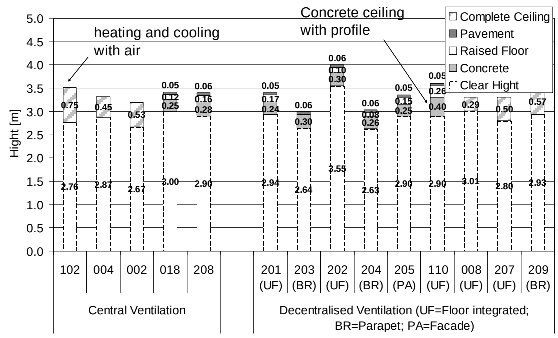


Figure 10. Height between the floors - comparison centrally and decentralized-ventilated buildings

Comfort measurements

Long-term measurement of air temperature and humidity

For the long-term measurement of thermal comfort in these buildings, up to four representative workplaces per building were measured regarding to ambient temperature and humidity at a height of 110 cm during a period of up to one year, see Figure 11a and 11b.

Figure 11a Temperature and humidity logger with four external channels

Figure 11b Long-term measurement of air temperature and humidity in the workplace

Figure 12 shows the distribution of the measured temperatures in selected offices. It can be seen, that besides a few exceptions barely excessive heat in the summer exists (temperature> 26 ° C). There are significant periods under 20 ° C measured in building 205. This is based on the fact of faulty adjusted sensors for ambient temperatures (also users made a complaint). Overall a very good thermal comfort in the offices is noted.

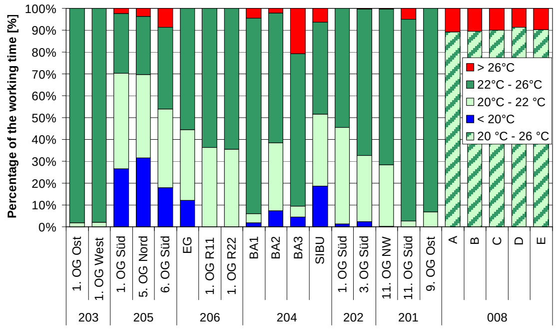


Figure 12. Statistics of temperature distribution - measuring period 1 year

Supply air with humidifying action is only used in two of the 10 surveyed buildings. The interior air humidity is regulated by a nominal value of 50 to 55% relative humidity in the building 206. Looking at Figure 13, the successful measurement in three exemplarily examined rooms during the whole measuring period is demonstrated. However, the effort to design a decentralized ventilation with humidifying action is substantial and should only be considered for special occasions.

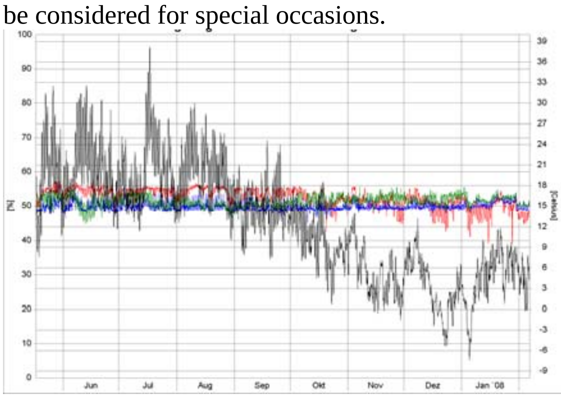


Figure 13. Measurement of air humidity for three rooms

Airflow

Within the investigation it was examined whether the decentralized ventilation devices reaching the air quantities within real implemented condition, which have to be reached according to the manufacturer in the various levels of the ventilators, Figure 14.

Figure 14. Volume flow meter.

The results demonstrated in Figure 15 are very positive except for one building. Within the accuracy of measurement the equipment meets the requirement even with modified pressure losses due to dirty filters etc.. Our investigations revealed that the devices in building 201 were incorrectly configured, and about 50% more air flow was generated. This was also the reason for increased noise pollution.

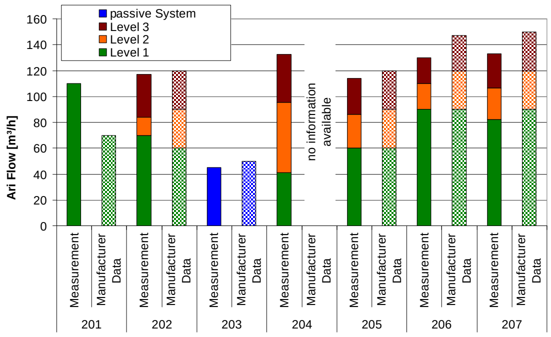


Figure 15. Comparing the measured volume flow with the manufacturer's specifications.

Noise emission of equipment at workplace

It is much more difficult to realize decentralised ventilation devices with low noise emissions than central devices. All technology (fan, heat exchangers, valves and silencer) must be fitted in confined space. Therefore, the actually reached noise pressure level at the workplace was measured as part of the research project (Figure 16).

Figure 16. Sound level measurement in the workplace.

The sound emissions of deactivated ventilation devices add up to 28.5 to 33.5 dB (A), see Figure17.

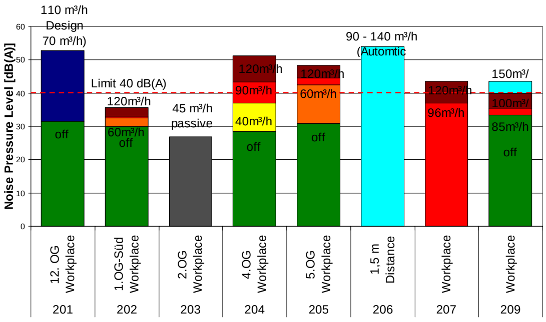


Figure 17 Noise emissions from the ventilation devices at work

Looking at building 201 the limit of noise level is significantly exceeded with 52.8 dB (A). This is due to a much higher volume flow than designed. It can be assumed that the noise emissions will be below the limit after this issue will be resolved.

