RESHYVENT

Cluster Project on Demand Controlled Hybrid Ventilation in Residential Buildings with Specific Emphasis on the Integration of Renewables

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IMPACT OF RESHYVENT CONCEPTS ON THE USE OF RENEWABLE ENERGY FOR HEATING, COOLING AND ELECTRICITY

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CONTENT

1 THE RESHYVENT PROJECT

Within the Fifth Framework Programme of the European Commission the research project RESHYVENT (Renewable Energy Systems Hybrid Ventilation) has been carried out, running from the January 2002 until December 2004.

The aim of the RESHYVENT project has been to research, develop, and construct demand controlled hybrid ventilation concepts for residential buildings.

This report is deliverable D3.3 in the project and deals with the quantification of the impact of hybrid ventilation systems and the impact on limiting and equalising ventilation losses especially on the application of renewables and low valued energy.

The specific tasks for this deliverable is:

- Task 3.2. Quantification of impact of RESHYVENT concepts on application of renewables and low valued energy.
- Task 3.3. Quantification of impact of RESHYVENT concepts on energy use for heating, cooling and electricity.

For information on the possibilities for integration of renewable energy, primarily solar power energy, please refer to the following two deliverables:

- D3.1 General information on renewable energy applications for auxiliary energy – suitable for use in hybrid ventilation systems.
- D3.2 Specifications of applicable renewable sources for integration in possible prototypes.

2 THE IMPACT OF APPLYING ADVANCED VENTILATION SYSTEMS IN RELATION TO HEATING, COOLING AND ELECTRICITY

2.1 Introduction

Advanced ventilation systems, such as demand controlled hybrid ventilation systems, can reduce the energy use due to ventilation to a significant degree, at the same time providing good comfort and indoor air quality conditions and those these systems have an impact on heating, cooling electricity in buildings.

This chapter will focus on some of the main issues in an advanced ventilation system, which influences heating, cooling and electricity.

2.2 Comparison of a traditional and an advanced ventilation system

Nowadays, a traditional mechanical ventilation system could be considered as a central ventilation system i.e. either supply or exhaust on/off ventilation system, with constant airflow rates not controlled by the users and without provision for heat recovery or free-cooling. An advanced air-handling unit consists of all components needed for the advanced functions as demand control, balancing supply and exhaust, heat recovery and free-cooling.

The energy performance of efficient ventilation systems for buildings has been studied in the framework of the THERMIE European Program [Thermie], which main objective was to provide designers with an objective criterion to decide the best option for each specific solution. In a constant volume system, the supply and the outdoor airflows are fixed. However, there is not always a need to supply with the same amount of total air flow. Cooling and heating loads change continuously, thus the needed supply air-flow rates depend on the space requirements and the occupant needs. In an advanced ventilation system with demand control (DCV) the rate of ventilation is continuously and automatically adjusted in response to the indoor environment. The control system relays on information from the air quality sensor to the ventilation system. In its most rudimentary form, this is simply a switch, which is connected to the fan of the ventilation system. When the sensor indicates a need for ventilation, the ventilation fan is switched on. For more sophisticated systems, the fresh air is modulated by frequency drives for the fans, controlled by the sensor. This ensures that ventilation is applied according to need. So, ventilation rates may be reduced to save energy. In many cases, it is possible to show energy saving of 60% or more when compared with the continuous operation of a traditional ventilation system. In the case of the School of Engineering at the University of Porto [Thermie], the total savings are 38% when using a DCV system (based on CO_2 control) in comparison with a traditional ventilation system. Figure 2.1 shows the energy consumption (for cooling/heating, pumps and fans) with the traditional and advanced system with the demand control unit.

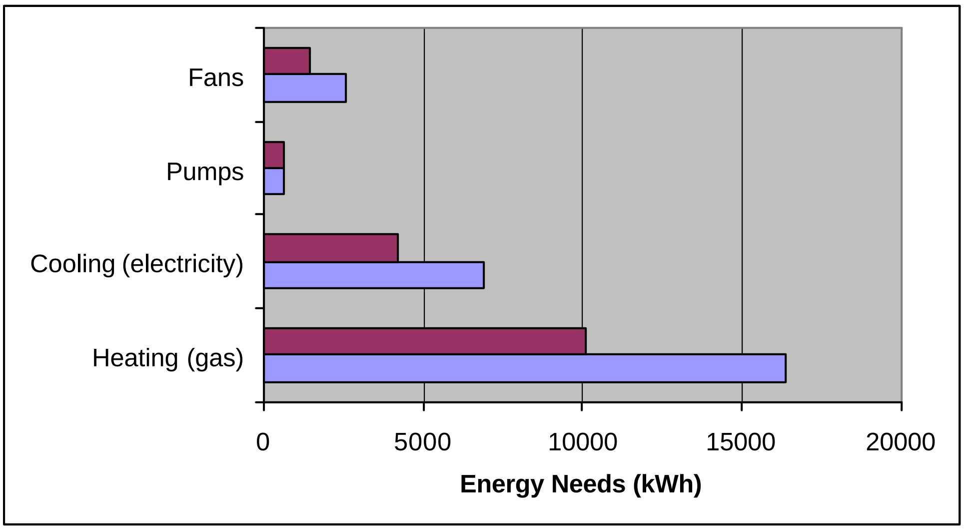

Figure 2-1: The difference in the bars symbolises the energy savings associated with CO_2 control at School Auditorium [Thermie], where the light purple bars symbolizes the advanced ventilation system and the dark purple the traditional ventilation system.

From figure 2.1 it may be seen that large energy savings can be obtained when using DCV (controlled by CO2) both for heating and cooling and fans.

