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The Better Insulated House Programme 1974–1982

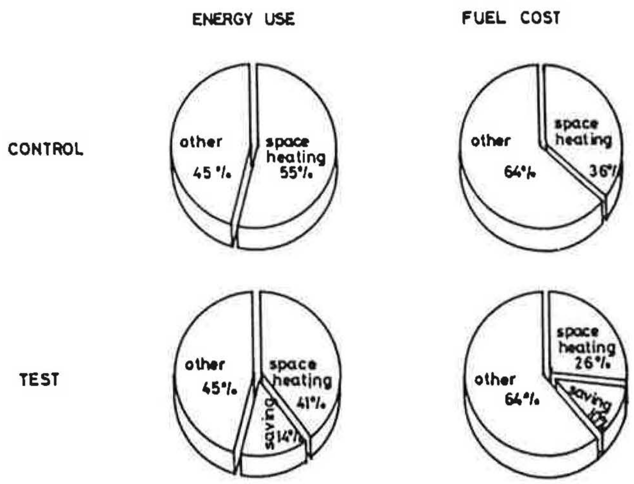
- The BIH programme of experimental projects was carried out by the DoE to test increased insulation standards in housing. About 350 dwellings were monitored on eight sites.
- Initial findings were sufficiently positive to allow the insulation standards under test to be incorporated into the **Building Regulations in 1981**.
- Energy savings averaged about **1,500kWh per annum for every kW reduction in Design Heat Loss.** This would have been one third higher except for an average rise in house temperatures of 1.5°C.
- The insulation measures cost an average of **£400 per dwelling and the payback period averaged eight years.**
- While these average results are robust, individual houses and sites showed variations in excess of 100 per cent, making extrapolation and generalisation somewhat difficult.
- Detailed analysis of these variations and discrepancies between calculated and achieved energy savings provided much insight into the complex issues which combine to produce a given benefit to cost ratio. For this to be maximised the design of new energy efficient dwellings must address not only insulation standards but also:
  air leakage by both expected and obscure routes;
  temperature control;
  heating system design;
  ventilation provision and control;
  heat distribution within the dwelling;
  energy uses other than heating;
  fuel costs;
  user understanding;
  on-site attainment of standards.
- The findings of BIH have been complemented, and extended, by subsequent projects and this knowledge and experience now needs to be widely disseminated to housing designers, managers, policy makers and users.

The pioneering **Better Insulated House Programme** (BIH) was implemented in the aftermath of the first oil crisis, and continued for about eight years. Its purpose was to measure the effectiveness of **increasing thermal insulation standards** in new and existing houses and to identify any associated technical problems.

Early findings provided evidence for the increase in thermal insulation standards in the building regulations revision of 1981, and for the loft insulation grant scheme. Fuller analysis not only confirmed the effectiveness of insulation, but also demonstrated the need for better control of ventilation, improvements to heating system design, and for a better understanding of heating system controls.

Furthermore, BIH helped to establish a tradition of field trials and related studies which has provided a continuous development of the understanding of energy consumption and conservation in houses.

Public sector occupied houses were monitored on eight UK sites, although comparative data are available from only seven. New and existing terraced houses and flats were included, varying in form and construction from site to site. Each sample site consisted of roughly twenty test (improved standards) and twenty control (usual standards) houses. Test dwellings usually had U values of 0.6 and 0.35W/^{2}°C for walls and roofs respectively, although higher standards, including double glazing, were occasionally tested.



