ELECTRICITY AND COMFORT IN THE HOME

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ABSTRACT

temperate maritime climates such as Britain experience a mild but damp winter. Insulation levels are poor and the occupants of the houses adjust their ventilation needs as best they can by opening appropriate windows. This traditional approach is badly controlled and wasteful. An integrated design is recommended. Fabric insulation is of a high standard. This not only reduces the heat losses but enhances the effect of the 'free' heat from sunshine, people and the equipment used in the house. Controlled ventilation with heat recovery enables 60% of the ventilation heat loss to be recovered. Fresh air is supplied to the living rooms and stale air extracted from the moisture generation zones such as bathroom and kitchen. New electrical techniques of odour destruction and moisture removal are being developed.

This approach moves away from space heating crudely making up the building deficiencies to one of responsive trimming to top up on those occasions when the 'free' heat is insufficient.

INTRODUCTION

Empirically derived data can usually be applied to similar situations. This has been true for energy data for houses but two new factors are changing this. The first is the application of insulation which should reduce the energy consumption. The second is the economic pressure of higher cost energy which may influence the user to change his living pattern. However before we can predict changes we need to have a [illegible] understanding of people in [illegible] today.

[illegible] night storage equipment operates by [illegible] up at night at a specially low tariff and the heat is released in the daytime. Central warm air units are termed Electricaire and the room thermostat operates the fan to blow out recycled air at 60°C when required. Market research has been closely allied to engineering development and design recommendations (Ref. 1). Since the customer has to store his thermal energy ahead of use then knowledge of energy patterns on the coldest design days (-1° outside air temperature) is essential for successful design.

This data shows several important findings which are critical for household energy management. Let us consider the subject in four areas. The first involves the power requirements, particularly those on the worst design day weather conditions. The second area, a neglected one, deals with the use of energy over a heating season. The third examines the user behaviour in terms of ventilation through window opening. The fourth deals with the house as an environmental system.

POWER REQUIREMENTS: SIZING FOR THE DESIGN DAY

Fabric Losses

The current British house is built to include 50mm of insulation in the loft, and to have a brick outer wall separated from a lightweight inner one by a 50mm air space. House dimensions total 90m^2 floor area for a three bedroom one and the current trend is to reduce this to 85m^2 by reorganising the service areas. Typical heat loss values are given in Fig. 1 for a popular semi-detached house with a design day outside air temperature of -1°C and an inside air temperature of 19°C.

Insulating techniques are now available to externally insulate the old solid wall houses

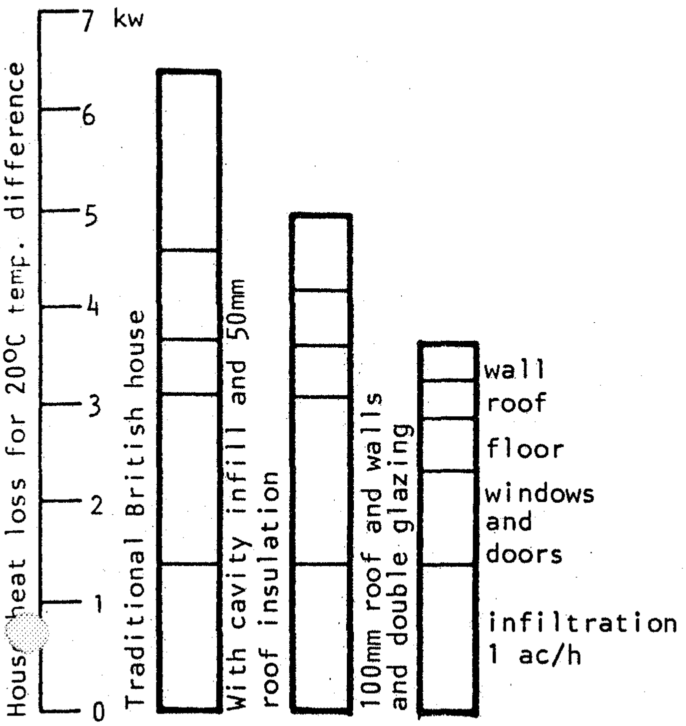

Fig. 1 The application of fabric insulation to reduce heat loss (Typical 90m² semi-detached house; 20m² window; 230m³)

or to fill the wall cavity with pelletised mineral wool or foamed polyurethane. Underfloor insulation is attractive but not really used. Loft insulation, regrettably missing in 50% of Britain's roofs, is slowly being installed. Double glazing, preferably of the second pane type to reduce infiltration, is also now popularly p[illegible]ced.

