# THE CASE FOR CONTROLLED VENTILATION OF HOUSES

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Summary

Fresh air requirements in individual rooms of an occupied house vary between 0.5 and 2 air changes per hour depending on the number and activities of the occupants. The most common method of ventilation control is by opening windows. However, measurements have shown that even quite moderate window opening results in air change rates greater than 2 air changes per hour throughout a house.

The energy cost of controlling ventilation by window opening has been measured in a test house having a heat loss coefficient of 5 kWh/K day. For example, one open upstairs window increased the whole house average ventilation rate from 0.3 to 3 air changes per hour and increased the heating energy requirement by 64%.

In a low energy house, controlled ventilation is essential to ensure that the benefits of improved thermal insulation are not lost by excessive ventilation.

A mechanical ventilation system which gives a constant trickle ventilation which is capable of being boosted locally has been tested. The energy cost is compared with the alternative of relying on window opening for fresh air control.

## Introduction

Ventilation is required mainly to remove objectionable odours and excessive moisture. Water vapour is associated with washing and cooking, and requires intermittent high level local ventilation for its removal. Odour removal in an average size room ($30m^3$) with three or four people in it requires more than 2 air changes per hour of fresh air, but for one or two people one third to one half of an air change per hour will probably be sufficient to avoid discomfort.

Thus, in a domestic environment it is necessary to be able to vary the ventilation rate between about one third of an air change per hour and 3 to 4 air changes per hour. The most common method of achieving the required ventilation rate is by openable windows but both the rate and route are then variable depending mainly on the wind direction. Mechanical ventilation enables both the rate and route to be controlled and, if a heat exchanger is incorporated, the ventilation heat loss can be reduced, for a given air change rate.

The economics of mechanical ventilation depend on the ventilation rates that would be achieved by other, less controllable means. This involves knowledge of window opening habits to estimate the resulting ventilation rates and energy loss, and the relationship between open windows and ventilation rate.

## Natural ventilation with windows closed

Even when all windows and external doors are closed, a house is ventilated through fortuitous cracks in the structure. The ventilation rate will be weather-dependent since wind and temperature differences are the driving forces.

Ventilation rates in two houses with all windows and doors closed, as measured by tracer decay, are given in Figure 1. Both houses would be classed as fairly 'tight' by British standards and neither has a flue. It is seen that under normal conditions the background ventilation rate is less than 0.5 air changes per hour.

The significance of these data is that they represent minimum possible ventilation rates under the prevailing weather conditions. The air change rate can only be increased.

## Ventilation with open windows

When the ventilation arising from open windows is considered, the immediate problem is the wide range of possible options of which windows to open and by how much. The usage of internal doors will also be significant but to reduce the number of variables, all internal doors were left open.

Surveys have shown that bedroom (i.e. upstairs) windows are commonly left open for long periods. The present investigation was therefore restricted to open windows in upstairs rooms.

The ventilation rate considered relevant was an average fresh air rate for the whole house, since this will determine the energy cost. Individual room rates depend on whether the room is ventilated from outside or with air from other rooms in the house.

Some results from a well insulated timber house during which the wind remained very conveniently directly onto the front of the house are given in Figure 2. This illustrates clearly the magnitude of the ventilation changes that open windows can produce.

More detailed measurements were carried out in a brick semi-detached house. The large front bedroom window was opened by various amounts and the average whole house ventilation rate measured continuously. Three open window conditions were used, with the equivalent slot area in brackets

- (01) catch on first notch (0.013 $m^2$)
- (02) back of catch resting on window frame (0.026 $m^2$)
- (03) window open to main stop (0.11 $m^2$)

By leaving this one window open all the time both leeward and windward orientations of the opening were achieved as the wind direction varied from day to day.

With the window open (01) the ventilation rate was not significantly greater than with the windows closed, except at high wind speeds.

With the window open (03), the most likely position that would be used in practice, the ventilation rate was very variable up to 7.5 air changes per hour throughout the house but sometimes as low as 0.5 air changes per hour depending on the wind speed and direction. Temperature difference appeared relatively unimportant in the range $\Delta T = 7$ to 13°C.

At the intermediate open window position (02) the ventilation was increased by a useful amount without being excessive. The ventilation rate throughout the house varied between 0.5 and 2 air changes per hour depending on the wind direction as shown in Figure 3.