The buildings 202 and 203 are very quiet. There are no workplaces in building 206, therefore, the limit for office buildings isn't valid in this case. The external air flow is measured with the control technology of the buildings conditioned by the concentration of CO2. The sound pressure level adds up to 54 dB (A) at a distance of 1.5 m to the devices.

Looking at the remaining buildings, the noise in the lowest levels of ventilators is at least within the limits. The noise emissions through the ventilation devices are evaluated very critically and also criticized by some users. In future, more attention has to be paid to quieter implementation of the devices.

Users' survey

The detailed measurements show the comfort of the room by objective criteria. Anyhow, in the end the subjective impression of the users is crucial for the use of decentralised ventilation technology.
Consequently, users' survey was carried out in the buildings. Therefore 10 to 20 standardized and anonymous questionnaires per building were distributed. Figure 18 shows the results as an average per building on various aspects. Air quality, temperature and overall satisfaction were judged very positive. Smell and draught did not occur. The only critical comments from users are due to dry air and noise.

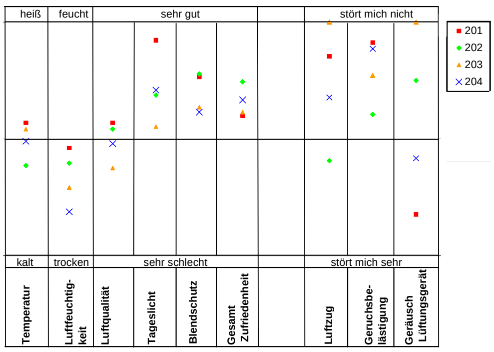


Figure 18. User satisfaction - poll in the buildings

Maintenance and filter change

A key objective of the research project was to examine the maintenance effort and maintenance costs for the decentralised ventilation devices. Therefore maintenance contracts were requested from the operators of the building and interviews were held on the issue.

It turned out that a determination of the maintenance costs based on the maintenance contracts is not possible. Either there are no maintenance contracts, because the maintenance is made by the technical facility management (FM) of the operator or the maintenance is as a total package assigned to sub-contractors, so that no conclusions regarding the maintenance costs of decentralised ventilation devices are possible. Therefore the maintenance effort was qualitatively recorded and evaluated, see Table 2.

Table 2. Maintenance costs of decentralised ventilation devices

object	201	202	203	204	205	206	207	209	110	008
implementation										
intern FM		X		X	X					
extern FM	X		X			X				
maintenance interval										
per year	1 x	1 x	0,5 x	1 x	n/a.	1 x			n/a.	1 x
duration of maintenance per unit										
minutes	5	15	5	2	5	30 – 60				
effort for maintenance work										
light				X						
normal	X		X		X				X	X
high		X				X				
previous work										
change of filter	X	X	X	X	n/a.	X			n/a.	n/a.
cleaning of H.E.	X		X		n/a..	X			n/a.	n/a.
number of replacement equipment in stock										
units	none	none	none	30	10	n/a.				

Approximately for half of the buildings, the maintenance of decentralized ventilation equipment was carried out by their own FM. The devices are maintained once or twice per year. The duration for each device varies in office buildings from 2 to 15 minutes. The maintenance at the museum lasts up to 60 minutes due to the intense maintenance of the complex system including the humidifying unit.

The expense of maintenance is from "light" to "normal" at six out of eight buildings. The effort is "high" at only two buildings. "Light” stands for maintenance without using tools for opening the equipment and accessible filter by velcro fastener or magnetic locks. If the work of maintenance staff can be done without prior knowledge and with simple tools (such as a screwdriver), a "normal" complexity will be expected. If several flaps under difficult conditions must be opened or the equipment must be completely pulled out of the slot, a "serious" accessibility is assumed.

The maintenance consists usually of changing the filter and partly the cleaning of the heat exchanger with a vacuum cleaner. The cleaning of the heat exchanger is not carried out in two of the buildings. Although the devices in terms of maintainability have been improved compared to previous devices, the effort is substantial in comparison to the maintenance of central ventilation devices. This should be explained by a calculation example below:

The maintenance of a ventilation device in building 205 lasts only 5 minutes. A total number of 815 units with an exterior air flow rate of 60 m³/h per device in Stage 1 were installed, which results a total volume flow of 48,900 m³/h. A central ventilation system would split the flow rate, for example, on two central units. Maintenance of the two central units are estimated about 3 to 4 man days. The total duration of maintenance for the decentralized equipment is 8,4 man days. In other words, the maintenance effort for decentralised ventilation technology is about two to three times higher than for the central ventilation technology.

SUMMARY

Above all a good comfort can be reached with ventilation technology. Partly problems with noise emissions and dry air occurred in the investigated buildings. The demand of thermal heat in the DeAL-buildings is very low. The electricity consumption is comparable to similar buildings with a central ventilation technology.

In the last 10 years the devices have been greatly improved. Maintenance is less problematic than expected, but the time exposure is 2 to 3 times higher than with central ventilation systems. An important advantage of decentralized devices is the possibility to activate the ventilation only in the presence of the users. This individual control hasn’t been used in the investigated objects (partly due to open-plan offices) and thus potential wasn’t utilized optimally.

The combination of decentralized ventilation devices as a fast system with a concrete core that makes the right temperature as an inert system has proved its worth. The feedback from the surveys of operators and users is generally positive. If the building concept is adapted to the decentralized technology, a very high surface efficiency is achievable.

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