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Improving energy efficiency in housing

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This paper summarises the principal opportunities for improving energy efficiency in both new and existing housing. It draws, in part, on the experience gained from projects carried out under the Energy Efficiency Demonstration Scheme.

INTRODUCTION

Energy efficiency is an indicator of the economic value obtained from the consumption of fuel. When applied to energy used in housing, it is best assessed in terms of the cost of energy needed to produce a given output or level of service such as a standard of heating. Accordingly, an energy-efficient house is one which, compared with houses of similar size, costs less to heat, to light and to operate its essential services. Effectively, that will mean that it has good thermal insulation and an efficient heating system. Additionally, it will be designed in such a way so as not to require excessive amounts of energy for other purposes such as lighting or cooling in warm weather.

This Information Paper offers a guide to the main opportunities for improving energy efficiency in both new and existing housing, and an indication of how the ensuing benefits may be assessed. It is based, in part, on work funded by the Department of Energy's Energy Efficiency Office (EEO) through BRECSU — the Building Research Energy Conservation Support Unit.

INSULATION

New housing is subject to Building Regulations which, among many other requirements, set standards for thermal insulation and the control of heating systems. The current Regulations ensure that new housing needs only about half as much energy for space heating as similarly-sized housing built 50 years ago (see Figure 1). Even higher standards are often appropriate: for example, when high internal temperatures are required or the fuel cost is unusually high. Such standards can often be achieved at little extra cost if an integrated approach to the energy design of the dwelling is adopted. Many examples of housing with standards exceeding those in the Regulations have been built, and several have been monitored under the Energy Efficiency Demonstration Scheme (EEDS).

In existing housing, it is generally more difficult to achieve high insulation standards than it is in new buildings, but there are many opportunities for making simple improvements. More opportunities arise during major refurbishment work when, for example, the extra cost of adding insulation is often sharply reduced. This is epecially true for the insulation of solid brick walls at the time of replastering or re-rendering. Table 1 shows the main measures that can be undertaken in existing housing, and their payback periods. EEDS projects also provide valuable examples of insulation improvements in existing houses, especially in situations where energy-saving measures have accompanied major refurbishment work.

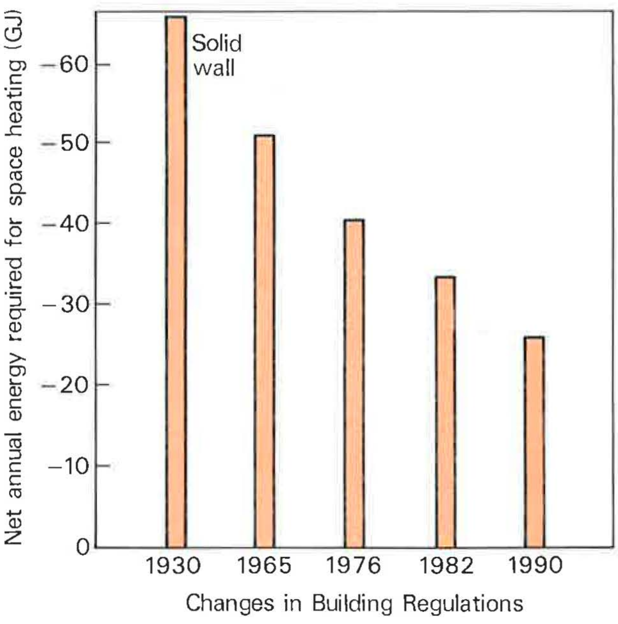

Figure 1 The impact of Building Regulations on annual space heating energy requirements (calculated for a semi-detached house, floor area 80 m²)

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Table 1 Energy efficiency measures for existing dwellings

Measure	Typical payback period	Applications and comments
Hot water cylinder jacket	6 to 12 months	All dwellings with hot water storage
Loft insulation	1 to 3 years	All dwellings with accessible lofts
Condensing boilers	2 to 4 years	At replacement of worn-out boilers
Draught stripping of windows and doors	2 to 10 years	All dwellings — subject to need to maintain adequate ventilation
Cavity wall insulation	4 to 7 years	Dwellings with cavity walls not subjected to severe driving rain
Double glazing	10 to 12 years	Cost-effective when windows need replacing

