Simple and reliable constant pressure ventilation for nZEB

Skanska has cut energy use of ventilation to a quarter in ten years

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There are many ways to reduce energy use and to achieve good energy performance in commercial buildings. Regarding ventilation and air conditioning, a popular way is a complicated decentralised system with many air handling units placed on the office floors and the reduction of the air flows locally by using a huge number of electromechanical equipment such as motorized supply air diffusers, one per office module. Another way is the non complex one, utilising the increased performance of the system by reducing air flow speed in both in the ductwork and through the air handling units, and keeping the number of motorized components on the office floors and number of AHUs low.

By using the second path, the non complex one, we have achieved a reduction of energy use for ventilation in our office buildings from 40 kWh/m² rentable area down to 11 kWh/m², including both supply air heating energy and fan energy. This has been achieved mainly due to increased performance of AHUs as a result of LCC-purchase procedure of AHUs as a routine in our project development. How is that possible?

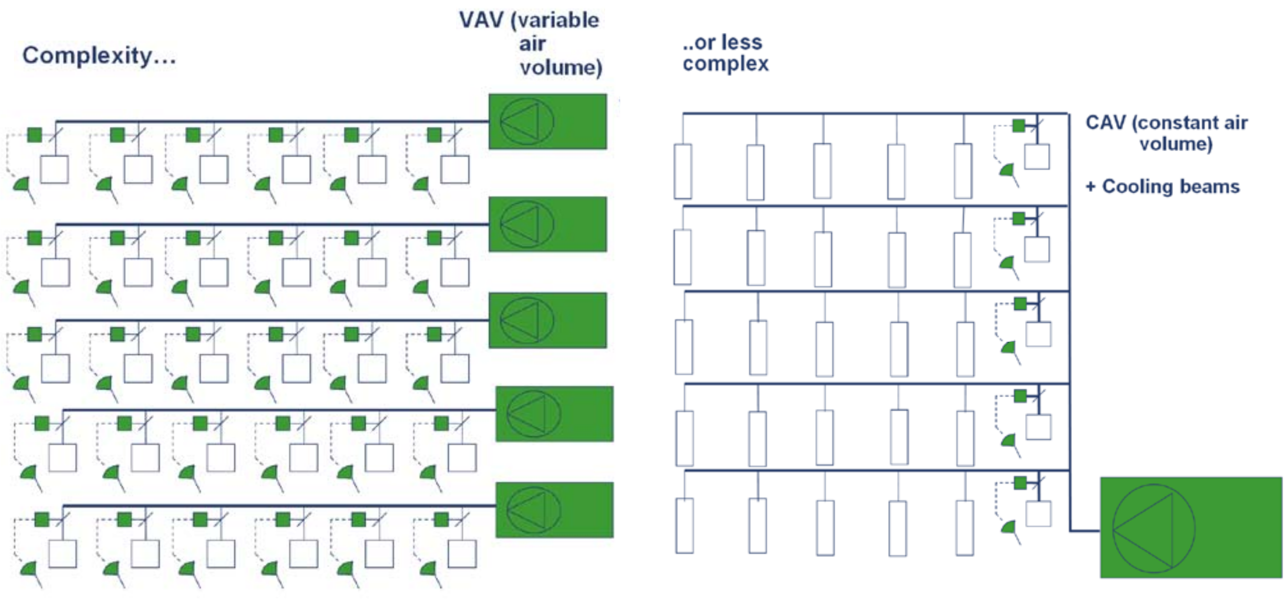


Figure 1. Complex solution vs. less complex solution. Left figure shows VAV system with motorized supply air diffusers for all office modules. In the right figure, dampers are used only to control air flows in the meeting rooms. Balancing, commissioning and maintenance are easier in more robust CAV system.

Duct work with final pressure drop

For a property owner, continuous tenant outfits are a part of the normal business. This causes problems due to expensive tenant outfit when having to do change of installations also in ductwork in distribution routes in the corridor above suspended ceiling.

The traditional sizing of ductwork with approx 1 Pa/m pressure drop gives almost constant speed in ducts and decreasing diameters of the ducts along the corridor and ends up with a small duct diameter at the end of the corridor. If a tenant wants to move a meeting room to the end of the corridor, the distribution duct has to be replaced for a number of meters by a duct with a larger diameter up to the point where you have the right diameter in the distribution duct. It could be many meters of ducts to be replaced. The rooms connected to the distribution duct from shaft to the end of the distribution duct have to be rebalanced when using the traditional sizing. Traditional sizing for a constant pressure drop results in a high static pressure in the shaft normally about 250 – 300 Pa and a low static pressure in the last supply air diffuser in the end of the corridor normally 40 Pa.