Such well established techniques are slowly becoming incorporated into housing. The likely stages are also illustrated in Fig.1. The relative importance of the ventilation loss increases as the fabric insulation increases (Ref. 2).

Ventilation Loss

The effect of wind on a building is to create a pressure on the windward face of 0.5-0.8 times the velocity pressure of the free wind. This is reinforced by a negative pressure of 0.3-0.4 times the velocity pressure on the leeward face. This combined pressure difference across the building is therefore approximately equal to the wind velocity pressure. This pressure difference forces cold air through the gaps around doors and windows (Ref. 3).

There is also a 'stack' effect caused by the differences in air density between warm air in the house and cold air outside. This pressure difference is proportional to the height of the building and the difference in temperature.

In windy conditions the air flow will be across the house. In still, cold conditions the air infiltration will tend to be from downstairs to upstairs. In normal conditions it will be a combination of both.

Conventional wisdom proposes that fresh air changes are calculated from a knowledge of the infiltration characteristics of the openable cracks around doors and to a lesser extent windows. Recent research by the Building Research Establishment showed that for British houses there was a significant leakage through other parts of the structure, particularly where the timber fitments such as window frames abut masonry (Ref. 4). The damp nature of the British climate means that much of the wood in a house is wet during the construction stage. During the first few months of occupancy the house dries out, the timber shrinks and large lengths of small cracks appear.

The arbitrary allowance in heating calculations in Britain is one fresh air change per hour. Current research by the Building Research Establishment suggests that while there is a large variation from house to house this value is a reasonable one. Opening the windows even by a small amount has a dramatic effect on air change, Fig. 2 (Ref. 5)

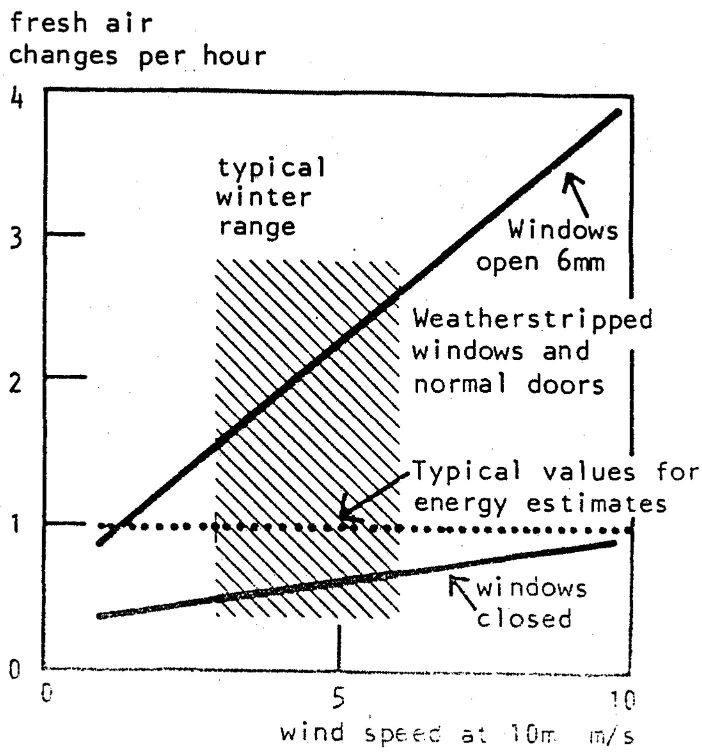

Fig. 2 The effect of window opening on ventilation (after Siviour 1976)

This highlights the key role of ventilation. It is the easiest step to miss in energy management and yet it has the largest scope for waste.