## Energy costs of open windows - experimental

A house was heated to a uniform temperature of 20°C by thermostatically controlled panel heaters in the main rooms, hall and landing, supplemented by a fan heater in the large front bedroom when the window was open.

Energy consumption was monitored by kWh meters. Temperature was continuously recorded on 6 thermohygrographs in the kitchen/diner, lounge, hall, landing and both large bedrooms. The ventilation rate was measured continuously at those same places and averaged to give a whole house value. Ten to fourteen day periods were considered. Table 1 summarises the findings.

Table 1 Ventilation heat loss as a result of opening one window

| Window condition | Measured $\frac{\text{Ventilation heat loss}}{\text{Total heat loss}}$ | Measured increase in heating energy as a result of open window | Mean ventilation rate ach |
|---|---|---|---|
| Closed | 10% | 0 | 0.30 |
| 01 | 12% | 3% | 0.35 |
| 02 | 21% | 14% | 0.73 |
| 03 | 45% | 54% | 3.0 |

This house (to 1975 Building Regulations) has fabric heat loss coefficient of 4.5 kWh per degree day and therefore would not be considered 'well-insulated'.

In a 'low energy' house the absolute values of the ventilation heat loss remain the same and so the relative proportion of heat loss caused by ventilation would be greater.

## Mechanical Ventilation

One way of controlling ventilation and reducing the associated heat losses is to use a ducted air supply and extract system incorporating a linking heat exchanger. The acceptability of this solution will depend on how closely the ventilation provided satisfies needs, whether the air can be supplied to the various rooms without draughts or noise and on the efficiency of the heat exchanger.

Fresh air is ducted into the main rooms of the house, and by suitable choice of extract and supply points, the fresh air route can be arranged to go from less to more contaminated areas (i.e. from living to utility rooms).

Provision can be made for increasing the fresh air supply to the lounge and dining area at the expense of the bedrooms and also for independently increasing the extract rate from the kitchen at the expense of the bathroom and W.C. Both boost controls being on a time switch, the system returns to normal operation at the end of a pre-determined interval.

A system of this type was installed in our test house. The heat exchanger, fans (2 x 40 watts) and distribution boxes were installed in the loft. Fresh air was supplied to the bedrooms, lounge and dining room. Air was extracted from the kitchen, bathroom and W.C. Temperatures and flows in the ducts were monitored. The ventilation rate of the house was measured continuously. All internal doors were open.

The air flows in the main supply and extract ducts were not affected by wind.

With the system operating the measured air change rate was in the range 1.0 to 1.3 air changes per hour. In the range 4-11 m/s wind speed a best fit straight line gave the air changes per hour = 0.90 + 0.032w where w is the wind speed. The difference between this ventilation rate and that obtained with no mechanical ventilation (i.e. 0.048 + 0.043w) is 0.85 - 0.01w air changes per hour which is sufficiently close to the value 0.87 air changes per hour obtained from the flow measurements in the ducts to conclude that the mechanical ventilation simply adds on to the existing natural ventilation. It is therefore essential that the house is made as leaktight as possible before installing a mechanical system.

The effective efficiency of the heat exchanger was found to be about 55% but could perhaps be improved slightly by insulating some of the ducting.

Energy costs

Since a mechanical ventilation system simply adds on to the natural ventilation, it must, at first sight, increase energy consumption. However, two assumptions are necessary to achieve a realistic assessment. First, the house with the mechanical system must be well sealed so that the background ventilation rate is as low as possible, probably of the order of 0.1 to 0.2 ach. Second, in the ordinary house the required ventilation would be obtained by opening windows and possibly by the use of extract fans in kitchen and bathroom.

Figure 4 shows the heat loss coefficient in kWh/Kday and approximate annual heating costs as a function of mean ventilation rate for a house with a heat recovery ventilation system compared with one which relies on opening windows. The assumed ventilation rates and consequent ventilation energy costs are given in Table 2.

