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CI/SfB 1976 8 (Y) (R3)

IP 1/87

January 1987

Investing in energy efficiency: 4 Domestic hot water systems

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This paper describes economic assessment of energy efficiency measures comprising the addition of an insulating jacket to a hot water storage system, installation of a shower for use instead of a bath, and installation of various heating system automatic controls. Sample calculations are given.

The paper is addressed to building services engineers, architects, builders, suppliers, housing authorities, home-owners and any others concerned with improving energy efficiency in buildings.

INTRODUCTION

Previous Information Papers in this short series have dealt with methods of assessing the economics of energy efficiency measures in housing[1], measures applied to existing housing[2] and measures applied to new housing[3]. All relied on data extracted from a detailed BRE Report[4] on the overall subject by John Pezzey.

This Information Paper goes on to describe some energy efficiency measures applied to domestic hot water systems and assesses the savings achieved in relation to their capital costs. All cost figures employed related to 1982. However, the examples illustrate the principles involved and the results of the assessments are still considered to be broadly correct.

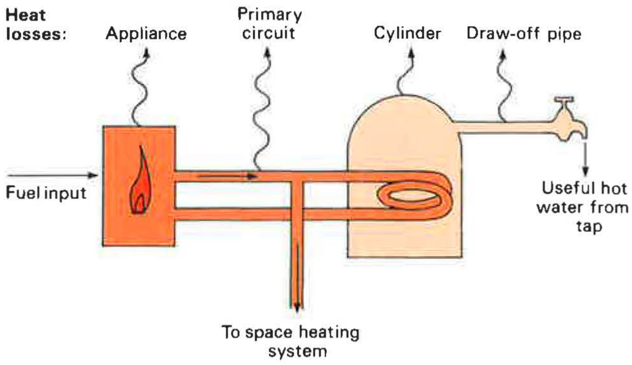
Water heating in homes accounts for nearly 20 per cent of UK domestic delivered energy, or some 5 per cent of energy delivered to all sectors. It therefore represents a potentially fruitful area for increased energy efficiency from both the national and householder's point of view. This paper therefore examines the economics of a few key methods for improving energy efficiency in conventional heating systems such as those illustrated in Figure 1.

The particular measures considered here are:

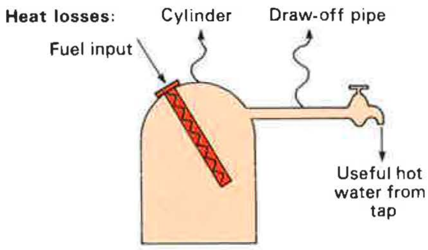
1 Storage cylinder insulation

2 Installation of a shower for use instead of a bath

3 Use of heating system automatic controls



System (a) Gas boiler



System (b) Electric immersion heater

Figure 1 Heat losses from conventional domestic hot water systems

THE ECONOMIC ASSESSMENT METHOD

Several methods of assessing the economic merits of capital investments were reviewed in *Information Paper* IP 17/86,. The one considered most appropriate for assessing energy efficiency projects in buildings related the Net Present Value (*NPV*) of the annual financial savings (*S*) to the capital cost (*K*) of the measure in question. The quotient *NPV/K* is therefore the assessment factor employed in this and the associated papers. If its value is positive this means that investment in the measure would pay and, if negative, it would lose. When comparing different measures, then the larger the value of *NPV/K* the better value for money it represents.

It is usually fairly easy to estimate the capital cost of a proposed energy saving measure. However, unless

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previous experience is available, prediction of the consequent energy savings may prove more difficult. To assist this process the Establishment has developed the BRE Domestic Energy Model or BREDEM. This is a mathematical procedure based upon practical experience. Given the necessary data upon the house, its heating system, heating requirements, local climate etc BREDEM allows energy requirements to be estimated for water heating, space heating, cooking, lighting etc. BREDEM and its applications are fully described in a BRE Report[5] and application software based on BREDEM is becoming available from various sources[6,7].