2.3 The impact on cooling

Another advantage of using demand controlled ventilation is the concept of “Free Cooling” which can be utilized. "Free Cooling" is a strategy that reduces or neutralizes the cooling energy demands of the conditioned zone using an excess of outdoor air when outdoor air temperatures are lower than indoors [Thermie]. Logically, the ventilation rates used when free cooling is used are:

- Larger of those needed to meet the basic fresh air requirements of occupants.
- Lower or equal to the supply air flow rates obtained for design conditions in every zone as a function of the design supply air temperature needed to meet the peak cooling loads.

In terms of energy consumption, the use of free-cooling reduces the electricity consumption of the cooling plants but increase the consumption associated to fans. Nevertheless, the net effect is in most of the cases a significant saving in electricity consumption terms. The more significant the contribution of the internal gains to the cooling requirements of the building, the higher the interest of using free-cooling as an energy saving strategy.

2.3.1 Cooling need when installing advanced ventilation systems in Europe

In the framework of the THERMIE European Project [Thermie] the cooling and heating requirements have been estimated for a reference building at a European level. The energy requirement calculations have been performed assuming two set-point temperatures, (one for cooling and one for heating), of 25°C and 20°C respectively. (when the indoor air temperature exceed 25 cooling is required, when the outdoor temp is below 20 heating is required) The equipment operates during the working period all the days, and the building free floats the rest of the time. Consequently, for every zone there are both cooling and heating loads. For the cooling regime, the latent energy requirements have also been calculated. For the reference case, a ventilation rate of 1 ach during the working period has been assumed (for this building, 1 ach is equivalent to 8.9 liters of air per second and occupant). The supply air flow has been sized using the peak cooling load of the building (without the ventilation load). Consequently, the supply air flow depends on the climate.

It has been found that the ratio of cooling requirements versus heating requirements is very dramatically dependent on the climate. Figure 2.5 shows the cooling and heating demands for the south facing zone of the hypothetical office building at a European level.

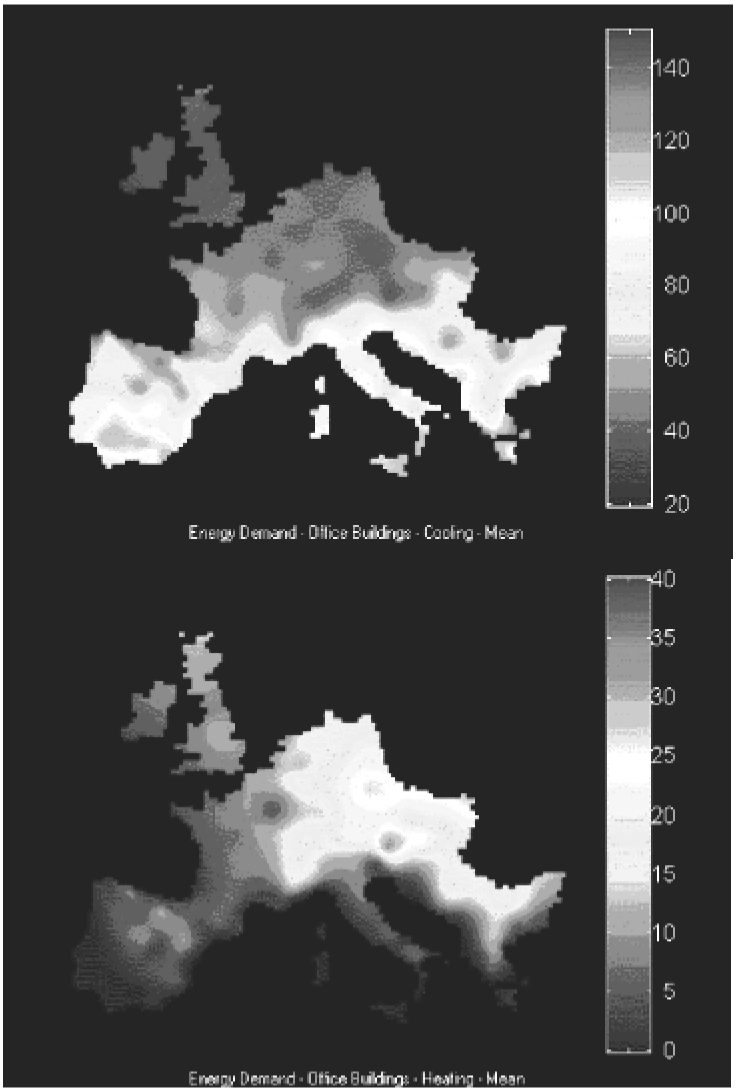

Figure 2-2: The top figure illustrates the mean cooling need in kWh/m2 per year, for the south zone of the hypothetical office building at a European level [Thermie]. The bottom figure illustrates the mean heating need in kWh/m2 per year, for the south zone of the hypothetical office building at a European level [Thermie].

From Figure 2-2 it is shown that cooling is dominant in a large area, (it is in the range of 3 times the demand for heating).

Figure 2-3 illustrates the ratio between the hours at which the south facing zone of a reference building requires cooling while the outdoor temperature is lower than 25ºC and the total number of cooling hours. This percentage is an upper bound of the energy savings percentage that can be achieved using free-cooling.