Table 2 Ventilation heat loss

| Condition | Ventilation ach | Ventilation heat loss kWh/year |
|---|---|---|
| One window open all the time | 3 | 12,000 |
| One window open half the time | 1.5 | 6,000 |
| Occasional window opening | 0.7 | 2,800 |
| Mechanical ventilation with 55% heat recovery | 1 | 1,800 |
| Trickle mechanical ventilation with occasional boost | 0.5 + boost | 1,000 |

## Conclusions

Windows are capable of providing the widely varying requirements for ventilation in a house, but if not used carefully they are likely to provide too much ventilation, resulting in excessive energy consumption. Open window ventilation could easily cancel the advantages gained by high levels of thermal insulation.

The common habit of opening bedroom windows can result in several air changes per hour throughout a house, including the downstairs rooms in which the windows may be closed. The amount of open window required for sufficient ventilation is much less than the minimum for which most window catches are designed.

Mechanical ventilation adds on to natural ventilation and therefore is only useful if the house is well sealed, i.e. with a background ventilation rate of the order 0.1 air changes per hour.

Mechanical ventilation will save energy only if the rate is carefully chosen to satisfy needs and if windows are not opened. It is likely that savings of several thousand kWh per year are possible in a typical British house.

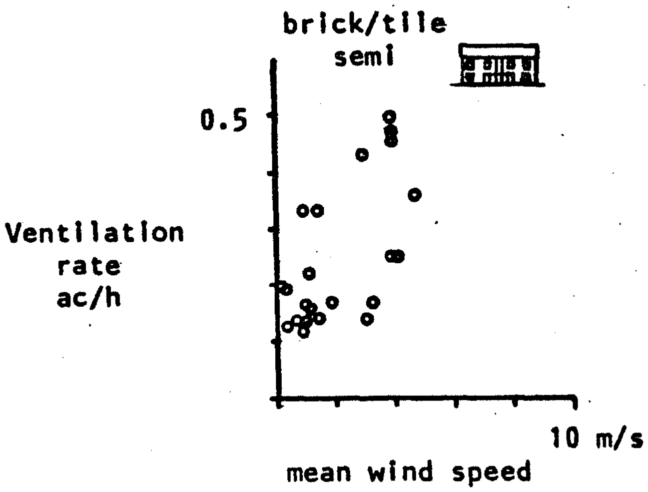
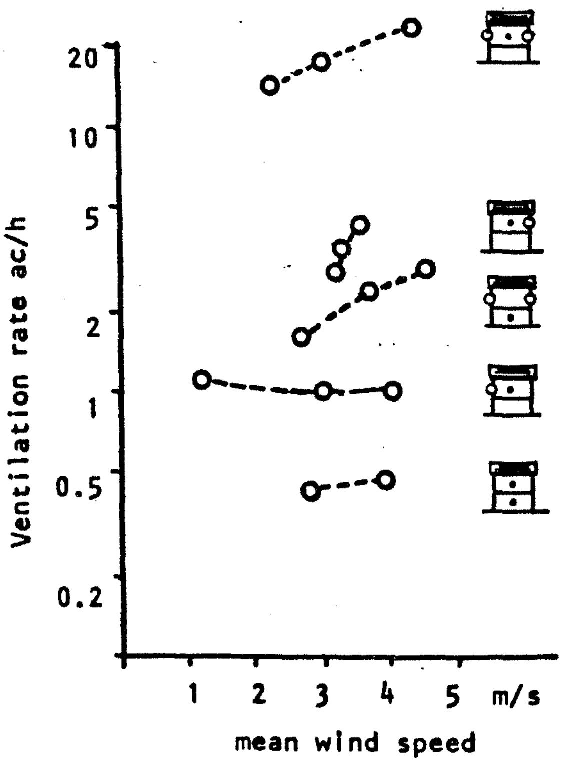



Figure 1 Measured ventilation rates with windows and external doors closed (tracer decay)




| Open windows | Measured ventilation |
|---|---|
| all upstairs | upstairs |
| upstairs windward | upstairs |
| all upstairs | downstairs |
| upstairs leeward | upstairs |
| none | whole house |