We have overcome this problem by using untraditional design, sizing for final pressure drop. The maximum speed in ducts are limited to 5 m/s in vertical duct in shafts and static pressure to 120 Pa, and the maximum speed 3 m/s in distribution duct on the office floors and static pressure to 100 Pa. The trick is to follow the maximum speed requirement with larger ducts and not to reduce the diameter of the ducts. The ducts on the floors are one size all the way.

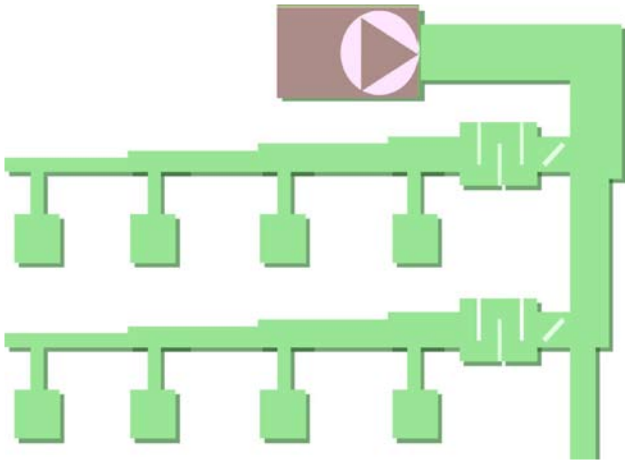
That results in a reduced air speed in the distribution duct when air flow decreases all along the way to the last connected supply air diffuser. The pressure drop per meter will decrease instead of being constant. At the end of the duct in the corridor there will even be a slightly increased static pressure when dynamic pressure turns into static pressure:

$$P_{dyn} = \frac{\rho v^2}{2} = \frac{1.2 \times 3^2}{2} = 5 \text{ Pa.}$$

The requirement for the supply air diffuser to be able to use final pressure drop, is a pressure drop over the supply air diffuser including the damper in the supply air diffuser of 100 Pa and induced noise not higher than 28 dB(A). Most of the manufacturers have such products in their portfolio. When we check the static pressure in the distribution ducts on the office floors, the pressure is approx 100 Pa both in the beginning of the duct and in the end of the duct. It is really constant pressure in the ducts on the floors in the final pressure ductwork.

The static pressure in the ductwork will be kept constant by frequency controlled fans in AHU and pressure sensors placed in the main shafts. The ducting system will be less expensive to install, because the traditional balancing dampers and sound attenuators are replaced with larger ducts in the end of shafts and corridors. One dimension for ducts, one dimension for fittings, one dimension for brackets means less complicated mounting and logistic of material on site. No balancing dampers and sound attenuators are needed for balancing of supply air ducting system. All balancing are done in the supply air diffusers, by final pressure drop.

Traditional ventilation



Final pressure drop ventilation

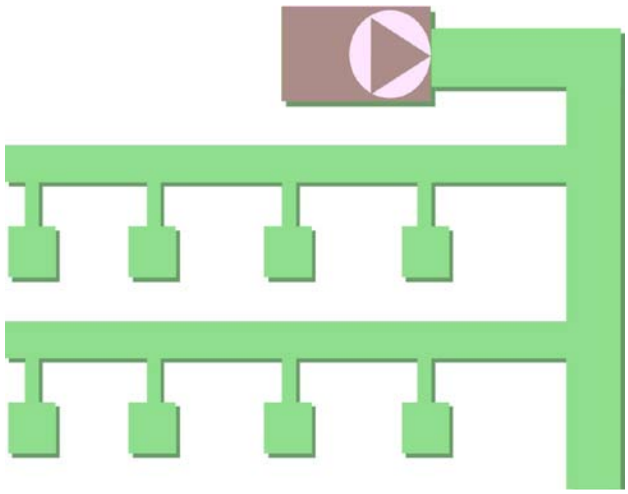


Figure 2. Traditional ductwork with dampers, silencers and decreasing diameters compared to final pressure drop ductwork with constant diameter and less components.

Figure 3. Free cooling coil as first step in the AHU. From the right: the heat exchanger that exchanges the heat from the glycol circuit in the coil in the AHU to the chilled water circuit for cooling beam system. Energy saving is approx 5 – 10 kWh/m² annually.

Extract ducting system is normally not problematic due to less terminals and less ducting, and they are normally more or less done with final pressure drop. For example, extract valves in toilets are excellent final pressure equipment.