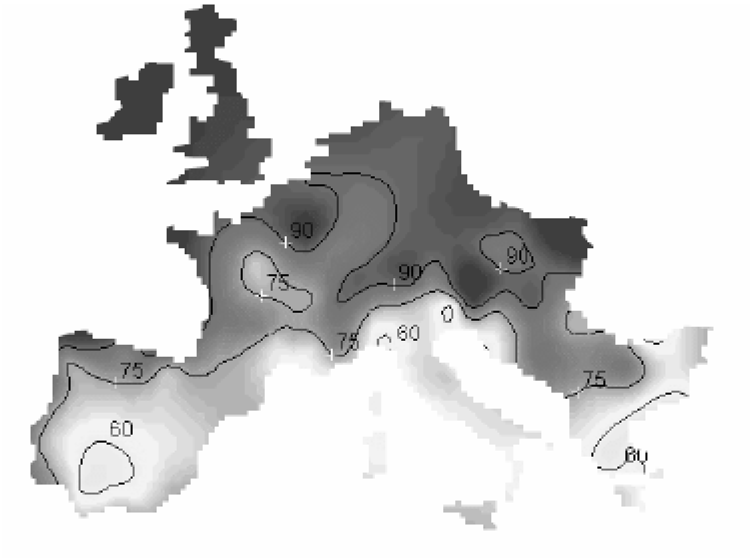

Figure 2-3: Percentage of hours in the year? in which free-cooling is applicable in different European countries [Thermie].

As far as, the influence of the ventilation rates on the energy savings for cooling is concerned, it has been found that in locations with cold or temperate climates the increase in the ventilation rates results in a decrease of the cooling requirements. In hot climates the trend is inverted so that the cooling requirements increase with the increase of the ventilation rates. In all cases, the increase of the ventilation rates, reduces the excess of air that can be used for free-cooling.

Thus, in an advanced hybrid ventilation system based on natural and mechanical ventilation, the use of natural ventilation is appropriate for temperature control in cold climates. In warm climates the use of natural mode is recommended in transitional periods or for night ventilation during summer the period.

2.3.2 Energy conservation for cooling

Energy conservation for cooling reasons is possible for a hybrid ventilation system when free cooling or passive cooling techniques are implemented.

In case of free cooling, it is important for the hybrid ventilation system to take maximum advantage of the natural driving forces, namely, wind and stack effect. The ventilation system must be capable to window opening in order to satisfy occupants comfort needs and to reduce fan energy. In addition it is important for the system to be designed for optimum use of the wind effect especially when the stack effect is minimized.

With regard to passive cooling, different techniques can be applied such as, utilization of daylight and effective solar shading for the reduction of internal gains, utilization of thermal mass, appropriate use of cooling materials etc. In the case of urban buildings, many barriers exist in applying some of the proposed techniques, due to the urban climate characteristics (heat island, reduced wind availability, noise and pollution) and the restrictions in constructions that occur due to the lack of space. The issues that should be considered during the design of an urban building in order to provide a comfortable indoor environment with the minimum use of energy, have been discussed in the framework URBACOOL European Programme [Urbacool] and are mentioned in the following paragraphs.

Control of heat gains is the starting point for improving thermal comfort conditions in buildings. This includes every measure to control the heat transfer between the building interior and the environment. In detail, protection from or prevention of heat gains, according to the season, involves the following design techniques:

- Features that prevent the heat gains (during summer).
- Features that modulate the heat gains of the building.
- Features that use natural sources for collection or dissipation of useful or excess heat respectively.

A number of considerations must therefore be taken into account at an early design stage to define a strategy, which suits the particular site. These are:

- Solar control: directly (through solar heat gain) or indirectly (through daylight) the sun is the most important part of the energy management of the building in low energy design. The use of shading devices and other solar controls need to be considered.
- Building form and layout: the form of the building is important as it should be appropriate to its orientation, in order to minimize solar gains and maximize natural ventilation and daylight

- Thermal insulation is clearly important in deciding the U-value of the walls and roof, and therefore a good mode to assess the efficiency of the building.
- Thermal Mass. Heat gains modulation can be achieved by properly using the thermal mass of the building, in order to absorb and store cooling energy and later return it to space when needed. Using appropriate materials can increase the thermal inertia of a building and the main effect of this procedure is the attenuation of maximum and minimum values of indoor temperatures.
- Passive or hybrid cooling techniques can be designed which use the available environmental sources either for excess heat dissipation during summer.

The appropriate use of these techniques leads to a decrease in - or even the elimination of - cooling loads and thus to the improvement of the indoor conditions. The use of natural and passive cooling techniques in the design of a building not only leads to energy conservation and to improvement of its thermal behavior but also is very closely related to the thermal comfort of its occupants.

In conclusion, the appropriate design of a building is very important because it contributes to the increase of the building's efficiency, to the improvement of its thermal behavior and to the extension of the comfort zone for its occupants.

2.4 The impact on space heating

The following hybrid ventilation concepts have a consequence on space heating in dwellings, listed in order of significance:

- **Heat recovery**: The economic benefit of heat recovery in very cold climates is very significant, dwarfing the cost of the fan energy. In Nordic countries, ventilation heat loss can constitute 40% of a house’s total space heating demand. It is therefore now normal for dwellings in most Nordic climates to have some kind of heat recovery. In many cases this is regulated by energy requirements in national building codes. Figure 2.7 illustrates typical energy savings due to heat recovery, as a function of climate (mean outdoor temperature).
- **Demand controlled ventilation**: Most conventional ventilation systems operate with constant ventilation flow rate. The RESHYVENT concept operates with an advanced variable ventilation flow rate of demand controlled ventilation (DCV), which leads to a reduction of ventilation flow

rates to a minimum level providing good IAQ. This reduces the ventilation heat loss. Conversely, when the demand is high (e.g. a party with many people) then DVC increases the flow rate in line with the higher demand, ensuring good IAQ. Most EU countries have building regulations requiring a constant ventilation rate of 0.5 air changes per hour in dwellings. However, if the regulations permit this flow rate to be reduced when the dwelling is unoccupied, then this can lead to measureable savings in space heating. Figure 2.4 illustrates typical energy savings due to DCV that halves the ventilation rate to 0.25 ach for 48 hours each week, as a function of climate (mean outdoor temperature). Slightly larger savings will be achieved if the DCV system takes account of the contribution of infiltration to total ventilation.

