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Investing in energy efficiency: 3 New housing

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This is the third of a short series of Information Papers concerned with the economic assessment of energy efficiency measures in housing. This paper, which examines the effects of installing additional thermal insulation or maximising passive solar energy heating in a 'standard' semi-detached house, is intended for architects, builders, suppliers, housing authorities, their managers and technical staff, and also home-owners.

INTRODUCTION

Information Paper IP17/86[1] reviewed techniques for assessing the economic viability of investing in measures to improve energy efficiency in housing, IP20/86[2] showed how the selected method could be applied to existing housing and this paper now looks at new housing. It starts with a 'standard' design of semi-detached house already insulated up to the requirements of the 1981 Building Regulations then examines the economic effects of incorporating different energy saving additions.

THE ASSESSMENT METHOD

The assessment method used and all the findings quoted here are taken from a BRE Report by John Pezzey[3] on energy efficiency measures in housing. The method relates the Net Present Value *(NPV)* of the annual financial savings *(S)* that accrue over the life of the measure to its capital cost *(K)*. This is expressed as *'NPV/K'*; if the value if positive then the investment would pay and if negative it would lose.

The value of K can readily be obtained from estimates of the work involved. However, the energy savings likely to result have to be predicted from the nature of the measure and the physical parameters of the building concerned. The BRE Domestic Energy Model[4] or 'BREDEM' explains how the energy requirements of a building to maintain given internal temperatures can be calculated from knowledge of its dimensions and make-up. Before and after calculations show what a projected energy efficiency measure is likely to save. Some microcomputer software[5,6] based on BREDEM is available to assist. Advice is also available from BRE through the Building Research Advisory Service; Tel 0923 676612.

NPV/K can also be written as $\dfrac{B-K}{K}$

where $$B = S \times \left[\frac{1-(1+r)^{-N}}{r}\right]$$

In this equation,

N = the life of the measure in years

r = the selected discount rate expressed as a decimal fraction, ie 5% = .05.

To save time, the discount factor in the large bracket can be obtained with the help of tables for discounted cash flow[7].

The paper now goes on to describe some sample

BASIS FOR THE ASSESSMENTS

As Figure 1 illustrates, built form and especially the degree of detachment has a strong influence on heat losses from dwellings. In this and the other related Information Papers the examples are based upon a 'standard' semi-detached house with a ground floor area of 43.7 m². The main dimensions are quoted in IP20/86.

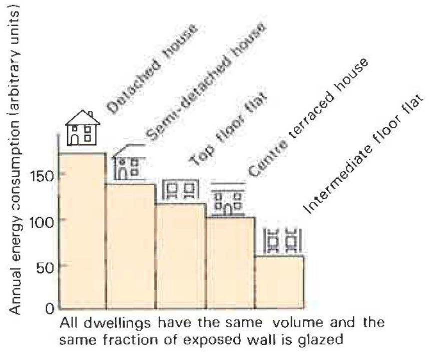

Figure 1 Effects of built form on heat losses from dwellings

Assumed U-values for the new version of this house are:

Element	U-value (Wm^{-2} °C)
Single glazed window, light curtaining 14 hours a day	3.5
Opaque wall	0.6
Loft	0.29
External doors	2.8
Ground floor	0.6

The house is heated by gas to controlled temperatures of 19°C downstairs and 16.5°C upstairs and it is assumed that the average ventilation rate is 1 air change per hour.

Other assumptions used in the calculations are:

Cost of gas (1982) = £3.18/GJ (1 Gigajoule = 10^7 Joules)
(1 Therm = 1.0551 x 10^8 Joules)
Fuel price rises in real terms = 0 *and* 3% per annum
Life of house *(N)* = 100 years
Discount rate *(r)* = 5%

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EXAMPLES

The examples that follow assess the economics of adding extra thermal insulation to the standard new house, which is already insulated up to the requirements of the 1981 Building Regulations, or of designing it to take better advantage of passive solar energy heating.

One additional bonus of providing a higher level of insulation is that this reduces the design heat load and so may permit a saving in the capital cost of the heating system. The main saving is in a reduction in radiator area possibly leading to the omission of one or two radiators. Furthermore, installation of double glazing could obviate the need to site radiators under windows and so allow an additional saving in reduced pipe runs.

A formula for estimating system savings has been devised by Pezzey (see p.204 of the Report) and suitable allowances have been made in the *NPV/K* values illustrated in Figures 2 to 6 on the assumption that a heating system is renewed every 15 years.

Measure 1: Installing ground floor insulation

(a) Solid ground floor slab

With new construction either whole floor or edge insulation can readily be incorporated below floor level. Edge insulation is usually more cost-effective and can be fixed vertically against the inside of the wall below floor level or horizontally under the floor slab or screed in conjunction with a vertical strip. See BRE Digest 145[8].