Distribution of energy use and fuel cost

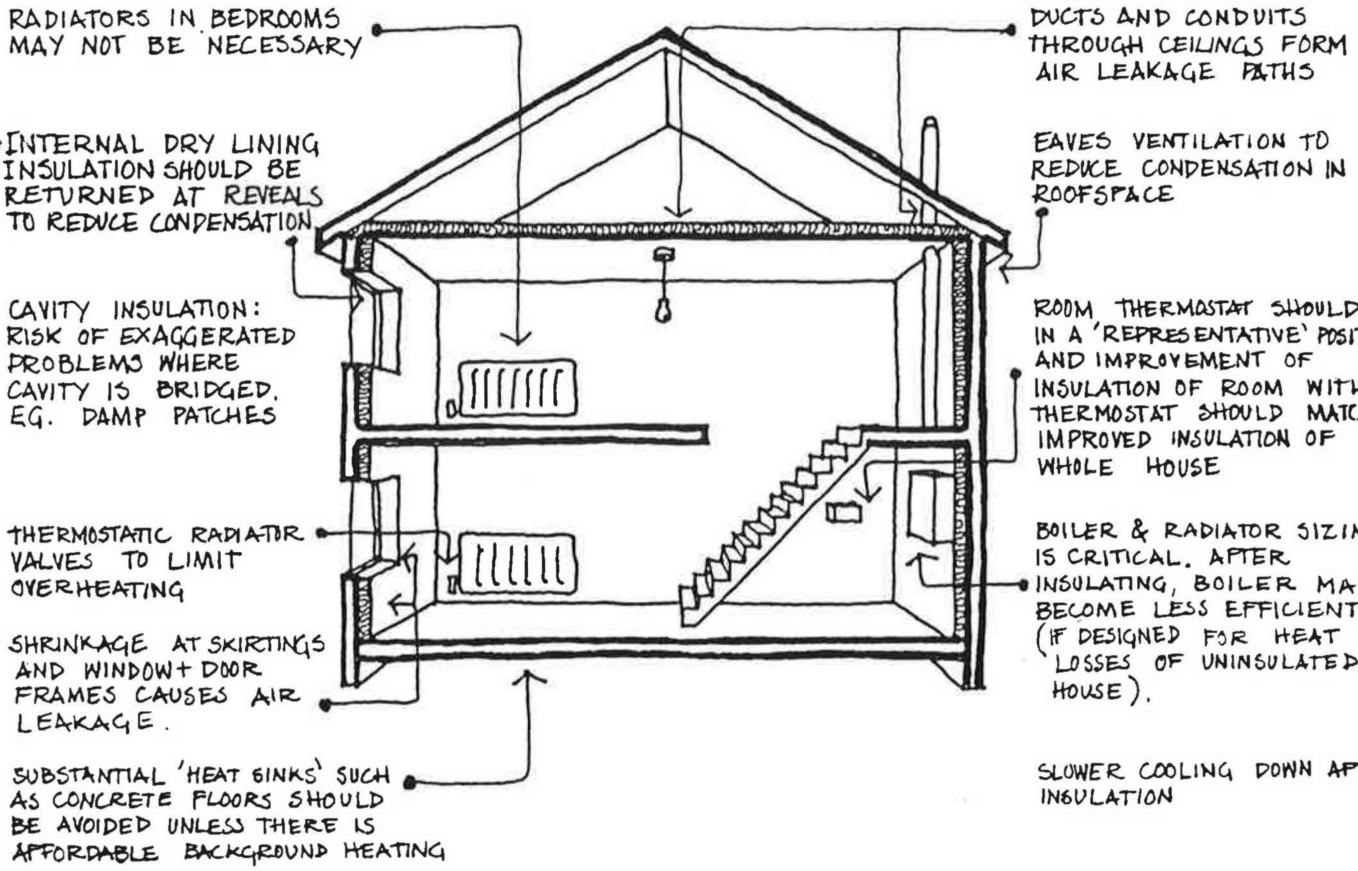
Individual projects were carried out independently but within a common overall strategy. Monitoring, house type, insulation type, climate and many other design features differed for each project, reflecting the diverse nature of UK housing but making comparisons difficult. Any overview of the whole programme must, therefore, concentrate on demonstrating the **broad implications** of its results in relation to improved insulation standards for energy savings. Fuller reference reports are available (1) and the results are now available as a computer database (2). This article uses supportive material from subsequent studies notably those carried out by the Building Research Establishment (3) and in the Department of Energy's Energy Efficiency Demonstration Project Scheme (4). It was prepared under contract to the Department of the Environment, Dept. HB7, but does not constitute Departmental policy.