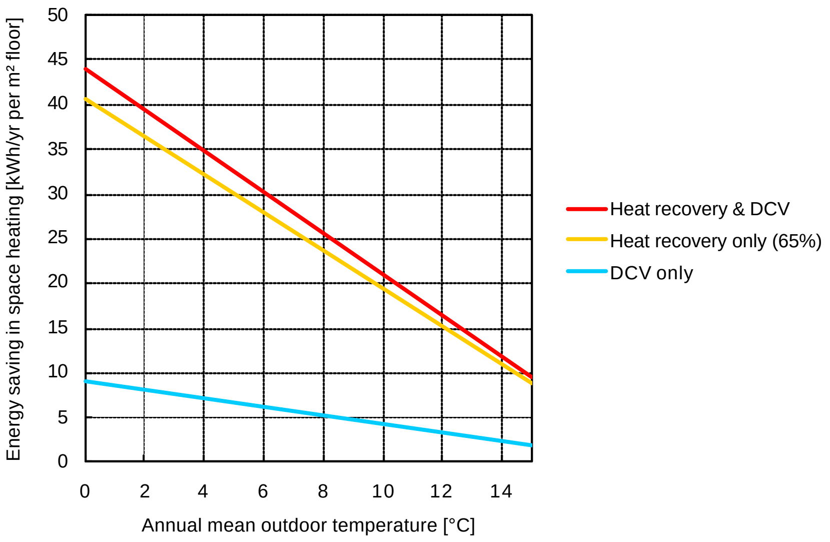

Figure 2-4:Annual energy savings [kWh/yr per m² floor] as a function of climate (annual mean outdoor temperature), for two ventilation technologies: heat recovery, or demand-controlled ventilation, or both. Here a normal ventilation rate of 0.5 ach is assumed, and DCV halves the flow rate for 48 hours per week.

- **Other measures to minimize ventilation flow rates:** Many other measures can lead to a reduction of flow rate and consequently reduce space heating costs for example a cascade flow or displacement ventilation.

- **Hybrid ventilation**: In principle, hybrid ventilation (i.e. reduction of fan power by assistance with natural driving forces) does not change the energy consumption for space heating. Even if the ventilation system has a supply fan, the reduction (or elimination) of supply fan power, as a result of exploiting natural driving forces, will generally have no effect on the energy consumption for space heating.

2.5 The impact on electricity consumption

Apart from significant energy savings in space heating or cooling (mentioned in other chapters), the main impact that RESHYVENT concepts have, in terms of electricity consumption, is to reduce fan energy consumption used for transport energy. Transport energy is normally much lower than the energy need for heating and cooling the air. Therefore there is also a need for adjusting the air flows to the demands in the building, hereby reducing the heat or cooling loss. This will lead to controls, which try to maintain the exact required airflow rates. The heart of a hybrid ventilation system is a sensor-based control. The ventilation system will direct respond to the demands resulting in optimal energy consumption. The control system including the sensors is also consuming energy.

The following RESHYVENT concepts have a consequence on fan energy consumption, listed in order of significance:

- **Flow resistance**: Reducing the flow resistance (i.e. pressure drop) through all the components in the ventilation system is the main means of reducing fan power. It overshadows any potential savings that may be achieved by exploiting natural driving forces. For example, reducing the pressure drop from 100 Pa to 10 Pa means a 90% reduction in fan power. If the fan efficiency is 30%, this means a reduction in specific fan power (SFP) from 0.333 W/(l/s) to 0.033 W/(l/s) respectively.
- **Fan efficiency**: The main difference between conventional ventilation systems and hybrid systems is the fact that the latter are intelligent systems with control systems that automatically can switch between natural and mechanical mode in order to minimise the fan energy consumption. Fan efficiency is a combination of motor efficiency, impeller efficiency, and aerodynamic design of the inlets and outlets to minimise total pressure loss (static regain etc.). Specific fan power is a function of the energy saving provided by more energy-efficient fan means.

$$SFP = \frac{p}{1000 \cdot h} \qquad [W/(\lambda/s)] \ or \ [kW/(m^3/s)]$$

where:

p = total pressure drop from fresh air inlet to exhaust air outlet [Pa]

? = fan efficiency (combined efficiency of motor, impellers, and aerodynamic design, etc.) [0 to 1] typically less than 0.3 for hybrid ventilation fans.

Minimising fan energy can be achieved by:

- better efficiency of fans
- lower resistances in the ductwork
- better aerodynamic properties (of: fittings, control valves, air terminals and heat exchangers)

Better efficiency of fans can be reach by changing to another electrical motor type that is better controllable. For instance changing an *A*lternating *C*urrent (AC) motor by a *D*irect *C*urrent (DC) motor. Another possibility is to really make a more efficient impeller of the fan, through a better aerodynamic shape. Sometimes a more aerodynamic shape can improve the fan housing itself. Finally the leakage of the fan might be minimised. Low resistance ductwork in hybrid ventilation means that the driving force can be natural (by wind or stack effect) and the rest of the time as low as possible in mechanical mode.