Figure 2 illustrates the economic assessment for placing 25 mm of edge insulation around the floor slab. Since the *NPV/K* figures are strongly positive then this measure would show a good return on investment over the 100 years estimated life of the house.

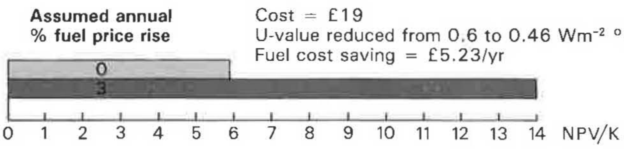

Figure 2 *NPV/K* values for placing 25 mm edge insulation around a solid ground floor slab

The figures employed in the calculation (current for 1982) and the method are as follows:

Initial capital cost of incorporating insulation = £19
Saving in heating system cost = £3.54 every 15 years
Net capital cost (K) = £19 − 3.54 = £15.46.

Present value of system saving $B1$ for $r = 5\%$:

$$B1 = 3.54 \left[\frac{1}{(1+r)^{15}} + \frac{1}{(1+r)^{30}} + \ldots + \frac{1}{(1+r)^{90}} \right]$$

$$= 3.54 \times 0.9153 = £3.24$$

Useful energy savings = 1.14 GJ/yr

Delivered energy saving = Useful energy savings/system efficiency
= 1.14/0.69 = 1.65 GJ/yr

Present value of energy savings $B2$ for $r = 5\%$:

$$B2 = S \left[\frac{1-(1+r)^{-N}}{r} \right] = 5.25 \left[\frac{(1-(1.05)^{-100}}{0.05} \right]$$

$$= £104.21$$

Total present value of savings $B = B1 + B2$

$$= £3.24 + £104.21 = £107.45$$

$$NPV/K \text{ for } r = 5\% = \frac{B-K}{K}$$

$$= \frac{107.45 - 15.46}{15.46} = 5.95$$

(b) *Suspended timber floor*

A suspended ground floor is exposed to air on both sides. The air temperature below the floor is usually higher than the outside temperature because the ventilation rate is low, and this enhances the effective insulation value.

Digest 145 reviews ways of insulating suspended floors and provides values of thermal resistance for the types of airspace involved. With allowance for the resistances of the floor structure and added insulation the U-value of the floor can be calculated.

In Figure 3, assessments are illustrated for first, 50 mm of insulation laid between the joists and second, increasing this thickness from 50 to 100 mm. In both instances the *NPV/K* values are positive so the measures would prove economically sound.

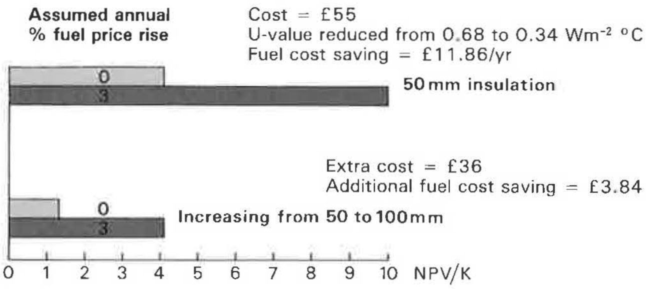

Figure 3 *NPV/K* values for laying insulation between the joists of a suspended timber floor

Measure 2: Insulation of exterior walls

There are numerous alternative ways of constructing and insulating exterior walls and here four basically distinct approaches are considered. In each case the economics are assessed for increasing the thickness of insulation so to reduce the U-value from some 0.5 to 0.6 down to 0.3 Wm^{-2} °C.

The four constructions, three masonry and one timber frame, are illustrated along with their *NPV/K* values in Figures 4 and 5. They encompass:

- *Total cavity fill* — in which the cavity has to be made wider to take the extra insulation. This is quite costly to construct since it requires extra wall ties, wider foundations and extra detailing around openings.
- *Partial cavity fill.* This has a somewhat wider cavity than normal so is also costly to construct. The residual cavity fulfills the traditional role of resisting water penetration.
- *External insulation of solid masonry.* This has to be protected and waterproofed by an external render but nevertheless making the layer of insulation thicker is relatively inexpensive.
- *Timber frame insulation.* In timber framed walls the space between the timber studding can be filled or partially filled with non-structural insulant at little extra cost.

The assessment shows that installing a greater thickness of insulation in masonry cavity walls is likely to prove uneconomic. The high cost of constructing the wider cavity would seem to be the main problem.

On the other hand, increasing the thickness of insulant in externally insulated masonry and in timber framed walls is either neutral or marginally positive in economic terms depending upon the rate of fuel price rise assumption.

