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Heat losses from dwellings

In the United Kingdom about 30 per cent of the primary energy consumed is used in dwellings. The need to conserve primary energy resources and the cost of energy have led to an increased awareness of the need for thermal insulation; recent amendments to the Building Regulations, introduced to minimise condensation, indirectly limit the amount of energy used for heating new dwellings.

This digest outlines an established method for determining the seasonal heat loss from dwellings and the most suitable measures for restricting it but does not deal with cost benefits. Nevertheless the method may be used to compare heat losses associated with different standards of insulation for ground floors, external walls and roof structures for flats, semi-detached, detached or terraced houses.

In practice, it is frequently found that thermal improvements to existing dwellings partly result in improved comfort conditions and partly in reduced energy consumption, and that it is in only a small percentage of dwellings that the benefits of reduced heat losses are all taken in reduced energy consumption. A survey of energy usage by local authority tenants in Scotland showed that on average only about half of the potential savings from improved thermal insulation were in fact realised as actual energy savings, the other half being used to produce higher temperatures; tenants with the lowest heat usage did not save any energy when the insulation was improved.

The major heat losses occur in dwellings which were built with a low standard of insulation and the examples indicate the savings that can be made by upgrading local authority houses built in the 1940s/1950s. This method of calculating heat losses can be applied to non-standard housing and to other buildings although the wall areas, etc, may be more difficult to determine, and in larger buildings there may be different temperatures in different parts of the building.

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Factors influencing the rate of heat loss

In any building where the air temperature inside is higher than that outside, heat loss will occur by conduction through the enclosing structure of the building and by the interchange of the inside and outside air; these two forms of heat loss may be referred to as *Fabric heat loss* and *Ventilation heat loss*. To maintain any required temperature conditions inside the building the rate of heat input must be equal to the rate of heat loss; the heat input in dwellings is provided mainly by the heating system but in addition some heat gain is obtained from the sun, some is due to heat produced by people and some is the result of cooking and the use of domestic hot water.

Many factors influence the rate at which heat will flow from the inside of the heated building to the colder air outside but it may be useful to summarise the major ones briefly.

The thermal transmittance or U-value of the exterior shell of the structure Those external parts of the dwelling which enclose the living space, usually the ground floor, the external walls and the roof and uppermost ceiling have to be considered. The Building Regulations 1975 require that the maximum U-value for the external wall should not exceed 1·0 W/m^2 °C and for the roof should not exceed 0·6 W/m^2 °C and assume that the U-values for single and double glazing are 5·7 and 2·8 W/m^2 °C respectively.

The air change rate This is the rate at which the heated air within the building is displaced by colder air from outside. The air flow will occur through open windows and doors, through any gaps in the structure such as those around closed windows and doors, and through ventilators and flues. The rate of air change varies considerably depending on the magnitude of the two motive forces, wind and the temperature difference between the inside and the outside air.

The difference in temperature between the inside and the outside air An increase in this temperature difference results in a greater heat loss through the exterior shell by conduction in addition to increasing the heat loss due to ventilation. Good thermal insulation is of particular importance in a building where a high standard of heating is maintained.

The area of the external part of the dwelling For a building of any given floor area and construction, the greater the area of the external surfaces the greater will be the rate of heat loss. In this respect a flat generally performs better than a house, and a terraced house better than a detached house of similar shape and size (this is discussed further under *Fabric heat loss*).

The area of windows During sunny periods some solar heat may be gained through south-facing windows; heat loss at other times and on other aspects is increased by large windows although this is influenced to some extent by curtaining. If large windows are desired they should preferably be placed on the south side of the building. The provision of unnecessarily large opening portions may add to the air gaps in the structure and increases heat loss by increasing the rate of air change.

The type of heating system Many modern heating systems are designed without any flues and require no ventilation and this can result in a low ventilation rate in the dwelling. However, if the heating appliance has a flue, appreciable heat loss can occur from an excessive volume of heated air passing up the flue, the influencing factors being the restriction to air flow provided by the appliance and by the cross-sectional area of the flue throat. For example, the volume of air passing up the flue of an open fire with a normal sized throat may be around 170 m^3 per hour but if the throat is not greater than 130 cm^2 in area or if the appliance is a flued gas heater, the air flow is likely to be less than half this volume.

Fabric heat loss

The rate of heat loss by conduction through the fabric can be calculated by multiplying the area of the various components such as the walls, windows, ground floor and roof by their appropriate U-value and by the difference between the inside and outside temperatures. The total obtained by the addition of these various products is the total fabric heat loss.