Given reliable estimates of the capital cost (K) and consequent annual financial saving (S), the method of calculating NPV/K is illustrated in the following example.

MEASURE 1: HOT WATER CYLINDER INSULATION

Heat losses from storage cylinders can be reduced in various ways: by insulating the hot water cylinder, by lowering the storage temperature, by reducing the amount of water stored or by insulating the primary heating circuit pipework.

In this example the economics of applying a segmented jacket to a 130 litre cylinder with a constant storage temperature of 60°C are assessed. The jacket cost £8.50 and its estimated life was 15 years.

For continuous operation of a gas heated system the saving in cylinder heat loss is estimated to be 12.4 GJ/yr. However, for intermittent operation the saving in appliance load is limited to 3.34 GJ/yr (see Pezzey page 96). Dividing this by the marginal system efficiency of 0.78 (see Pezzey page 195) gives a saving in delivered energy (ie fuel) requirement equal to 4.28 GJ/yr. At a 1982 gas tariff of £3.18/GJ (or 33.5p per therm) this yields an annual financial saving (S) of £13.61. The Net Present Value of savings in relation to capital cost, NPV/K can then be calculated as follows:

$$NPV/K = \frac{B-K}{K}$$

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

r = selected discount rate expressed as a decimal fraction

and N = estimated life of the measure in years

In this example it is taken that $r = 0.05$, $N = 15$ and $K = £8.50$; also that the rate of fuel price rise is zero in real terms.

Thus $$B = 13.61\left[\frac{1-(1.05)^{-15}}{0.05}\right]$$

The discount factor in the square bracket can conveniently be obtained from discount tables[8] and equals 10.38.

Therefore $$B = 13.61 \times 10.38 = 141.2$$

and $$NPV/K = \frac{141.2 - 8.50}{8.50} = 15.6$$

Pezzey adjusts the discount factor (ie puts 0.0194 instead of 0.05 for r, see page 232) to allow for an alternative assumption of a 3% real annual rise in fuel cost. With this assumption the value of NPV/K rises to 19.6

The economic assessments for hot water cylinder insulation are illustrated in Figure 2 for both gas and electric water heating. In both cases the improvement in energy efficiency shows a positive return on investment. As might be expected, that for the more expensive fuel, electricity, is the higher. Here, the 1982 unrestricted tariff of 5.1 p/kWh or 14.15 £/GJ has been used and the appliance efficiency of the electric immersion heater taken to be 100%.

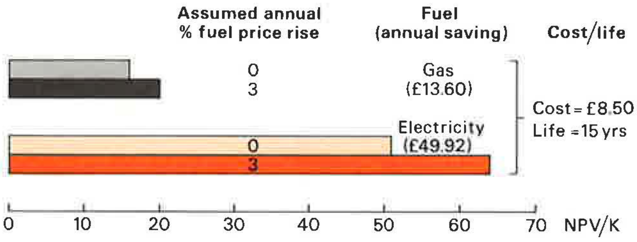

Figure 2 *NPV/K* values for hot water cylinder insulation

Where the cylinder is well insulated and of sufficient storage capacity it would be more economical to heat all or most of domestic water off-peak on Economy 7 tariff. Allowance for this could readily be made in the economic assessment calculation.

Supplementary heat recovery or solar heating

Pezzey also considers the economics of providing supplementary heating of domestic hot water by heat recovery from waste hot water or by solar heating.

If the waste water from the bath or domestic appliances is collected in an insulated catch tank then some of the heat content can be recovered by means of a heat exchanger or heat pump. Also, solar energy absorbed in a heat transfer fluid circulated through a roof-mounted solar collector is now sometimes employed to pre-heat domestic hot water via a heat exchanger.

However, using the best available estimates of the capital costs involved and the corresponding energy gains or savings achievable, in all instances the values of NPV/K proved negative. Hence, on the information available, none of these supplementary water heating methods would make rewarding investments.

