Association for the
Conservation of Energy

EEASOX

Energy Efficiency Advice
Services for Oxfordshire

BUILDING IN IGNORANCE

Demolishing complacency: improving the energy performance of 21st century homes

October 2001

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I also wish to express heartfelt thanks to experts in Scandinavia, North America and central Europe who, over the years, have tirelessly supplied information and feedback on their countries' experience. To make rapid progress with energy efficiency, reduced CO_2 emissions and lower environmental impacts, a determination and willingness by the UK to learn lessons from these regions is absolutely vital.

David Olivier, Leominster

October 2001.

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BACKGROUND TO THIS WORK

EEASOX - Energy Efficiency Advice Services for Oxfordshire

The Trustees of the charity EEASOX commissioned this report from David Olivier in order to make a constructive contribution to the debate about UK building standards. This report is the first in a series.

Between 1993-9, the Trustees set up and managed the Oxfordshire Energy Efficiency Advice Centre, one of the first such centres set up with funding from the Energy Saving Trust. Its aim was to improve the energy efficiency of homes and small businesses in Oxfordshire. During the course of its six-year life, the Centre advised many thousands of households, and raised the profile of energy efficiency in the county. It worked with six local authorities in Oxfordshire. The Centre was closed in 1999.

The Trustees hope that this report will stimulate a debate about the energy performance elements of new housing standards - important in their own right - but also because of the longevity of the housing stock.

The Trustees

Brenda Boardman was for eight years the Powergen Energy Efficiency Fellow at Oxford University. She now manages Lower Carbon Futures at the University's Environmental Change Institute. She has conducted many studies into the efficient use of energy by households; the best known of these are related to the energy efficiency of electrical appliances and fuel poverty.

Liz Reason is a director of ILEX Energy Consulting, specialising in the energy markets. With her husband, in 1991, she commissioned a low energy home, sited in a conservation area - a feature which required it to be of very conventional appearance. Their experience demonstrated that, given proper supervision of both the architect and the builders, it is perfectly possible to construct a well-insulated draught-free building, with a low energy demand, at average Housing Corporation yardstick costs.

Eileen Pirie (formerly Polgreen) was Chairman of the West Midlands Gas Consumers' Council from 1984 until 1992. Her recent experience of renovating a Victorian house taught her in no uncertain terms that neither architects nor builders had sufficient knowledge, let alone practical expertise to improve the energy efficiency of an existing building nor did they see it as being their responsibility.

Richard Smith is an environmental lawyer with Manches, in Oxford.

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ACE – Association for the Conservation of Energy

The Association for the Conservation of Energy (ACE) is a lobby organization which also carries out policy research on energy conservation. The Association recently piloted the Home Energy Conservation Act through Parliament, and continues to maintain a high level of parliamentary activity. ACE was formed in 1981, with a remit to encourage a positive national awareness of the need for and the benefits of using energy conservation in buildings, to help establish a sensible and consistent national energy efficiency policy and programme, and to increase investment in all appropriate energy saving measures.

Membership of ACE is limited to twenty-four UK based companies which have substantial interest in energy conservation equipment and services. Current members include controls manufacturers, energy service companies, and manufacturers and distributors of insulation materials. ACE produces a free newsletter called The Fifth Fuel, copies of which are available on request, as is its publication list.

ACE spends much time researching energy efficiency policy ideas, assessing how they would work in the UK, and then presenting the arguments for energy conservation at Westminster to MPs and Parliamentary Select committees, to the gas and electricity industries, to the European Commission, and to the public, through TV, radio and the press. We also liaise with other organizations who are working in the field of energy conservation and climate change from professional institutes to environmental and social NGOs, trade unions, local authorities and other housing providers.

ACE has successfully kept the issue of energy conservation in the forefront of the national media, and maintains close working relations with politicians, bureaucrats and other key decision-makers. It has been acknowledged to be one of the most vocal lobby groups in the UK, and will continue to exert pressure at home and in the European Parliament to ensure that energy conservation - the fifth fuel - is not overlooked.

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EXECUTIVE SUMMARY

The environmental imperative, and legally binding Kyoto agreement, requires that the UK reduces its carbon dioxide emissions significantly both immediately and in the longer term. In addition, British consumers are entitled to homes with low running costs which do not unnecessarily contribute to global warming.

If we are to move towards more sustainable housing, the Government has to provide the right background conditions and signals and the private sector has to implement the strategy successfully. Neither of these objectives are being met at the moment.

The longevity of the housing stock, particularly in Britain, means that today's building standards affect the country's carbon emissions for well over 100 years. Therefore, the continuing low standard of new British homes is jeopardising our ability to reach climate change targets in 2010 and beyond.

- The Building Regulations should promote higher standards for energy conservation and should force the elimination of poor building practice. The new revision of the Approved Document Part L [2001] represents a missed opportunity to improve the quality of new housing in England and Wales.

- Previous Part L revisions in 1982, 1990, 1995 – cumulatively were supposed to reduce energy consumption for space heating by 60%. No evidence exists to show that these benefits were achieved in practice and the net effect may have been only a third of this target. The present aim of a further reduction of 23% may well be barely 10% in practice.

- This Report demonstrates that our current Building Regulations commit us to dwellings with unnecessarily high carbon dioxide emissions, for the life of the building - decades, if not centuries. British householders will also be subject to higher energy bills than could have been the case.

- Experience of energy conserving projects has existed in the UK since 1980 showing that good building standards can at least halve energy consumption. Yet the new Part L still allows for standards in one part of the building fabric to be 'traded off' against standards in other areas, resulting in worse energy performance - for instance, less insulation when the windows are small - resulting in higher heating and lighting bills, and the encouragement of speed-driven building practices at the expense of energy saving, eg the use of plasterboard instead of wet plaster, which is more airtight.

- The Report argues that official UK figures for heat loss values (U-values) in construction are optimistic- theoretical savings are not achieved in practice. Further, new homes often have excessive heat loss through uncontrolled air leakage, a problem that is not being regulated.

- As a result of the current inappropriate Part L, the UK construction industry – design professionals, developers and component manufacturers - is delivering an

energy-inefficient, poor-quality end product of which consumers – the householder – is largely unaware.