$\Delta T \sim 10^{\circ}C$

Figure 2 Ventilation rates floor by floor with upstairs windows open

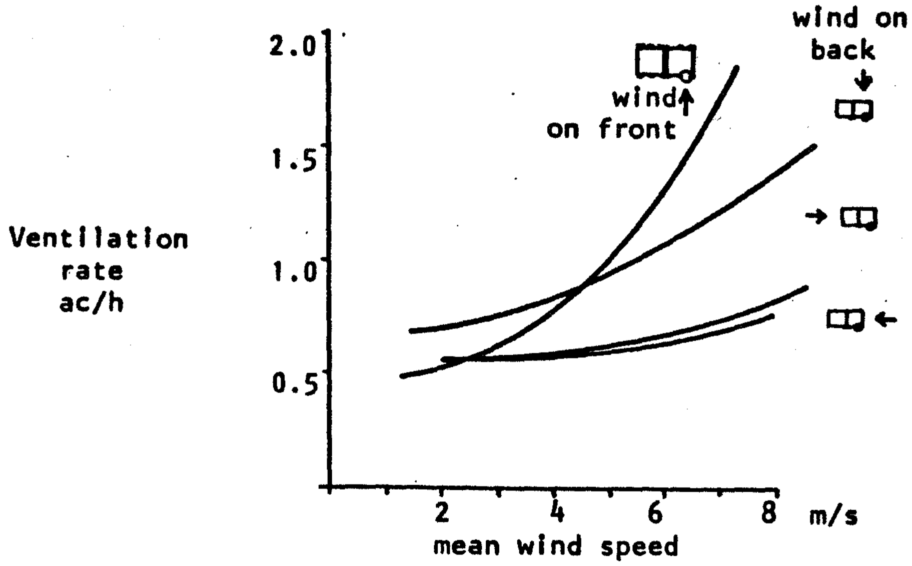



Figure 3 Ventilation rate with front bedroom window open on back of catch (02)

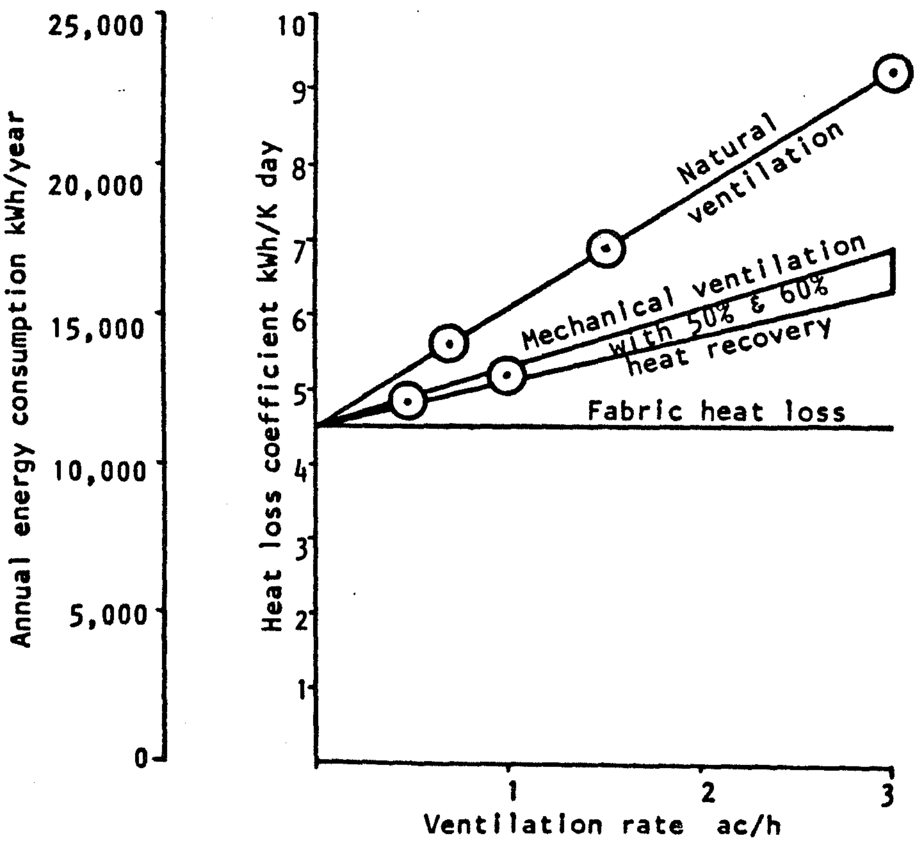



Figure 4 Heat loss and ventilation rate for a typical British house for conditions referred to in Table 2.