MEASURE 2: USE OF A SHOWER INSTEAD OF A BATH

If a householder is prepared to accept a significant change to his or her personal life style and take showers instead of baths, experience shows there will be a distinct saving in both energy and water consumption. A new shower can take hot water from an existing heating system, use an instantaneous electric or gas heater and be installed either over the bath or in a separate cubicle.

In this particular example it is assumed that the shower is installed over the bath and is supplied through a mixing valve from a gas or electric heated hot water storage cylinder. It is also assumed that all baths are now taken as showers at the rate of 1.6 per person per week and that an average shower uses 23 litres of water in comparison with 90 litres for a bath.

The results of the assessment are illustrated in Figure 3 for both gas and electric heating and for two and four person households. The values of *NPV/K* (shown at five times the scale of Figure 1) are borderline negative for a 2 person/gas heated installation but are just positive if there is a four person household.

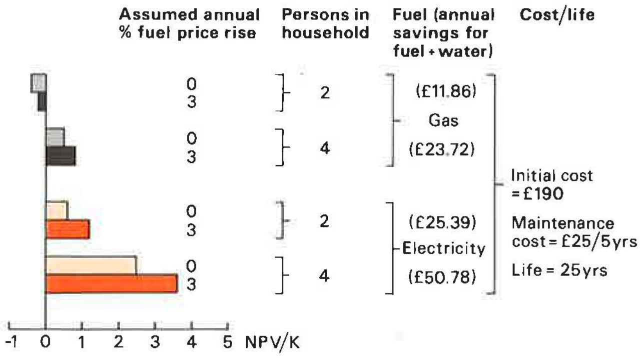

Figure 3 *NPV/K* values for installing a shower

On the other hand, if the water is heated by electricity then investment in a shower would pay for both the two and four person households.

MEASURE 3: USE OF DOMESTIC HEATING CONTROLS

Controls of varying complexity are available in dwellings to control the timing, distribution and temperature of space heating and domestic hot water. As well as providing energy savings such controls can improve comfort and convenience by automatically maintaining the required temperature throughout the house, preventing possible over and under-heating of rooms, and assist in maintaining an adequate supply of hot water at the desired temperature, preventing scalding.

Controls available for gas central heating systems include time controls which switch the system on or off according to a user programme, sensing elements which detect and signal changes in temperature, and valves (manual or triggered) to regulate the flow of water. In the present paper three controls are examined: the uses of a clock programmer to control space and water heating, of a room thermostat for space heating and of a cylinder thermostat (possibly combined with a motorised valve) for water heating.

(a) Clock programmer

A clock programmer automatically starts and stops operation of the domestic space heating and/or hot water heating systems. Whether this increases or reduces energy efficiency depends upon the settings made in comparison to previous manual operation.

If the programmer is used just as a convenience mechanism to replicate manual operation then there will obviously be no gain or loss in energy efficiency. On the other hand, if the householder uses it to increase the pre-heat period in intermittent heating then extra energy will be used and if to reduce the overall heating period then energy will be saved.

Since the pattern of use is under personal control it would not be meaningful to employ the previously described method of economic assessment as it stands. Instead, the calculation has been inverted to determine the reduction in heating time that would be needed for *NPV/K* to equal zero. Then, any further reduction in heating time would represent a positive benefit.

The full equation for calculating *NPV/K* is:

$$NPV/K = -1 + \frac{S}{K}\left[\frac{1-(1+r)^{-N}}{r}\right]$$

Thus for $NPV/K = 0$,

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

and $$S = \frac{rK}{1-(1+r)^{-N}}$$

In this instance, S is the value of annual financial saving whose present value over N years would equal the capital cost K. This is the equivalent annuity of K over N years at the discount rate r.