- Examples of good housing practice abroad demonstrate the potential for the UK housing stock:
  - energy consumption and CO_2 emissions could be reduced by 80% in new homes;
  - authorities in Germany, Sweden, Switzerland and Canada expect to deliver mass housing which consumes no fossil fuel at no extra building cost, from 2020;
  - new homes in Sweden, Norway, Denmark, Switzerland, Germany and northern USA are already at a higher standard of energy efficiency than the new standard proposed for 2002 in England and Wales;
  - new British houses retain the heat less effectively than Scandinavian houses built before the Second World War;
  - Swedish high standards have added only 1% to building costs; homes are now consistently so well built that testing for air leakage is no longer necessary;
  - The Canadian R-2000 scheme is a Government-funded training programme to encourage builders to construct to a higher standard than the Building Regulations - there are no such proposals to train the British building workforce.

RECOMMENDATIONS

The aim should be for the energy efficiency standard of new British homes, within 10 years, to be among the world leaders and, shortly after, for new homes to produce only 10% of the carbon emissions of today's new buildings. To support this aim, the Report's recommendations are to:

- establish, through systematic measurements, the real energy performance of new buildings completed to 1995 Building Regulations in order to confirm the baseline for the next round of revisions. The scale of the deficit will then be known;

- undertake pilot schemes that give builders incentives to guarantee maximum heating bills. The results of the pilots should inform the next revisions to the Building Regulations;

- set higher, but simpler standards and reduce the scope for 'trading-off';

- adopt, within four years, U-value calculation methods which fully correspond to physical reality. These procedures are set out in existing European standards;

- provide more detailed support and guidance to the industry on how to deliver these higher standards, in practice;

- introduce random testing of the construction quality of new dwellings immediately;

- invest in a programme of training, education, research, development and demonstration for the industry as a whole;

- have a planning system that encourages developments built for or by private individuals. This self-build market is receptive to high standards of energy efficiency and is responsible for over 25% of new housing, by floor area;

- achieve UK involvement in international projects on good practice and actively disseminate successful new techniques and technologies.

The 2001 revisions to Part L do not provide the real and practicable leap in standards that is required and represent a real missed opportunity. It is time for all new British homes to be among the most energy efficient in the world and to demonstrate that we have learnt the lessons from the best developments in Britain and in other countries.

We no longer need to be building in ignorance.

1. INTRODUCTION

1.1 In its pre-1997 election policy document, "In Trust for Tomorrow", the Labour Party made a commitment to improve the thermal insulation standards of roofs, floors, walls and windows. It was with high hopes that the process of reviewing the Building Regulations was started soon after the government came into power. Most encouraging was the implementation of an all-inclusive consultative process, which invited not only the construction industry, but also other acknowledged experts, to contribute to the development of new standards.

1.2 In June 2001, by coincidence in the same week as the DETR - now DTLR - published its first Consultation Paper, the Royal Commission on Environmental Pollution (RCEP) published its 22nd report 'Energy - the Changing Climate'. The RCEP's key message was that there is an imperative on the UK to take immediate and radical action to reduce its CO_2 emissions by 60% by the year 2050, in order to contribute to an effective global programme to combat climate change.

1.3 The RCEP stated that recent CO_2 reductions in the UK relative to emissions in 1990 have been a fortuitous by-product of other trends in the UK economy and that there has been no fundamental improvement in the energy efficiency of UK buildings. In its discussion of the progress made under successive revisions to the Building Regulations, the RCEP comments upon the consultations made by government with the building industry and the industry's reluctance to adopt "innovative energy conservation requirements".[1]

"The main objection raised by UK housebuilders to a substantial raising of energy efficiency requirements is that it would require them to adopt alternative construction techniques......These arguments are tantamount to saying that United Kingdom householders wish to be permanently disadvantaged in comparison to those in other North-western European countries".[2]

1.4 This report almost entirely covers improvements to the design of the thermal envelope of new homes - not existing buildings, conversions or extensions. In the very long term it is both critically important and technically feasible to secure large improvements in the energy efficiency of new buildings. Exemplars of this kind are a logical prelude to achieving the same energy efficiency levels, wherever possible, on existing buildings.

1.5 This report is structured into three main sections. The first section sets out the problems referred to above, namely:

- 20 wasted years - the forgetting curve
- unknown savings - a triumph of hope over experience
- design and construction quality: theory, practice and verification

1 “Energy: The Changing Climate” – RCEP 22nd Report, paragraph 6.92, p.106

2 Op.cit: paragraphs 6.96 and 6.97, pp106-7

1.6 The second section proposes a new approach to Building Regulations which not only starts from higher initial standards, but which includes parallel regulations governing the quality of finished buildings.

1.7 The final section sets out recommendations for taking the UK's housing stock from its low standards now to homes fit for the 21st century.

1.8 References in this document to 'the Paper' are to the DTLR's June 2000 Consultation Paper. References to ‘the Approved Document’ are to the March 2001 Interim Draft Approved Document. References to 'the report' are to this report.

2. BUILDING STANDARDS IN THE SLOW LANE

20 wasted years: the forgetting curve

2.1 To examine the feasibility of constructing energy-efficient masonry walls - of which 92% of new homes in England and Wales have recently been built, very close to masonry's market share elsewhere in Europe - we should look back a generation to 1976. In that year, the Department of Environment (DoE) - the DTLR's predecessor in the last Labour government - sponsored the design, construction and monitoring of two energy-efficient housing estates in Milton Keynes. With help from the Open University Energy Research Group, property developers John Mowlem and Co. duly built 170 rented terraced and semi-detached houses on the Pennyland estate. Half of the houses had 100 mm cavities, fully-filled with insulation. At nearby Great Linford, S&S Developers of Woburn Sands built eight detached houses for sale, all with plastered brick/block walls and fully-filled 100mm cavities.

2.2 The Open University monitored the energy use of both estates in detail over three years and published reports on Linford and Pennyland, examining the building and running costs of the houses and the extent to which the building methods might be replicated elsewhere. The final reports in 1984 said that the cost of building this way was 1.5% more than conventional buildings and that the energy costs were just half of those of normal houses. On top of the fuel saving, the houses were more comfortable too.