When considering groups of dwellings, such a procedure is likely to prove tedious as the temperatures in the various parts of the dwelling will vary and the areas of exposed walling, roof and floor structure, and of windows, need to be calculated for each part of the structure according to the variation of inside temperature. There are also likely to be differences in the plans and elevations of the dwellings necessitating the repetition of such calculations for each individual design. For most practical purposes, however, when a comparison of heat losses from different constructions is desired, or the heating load for a group of dwellings is required, certain approximations may reasonably be used in dealing with average dwellings to avoid the need for lengthy calculations.

Heat losses are high in dwellings which were built with a low standard of insulation, and a substantial energy saving could be obtained by upgrading these dwellings. Typical data on the area of windows, walls, etc, and their relation to floor area in dwellings were obtained some years ago for over 200 pre- and post-war local authority dwellings. Little difference was observed between the results for pre- and post-war houses or between different local authorities. Table 1 gives the ratios of exposed wall, ground floor, roof and window areas to the 'floor area' for typical dwellings.

Table 1

Floor type	Exposed wall to 'floor area'	Ground floor to 'floor area'	Roof to 'floor area'
Semi-detached (2-storey)	1·00	0·5	0·5
Terraced (middle) (2-storey)	0·75	0·5	0·5
Flat (ground floor)	0·75	1·0	0·0
Flat (top floor)	0·75	0·0	1·0
Detached (2-storey)	1·25	0·5	0·5
Flat (middle floor)	0·75	0·0	0·0

('Floor area' is the total of the floor areas within the external walls. It was found that the ratio of area of windows to floor area was very similar and an average figure of 0·18 can be adopted for typical dwellings)

For most purposes in calculating heat loss from typical local authority dwellings built in the 1940s/1950s, the areas of the various components of the surrounding structure (that is of the exposed walls, ground floor, roof and windows) can be obtained with sufficient accuracy from the above data if the floor area is known.

For these typical houses it is sufficiently accurate to use a mean house temperature as the temperature throughout the whole of the house on which the heat loss calculation can be based. In this way the difference in temperature between the air inside and outside the house may be taken as the same for all parts of the house, avoiding the necessity of calculating the heat loss for each room in turn and enabling the total areas of the exposed walls, ground floor and roof to be used. The temperature difference between the inside and the outside of typical houses with heating methods normally used averages between 5 and 10 °C throughout the heating season.

Example

The following example uses the above data to calculate the conduction heat loss from a typical semi-detached house of 100 m^2 'floor area', with U-values for walls, ground floor and roof of 1·7, 0·6 and 1·8 W/m^2 °C respectively. These U-values are for 275 mm cavity brick walling, concrete ground floor, and a pitched roof of tiles on battens on felt with plasterboard ceiling. The following example shows the conduction heat loss calculated for the various components of the enclosing structure using the ratios of the areas as given in Table 1. The mean temperature difference is assumed to be 7 °C.

To obtain the heat loss for a heating season of 33 weeks, using the 'degree–day' method,* the average heat loss of 2748 W should be multiplied by 5544 (33 weeks × 7 days × 24 hours) to obtain the heat loss in W and divided by 278 to convert to Gigajoules (GJ). Thus the conduction heat loss in a heating season is 15,250 kWh, or 55 GJ.

From this calculation the relative value of any desired improvement of the thermal insulation of the walls, ground floor or roof can be assessed. *The average heat loss should not be used to determine the rating of a heating appliance, since the appliance must be able to meet the maximum demand. Calculations of appliance ratings should be based on the design temperature difference between inside and outside.*

Ventilation heat loss

The ventilation rate of dwellings can vary widely but for typical dwellings on sheltered and exposed sites the ventilation rate can be taken as one and two air changes per hour (ach) respectively. In houses without flues (or with appliances with balanced flues), ventilation rates will be lower and rates of $\frac{1}{2}$ ach are not uncommon. To estimate the heat loss due to ventilation, the volume of the dwelling within the external structure should be calculated and a deduction of, say, 10 per cent made for dead space (cupboards, partitions, etc). For a typical dwelling in which the floor area is 100 m^2 and the ceiling height is $2\frac{1}{2}$ m, assuming a ventilation rate of 2 ach for quite exposed site conditions and an average temperature difference between inside and outside of 7 °C, the ventilation heat loss for a heating season may be calculated as follows:

volume (m^3)		temperature difference (°C)		0·33*		hours in heating season		no. ach
225	×	7	×	0·33	×	5544	×	2

= 5750 kWh
= 21 GJ

* Where 0.33 = W required to raise the temperature of 1 m^3 of air through 1 °C.