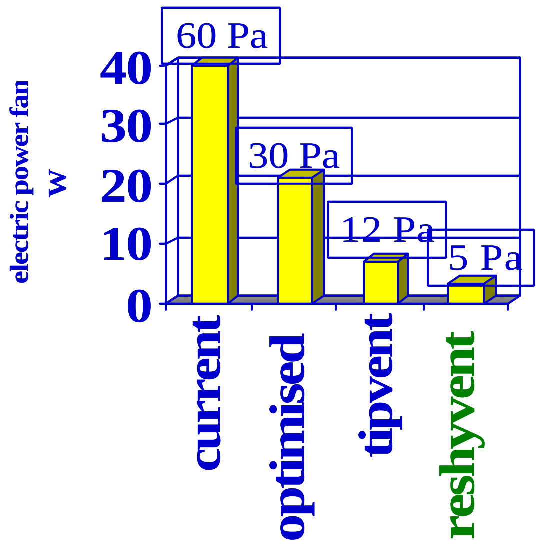

Figure 2-5: Reduction in installed fan power for domestic ventilation

During the last decade a number of projects has been carried out to show the possibilities of reducing electrical energy used for the transport of air. From the EU project TipVent a typical current exhaust system in a dwelling has a electrical fan power of about 40 W. Due to bad commissioning and a better lay out of the ductwork this could be optimised to 21 W. In the TipVent project the 21 W fan was reduced to 7 W delivering the same flow rate. In the Reshyvent project a further reduction is achieved to 2 W.

Expressed in terms of *S*pecific *F*an *P*ower (SPF) in W/(dm3/s) these developments mean:

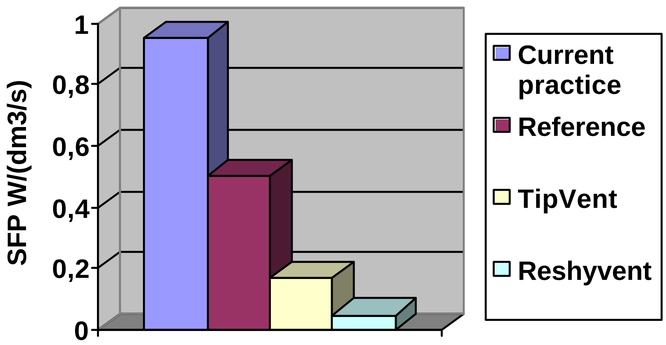

Figure 2-6 The reduction of specific fan power for a domestic ventilation system

- **Hybrid ventilation**: The available natural driving forces (wind & stack effect) are generally quite weak, usually in the range of 5~10 Pa for a system with optimised wind scoop & cowl combined with a stack. This means that only very low pressure drop ventilation systems will get a substantial contribution from natural driving forces. This is illustrated in *Figure 2-7*.

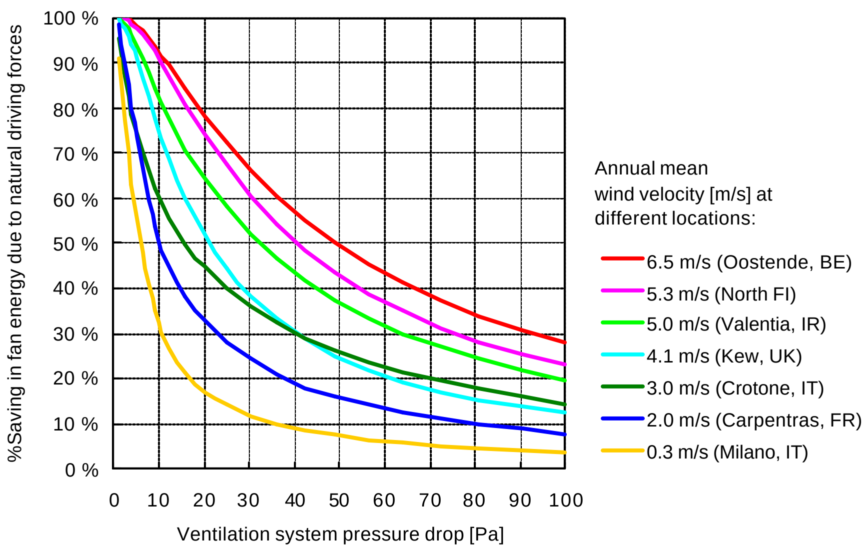

Figure 2-7: Percent reduction in fan power due to hybrid ventilation, as a function of ventilation system pressure drop (at design ventilation rate), for different climates (according to local wind conditions). Here we assume a stack height of 5m, 30% fan efficiency, wind coefficient (cp=0.7 , Sum of windward + absolute leeward, relative to 10m windspeed at Met. station.)

Take, for example, a hybrid ventilation system that has 10 Pa pressure drop at normal flow rate: *Figure 2-7* shows that the natural driving forces will reduce the fan power by anywhere between

35% and 95% depending on local wind conditions. If the fan efficiency is 30%, this means a reduction in specific fan power (SFP) from 0.012 W/(l/s) to 0.031 W/(l/s) respectively. *Figure 2-7* is too conservative for wind scoop/cowl designs that exploit wind kinetic energy over a large area (e.g. wind turbines, tapered funnels).

- **PV systems**: Photovoltaics can be used to run low-power fans and other auxiliary equipment in an advanced ventilation system, on the condition that the fan power is extremely low, and that the PV battery is sizeable (or the fan is also grid-connected). The IC2 Reshyvent system developed by the Dutch consortium and the IC3 Reshyvent system developed by the France/Belgium consortium requires only 2W for fan power. Therefore, it is quite clear that a PV application for a 2 W electrical power belongs to the possibilities, and has indeed been applied to the IC3 ventilation concept. For specifications please be referred to D3.2 in the Reshyvent project.