2.3 25 years ago, Salford City Council near Manchester was also working on energy efficiency, not only as a solution to world energy shortages but as a response to the problem of cold homes and acute social deprivation. In 1978, it built two experimental masonry-walled, concrete-floored houses at Strawberry Hill, with 173 mm fully-filled cavities and other energy efficiency measures. By 1980, it had built six more. The package was by then proven, costed and ready to be applied to production homes. Compared to normal houses, the Salford houses cost 4% more to build. The measured energy saving was 65%. On top of this large fuel saving, there was a big increase in internal temperature; tenants could afford to heat their whole house to 21°C for a measured cost of only £1 per week. This achievement was unprecedented for the time.

2.4 In fact, this achievement is still unusual today. Little housing built by housing associations or volume developers since 1980 - even so-called 'low-energy' housing - actually matches the measured performance of the three projects at Salford, Linford and Pennyland. Approximately 20% of the entire English and Welsh housing stock is made up of dwellings which have been built since 1977. Their energy consumption and CO_2 emissions would be half what it is now if Linford/Pennyland standards had been promptly applied to new housing from 1980 and Salford standards to new housing from 1985.

2.5 The failure to learn from successful projects of 20 years ago has had regrettable consequences. In 1995, a UK energy expert visited Salford to interview tenants for a report on energy-efficient housing. He found that subsequent houses built for rent on the estate had not applied the energy-efficient package of measures used in the 1978-80 Strawberry Hill houses. These later houses had serious condensation and the tenants said that the gas heating systems were unable to keep their homes warm enough in winter.

Unknown savings: a triumph of hope over experience?

2.6 The present proposed building standards seem set to perpetuate the process of the last 20 years. The last three changes to the Building Regulations all appear to have followed the same course - promises were made on each occasion about making radical and substantive changes to building energy use. But then, not only have the changes been less radical than initially claimed, but also little monitoring of the actual effect of the new standards has been undertaken. Each round of development of the new Building Regulations has apparently involved the following sequence of events:

- government consults and proposes;
- volume housebuilders oppose;
- government retreats;
- industry agrees to much lesser changes.

2.7 Large improvements in so-called 'headline' values for energy efficiency standards have been compromised by government agreeing to allow the building industry to use 'flexibility' to make trade-offs between different elements of building fabric energy efficiency standards, and tradeoffs between the fabric and the heating plant. This approach was set out in the June 2000 Paper and is largely retained in the March 2001 Approved Document.

2.8 Promised space heating energy savings are perceived to have been reduced by several factors. These factors include: inaccurate U-value calculations, whose percentage error actually rises as insulation levels improve; poor thermal envelope design and poor workmanship. The influence of these factors leads to growing discrepancies between calculated and real heat losses, and between calculated and measured fuel bills.

2.9 The three versions of the Building Regulations which were implemented in 1982, 1990 and 1995 promised 60% space heating energy savings in a house built in 1996, compared to one built in 1981. There is little or no evidence that this actually happened, and much circumstantial and anecdotal evidence that it did not happen.

2.10 The 1990 Building Regulations were predicted to save 20% of the energy consumed by previous dwellings. A survey in 1991 by Liverpool John Moores University of 64,000 dwellings[3], using information supplied by housebuilders on

[3] Johnson, J A “Building Regulations Research Project”. School of Architecture, John Moores University, Liverpool (1993).

the techniques they used to construct new houses, calculated that the 1990 Regulations would actually save only 6%. This was because various trade-offs were being used to avoid the need to meet the new 'headline' U-values.

2.11 Whether the 1990 Regulations did reduce CO_2 emissions by 6% is unknown. This is because, other than the study of plans by John Moores University, apparently no-one has measured the actual 'as-built' energy consumption of homes which were built to any of these three standards - the 1982, 1990 or 1995 Regulations.

2.12 The 1995 Regulations were supposed to save 30%, compared to the 1990 Regulations. It appears that such a saving would only be possible if houses built to the 1990 Regulations actually used as much energy as older dwellings whose standards they were intended to improve upon. Again, there are no systematic measurements or other research material to allow a proper comparison to be made.

2.13 According to the Paper, a house built in accordance with the 2003 Regulations would produce 23% less CO_2 than a house built to current standards. This saving has already been eaten away; the Approved Document stipulates that the required wall U-value in 2002 will fall to 0.35, not to 0.30 W/m^2K. Given the past history of practice failing to match theory, there is no reason to suppose that this revision to the Building Regulations will be any different. Indeed, many factors in the current proposal could eat further away at this and reduce the real saving to less than 10%.

2.14 The main factor is complexity. The proposed elemental U-values[4] differ between fuels. This means that the target U-values must be adjusted for different heating systems by the application of a complex equation[5].

2.15 There are two sets of headline U-values, with gas, oil and LPG boilers in one group and coal and electric resistance heating in a second group. The target U-value for the latter is 1.15 times lower. If very efficient gas and, to a lesser extent, LPG boilers are used, the target U-value may be increased by up to 0.08 W/m^2K. Thus a condensing boiler with extremely good controls, operating at 96% seasonal efficiency instead of 78%, would permit the target U-value to be raised by a factor of 1.23.

2.16 Yet, the fabric of the building will remain standing for a much longer time than the heating plant will function. There are no guarantees that a heating system of equal efficiency will be fitted when the boiler, heat emitters and controls that met the original legal requirements are replaced.

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[4] ‘U-value’ means the rate of heat lost per square metre of the element for every degree (Celsius or Kelvin) difference in temperature between the inside and the outside, expressed as W/m^2K. The lower the number, the more the element provides resistance to heat loss. So, the lower the U-value of an element of a building envelope, the more energy-efficient it is.

[5] $Ut = [0.35 - 0.19*(Ar/At) - 0.10*(Agf/At) + 0.413*(Af/At)]$, where Ar = roof area; Agf = ground floor area; Af = total floor area and At = total thermal envelope area.

2.17 The 'headline' U-values now published by the DTLR are 0.25 W/m^2K in ground floors, 0.35 W/m^2K in walls and 0.20 W/m^2K in pitched roofs with insulation in the plane of the rafters[6]. Yet, by following a target U-value approach, and making other changes, it appears that it would be permitted in some circumstances to use U-values as high as 0.7 W/m^2K in the ground floor and walls and as high as 0.35 W/m^2K in the roof. This 'flexibility'[7] is totally unacceptable.

2.18 There are other 'trade-offs' too, similar to those which allowed housebuilders to reduce the potency of the 1990 Regulations. For instance, the Paper suggests that dwellings could continue to use poorer levels of thermal insulation in opaque areas if their windows are reduced in size to less than 25% of floor area. This proposal has been carried through into the Approved Document. The underlying argument for this trade-off is that it leaves the dwelling's total heat loss unchanged.