If the dwelling is in a sheltered position, eg in a built-up area, the typical air change rate is likely to be 1 ach and the ventilation heat loss will then be 10 GJ.

Fabric heat losses for	Area (m^2)		U-value (W/m^2 °C)		Mean temp. difference (°C)		Average rate of heat loss (W)
External walls	(1·00 × 100)	×	1·7	×	7	=	1190
Ground floor	(0·50 × 100)	×	0·6	×	7	=	210
Roof and top ceiling	(0·50 × 100)	×	1·8	×	7	=	630
Windows	(0·18 × 100)	×	5·7	×	7	=	718
							2748

* The 'degree-day' method is an approximate method of calculating seasonal heat losses and does not take account of varying solar heat gains through the heating season.

Total heat loss

It will be seen that the total heat loss from a typical semi-detached house of 100 m^2 in floor area on a reasonably exposed site is around 76 GJ per heating season, this total being composed of 55 GJ due to conduction loss and 21 GJ due to ventilation loss.

In the absence of any precise data on gain from the sun and from people in the dwelling, an average of 15 GJ per heating season seems a reasonable value to assume. The input required for the heating system in the typical semi-detached house described will, therefore, be around 61 GJ per heating season; this figure includes heat gain from cooking and from the use of domestic hot water.

Reduction of heat loss

The relative value of improving in various ways the structure of a typical house to reduce the heat loss can be obtained from the data given above.

1. Providing a 50 mm layer of insulation material at the ceiling level immediately below the roof will reduce the U-value of the roof to, say, 0·55 W/m^2 °C, this will result in a reduction in heat loss of about 9 GJ per heating season.

2. Insulating the cavity of a twin-leafed wall will reduce the U-value of the external walling to about 0·5. The reduction in heat loss will be about 17 GJ per heating season.

These two improvements will reduce the heat loss by 26 GJ and the required heat input to maintain the same conditions will be reduced from 61 GJ to 35 GJ per heating season, a reduction of 42 per cent. A 14 per cent reduction is due to the improvement of the roof insulation, an improvement which can be made easily and without undue expense in many existing dwellings.

3. The provision of double-glazing (U-value say 2·8) throughout the house will reduce the heat loss by not more than about 7 GJ per heating season.

4. In addition to any improvement in the thermal insulation of the structure, a reduction of the air change rate will also reduce the heat loss. In some experimental houses where the average ventilation rate was about 2 ach it was found that weather-stripping the two external doors only could reduce the rate by approximately $\frac{1}{2}$ ach on an exposed site. This would reduce the hourly air change rate to $1\frac{1}{2}$ thus making a reduction in the heat loss of about 5 GJ per heating season.

Dwellings built to modern design without flues can have very low ventilation rates and it is suggested that weather-stripping is not undertaken in these cases because of the increase in the risk of condensation.

For well-insulated construction, the grouping of dwellings also assists in limiting the heat loss because of the smaller area per dwelling of exposed surface of the enclosing structure. The heat input for a heating season will be about 37 GJ for a detached house, 35 GJ for a semi-detached house and 33 GJ for an inner house in a terraced block assuming dwellings of 100 m^2 floor area, having U-values for the external walls, ground floor and roof of 0·5, 0·6 and 0·55 W/m^2 °C respectively and with single glazing an area 18 per cent of the floor area, a 7 °C difference of temperature between the inside and outside air and a ventilation rate of 2 ach.

The heat loss from a terraced house is, therefore, over nine per cent less than that from a detached house of the same size and construction.

Building Regulations (thermal insulation) give a minimum statutory requirement. From the examples given a saving of about 40 per cent in the heating requirements can be obtained by increasing the insulation above the minimum in walls and roofs and this should be a standard at which to aim.

As any improvement of the wall insulation in existing houses is likely to be expensive, the most reasonable measures to adopt are the provision of roof insulation at the ceiling level.

In providing roof insulation it should be remembered that water tanks or pipes situated in the roof space must also be well insulated and the small part of the ceiling immediately under the tank should be left uninsulated.

It should be emphasised that the calculations give an indication of the fuel savings to be obtained if internal temperatures are not increased after improving the insulation standard. In general this is not the case and part of the benefit of insulation is to provide higher temperatures.

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