ENERGY REQUIREMENTS

Theoretical Daily Losses

The theoretical heat loss from a house is proportional to the difference between inside and outside air temperature. Solar gains are neglected since they cannot be relied on. This is a reasonable assumption for sizing space heating equipment which has to cope with the worst design day weather. It is a very pessimistic assumption for the heating season which includes many sunny days. The theoretical heat loss relationship for a town house at Bromley is shown in Fig. 3.

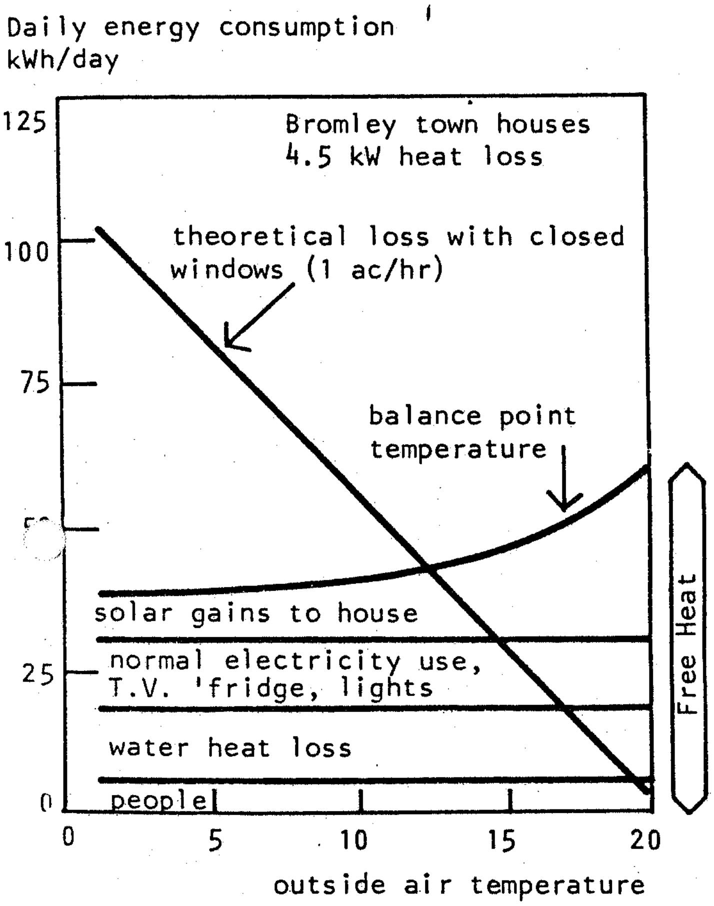

Fig. 3 Theoretical balance between heat loss and 'free' internal heat

In practice many internal gains contribute to the heat release within a house and the space heating energy can be reduced accordingly (Ref. 6). Hot water is inefficiently distributed to the taps; equipment such as lights, refrigeration, deep freeze and television add to the background; people also dissipate part of their metabolism as sensible heat. With present poor insulation standards this 'free' heat provides a third of the design day heating energy. The space heating equipment only provides two thirds. Market trends suggest that the electrical appliance load will continue to increase, Fig. 4.