2.19 Following this path, and reducing the window area to 12% of floor area, the wall and floor U-values of new dwellings could legally continue to be 0.45 W/m^2K if not higher. Table 1 shows that in a terraced house this essentially allows housebuilders to ignore the 'headline' insulation levels and go on using elemental U-values in line with current practice.

2.20 Although the heat losses of the well-glazed dwelling and the dwelling with small windows appear identical (Table 1), we expect that the measured energy consumption of the two dwellings would be markedly different. This is because of the failure of the house with smaller windows to take advantage of solar gain. The smaller windows encouraged by this trade-off can actually increase a dwelling's energy use, because the smaller windows:

- admit less daylight, increasing a house's electricity consumption for lighting;
- admit fewer passive solar gains. Many new homes could benefit from using well-orientated glazing equal to over 25% of floor area, rather than less than 25%. The enlarged south-facing windows could provide a net heat gain from the sun over much of the heating season, so that the dwelling uses less energy overall.
- The Approved Document cites BS 8206 Pt 2 and goes on to suggest that glazing equal to less than 17% of floor area "might be inadequate" for

6 The Building Regulations 2000 - Interim Draft Approved Document - DTLR, March 2001, p21. This also states on p 24 that the whole-wall U-value could not normally go as high as 0.7 W/m2K, nor could the whole-roof U-value go as high as 0.35 W/m2K. Unfortunately, by making substantial allowances elsewhere in the building, it seems that both could happen - and in the same building, too.

7 Proposals for amending the Building Regulations - Consultation Document - DTLR, June 2000 p42 para.

daylighting purposes[8]. However, it does not actually propose any legal sanctions against this practice. We have therefore explored the implications of the glazing area being reduced to around 12% of floor area, given that some new dwellings appear to have windows which are this small. It is clear from the second entry in Table 1 that, by making allowances elsewhere in the building, it would be legal to continue with far higher fabric U-values than those "headlined" in the DTLR's proposals.

2.21 The problem with permitting these fabric U-values, of 0.45 W/m^2K and even greater, is that they just perpetuate a pattern of high building energy use far into the future. If cavity walls, concrete floor slabs and, to an extent, roofs are not well-insulated now, they never will be.

2.22 This 'trade-off' is an example of how to write the Regulations so that housebuilders who oppose a real increase in standards can meet the letter of the law, yet almost completely evade its spirit. This loophole should be blocked.

8 The Building Regulations 2000 – Interim Draft Approved Document – DTLR, March 2001, p 21 para 1.16.

Table 1 - Implication of Trade-offs, Proposed 2002 Building Regulations

100 m^2 Semi-Detached House

100 m^2 Semi-Det House	AREA	U-VALUE	HEAT LOSS W/K
ELEMENTAL METHOD, GLAZING AT 25% OF FLOOR AREA			
Roof	50	0.2	10
Walls	77	0.35	27
Windows, etc	25	2.0	50
Floor	50	0.25	13
TOTAL			**99**
GLAZING REDUCED TO 12% OF FLOOR AREA			
Roof	50	.3	15
Walls	90	0.5	45
Windows, etc	12	2.0	24
Floor	50	0.3	15
TOTAL			**99**

NOTES:

1. Assumes, for illustration, that the window U-value is kept unchanged and that roof/wall/floor U-values are increased to 0.35/0.60/0.40 respectively. This roof U-value is the maximum permitted in the Approved Document.
2. As the text notes, higher boiler efficiency would permit some of these U-values to be increased further. If the permitted increase in heat loss was taken up in the form of a higher wall U-value, the whole-wall U-value could approach 0.70 W/m^{2}K.
3. The same could happen if the floor U-value was retained at 0.25 W/m^{2}K.

Design and construction quality: theory, practice & verification

Theory - A move to real U-Values

2.23 For almost 20 years, there have been reports that calculated U-values in the UK are over-optimistic. Concern in the early 1980s centred on cavity walls with very lightweight block inner leafs. In the early 1990s, the realisation dawned that the heat loss of most common UK wall and roof constructions is much more than we generally assume. This realisation arises from what has been learnt from practice in the USA and other countries in Europe which apply more accurate heat loss calculations and robust monitoring processes to their finished buildings. Applied to UK buildings, these practices would radically change our assumptions about the real heat loss from UK buildings (Table 2).

Table 2 - Actual U-Values

	U-VALUE W/m^{2}K		EXCESS HEAT LOSS
ELEMENT	Official Value	Estimated Actual	Relative Factor
1. Tiled timber pitched roof with insulation on attic floor, 50 x 100 mm joists on 450 mm c.	0.25	0.36	1.44
2. Cavity wall with plaster, 100 mm lightweight block inner leaf, 40 mm dense mineral fibre slab, 25 mm residual cavity, brick outer leaf	0.45	0.62	1.38
3. Concrete ground slab, 25 mm expanded polystyrene	0.45	0.61	1.36
4. 140 mm timber-frame wall with mineral fibre batts	0.24	0.35	1.46
5. Metal-clad wood-framed rooflight, sputtered low-emissivity 12 mm argon-filled double glazing	2.0	3.8	1.90

NOTES:

1. Engineers and regulatory bodies in Denmark in cases 1-3 and the USA in cases 4-5 have estimated the real U-values. Material conductivities, surface coefficients, etc are identical in all cases. These discrepancies relate to particular cases. The industry-wide discrepancy, averaged over all forms of UK construction, may be more or less than this but no more detailed estimate is known.
2. Some wall and roof constructions experience elevated heat loss due to air movement within the insulation layer or through large gaps in the insulation layer. This table deals only with conduction losses through walls and roofs which are perfectly-built.

2.24 There are many reasons why real U-values may exceed those which were calculated by the designer:

- UK calculations still exclude many types of thermal bridge where conductive materials such as timber, metal or concrete interrupt the thermal insulation layer. This accounts for most of the discrepancies in Table 3;
- they neglect the adverse effects of wind on heat loss, especially in the outer portions of the thermal insulation layer;
- they make little correction for the effects of moisture on thermal conductivity;

2.25 However, these are not newly-discovered problems and have largely been taken into account in the writing of standards in the EN[9] ISO series. New CEN[10] standards are intended to make more allowance for the above points, but this seems to be uncoordinated with UK activity. Consequently, guidance to builders on minimum insulation thicknesses could change several times in the space of four years. This process should be integrated with current UK proposals.