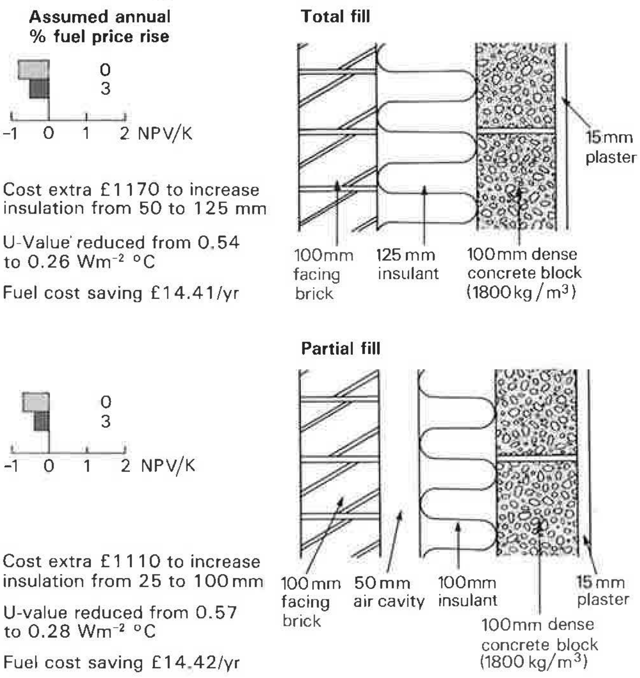

Figure 4 *NPV/K* values of increasing masonry cavity insulation

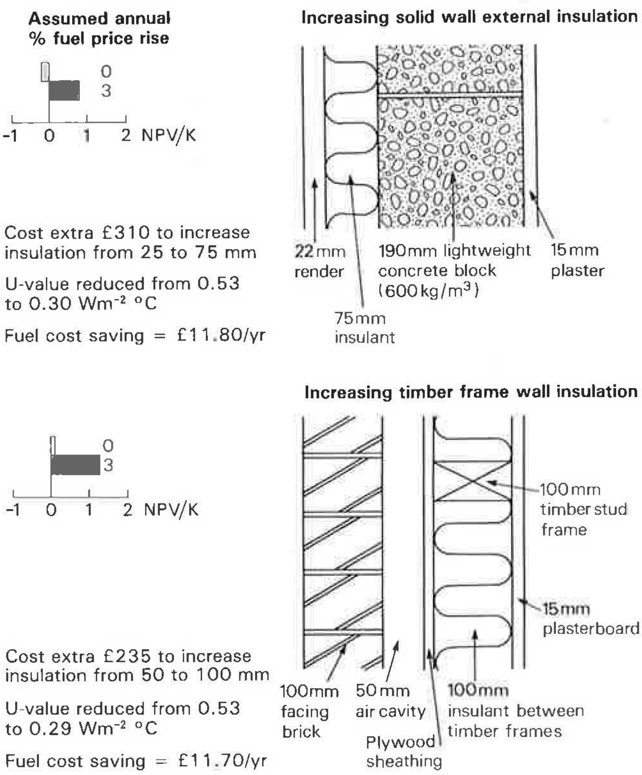

Figure 5 *NPV/K* values for increasing the insulation of solid masonry and timber frame walls

Measure 3: Increasing loft insulation

Figure 6 displays the assessment for increasing loft insulation in 25 mm steps from 100 mm to 200 mm. The first two steps are marginally economic and the last two marginally neutral or uneconomic depending again on the fuel price rise assumption.

Overall, the series is a good illustration of the effects of diminishing returns as thickness increases.

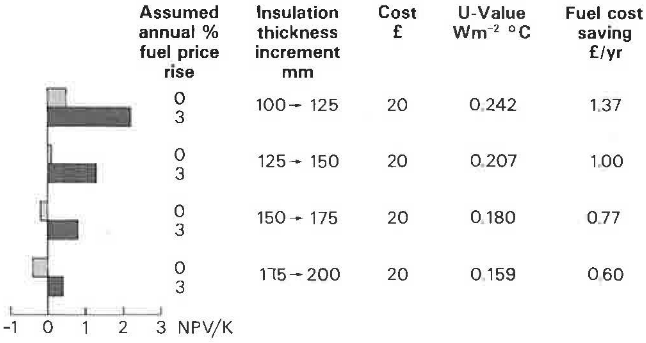

Figure 6 *NPV/K* values for progressively increasing the thickness of loft insulation

Measure 4: Double glazing

The economics of installing timber framed double glazing in new housing are compared in Figure 7 for downstairs only and then for extending this to upstairs as well. The bar charts also demonstrate the effect of assuming that £60 per floor can be saved in reduced pipework runs by not siting radiators under windows. In both instances it is assumed that the glazing will have to be replaced every 25 years as the frames are renewed.