Findings

The results broadly indicate that for every one kilowatt reduction in 'design heat loss' there is likely to be a potential fuel saving of about 2,000 kilowatt-hours pa. However, up to 25 per cent of this potential appears as increased temperatures and the realised saving is around **1,500 kilowatt-hours pa per kilowatt reduction.** This is similar to the 2,100kWh saving in delivered energy, per kW reduction in DHL (equivalent to 1,470kWh in use) reported by British Gas(5) and others (6).

Owing to the experimental nature of the projects, actual insulation costs are not necessarily representative of conventional projects. Allowing for this, the average extra capital cost was about **£400** per house, with a

TYPICAL FEEDBACK FROM THE BETTER INSULATED HOUSE PROGRAMME



simple payback period of around **eight years** (1984 prices). However, where expensive forms of insulation (eg double glazing and dry-lining) were used the simple payback period was significantly longer.

Potential versus Actual Energy Savings

The relationship between calculated (potential) and realised (actual) energy savings has been shown by BIH and subsequent studies to be more complex than first appeared. Differences are often viewed as a shortfall in the achieved savings but in fact they say more about the assumptions and limitations of calculations than about the vagaries of building performance.

A major cause of achieved savings being less than calculated is that part of the potential saving is converted into **temperature increases**. This was about 1.5°C (whole-house average) where test and control houses employed the same heating system. These increases were both **voluntary** (where occupants were consciously increasing comfort conditions) and **involuntary** (ie not controlled by the occupants). This latter could, in some cases, be related to poor thermostatic control but often was related to higher average temperatures in spite of unchanged demand or comfort temperatures. Whilst an increase of 1.5°C may be imperceptible in comfort terms it will have a large impact on energy use, adding perhaps 15 per cent to the dwelling's average heat requirement over the heating season. Since heat gains from inadequate sources may meet about half of this requirement, the increase in purchased fuel to provide the temperature rise could be as much as **30 per cent of space heating fuel.**

A related point is that well insulated houses **cool down more slowly** such that higher temperatures may be retained in rooms after heating. Increased temperatures may also affect the **heating season length**, which, theoretically, should be shorter for a well insulated house. However, at Darlington the end of the heating season in the test houses was extended because occupants had become acclimatised to higher temperatures. Here the heating season was shifted rather than shortened.

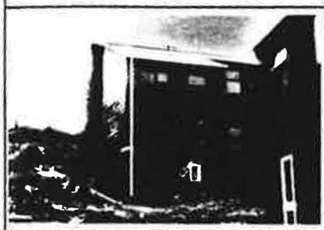
Discrepancies may arise due to differing practices in **ventilation and window opening**. For example, at Bo'ness most of the expected savings were forfeited by high ventilation rates in the test houses. This was related to the off-peak electric, block storage, warm air, central heating. This allows only coarse control of room temperatures and in the lower heat loss dwellings increased the incidence of overheating which, once noticed, could only be remedied by opening windows. Ventilation heat loss still remains the greatest uncertainty in any prediction of energy savings.

Further differences can be accounted for by less than perfect **control of heating systems.** In particular, the position of thermostats is critical. Thermostats only respond to the temperature of the room in which they are located,

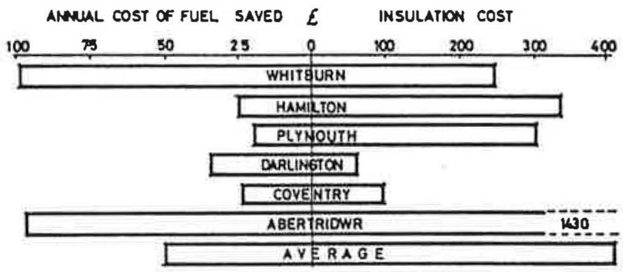
TYPICAL LEVELS OF INSULATION W/m²°C	TEST	CONTROL
ROOF	0.35	0.6
WALLS	0.6	1.0

- SAVINGS IN DELIVERED FUEL: 1500 KW hrs pa. FOR EVERY 1 kW REDUCTION IN D.H.L.
- LIKELY INCREASE IN AVERAGE TEMPERATURE: 1.5°C (EQUIVALENT TO £30 WHICH COULD BE SAVED) SIMPLE PAYBACK PERIOD = 8 YEARS

The BIH File . . .