3 IMPACT OF DEMAND CONTROLLED HYBRID VENTILATION ON THE APPLICATION OF LOW VALUED ENERGY

The long term planning perspective for Europe is to turn to a sustainable society. Consequently, future buildings in EU should be planned to use or to be suited to use sustainable energy sources for heating and cooling. Both new and existing buildings should be planned with this perspective. Even though the sustainable sources not yet are fully exploited the development is on the way. Characteristic for the use of all these energy sources is that only a relatively moderate temperature level is possible to be reached. The lower the temperature level the better the efficiency can be of the total system, i.e. as well as on the generation side, the distribution side as the emission side. The development of low temperature heating and high temperature cooling systems is a necessary prerequisite for usage of the alternative energy sources. Renewables, low valued energy sources and low exergy systems will be the common practice in the future.

3.1 Optimal use of energy sources

Energy saving and emission reduction is both a matter of energy efficiency of the built environment and a matter of the quality of the energy carrier in relation to the required quality of the energy. Tuning these qualities of energy is called exergy optimisation. Common energy carriers like fossil fuels deliver high valued energy. Low valued energy is delivered by renewable and sustainable energy sources e.g. by using heat pumps, solar collectors, either separate or linked to waste heat, energy storage etc. Some of those energy sources can be used also for cooling purpose. All together a flexibility of the systems is a means to meet the future demands on heating and cooling systems in buildings.

The thermodynamic concept of exergy assigns a qualitative value to an amount of energy. The second law of thermodynamics makes it possible to compare the output of a technical process with the theoretical maximum output in a thermodynamic point of view. Energy can have different types; for example heat, electricity, mechanical workload etc. Energy which is entirely convertable into other types of energy is exergy (high valued energy such as electricity and mechanical workload). Energy, which is very limited convertable such as heat close to room air temperature, is low valued energy. The precise threshold value of low valued energy is, of course, a question of definition.
Low exergy heating and cooling systems use low valued energy sources. Low temperature heating and high temperature cooling systems are an integrated configuration. The different parts of the

configuration are the source, the distribution systems outside the building and the system within the building. The heating and cooling system is a part of the building system. The building envelope, ventilation, and the thermal mass of the building constitute together with the climate what heat losses can be expected.

Starting with the improvement of the energy efficiency of separate options nowadays an integral approach becomes of increasing importance. The improvement of the energy efficiency of supply and conversion systems is mostly based on the energy balance of systems. In principle no distinction is made between the different forms of energy, for example heat or electricity. This means that the efficiency is based on the quantitative comparison of energy flows with no distinction in qualitative aspects. Taking into account qualitative aspects of energy leads to introduction of the exergy concept in comparison of systems.

To realize these global objectives of energy saving and emission reductions in the built environment and to implement the exergy concept the use and implementation of Low Valued Energy is necessary. Low Valued Energy is available from residual heat, ambient heat, renewable sources etc. Often in these heating concepts heat pumps are applied to transfer the supply temperatures to another (higher or lower) level. Low valued energy can be used for Low Temperature Heating (LTH) and High Temperature Cooling (HTC) in residential and commercial buildings. For this purpose the buildings and installations should be designed for low temperature distribution and emission systems. Appropriate distribution systems, like floor and wall heating, have a life cycle of 40 to 50 years. So to implement Low Valued Energy sources within the next half of a century heat distribution systems should as soon as possible be designed for lower temperatures.

3.2 Low values energy and demand controlled ventilation

Traditionally the heating of dwellings and residential buildings is often accomplished by a heat distribution system operating at high temperatures (90-70 °C). In many European countries the most common heating systems (especially in residential buildings) are built up from the following components:

- gas boiler (often with improved or high efficiency);
- piping system based on hot water as a heat transport medium;
- radiators or convectors as heat supply elements.

These types of heating systems are often characterised as follows:

The dimensioning of the total capacity of the boiler as well as the heating system is not a problem as there in most cases is a certain amount of over dimensioning of the boiler as well as in the emission system. Because of these two factors peaks in heat demand will not cause any problems. However, heating concepts based on low valued energy sources, alternatively in combination with heat pumps, are much more sensitive for peaks in heat demand. To avoid over dimensioning of emission systems as well as sources and heating generation (i.e. heat pumps) these peaks must be avoided. In dwellings the peaks in heat demand are mainly caused by uncontrolled ventilation and infiltration losses. In other words, application of low valued energy and renewable energy sources for space heating is only rational possible in combination with controlled ventilation losses and strictly limited infiltration, i.e. air tight building. The latter boundary condition itself also requires controlled ventilation systems with a good level of thermal comfort.

Until now the only type of ventilation system fulfilling these conditions is fully mechanical ventilation with heat recovery. Despite the fact that natural ventilation has many benefits and is often preferred by occupants as well as architects the combination with renewable and low valued energy heating concept is often in conflict. This conflict is a special problem in sustainable and green building concepts were both natural ventilation as renewables are key elements.

Demand controlled hybrid ventilation systems offer the solution for this conflict as they combine controllability, thermal comfort and a natural ventilation mode.

The next figure show calculations of the load duration curves for three ventilation systems in a reference dwelling (Dutch Building code 2004; EPC = 1.0) in a moderate climate:

1. The reference system: natural supply, mechanical exhaust
2. A mechanical ventilation with counter flow heat recovery ($n_{energy; practice}$ = 80%)
3. The RESHYVENT IC2 system (demand controlled hybrid ventilation system)