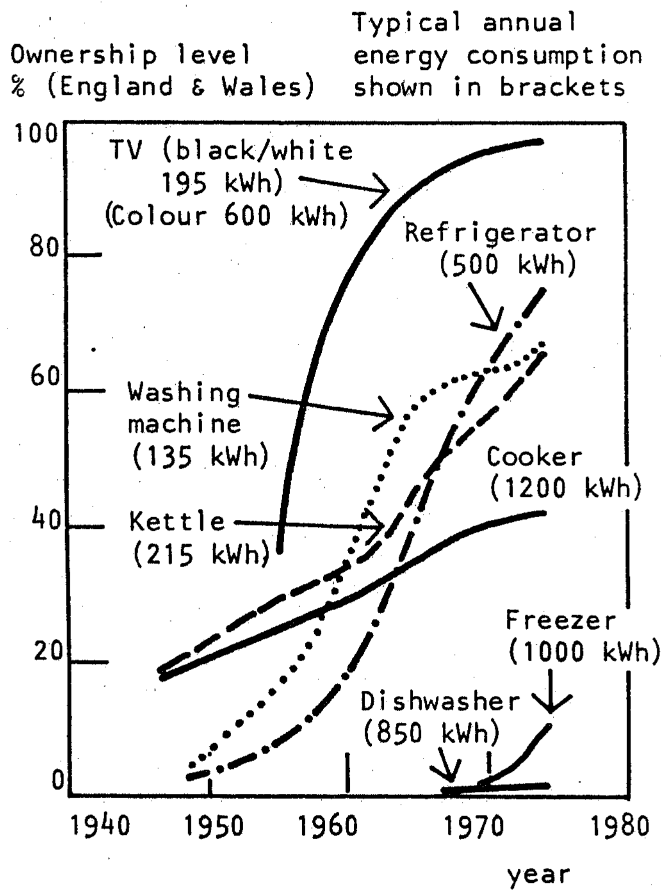

Fig. 4 Changes in electrical appliance ownership

Careful field trial measurements of six centrally heated houses at Bromley near to London showed the magnitude of these free heat gains (Ref. 7). The houses were each equipped with an Electricaire off peak, thermostatically controlled, warm air unit. The hot water system contributed some 11 kWh/day to the house simply getting it to the taps. Casual domestic use of electricity added another 12 kWh/day. Heat from the occupants themselves amounted to 7 kWh/day. Solar gains made up the difference. The theoretical reduction in heat demand which these gains could create is also shown in Fig. 3. This assumes they occurred when and where the heat was needed.

Actual Daily Heat Loss Requirements

The typical variation of energy consumption with external temperature is shown in Fig. 5. There is close agreement with the predicted theoretical value in the coldest weather but in mild weather it is much higher than expected. The heating season is also longer than expected, since heating is required on days above the balance temperature.

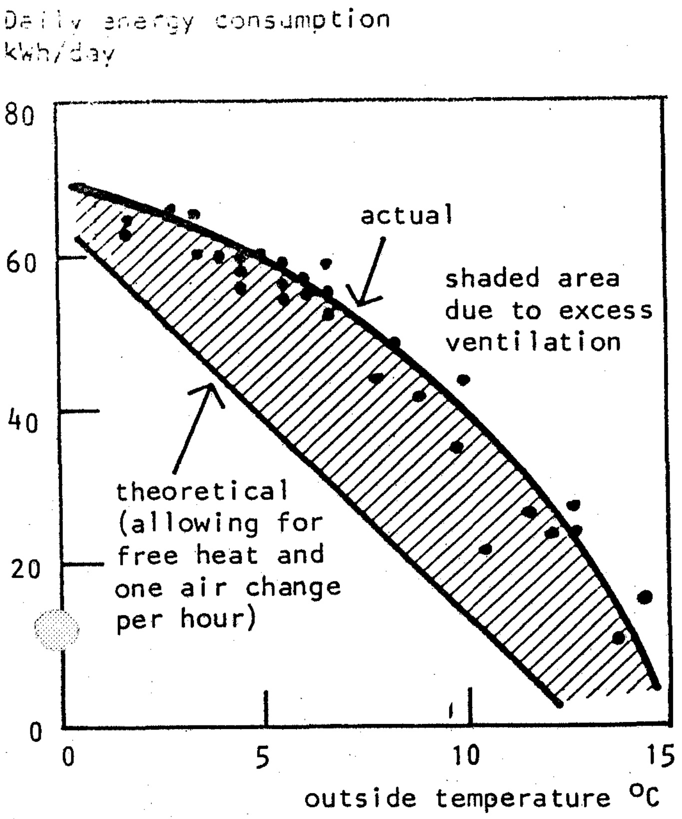

Fig. 5. Comparison between actual and theoretical energy consumption

There are at least two possible reasons for this energy overspend. The first is that the design conditions for the bedrooms are exceeded in mild weather. The room temperature records from the trials support this viewpoint. It is unavoidable when all the temperature control is from one downstairs thermostat. The second reason is that windows are opened for part of the day in the milder weather and the ventilation heat loss is high during this period. Calculations of fabric heat loss through bedroom overheating suggest the energy loss is small. The real loss appears to be over-ventilation. This is illustrated in terms of air changes in Fig. 6 based on a minimum rate of one air change an hour. This relationship is remarkably similar to earlier studies by Dick and Thomas, 1951 (Ref. 8).