	WHITBURN 56 dwellings, 2 and 3 bed terraces, 1961 Control:- rendered brick cavity brick, 25mm roof insulation Test:- UF foam cavity fill, 125mm roof insulation Heating:- Off-peak electric underfloor or block storage (ground floor only) - electric fire on-peak top-op
	HAMILTON 40 flats, 4 to a 2 storey block, 1934-1975 refurb. Control:- part rendered brick cavity brick, 25mm roof insulation Test:- UF foam cavity fill, 125mm roof insulation Heating:- (new, for test and control) 90% gas fired LPHW radiators + living room gas fire Hall thermostat
	PLYMOUTH 38 dwellings, 3 bed, 2 storeys, short terraces, 1960-65 Control:- rendered block cavity block, 25mm roof insulation Test:- Mineral fibre cavity fill, 100mm roof insulation Heating:- 70% by gas fired warm air to downstairs only - Living room thermostat Remainder by on-peak electric fires
	DARLINGTON 56 dwellings, 2 similar blocks of sheltered 1 and 2 person flats 1968 and 1972 Control:- 2 storey brick block cavities, 100 mm roof insulation Test:- UF foam cavity fill, 100mm roof insulation, living room double glazing Heating:- Electric ceiling heating with electric fires
	COVENTRY 40 dwellings, 3 bed 2 storey short terraces, 1975 Control:- brick clad timber frame (brick-block gables) with 25mm quilt in walls, 50mm in roof Test:- 75mm quilt in walls, 100mm in roof, UF foam in gables, floor edge insulation (10 with double glazing throughout) Heating:- Gas fired LPHW radiators, TRVs but no time clock
	WASHINGTON 33 dwellings, 5 persons, 2 storey, short terraces, 1975 Test:- (No control) Timber frame with 100mm glass fibre in walls, 100mm in roofs Vertical edge insulation to floors. Double glazing throughout Heating:- Electric panel radiators with individual thermostats + central control (10 dwellings had mechanical ventilation system)
	ABERTRIDWR 39 dwellings, 4 persons, 2 storey split level terrace, 1976-1980 Control:- brick cavity insulating block, 50mm glass fibre in roofs Test:- 20mm urethane foam dry lining board, 100mm quilt in roof, perimeter insulation to floors Heating:- Gas fired LPHW radiator system. In test houses no bedroom radiators (landing only)
	BO'NESS 42 dwellings, 3 to 5 persons, 2 storey, det, semi det + terrace, 1977 Control:- No fines concrete - rendered, with 22mm dry lining insulation, suspended timber floors, 50mm roof insulation Test:- 34mm dry lining insulation, 50mm floor insulation, 125mm roof insulation Heating:- Off peak electric, block storage warm air, ground floor only. Much supplementary heating (elect., LPG, paraffin)