VENTILATION

Ventilation is essential to maintain good air quality in housing and must be sufficient to keep moisture and contaminants at acceptable levels. Moisture and contaminants in housing are commonly derived from the combustion products of fuels, from materials used in the building and its contents, and from the occupants. The required level of ventilation depends upon how the house is used and particularly on the flue arrangements for fuel-burning appliances. Heat losses due to ventilation form a significant part of total heat losses, particularly in well-insulated homes. It is important, therefore, that ventilation rates are kept close to the minimum necessary for satisfactory air quality if improvements in energy efficiency are to be achieved.

The principles of good ventilation design in housing are described in BRE Digest 306[1]. In general terms, it is essential to adhere to the statutory requirements for providing ventilation for heat-producing appliances. Beyond that, the objectives should be to provide controllable ventilation, and to remove moisture and contaminants at source such as by the use of vented cooker hoods and extractor fans. Good control of ventilation is achieved by making the dwelling relatively airtight; this may be measured using a standard pressurisation test.

While it is possible to achieve some control over ventilation using the natural airflows caused by wind and convection, a higher degree of control may require the use of mechanical methods. Mechanical or forced air ventilation is inherently more complicated in terms of the equipment it requires, but it opens up the possibility of using a heat-exchanger to recover much of the heat that would otherwise be lost with the outgoing stale air. The full energy efficiency benefits of mechanical ventilation can only be obtained in buildings that have good airtightness. Guidelines for the design and installation of domestic mechanical ventilation are given in BRE Information Paper 18/88[2].

HEATING SYSTEMS

Once the rate of heat loss through the fabric of the dwelling has been reduced and proper provision made for minimal but controllable ventilation, it is necessary to look closely at the design of the heating system. The aim is to minimise the cost of providing space heating and hot water. There are three major considerations.

The first is to ask whether a heat source is necessary in every room of the house. For example, it is quite possible to design a well-insulated, two-storey family house in which just two individual heaters, situated downstairs, are sufficient to heat the whole house to acceptable standards[3]. This has the advantage not only of simplicity, but of a significant saving in installation costs. The saving can more than offset the additional cost of insulation, resulting in a warm house which is economical to run and, yet, costs less to build than an equivalent house built to current Building Regulations standards. This same result can be achieved with other forms of heating such as modern, electric storage radiator systems, or gas-fired 'Heatsavers'.

The second consideration is the sizing of the components of the system — boilers, circulation pumps, etc. Almost all heating installations perform more efficiently when running at or near their maximum ouput. It is therefore desirable to match the output of the components as closely as possible to their expected maximum load.

Finally, where a traditional heating system is used, the heat generator should be selected to be as efficient as possible in converting the fuel into energy. For example, condensing gas boilers can achieve annual system efficiencies of up to 90% compared to no more than 70% for modern conventional gas boilers. The use of condensing boilers is described in a number of publications including, for example, Information Paper IP10/88[4], and a new CIBSE Applications Manual[5] produced with BRECSU assistance.

PASSIVE SOLAR DESIGN

The radiation entering dwellings through windows forms a significant source of heat, even in a typical existing house in the United Kingdom.

Passive solar design sets out to deliberately minimise heating requirements by taking advantage of solar gain. This may be achieved either by direct gain (ie solar radiation through windows) or by the use of special architectural features such as conservatories and Trombe walls. It is possible to reduce space heating needs simply by ensuring that glazing is predominantly on the south facing aspects of the building and is not overshaded. This can often be done at minimal extra cost and is especially beneficial if it can be applied to the layout of new developments where there may be more opportunity for controlling orientations. Advanced passive solar designs, in which a large proportion of heating requirements are met by solar gain, require careful analysis to optimise design features and to ensure that overheating does not occur in summer. Studies of the benefits deriving from passive solar design are being funded by the Department of Energy[6].