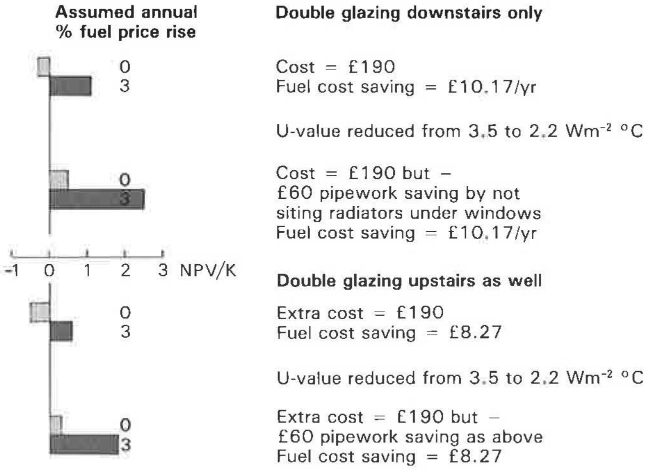

Figure 7 *NPV/K* values for timber framed double glazing

For both storeys the value of double glazing appears to be borderline to marginally positive unless the pipework saving is taken into account.

Measure 5: Passive solar heating

Passive solar design is a term applied to design systems which explicitly use conventional building elements to collect and store solar energy and to distribute it as useful space heat. All such systems use the south side of the building as a solar collector and the building structure itself as a heat store. They mainly rely only on modification of windows and walls, and so form part of the building fabric that will last as long as 'ordinary' parts of the building. Some designs use an electric fan to assist circulation of heated air, which is clearly an 'active' element, but an active solar space heating system (not considered here) is usually taken to include a seasonal heat store, a heat exchanger and a full heat distribution system, and so is quite different.

In direct gain systems, applicable to new construction only, the south facing windows are large compared with the others and thermal storage is provided by internal walls built from dense blockwork.

A conservatory on the south facing wall both provides a pleasant addition to living space and serves as a solar collector. Heat is stored in the floor and back wall of the conservatory and transferred to the rest of the house by open doors, windows or special ducts or by conduction through the walls.

Figure 8 compares assessments for direct gain and conservatory solar heating for two levels of overall external wall U-value, 0.6 and 0.3 Wm^{-2} °C respectively. For both of these levels the assessment for direct gain is distinctly positive. However, the higher capital cost of the conservatory, despite a credit allowed for extra living space, makes this approach marginally uneconomic.

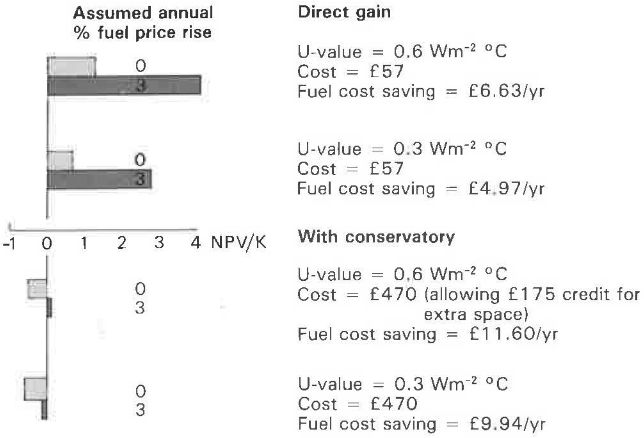

Figure 8 *NPV/K* values for passive solar heating

CONCLUSIONS

1 This paper has shown how the chosen economic assessment method can be used to appraise the installation of extra thermal insulation in new housing or of designing a house to maximise passive heating by solar energy.

2 The method was applied to a 'standard' semi-detached house and although 1982 material, labour and fuel costs were used the results are considered broadly applicable today.

3 Whereas edge insulation of a solid ground floor slab showed a good return on investment, widening the cavity in a masonry wall to increase the thickness of insulation gave a negative assessment. The value of increasing the insulation thickness on the exterior of a solid wall and within timber-framed walls was either neutral or marginally positive.

4 Inceasing the thickness of loft insulation from 100 mm up to 200 mm gave a positive assessment but with diminishing returns as more insulant was added.

5 The value of installing double instead of single glazing was borderline unless it was assumed that pipe runs could be shortened by not siting radiators under windows.

6 Designing the house to maximise direct gain solar heating was shown to be cost-effective but the erection of a conservatory to aid solar gain seemed marginally uneconomic even allowing for the value of the extra living space obtained.

7 These examples show how energy efficiency schemes in housing can be assessed for value for money but practitioners should evaluate their own particular projects using current cost figures and projections.

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