2.26 Designers in most European countries are required to use the standard method described in EN ISO 6946 to calculate the U-value, including homogeneous thermal bridges. They must then use the approach set out in EN ISO 14683 to allow for linear thermal bridges in the wall, roof or floor. Following this process in full can lead to realistic estimates of heat loss from buildings.

2.27 Unfortunately, the Paper and Approved Document imply that we should put off applying the complete set of standards yet again and should only allow for the minor thermal bridges dealt with by EN ISO 6946. This further delay seems unnecessary. Three years have passed since the DTLR's 1998 Consultative Workshops on which new standards should apply, ample to require the industry to move substantially to real U-values for walls, floors and roofs in 2002.

2.28 For over 30 years, most designers have understood the 'wall U-value' to be a thermal transmittance figure which may be used to calculate the total heat loss through the walls of a building. The oversimplified way in which U-values are presented in the Paper[11] and the Approved Document[12] will seriously mislead designers and builders as to the relative merits of different construction systems, and will lead them to underestimate the changes needed to reach an overall wall U-value of 0.35 W/m^{2}K.

2.29 The timber-frame wall U-value on p.121 of the Paper is particularly misleading, as it refers to an idealised wall section. This excludes large areas of solid timber, such as:

- the edges of window and door openings;

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9 EN: European Norm

10 CEN: Comité Européen de Normalisation

11 on pp. 118-footnotes 124 and p. 126

12 on p. 82.

- blocking;
- sometimes extra timber in lintels;
- extra corner studs;
- doubled-up studs at sides of panels in factory-built frames;
- floor joists and
- top and bottom plates.

2.30 As a figure for the whole building, it could be 30-40% over-optimistic. Recent UK studies suggest, indeed, that the real proportion of solid wood in timber-frame walls of factory-built panels - the most common type here - may be in the region of 32%[13]. This is approximately twice the timber fraction which the industry is assuming.

2.31 The industry probably perceives that to meet requirements for U- values of less than 0.35/0.2 W/m^{2}K in walls/roof, net of all thermal bridging, is more demanding. Hence it has resisted the change. As the wall constructions in the Appendix illustrate, we believe that to meet a U-value of 0.35 W/m^{2}K would need 65-100mm insulation in most cavity masonry walls and 140mm in many timber-frame walls. To move to a U-value of 0.25 W/m^{2}K in around 2005, as this report proposes, would generally need 80-150mm in masonry walls and 200mm or more in timber walls.

Practice

2.32 Whatever the theory propounded in the Building Regulations, what happens when buildings are put together on site is more important. Three examples demonstrate this point.

2.33 The 1995 Building Regulations specify a maximum U-value of 0.7 W/m^{2}K at any point in all construction systems. This rule prohibits the way that the steel-frame buildings in Figure 4, Figure 5 and Figure 6 are being constructed, with the insulation coming to a complete halt at the steel columns, beams and diagonal bracing. In one building, metal struts protrude through the insulation.

Figure 1 - Bridging of thermal envelope by metal struts.

13 Bell, M. Overend, P. and Lowe, R. J. (2001), An empirical investigation of timber proportions in insulated timber framed walls in domestic construction. CeBE working paper No. 20, Centre for the Built Environment, Leeds Metropolitan University, Leeds, UK.

Figure 2 - Bridging of insulation by steel column

Figure 3 - Thermal bridging at reveal

2.34 Mild steel has a thermal conductivity 1500 to 2500 times greater than common thermal insulation materials. Constructing walls with steel protruding through the insulation is therefore a recipe for large discrepancies between nominal and actual U-values, possibly two-fold.

2.35 Building control officials have the chance to spot the problem when plans are submitted. However, from these sorts of examples, which were seen and photographed in summers 1999 and 2000 in English cities and towns as diverse as Exeter, Hereford, Leeds, London, Warrington and York, they have clearly not enforced the rule.

2.36 Steel-frame is used to build many new schools, hospitals and offices. The DTLR appears to want to move towards using it on low-rise houses and flats too, albeit possibly in light steel stud framing rather than beam-and-column frames. It is of vital importance that such a move is made with full knowledge of the performance and properties of the proposed alternative system.

2.37 The Paper[14] and Approved Document[15] show a cavity masonry wall with a plasterboard-lined inner leaf. This seemingly minor move, from masonry walls lined with wet plaster to walls lined with plasterboard, began around 1980 and has since spread throughout England and Wales to a point where it is used on 60% of new homes. This is often with a disastrous impact on energy performance.

2.38 The Building Codes in some northern countries prohibit this generic construction practice. It creates a void behind the plasterboard, allowing air circulation and

14 Vol. 2, p. 119.

15 p. 80.

resulting loss of heat[16]. The author has never heard of a single dwelling built this way on mainland Europe, where masonry construction is totally normal but where all walls are plastered. As the inclusion of this drawing in the Paper and now the Approved Document shows, the UK has a lamentable tendency to persist with sub-standard thermal envelope design and to describe as 'good' practice what other countries simply regard as 'standard practice'.

2.39 A major change in philosophy is overdue. UK Regulations should not only promote higher standards but should also force poor building practice to be phased out. The government should not adopt the lowest common denominator approach of permitting everything which has its commercial advocates, regardless of its real energy performance.

2.40 The government/industry Robust Details Panel seems to include many housebuilder representatives and manufacturers but almost no experts on building energy performance or thermal envelope design. A broader membership might enable real improvements to be made.

Verification

2.41 Despite all the evidence of poor design and construction quality, the UK has hesitated to test new buildings to verify that they meet minimum insulation and draughtproofing standards. The Paper proposes to test large buildings above 1,000 m^2 to see that they have been properly-constructed - a very welcome move - but the recommendation of this report is that random samples of all new buildings should be tested.

2.42 Just as there are accounts[17] of corporate headquarters which are so shoddily-built that the central heating system has to be topped up in some areas by portable electric heaters, some new houses are built like this. Private householders need even more consumer protection against sub-standard products than the owners or tenants of large non-domestic buildings.