Figure 2 Low-energy housing built by Manchester City Council

CALCULATION OF ENERGY REQUIREMENTS

Calculations of annual energy requirements are needed in order to estimate running costs and to assess the benefits of energy efficiency improvements. Such calculations must take account of:

- physical details of the house, its heating system and controls;
- climate, including temperature and solar radiation; and
- the way the house is used, including heating patterns, internal temperature, and the use of electrical appliances which produce heat as a by-product of their operation.

The Building Research Establishment Domestic Energy Model (BREDEM), which is based on accumulated experience gained from monitoring a large number of occupied dwellings, has been developed for carrying out such calculations. Several standard versions are available, tailored to particular applications and varying in their degrees of complexity. BRE Information Paper IP13/88[7] describes a 'worksheet' calculation which can be carried out using either a hand-held calculator or a personal computer, and which is appropriate for assessing energy efficiency measures.

ASSESSING THE BENEFITS

In addition to energy savings and the consequential reduction in fuel bills, other benefits follow from improving the energy efficiency of houses, especially of existing dwellings. These further benefits are often difficult to quantify but may be of equal or greater importance in the assessment process; they particularly apply in the case of rented housing where the landlord makes the investment in energy efficiency, but the tenant reaps the direct benefit from reduced fuel costs.

Figure 3 Birmingham enveloping project: house after upgrading

For example, with insulation, the most obvious additional benefit is a rise in average temperature within the house and a more even distribution of warmth throughout all the rooms. For tenants on low incomes, and for the elderly in particular, this can be a very important improvement. Furthermore, the presence of insulation and the rise in room air temperatures usually leads to a reduction in the occurrence of condensation and of subsequent mould growth, though it is also important to make provision for adequate controllable ventilation.

These two benefits — the results of measures adopted as part of a general refurbishment package — can transform rented property which is cold, damp and therefore difficult to let into attractive, sought-after dwellings with a corresponding reduction in the frequency, duration and cost of vacancies. Tenants are happier and less inclined to complain — hence management costs fall and rent may be paid more promptly. In addition, the reduction in condensation, the higher average temperatures and increased occupancy rate leads to reduced maintenance costs and, ultimately, to a longer life for the property.

CASE STUDIES — SOME EXAMPLES OF ENERGY-EFFICIENT HOUSING

The Energy Efficiency Demonstration Scheme projects, managed and monitored by BRECSU on behalf of the EEO, offer many examples of successful low-energy housing, both as new dwellings and as refurbished older buildings. Results from these, in the form of Project Profiles and monitoring reports, are available from the BRECSU Enquiries Bureau at BRE. Some examples from the range of projects will serve to illustrate the proven benefits.

In new housing, a series of projects has developed the principles through several stages. Manchester City Council hosted the first one in which the basic design of standard three-bedroomed houses was thought through from the beginning, integrating all the relevant measures for energy efficiency. These homes were given 100 mm cavities in the external walls filled with blown mineral fibre insulation; polystyrene boards were placed under the ground floor boarding, and the loft had 150 mm rather than 100 mm of fibre insulation (giving a U-value of less than 0.3 W/m^2°C). The result of these measures was to cut space heating costs by 46% compared to those for houses on the same site built to the then current (1985) Building Regulations standards. In addition the low-energy houses were significantly warmer — this and the low fuel bills ensured well-satisfied tenants. All this was achieved for an additional capital cost of only a few hundred pounds per dwelling.

Other Energy Efficiency Office projects at Giffard Park, Milton Keynes, and Laurie Park Road, Lewisham, confirmed the principal measures for energy efficiency: an extra layer of insulation applied evenly around the whole envelope of each house, together with an internal layout and orientation of the house and distribution of glazing which take full advantage of the heat of the sun. These designs helped to achieve space heating energy savings worth 60% on average, again for very low additional costs.