OCCUPANTS' BEHAVIOUR

The inferential calculations of ventilation are notoriously inaccurate though useful as an indicator. British houses only need ventilators in food storage compartments. Since the refrigerator is now standard equipment, modern kitchens no longer include a pantry for food storage. The only way the occupant can modify the ventilation of the house is therefore to open the windows. Positive identification

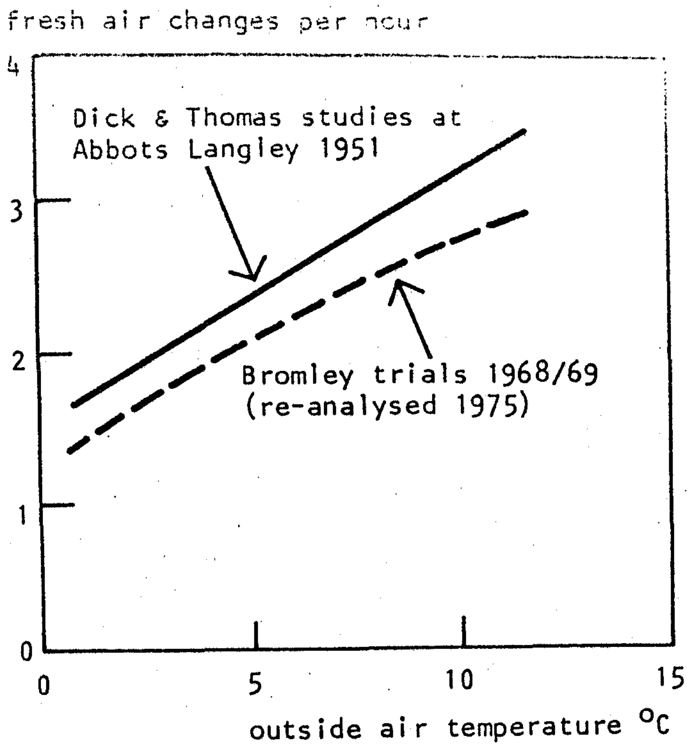

Fig. 6 Estimate of seasonal ventilation

of a ventilation pattern should be possible by simply observing open windows regularly. Two separate influences were expected, the first was the weather and the second was the personal characteristics of each particular family. Three surveys were therefore undertaken. The first and most important was the regular observation of a number of houses over a long