2.43 When Oscar Faber held a series of workshops for the DTLR in 1998, the vast majority of participants, responding to an initial questionnaire on what they believed to be the issues to be addressed, felt that maximum air leakage should be regulated in both residential and non-residential buildings. This body of professional opinion should surely be respected over the views of a narrow interest group represented largely by speculative housebuilders. Random tests on dwellings could well contribute more to CO_2 savings than testing all our non-domestic buildings put together.

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16 The UK has resisted adopting BS EN ISO 6946:1997 "Building Components and Building Elements: Thermal resistance and thermal transmission calculation methodology" as it recommends including an upward correction of $0.04W/m^2K$to calculated U-values if this form of construction is used.

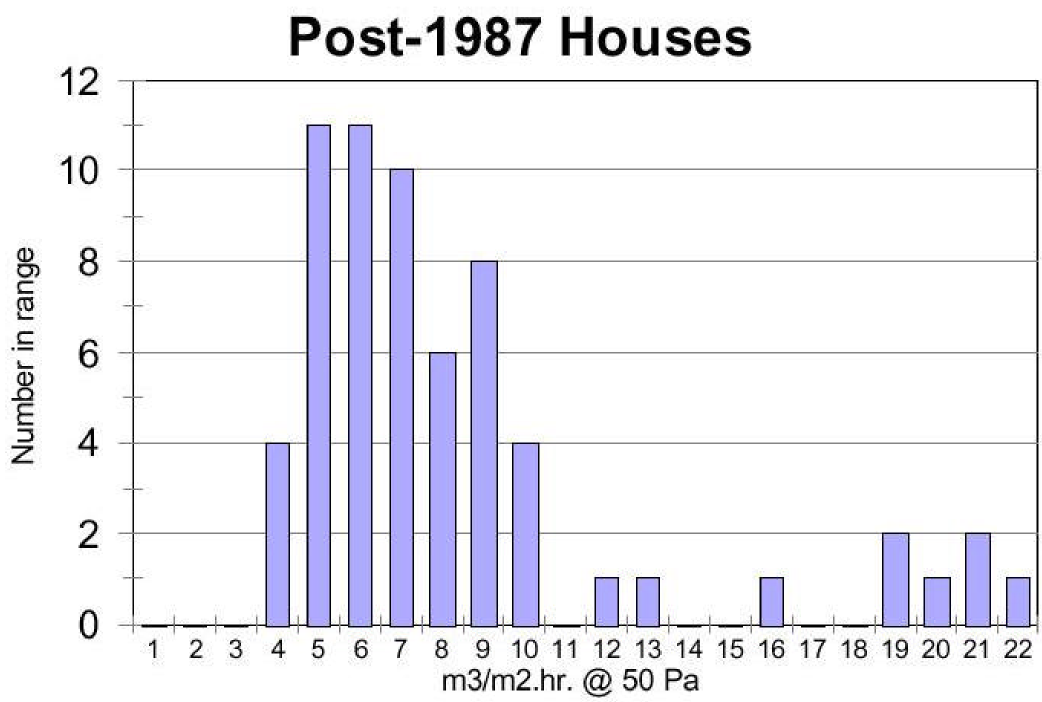
17 Standeven, Mark et al, "PROBE 3 : Cheltenham & Gloucester Head Office", Building Services, pp. 31-34 (February 1996).

2.44 The Paper suggests that following written guidance would exempt a builder from a requirement to submit to random tests of air leakage. This shows a gross misunderstanding of the current situation. Written guidance on air leakage was published in the 1995 Building Regulations, and was predicted to reduce maximum leakage to 10 air changes/hour at 50 Pascals. No evidence has ever been produced that it had any effect.

2.45 This exemplifies a grave weakness of the UK's approach to building energy efficiency - a tendency to take a hands-off approach and to publish written guidance but not follow it up with resources for research, education, training or ultimately, enforcement action. The results tend to be disappointing, because even if the technical guidance is flawless - which often it is not - it may remain on the printed page and not reach those who design or construct the building.

2.46 As the distribution curve in Figure 4 shows, some new UK dwellings are extraordinarily leaky compared to the average air permeability of 8 m^3/m^2hr at 50 Pascals. However, most designers and builders have not seen an air leakage test and believe that current practice is fully satisfactory. A dedicated resolution towards airtightness testing must be included in any review of Approved Document 'L' if assumed savings are to be realised.

Figure 4 - Distribution of air leakage data for houses built after 1987[18]



2.47 It seems that the mass housebuilding industry has been objecting to testing on the grounds that we do not know how to do properly-randomised tests. It is curious,

[18] BRE database, published in 1999 at DTLR request.

then, that Sweden and Norway[19] both established random testing regimes for new dwellings over 20 years ago!

2.48 This objection is spurious. It is tantamount to a demand for the status quo to continue, with a minority of housebuilders ignoring demands for environmental improvements and continuing to build homes with high air leakage, high energy consumption and elevated CO_2 emissions.

2.49 The Paper suggests[20] that it might be possible to relax the level of control over design and construction of prefabricated housing in comparison with on-site construction. This is wholly unwarranted. Tests show that some of the prefabricated housing systems in vogue clearly under-perform site-built ones and need more supervision and control, especially to yield low air leakage.

2.50 Plastered masonry and in situ concrete-floored construction, as used extensively across mainland Europe and Asia, does default to being airtight. As such, one would think that techniques which are inherently fairly energy-efficient would be promoted in Building Regulations guidance. In fact, we have actually seen a focus on changing construction materials and systems and possibly moving away from masonry.

2.51 Across the North Sea, Denmark, north Germany, the Netherlands and Belgium have built millions of walls with relatively wide, insulated cavities. Research and testing in Denmark[21, 22, 23, 24] showed that fully-filled cavities with appropriate materials were as weather-resistant as partly-filled ones. Consequently, a standard Danish wall since the 1970s has had a plastered concrete block or concrete inner leaf, a cavity fully-filled with mineral fibre batts and a brick outer leaf.

2.52 At BRECSU workshops in 1998, the findings of a DTLR-sponsored report[25] on highly-insulated masonry walls were reported. Independently of Danish

19 Vik, Bjorn, Norwegian Building Research Institute, personal communication, 1984.

20 on p. 181.

21 Kristensen, Poul, Danish Building Research Institute, Horsholm, Denmark, personal communication, 1992.

22 Korsgaard, Vagn and Mogens R Byberg, "Driving Rain Tests with Cavity-Filled Brick Walls", Proc. CIB Symposium on Moisture Problems in Buildings, Helsinki, 1965.