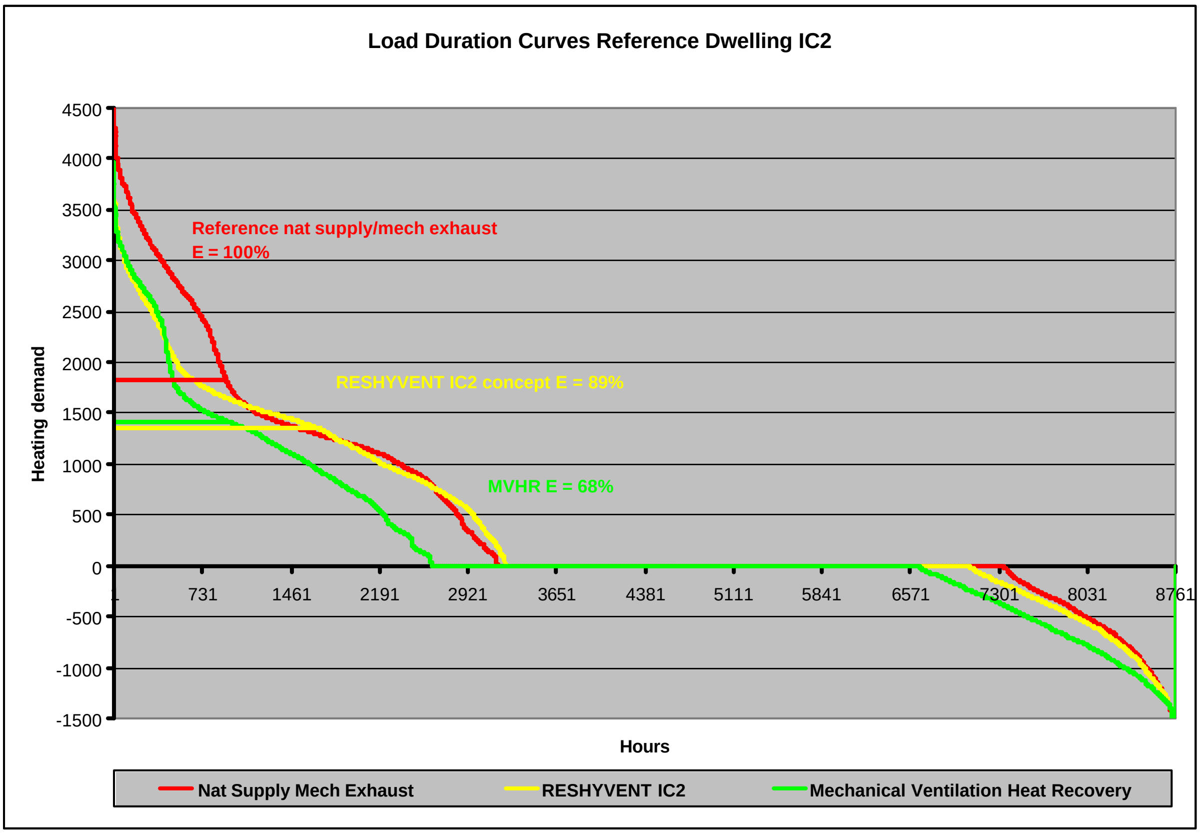

Figure 3-1: Load duration curves for reference Dwelling IC2

In following table a comparison is made for the needed heating capacities, total energy demand and the dimensioning of a heat pump, based on covering 80% of the total yearly energy use.

	Ventilation system		
	Reference Natural Supply Mech Exh	**RESHYVENT IC2**	**MVHR**
Maximum heating capacity	4,838 W	3,931 W	3,969 W
Heating period	3,163 hours	3,225 hours	2,621 hours
Total energy	5,042 kWh	4,498 kWh	3,409 kWh
50% * maximum heating capacity	2,419 W	1,966 W	1,985 W
Heat Pump part	4,541 kWh	4,163 kWh	3,065 kWh

(0 – ½ P_{max})	(= 90%)	(= 93%)	(= 90%)
Back-up part (boiler) **(½ P_{max} – P_{max})**	501 kWh = 729 h/year (10%)	335 kWh 524 h/year (7%)	343 kWh 401 h/year (10%)
80% * total energy	4,034 kWh	3,598 kWh	2,727 kWh
Capacity Heat pump	1,800 W 933 h/year	1,375 W 1620 h/year	1,415 W 940 h/year

Table 3-1: Comparison of different ventilation concepts

Both mechanical ventilation with heat recovery as hybrid ventilation can reduce the maximum heating capacity by approximately 20%.

Covering the heating demand 80% of the year by a heat pump limits the capacity of the heat pump to 1375 W for the IC2 concept and 1415 W for MVHR. Applying the IC2 concept in combination with a heat pump is very effective in terms of operational hours (1620 hours). Also remarkable is the summer situation. The load duration curves show that mechanical ventilation with heat recovery has a larger risk of overheating in summertime then natural and hybrid ventilation.

4 THE EFFECT ON ENERGY SAVINGS IN EU BY SUBSTITUTING AUXILIARY ENERGY WITH RENEWABLES

4.1 Potential for reducing auxiliary energy in ventilation systems

At present, the fan energy represents a rather important part of electrical energy use of buildings. For a typical system, the electricity consumption can be of the order of 300 kWh/year (mechanical ventilation) to 650 kWh/year (heat recovery), [Danish building research institute, 2004] whereas the typical electricity consumption per household (if no electrical heating or hot water production is included is in the range of 2000 to 5000 kWh/year[1].

In terms of the total net energy use at building level (including heating), the fan energy is a much smaller proportion. However, the percentage becomes substantially higher if its share is expressed in primary energy terms. (Most countries consider a conversion factor of the order of 2.5 for electricity whereas only 1.0 for gas and fuel).

Most of the present air distribution systems are not very efficient in terms of the net energy use required for transporting the air and with respect to the energy efficiency of fans. In order to reduce the energy consumption, the following approach may be used:

An energy optimization of the air distribution system, could be achieved by:

- Reduce the resistance in the ducts when transporting the air
- Improve the airtightness of the ductwork.
- Optimize the fan characteristics in order to increase its efficiency.
- Optimize the fan control, in order to minimise its use (including but not only hybrid ventilation).
- Optimize the air flow requirements by applying demand controlled ventilation.