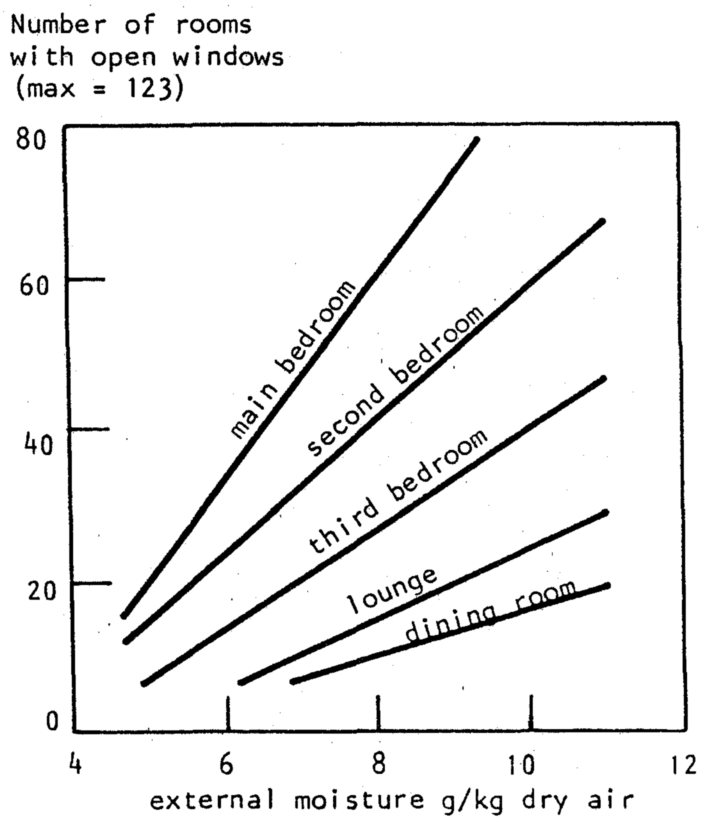

Fig. 7 Relationship between windows open and external moisture

period of time. The second was a systematic recording of the weather over the same period. The third was an interview with the husband or housewife in each family. This was necessary to identify certain basic parameters such as number and age of people in the house, and also to record habits of use such as whether they were usually in the house or not. This interview was also used to elicit the person's own reasons for opening windows.

The behaviour pattern over a year is given in Fig. 7. This shows the rooms which had an open window as a function of external moisture. Since Britain is approximately 90% relative humidity for most of winter there is a close relationship between moisture content and outside air temperature (Ref. 10). Moisture values of 5 gms/kg dry air are closely associated with dry bulb temperatures of 4-6°C. Moisture values of 11 gms/kg dry air are associated with a dry bulb temperature of 18°C.

There were two important family characteristics which influenced ventilation. The first was whether or not the housewife had a job. Those housewives out at full time employment had only half the windows open of those who stayed at home. The second characteristic was size of family. Analysis of the ventilation of those houses occupied during the day showed the number of rooms with open windows increased with the number in the family. These detailed values together with their own reasons are given in Tables 1 and 2.

The three most likely reasons for wanting fresh air are odour dilution, moisture control and convective cooling. Body odour dilution is a function of personal space and elapsed time between baths. Adult requirements approximate to 14 m^3/h of fresh air and children need rather more. This is a basic minimum and unrelated to weather. It will be a function of family size and time spent in the house.

TABLE 1 Family factors: influence on rooms with open windows in winter

Factor	Characteristic	Daily winter average of rooms with open windows
Employment of housewife	In full time employment (30 hrs +) In part time employment (8-29 hrs) Full time housewife (< 8 hrs paid)	0.36 0.71 0.74
Housewives at home	With two in family (sample of 2) With three (sample of 15) With four (sample of 22) With five (sample of 11) With six (sample of 2)	0.34 0.59 0.60 1.30 1.06

Each family who believed windows were opened in winter was given the opportunity of saying why this may be. The distribution of these spontaneous reasons is given in Table 2.

TABLE 2 Spontaneous reasons for open windows in winter

Factor	To freshen	To avoid condensation	To avoid stuffiness	To remove smoke	Too hot	Cooking smells	Air room
No. of mentions (Max. = 100)	68	31	20	14	9	9	5

Moisture is always a potential problem in Britain's mild damp winter. Loudon, 1971 (Ref. 11) estimates 7-15 kg moisture release in a house each day. Ward, 1974 (Ref. 12) made a particular study of kitchens and found 45% of the public housing sector inhabitants complaining of inadequate ventilation and 42% reported condensation troubles. Since the moisture generation rate will be relatively constant over the year the fresh air needed to maintain an acceptable indoor climate will be a function of the outdoor moisture level. In cold weather a small amount of dry outdoor air will be sufficient. In milder weather this ventilation will have to be increased. Bigger families will be associated with more moisture and hence need more ventilation. Ventilation rates needed to remove moisture are seasonally linked in Fig. 8.