23 Korsgaard, Vagn and Thomas L Madsen, "A Method of Determining Water Vapour Transmission Through Outer Walls", Proc. CIB Symposium on Moisture Problems in Buildings, Helsinki, 1965

24 Korsgaard, Vagn and Thomas L Madsen, "The Thermal Insulation of Some Typical Danish Outer Walls Exposed to the Natural Climate" JIHVE, pp. 106-116-, July 1967.

25 Warm, Peter and John Willoughby, "INNOVATIVE ENERGY AND ENVIRONMENTAL TECHNOLOGIES IN UK HOUSING: HIGHLY-INSULATED MASONRY WALLS". Contract F10/9/422/6693. March 1998. Unpublished DTLR Report, whose significant findings on costs and buildability were presented at BRECSU Energy Efficiency Workshops in 1998-99.

experience, the authors had found that walls with wide, fully-filled cavities were a cheaper and better way forward to the future than empty or partly-filled cavities. Such findings must quickly be reviewed and issued to an industry which, clearly, utterly lacks authoritative guidance on improved standards in masonry construction.

Wrong costings - how to improve them:

2.53 The Consultation Paper says that the new standards will add 1.5-3% to housing costs. It makes proposals for higher standards on that basis. However, there is a long history of basing such calculations on the short-term, not the long-term costs, of proposed changes to the Building Regulations. The DTLR's costing either understates or omits three factors which lead to lower costs for higher energy efficiency standards, and which all favour our adopting better standards now. For example:

- mass production of new materials, products or components;
- reduced labour costs after builders have learned to use new techniques and have integrated them into the work process;
- new approaches to design which may completely circumvent the problem.

2.54 In addition, the UK Treasury uses a real discount rate of 6%/year to set the Building Regulations and decide what is, or is not, cost-effective. This markedly exceeds the return which is offered on other safe investments, like government bonds, building society accounts and many pension plans, and it exceeds the typical rate charged on mortgages over the last 30 years. By using 6%/year the government is effectively demanding that improvements in the Building Regulations - including cavity wall insulation and the insulation of concrete ground floors, measures which may last centuries - yield twice as high a return as other safe uses of the capital would currently offer.

2.55 To date, the government is not taking proper account of the costs of environmental externalities either, at a time when it is expressing increasing concern about the impact of climate change on the UK and world environments.

2.56 This report suggests that the government reviews its methodology for assessing the benefits of revisions to building standards by:

- reducing the interest rate used in these calculations to a lower figure which will take account of the very long-lived nature of energy efficiency investments. We consider that a real rate of 2-3% per year would be reasonable, an exact figure to be arrived at by further debate. On public policy grounds, many states of the USA, including California and Washington, already use a "social discount rate" of 3%/year for the purpose of setting their minimum building standards;
- using in calculations the notional figure for externalities which are derived from the levels at which the government has already set the Climate Change Levy to be charged to commercial and industrial customers. Even though the government does not wish to apply this tax to the domestic sector, it would be

intellectually consistent to include the implied environmental costs when undertaking cost-benefit analyses for new dwellings.

2.57 We believe that an approach which includes realistic interest rates and allowance for mature markets would lead to minimum standards in the same range as other developed countries. These are set out, for six completely different regions, in Table 3.

UK situation - the knowledge gap:

2.58 Government policy towards the construction industry since 1980 has depended upon publicising good practice and relying on industry-led initiatives to lead to rapid take-up of new ideas and reductions in energy use and CO_2 emissions.

2.59 This does not appear to have happened. There is a clear lack of information and there is no detailed, holistic understanding on how to implement better house-building practice. The result has been that an energy performance better than expected under current Building Regulations remains exceedingly rare.

A bold move forward - a decade of transformation:

2.60 The government can be bolder and show stronger leadership. Sweden provides a good example of how determined political will can produce a major step forward. In 1975, just after the first oil crisis, the Swedish government proposed new building standards which would make triple glazing mandatory and would require real U-values of 0.2/0.3/0.2 W/m^2K in roofs/walls/floors. The maximum air leakage was to be set at 3 air changes per hour at 50 Pascals in detached houses and 1 air change per hour at 50 Pa in flats. This is five times stricter than the air leakage standard which DTLR hesitates to introduce in the UK, 25 years later.

2.61 The Swedish government demonstrated that these new standards would require minimum insulation levels of 160 mm in timber-frame walls and 100-120 mm - depending on insulant - in concrete and masonry walls. 60% of timber-frame dwellings then being constructed were so leaky that they would have to be re-designed to meet the new air leakage standard.

2.62 The construction industry opposed the 'extreme' proposals and warned of 'prohibitive' rises in housing costs. Nevertheless, the measures became law in January 1978. In the intervening three years, 1975-78, Sweden erected hundreds of experimental dwellings to show what worked, what didn't and which building techniques should be phased out. Two years later, Norway followed a similar path.

2.63 By 1990, Sweden had implemented not one but two radical changes in its Building Code and the walls of new timber houses had 200-300 mm of insulation instead of 100 mm in 1975. Subsequent analysis suggested that the real rise in housebuilding costs was probably around 1%. Measures which industry had resisted became second nature. Swedish buildings are no longer routinely tested for air leakage; within 15 years of the first step forward, nearly everybody had learned how to build tight. It was no longer controversial, it was standard.

2.64 Where government shows real leadership, much more can be achieved. It is not just the standards that the British government must follow, but the commitment to rapid improvement and the confidence that industry will adapt and remain profitable in the face of improvements which give a better deal to consumers and help to protect the environment.

3. A NEW BEGINNING

The technological gap: international best practice

3.1 In general, the UK's disappointing experience has not been paralleled elsewhere in the developed world. There are many examples of highly-insulated houses that use solar energy for heat, in locations as diverse as Zurich, Salzburg, Freiburg, Trondheim, Göteborg, Toronto, Portland, Davis and Sacramento. These provide a vivid comparison with what the UK is promoting as acceptable standards. While we promote schemes with energy savings of 25%, occasionally 50%, versus the existing housing stock, these regions are pushing forward with changes in housing design and construction that can reduce energy consumption and CO_2 emissions by over 90%.

3.2 Five building projects are described in the following case studies, but they are not unique. They are but a few out of tens of thousands which have explored the way forward towards sustainability.