Manchester City Council pursued their policy of energy efficiency in their new housing by combining well-insulated dwellings with simple, partial central heating systems, as shown in Figure 2. This solution offered warm houses, with low fuel bills, at a construction cost significantly less than that of a conventional design using full central heating. Many other examples exist, some of which feature in

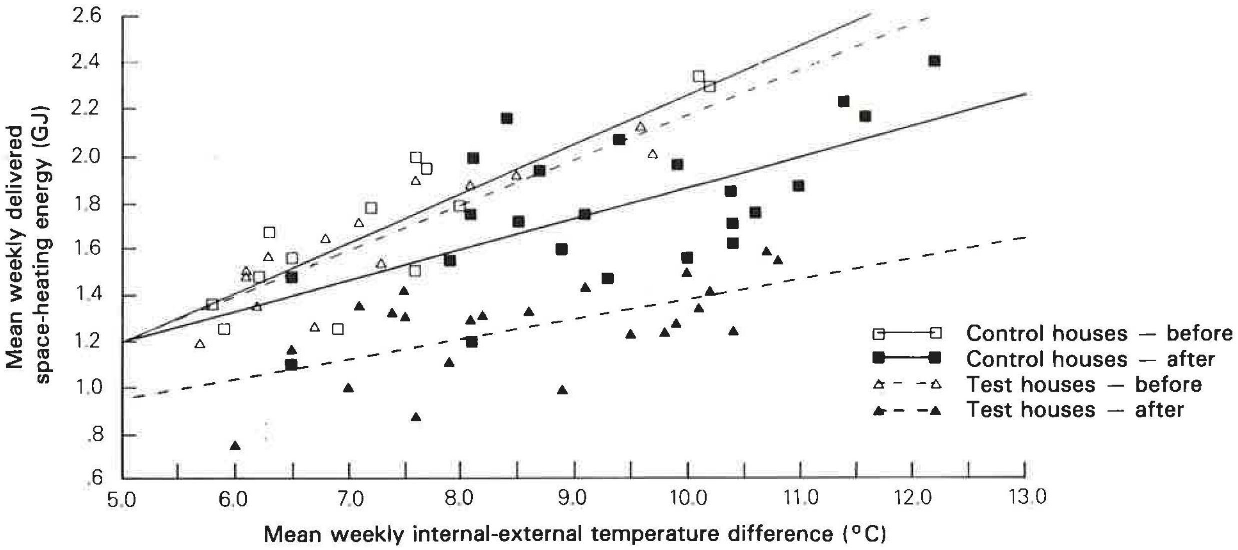

Figure 4 Comparisons of energy consumption for terraced houses in Birmingham before and after the application of the standard improvement package (for control houses) and the energy-efficient package (for test houses)

BRECSU case studies in the private sector[8], others in the successful Energy Park at Milton Keynes.

In existing housing, one housing association project for pre-1920 terraced cottages on Merseyside has demonstrated the benefits of applying internal wall insulation, partial central heating and proper draught-proofing. These cottages now enjoy space heating bills 40% less than other, non-insulated dwellings, **plus** temperatures on average 1°C higher. The project also demonstrated the benefit of providing tenants with relevant, practical advice on how to make the most of their low-energy homes.

In another project in Birmingham, energy-saving measures were incorporated into an enveloping programme operated by the City Council to upgrade the structural condition of Victorian terraced houses (see Figure 3). High performance double glazing, extra loft insulation and thorough draughtproofing resulted in an energy saving of nearly 13 gigajoules (GJ) per year (22%).

Temperatures, averaged over all rooms of the houses, were 1.4°C higher, and condensation was eliminated. Figure 4 illustrates the results graphically, showing how the heating energy necessary to achieve a temperature rise inside houses (as compared with the temperature outside) was reduced.

CONCLUSIONS

The Building Regulations require much higher standards of energy efficiency in new dwellings than is found in most of the existing stock. Nevertheless, they are minimum standards and it is often cost-effective to go beyond these requirements. In existing buildings, there are many opportunities for taking measures to improve energy efficiency, including both insulation and better heating systems. Such opportunities are often greatest when major refurbishment work is being undertaken. Information on many practical examples of successful energy efficiency improvements is available through BRECSU.

Also, BREDEM is proving to be a valuable aid to calculating the benefits of energy efficiency improvements in both new and existing housing. It provides a uniquely simple and effective means of assessing the cost-effectiveness of energy measures and the likely changes in internal temperatures, and helps to identify the most appropriate package in individual cases.

Full details of the case studies and demonstrations referred to in this paper are available from the BRECSU Enquiries Bureau at BRE, telephone 0923 664258.

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