and a heat demand from that room does not necessarily imply a demand from other rooms, which may overheat. Conversely under-heating of other rooms may occur when there is no heat demand in the room with the thermostat. Individual room thermostats (eg thermostatic radiator valves) will avoid these effects to some extent. In Coventry test houses, heat gains in the bedroom, from ground floor rooms, meant that radiators were unnecessary in all but the coldest weather. Bedroom radiators were omitted in test houses at Abertridwr with reasonable success and the lower temperatures substantially increased energy savings.
This delicate balance of **heat transfer and distribution** within a house is disturbed by additional insulation since it will not equally affect all rooms. Thus double glazing a living room containing the thermostat for the whole heating system will lead to underheating of other uninsulated rooms, whilst bedroom ceiling insulation will result in overheating of the bedrooms if room heaters do not have thermostats.
In general, heat distribution and movement within a building was revealed to be a significant but poorly understood aspect of the thermal behaviour. Subsequent research has shown convection to be a principal transfer mechanism but that house layout and heating system type are also important factors.
It was also evident from some projects that occupants did not **understand** their heating control systems. In Abertridwr, for example, thermostats were thought to alter the rate, rather than level, of heating. This resulted in higher temperatures rather than the desired faster response. Taken with the generally poor ergonomics of control hardware and the inadequate, if any, instructions given to users, it is perhaps not surprising that effectively controlled heating systems are rare.
The widespread demand for intermittent and partial heating in UK houses strengthens the BIH evidence for a fuller consideration of design aspects such as the thermal response of building fabric and heating systems together with their **control systems.**
Heating system efficiences probably accounted for a further difference between calculated and actual savings. In existing houses the increased insulation standards rendered the boilers oversized with an assumed subsequent loss in seasonal efficiency.
The BIH project was primarily concerned with insulation measures aimed at reducing the demand for delivered energy but it is now recognised that in well insulated houses this separation of fabric and services should be avoided.
The effects described above all significantly influence energy conservation, and may be cumulative. It is surprising that there is even a reasonable correlation between predicted and actual savings, although many effects may be self-cancelling. For example, underestimates in heat loss by ventilation may be disguised by underestimates in incidental heat gains.
These points should not be regarded as theoretical niceties—they are of immediate concern, to the designer since his **specifications** are, in effect, **prediction.** the BIH project confirmed that the designer's task is complicated in the case of insulation since there are several interactions which can enhance or militate against its effectiveness.



Benefits and Costs

Technical Implications

An important objective was to identify technical problems associated with improved insulation standards, especially those concerned with detail design and workmanship.
Generally the insulation presented few direct difficulties although infra-red photography identified cold bridges, in particular around openings in the walls and where wall insulation was discontinuous. Cavity wall insulation will tend to exaggerate any existing problems due to bridging (eg mortar droppings) causing damp internally. On site practices were noted to be, occasionally, incompatible with the installation requirements of insulation and whilst in many respects this would not produce visible serious defects it could lead to loss of insulation efficiency (for example small amounts of missing insulation or draughtstripping). The evidence suggested that a greater degree of site **supervision** and **training** is required.
Air infiltration through the structure is one of the more significant unquantified heat losses. Work elsewhere has revealed that holes in ceilings, around pipes, flues etc. are major air leakage routes together with gaps around window and door frames and where floor joists penetrate the wall's inner leaf. Such air leakage paths not associated with draught stripping doors will generally account for more than **half** the total dwelling **air leakage**.
There are implications for **heating system design.** In particular, BIH revealed the necessity to match the sysem (both boiler and radiators) to the reduced heat demand of a house and to ensure that heat can be distributed when and where required. This is possible in new housing but is unlikely to be so for improvements to existing houses, unless both fabric and services are being refurbished together. The eivdence of BIH and other projects is that energy conservation should address both aspects simultaneously. In any event, the cost and space advantages of reduced heat emitters need to be balanced by considerations of thermal response.
In addition to these issues several others have been adequately researched in subsequent projects or remain unresolved. For example, **heat distribution** is now confirmed as primarily resulting from convective transfers and consequently the control of air movement via staircases is important; however even this is less true in dwellings with radiant heating. Conversely the influence of heat flows via **party walls** and **ground floors** is still subject to investigation. Similarly, the importance of incidental heat gains from people, electrical appliances, solar gain etc. is now properly recognised. In well insulated

dwellings where these gains can exceed 50 per cent of the space heating demand there are powerful implications for the design of heating systems.
Overall, well insulated dwellings are **more sensitive** to both heat losses and gains, and in particular to unusual variations in these.