In the following examples the assumptions and estimates are:

- Gas central heating system in use
- Normal annual gas consumption = 80 GJ/yr
- Capital cost of programmer = £43.50
- Life = 15 yrs
- Financial saving S to make *NPV/K* equal zero = £4.19/yr

$\therefore$ At gas price = £3.18/GJ, the delivered gas saving required = 1.32 GJ/yr

$\therefore$ Required gas saving as a fraction of normal annual gas consumption = 1.6%

Theoretical studies of intermittent heating in a 'standard' well heated semi-detached house indicate that a reduction of 1 hour's heating per day results in a 2.5 – 5% saving in annual fuel consumption. Hence the above mentioned gas saving would require a reduced heating time of 20 – 40 minutes per day. This is the break-even reduction for the cost of the programmer installation. Any further reduction would show a net return on investment.

(b) Room thermostat

A room thermostat can save energy if the mean temperature in the room concerned is too high because of inadequate control. The economic assessment below also uses the inverted *NPV/K* calculation.

The following assumptions and estimates are made for the standard house heated by gas central heating in which the desired downstairs temperature is 19°C:

- Cost of thermostat installation £30
- Life = 15 yrs
- Annual money saving to make *NPV/K* equal zero = £2.89/yr

∴ Corresponding delivered gas saving = 0.91 GJ/yr
∴ Gas saving as a fraction of annual consumption of 80 GJ/yr = 1.14%
∴ Required reduction of downstairs temperature to obtain this saving = ca. 0.3°C
(see Pezzey, page 111)

Thus any reduction in room temperature in excess of 0.3°C would show a financial return on the cost of the thermostat installation.

(c) Cylinder thermostats
Automatic control of domestic hot water temperature raises energy efficiency and ensures ready availability of water at a desired safe temperature.

Partial control is achieved by arranging for the cylinder thermostat to switch the boiler on and off whenever space heating is not required. However, when both space and water heating are required simultaneously the hot water temperature will rise under control of the boiler thermostat causing higher heat losses and danger of scalding.

Full automatic control obviates these problems. In this case the cylinder thermostat operates a motorised valve which limits the flow of hot water through the primary circuit and so allows the cylinder water to remain at a lower temperature than it would otherwise be.

In this last example the economics of installing partial and full control are compared by the conventional method. It is assumed that a clock programmer is also in use and that the boiler thermostat settings are:

Summer: 60°C (22 weeks)
Winter: 80°C (30 weeks)

It is also assumed that space heating is used for half of the winter cycle.

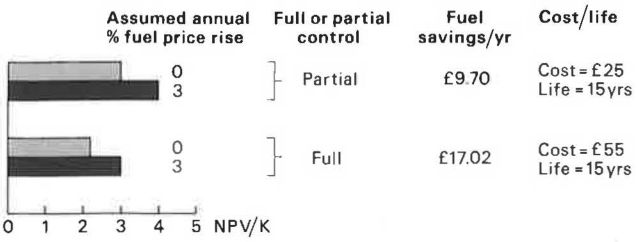

Figure 4 *NPV/K* values for installation of domestic hot water cylinder thermostats – gas boiler

The assessments are illustrated in Figure 4 which indicates that both full and partial control would represent good value for money as investments in better energy efficiency.

CONCLUSIONS

These conclusions are based on economic assessments which employ 1982 fuel and other costs. Whilst the results are still considered to be broadly correct, persons assessing their own energy efficiency projects should use the latest figures available.

1 Application of an insulating jacket around domestic hot water cylinders showed very positive economic benefits. However, employment of supplementary heat recovery from domestic waste hot water or of supplementary solar heating of the stored hot water did not seem to be good economic propositions.

2 Installation of a shower for use instead of baths gave only marginally negative to just positive economic assessments for gas heated hot water but clearly positive values where the water was heated by an electric immersion heater.

3 It was shown how the calculation method could be inverted to find what reductions in heating time or temperature would have to be achieved by installing a clock programmer or room thermostat in order to secure higher energy efficiency.

4 Installation of either partial or full automatic control of the storage cylinder water temperature when using a gas boiler gave positive economic assessments.

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Printed for HMSO by Stewkley Press Limited – 1/87 – 8895425