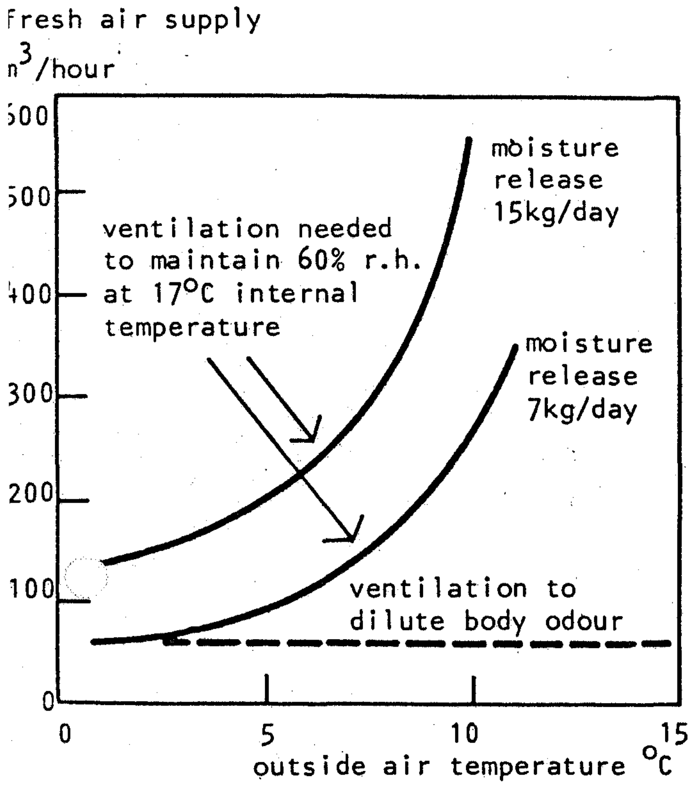

Fig. 8 Theoretical ventilation needs to control moisture and odour (based on four person dwelling and British weather)

Finally, overheating would occur in summer if houses were not ventilated. It could also occur in winter if the heating was badly controlled. Only a very small proportion of occupiers reported overheating in winter. Borel, 1974 (Ref. 13) has proposed a two season controlled ventilation scheme. Winter needs for body odour control are separated from the summer [illegible] of cooling. The introduction of a third season, moisture control, is essential for mild winter climates.

ENVIRONMENTAL SYSTEMS

The traditional approach to space heating neglects ventilation habits which can negate some of the potential savings of insulation. The new approach has to be an integrated one of environmental control designed for low energy. There are four interconnecting parts to this, namely fabric insulation, heating equipment, odour control and moisture extraction.

Fabric insulation has a double benefit. It reduces heat loss and enhances the value of 'free' heat. In mild climates it also enables the role of space heating to change from a crude thermal input masking building deficiencies to an elegant trimming device compensating for small changes in 'free' heat. Electricity is most versatile in this role. The bulb of space heating energy is lost during the mild winter days when the 'free' heat from sunshine can be large. The heating equipment has to switch off quickly in these circumstances or the room will overheat and the occupants will be tempted to dissipate the energy through ventilation. New electronic circuits enable this control to be achieved sensitively and with a continuous proportional band rather than the wide differential on/off of some thermostats. Large low temperature panels will avoid severe vertical temperature gradients (Ref. 14). Individual room heat pumps are also becoming attractive. Such units are designed for space cooling with heating as a bonus. Optimisation for space heating gives up to 50% improvement on coefficient of performance (Ref. 15).

Controlled ventilation is the next step. This is to remove the motivation to open windows rather than to prohibit such opening. Mechanical ventilation allied to weather-stripping the windows and doors is already commercially available. This provides an air supply into the living rooms and extracts stale air from the service rooms such as kitchen and bathroom. It also includes a counterflow heat exchanger to recover 60% of the sensible heat which would otherwise be lost. Special features such as a kitchen boost are situated as closely as possible to the moisture sources such as the cooker top, the bathroom and the clothes drying or airing cabinet. Current research is aimed at electrical techniques of air treatment. At its simplest this is a combined ozone and ultraviolet irradiation technique. This works particularly effectively at low contaminant concentrations and oxidises malodours into less offensive harmless compounds. More complex equipment includes a heat pump dehumidifier which dries the room air down to comfort conditions. The latent heat absorbed is released usefully as sensible heat. This creates a thermal benefit out of a potential nuisance.

This change of emphasis in space heating means that the space heating energy consumption can be brought down to a value comparable with that used for domestic hot water heating, i.e. 3,500 kWh/year. This offers the electricity utilities the opportunity of a high load factor house by judicious design of direct acting electricity for trimming space heating and off peak storage for background space heating and hot water.

CONCLUSION

The new approach to energy in the home is essentially an integrated one. High levels of insulation enable the free heat generated within the house to provide the bulk of the space heating energy. To be successful the heating equipment must have responsible switch off controls and the ventilation system must cope with both odours and moisture. Electricity can play a versatile role in this development.

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