Conclusions

The Better Insulated House programme has demonstrated that, when allowance is made for temperature rises, predicted energy savings due to improved standards of insulation, on average, have been realised. These are of the order of 1,500 kilowatt-hours per annum for every kilowatt reduction in calculated Design Heat Loss.
Greater savings would result from:
(a) an improved understanding of the technical issues involved in construction related to **insulation amounts, thermal response** and **heat movement**.
(b) better **matching** of heating systems to fabric performance including improved strategies and equipment for their **control**. (ie as at Abertridwr).
(c) improved **occupant understanding** of control mechanisms for heating and ventilating.
Although the reduction in space heating fuel use was 25 per cent this would have been around 35 per cent if internal temperatures increases had been avoided. However, since some of this rise is unavoidable then the lower figure is more realistic. In contrast the average annual cost savings was only about **10 per cent** of the annual total fuel cost (ie for cooking, hot water, light and appliances. This highlights the importance of other energy uses and fuel types to any energy conservation exercise.
Direct technical implications were minor but related issues such as heating system design were revealed to be of great importance.
The knowledge gained from monitoring the thermal performance of houses and their heating systems is of use in establishing guidelines for both the design of new, and the improvement of existing, houses. Work is continuing to extend this knowledge into practice.
The numerous factors that account for differences between calculated and actual savings show the necessity for continued research in order to improve the assumptions made in **modelling** thermal performance and to increase the energy savings that can be attained in practice. Further research is in hand, and the findings of design studies, field trials, laboratory investigation, and computer modelling are beginning to feed into the industry.
An Archive of measured data from BIH and other similar research will shortly be available, to inform both design and research. A family of computer programmes has also been developed by BRE to assist in the design and analysis of energy-related factors of domestic build-up: this suite of programmes is called BREDEM, and will shortly be available.

Recommendations

- The main recommendation has been implemented through the Building Regulations—namely that walls and roofs should be designed with U values of 0.6 and 0.35W/m^2°C. More **recent projects** suggest 0.4 and 0.25 W/m^2°C are practical and economically justifiable and that in some cases clear double glazing (U= 3.0W/m^2°C) or even low emissivity double glazing (U= 1.6 to 1.9W/m^2°C) can be justified.
- In highly insulated dwellings, **ventilation** provision and control, becomes critical. Air leakages routes other than opening components should be sealed. Recent work has concluded that trickle ventilators are an effective means of providing limited amounts of fresh air for comfort and condensation control.
- Energy saving measures should be applied **'evenly'**. High performance in one place (eg double glazing) does not necessarily compensate for low performance elsewhere (eg cold bridges).
- BIH and its successors have confirmed that target savings can be achieved by the considered application of **well-proven technology**. Dissappointing cost/benefit ratios have generally been associated with complex and/or expensive measures. The message is **'keep it simple'**.
- Where the design heat loss is reduced to four kilowatts or less, the specification of the heating system becomes critical if unwanted temperatures increases are to be avoided (ie energy savings maximised). This is not simply smaller systems and more thermostats but may justify a radical re-appraisal of conventional attitudes to **central heating**. If typical room heat losses are only a few hundred watts, much of which will be provided by incidental heat gains, then responsive room heating with room thermostats is required. The industry has been moving to meet this demand.
- The design of energy efficient dwellings should include considerations of energy uses such as hot water as well as the impact of differentials in **fuel costs**. Nevertheless, unlike most other aspects of energy use the insulation and infiltration standard of the fabric is not easily amenable to future changes that will be cost-effective in energy terms. Consequently the initial design should err towards the maximum justifiable standards rather than the minimum or even optimum.
- It is now a cliché, but **people** not **buildings** use energy. Yet how often is this properly taken into account in the design of, and provision for, user controls? Even if this is adequately covered it is still essential to provide good **instructions**.
- Finally, designers should keep in touch with the results of ongoing research pertaining to energy efficient dwellings. Such results indicate what standards can be achieved, and frequently how to ensure effective and trouble-free construction.

References

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