LCC-purchased Air Handling Units

A Swedish industrial standard for purchasing energy consuming products such as fans, chillers etc were developed by the industry and community in cooperation to simplify the process. Both client and manufacturer use templates that standardize how to tender and how to bid, that is how to make a tender document and how to make an offer. This enables it for the client to compare the LCC offers of air handling units from different manufacturers.

We started to LCC-purchase for twelve years ago. Our specification of requirements for air handling units consists of big units between 10 m³/s to 20 m³/s in air flow and runaround coils (rotors) for heat recovery, and that the supplier shall be Eurovent-certified. We also require a free cooling coil as first step in the AHU that can manage all cooling beam circuit cooling demand during winter period. This coil also preheats the outdoor air in wintertime with the energy of internal heat gains, see a connection principle from **Figure 3**.

Our requirements for heat recovery efficiency and specific fan power have been increased step by step in around 30 different commercial building projects during the years.

The performance has increased from air speed of 2.3 m/s through AHU, corresponding SFP of 2.9 kW/m³/s and heat recovery temperature efficiency of 54%, in steps during the years and developing about 400.000 m² rentable area in 30 projects to the latest project with air speed of 1.0 m/s through AHU, SFP of 1.3 kW/m³/s and heat recovery temperature efficiency of 81%. When using such a low speed through AHU, sound attenuators between the AHU and the ducting system are not needed. The AHU turns "short and fat" instead of traditional "long and thin" by having large front area and no sound attenuator compared to the traditional AHU with small front area and sound attenuators in both ends of the AHU.

Figure 4. Low Speed Air Handling Unit without sound attenuators. The air flow is 13 m³/s. The speed through the AHU is 1.6 m/s.

Air Handling Units, from 2,3 m/s to 1,0 m/s

HagaPorten I (2000) [22 m³/s, 2.3 m/s]	**"Trad alt"**	**Chosen alt**	
energy (fans & heating)	40 kWh/m²	32 kWh/m²	
heat recovery eff. η_t, %	54 %	63 %	
operation cost, €	471.000	367.000	
investment cost, €	124.000	131.000	(+7.000)
TOTAL cost, €	595.000	498.000	
Sundbypark (2003) [14.5 m³/s, 1.6 m/s]	**"Trad alt"**	**Chosen alt**	
energy (fans & heating)	28 kWh/m²	22 kWh/m²	
heat recovery eff. η_t, %	60 %	66 %	
operation cost, €	211.000	168.000	
investment cost, €	72.000	94.000	(+22.000)
TOTAL cost, €	283.000	262.000	
Lustgården 14, prel. (2011) [14 m³/s, 1.0 m/s]	**"Trad alt"**	**Chosen alt**	
energy (fans & heating)	20 kWh/m²	11 kWh/m²	
heat recovery eff. η_t, %	69 %	81 %	
operation cost, €	238.000	116.000	
investment cost, €	99.000	193.000	(+94.000)
TOTAL cost, €	337.000	309.000	

Figure 5. LCC evaluation and chosen alternatives. The life cycle energy cost has been calculated as net present value of 25 years of operation for supply air heating and fan power.

Increased investment cost due to chosen alternative of AHU during the years could be illustrated by the examples in the **Figure 5**. From being slightly more expensive in investment and giving a big reduction in operation cost over 25 years it becomes low-hanging fruit. As we now are doing extra investments that are more or less as big as the savings over 25 years of operation expressed as net present value, it has become high-hanging fruit.

To be sure that the equipment is according to the specification in the offer we do LCC-commissioning of AHUs. External temperature sensors are placed to the AHU, tracer gas measured air flows and current meters give the SFP and heat recovery efficiency that is compared with the specification and converted by the simulation program for the bought unit. When doing these commissions we have found wrong placed heat exchanger coils in AHU, wrong connected coils, wrong brine flow, etc. Thus, to do LCC-commission is essential.

A philosophical aspect regarding the solutions selected on LCC and LCA basis, is that it is also dependent of in which order you add the possible solutions. If you first recommend the complex system with demand controlled ventilation in all areas in order to reduce air flow, the resulting energy use will be reduced. The economical possibility also to choose the low speed AHU will then be reduced, because the remaining energy need after demand controlled ventilation in all areas is smaller. Therefore, the possibility to reduce the energy use a bit more by low speed AHU is less attractive. If you first recommend to use a low speed and high efficiency AHU and then add the demand controlled ventilation in all areas, it will be economically difficult to choose demand controlled ventilation, as the remaining energy need is low because of the energy use reduction already achieved by using the low speed AHU.

Finally, now only the high hanging fruits are left to be picked. But we are convinced that we have to stick to our strategy of simple solutions and high performance equipment in order not to get lost in all maintenance issues.