By combining all these measures, a reduction in required fan power between 25-50%, is possible, depending on the reference scenario.

4.2 Required characteristics of PV driven mechanical/hybrid ventilation systems

In case of grid connected buildings, it is in most cases logical to have a grid connected PV system.

[1] Data for the Walloon Region in Belgium: 3700 kWh [ICEDD]

For modern systems in a Nordic climate, the following characteristics are representative [Solar energy centre Denmark, 2004]:

- peak power : 100 Wp/m² of PV
- energy output : 90 kWh/year.m² of PV panel

The numbers account for PV-systems in Denmark. The performance of the system are highly depending on the geographical location. An equivalent system placed closer to the equator will have a higher peak power and energy output.

4.3 Estimation of energy use in dwellings

As far as the authors know, there is no data available about the share of the auxiliaries in the total energy consumption of residential buildings in EU. This energy must therefore be estimated from available data.

In 2000, the final energy demand of the residential sector was estimated [European Commission, 2004] to 245 Mtoe in EU-15 and to 279 Mtoe in EU-25[2] [European Commission, 2004]. This corresponds to to 26% of the final energy demand of all sectors.

For new dwellings in the Flemish region of Belgium, the average yearly energy consumption of fans of a new dwelling (with a fan assisted exhaust ventilation system) is estimated[3] to 670 kWh, which represent about 2.5% of the average final energy demand of a Belgian dwelling[4].
Figures from Sweden indicate that the share of auxiliaries (mainly fans) in the final energy consumption is about 3%.

The share of auxiliaries (mainly fan) in the final energy consumption in EU-25 could be roughly estimated to 2%. This means about 5.6 Mtoe or 65000 GWh.

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[2] Data for non EU countries represented in RESHYVENT: Norway: 3.74 Mtoe (20%) – Switzerland 5.6 Mtoe (26%)

[3] Sources: Calculations according to the coming EP regulation extrapolated for the Belgian building stock and data from National Institute of Statistics (average surface of existing dwellings).

[4] Final energy demand of Belgian residential sector: 9.47 Mtoe ≅ 110135 GWh, number of dwellings: 4.3 millions → average energy demand of Belgian dwellings: 25800 kWh.

4.4 Quantification of potential for substitution of auxiliary energy by renewable energy

If 100% of the (estimated) energy consumption of auxiliaries was substituted by renewable energy, it would correspond with a reduction in peak power equivalent to 3 large (1000 MW) power plants, or to 1/4 of the Belgian electricity production. However, because of economically reasons it is not possible to substitute all the energy consumption of auxiliaries, but only a part of it. Firstly, auxiliary energy could probably be substituted by renewables only if a *new hybrid* ventilation system is installed. According to WP2, the market potential for hybrid ventilation in countries represented in RESHYVENT is about 150 000 units, including 62 000 new constructions and 88 000 refurbished dwellings. If these numbers are extrapolated to EU-25, the market in EU-25 can roughly be estimated to 480 000 units a year, which represents 0.3% of the number of existing residential buildings. Assuming that all existing residential buildings are equipped with a mechanical ventilation systems and that the auxiliary energy is totally substituted by renewables, the maximum potential savings by installing hybrid ventilation systems becomes 170 GWh. Based on these assumptions WP3 has shown that 0,3% of the auxiliary energy consumption can (in the next future) be substituted by renewable.

Based on experience of other projects, at least 10-15 years will be necessary to reach the maximum annual savings estimated. This of course will depend on the actual market penetration of hybrid ventilation systems, which could be favoured by the actual application of the EPBD.

5 SUMMARY AND CONCLUSION

By applying advanced ventilation, investigations have shown that large energy savings (up to 50%) can be obtained, especially when applying demand controlled ventilation.

Impact on cooling

Installing advanced ventilation systems can have a positive impact on cooling, especially the use of free-cooling, has an impact on the net energy consumption. The more significant the contribution of the internal gains to the cooling requirements of the building, the higher the potential for using free-cooling as an energy saving strategy.

Impact on heating

Installing advanced ventilations systems can have a positive impact on the heating demand if demand control is used, as this can decrease the heating consumption. For Nordic climates the installation of a heat pump in connection with the ventilation system gives the most significant decrease (in the range of 40%) of the space heating consumption.

Impact on electricity

The most significant element which influences the energy use of the fan is the flow resistance in the duct work, secondly the fan efficiency and demand control, third the use of natural driving forces. By optimizing on all these parameters the required effect of the fan can be as low as 2W (proven by the IC2 and IC3 system in Reshyvent). At an effect of 2W, a PV system (solar power system) can be used to supply the rest of the energy demand, this has been realized in the IC3 ventilation system. Hence, the use of advanced ventilation systems can have a very large effect on the electricity consumption.

The effect of energy savings in EU by substituting auxiliary energy with renewabels

Based on rough estimation and the assumption that all existing residential buildings are equipped with a mechanical ventilation systems and that the auxiliary energy is totally substituted by renewables, the maximum potential savings by installing hybrid ventilation systems becomes 170 GWh per year. Based on these assumptions, 0,3% of the total auxiliary energy consumption for fan power in EU can (in the next future) be substituted by renewable. Based on experience of other projects, at least 10-15 years will be necessary to reach the maximum annual savings estimated.

This of course will depend on the actual market penetration of hybrid ventilation systems, which could be favoured by the actual application of the EPBD.

Conclusion

Advanced ventilation systems, such as demand controlled hybrid ventilation systems, can reduce the energy use due to ventilation, both for heating, cooling and electricity, to a significant degree (up to 50 % in savings can be achieved), and at the same time provide good comfort and indoor air quality conditions.

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