House G , Hjortekaer, Denmark (1985)

This was a sequel to six earlier houses supported by the Danish government in 1978. It applied advanced energy efficiency technology, The measured energy consumption is 35% that of a normal Danish house. It uses 25% as much as a new UK house in 2000.

The measures were chosen for minimum overcost and maximum effectiveness. The walls were built not of bricks or blocks, which are common in Denmark, but of lightweight concrete storey-height elements, craned into place. The walls were then externally-insulated and clad with timber.

Analysis showed that if the technology in the house was mass-produced and widely-used, the extra energy saving would give a 7% per year return, measured relative to a house which already meets the 1985 Danish Building Regulations. Yet this base case standard is actually ahead of the proposed 2002 Building Regulations for England and Wales.

Photo: Jorgen Norgaard.

The Boyne River Ecology Centre

The Boyne River Ecology Centre is not connected to mains energy services but it provides the comforts of a wealthy industrial society, using just the renewable energy resources of a rural site. Built into a wooded south-facing slope above the River Boyne, on the Niagara river escarpment, it is powered by a wind turbine on a nearby hilltop, a pair of water turbines on the nearby river and solar cells on its turf roof. It is used at weekends as an outdoor educational centre by schoolchildren from throughout the Toronto School Board.

As a response to the cold climate, the building is 16-sided, giving a very compact form and minimising the ratio of surface area to volume. The mean January temperature in this region, 120 km north-west of Toronto, is about -8 degrees C but nevertheless, the 500 m2 centre is heated mostly by passive solar gains. There is a backup wood-burning fireplace in the centre of the space and this is lit during extreme "cold waves".

For a cold climate building to be heated substantially by solar energy, it is necessary to use high levels of insulation and draughtproofing. An innovative post-and-beam timber structure is used, with the thermal envelope - both the vapour barrier and the thermal insulation - "hung" on the outside of the structure, just inside the cladding. The windows make up 25% of the floor area and they are state of the art double low-emissivity argon-filled warm edge triple glazing, in insulated fiberglass frames. Essentially, the windows help to heat the building.

The appliances, lights and ventilation system are all highly efficient in their use of electricity. Thus, for instance, the ventilation system uses just 18 watts, and as an average over occupied hours, the lights in the whole building take just 200 watts. The building was formally opened at summer solstice, 1993.

Photo: David Olivier

Healthy Houses, Toronto, Ontario, Canada (1995-96)

These 140 m^2 four-storey semi-detached houses are on an inner-city site without mains services connection. It proved cheaper not to connect them to existing water, gas, drainage or electricity services, instead providing autonomous service provision.

They have twice Ontario's minimum levels of insulation - five times the level stipulated by our 1995 Building Regulations. They follow the "build tight, ventilate right" maxim, with mechanical ventilation/heat recovery.

The *in situ* concrete structure has a thermal capacity 20 times that of a normal Canadian timber-frame house. It can absorb the passive solar gains through large south-facing windows on a winter day without a risk of overheating. The suspended ground, 1st and 2nd floors hold 45 tonnes of concrete and low-grade solar heat is captured and run through an array of underfloor pipes.

The result of the low heat loss and high thermal capacity is that most space heating comes from passive solar. The rooms generally stay warm just on solar gains through the south windows. 75% of the heat consumption over a year comes from passive or active solar.

The houses have very electricity-efficient appliances, including an experimental refrigerator with an external condenser. The electricity comes from solar cells; the rest comes from a wood-fired CHP system in the basement. The CHP plant provides backup space and water heat at times when solar-heated water itself is insufficient.

The PV panels completely shade the south windows from spring to autumn. The result of low solar gains, low internal heat gains from the appliances and high thermal capacity is that the houses stay comfortable throughout Toronto's hot, humid summers and do not need an active cooling system.

Materials with reduced or no emissions were used, to reduce air pollution at source. Many recycled materials were used, including recycled glass in the floor tiles, slag from steel-making in the mineral fibre insulation, waste wood fibres in the basement wall formwork and cellulose in the fibre-cement cladding.

The overcost was 20%. This premium is expected to fall sharply as the relevant measures become more widely-used in Canada. The project was supported by Canada Mortgage and Housing Corporation.

Photo: Bob Lowe

Zero-Energy and Ultra Low-Energy Houses, Wädenswil, Switzerland (1990)

The houses were designed as a completely integrated system in 1989, based on what had worked best in previous Swiss projects since 1974. The development employs advanced energy efficiency features and each house has a small solar thermal energy system. It was built in 1990 with support from Zurich Canton Energy Department and Wädenswil Town Council.

The six "ultra-low energy" houses have solar water heating for summer use and a small LPG-fired CHP system for winter space and water heating. It produces surplus electricity for the national grid in mid-winter, when demand is at a maximum.

The other four houses are zero-energy. They use solar energy for all their heating needs and each house has a small seasonal heat store; the amount of backup is insignificant. Besides being very heat-efficient, with externally-insulated masonry walls, the houses used top of the range electricity-efficient appliances. These reduced electricity use to half the Swiss norm.

Stephen Reyburn, a London architect who visited Wadenswil commented that by Swiss standards, his 1986 house would not even qualify as "ultra-low energy", yet it seems to be in the UK's top ten for measured energy performance. Although his own house was and remains advanced by UK standards, he believed that this project was a massive further step forward.

Wädenswil led to the construction of many other similar houses in Zurich canton and elsewhere, in masonry and timber-frame alike. From 1998 onwards, Switzerland participated in the EU-funded CEPHEUS Project, a trial of even more advanced standards in several hundred houses, with particular stress on glazing and ventilation systems.

Photo: Ruedi Kriesi

Passive Houses, Kranichstein, Germany (1991)

These are the end result of an exemplary process of research, design, construction and monitoring. The project formally began in 1988, when Hessen state government funded the background research and later supported 50% of the design and construction overcosts.

Kranichstein is near to the small city of Darmstadt, Hessen. The site is at a latitude of 50^oN - the same as Cornwall - though being in a mid-continent location, it has colder winters and warmer, sunnier summers.

The four houses are so well-insulated, so draughtproofed and the heat exchanger in the mechanical ventilation system recovers so much heat from the exhaust air, that the recorded peak heat demand of a $156m^2$ terraced house is 800 W when the outside temperature falls below -10^oC for a sustained period. The entire row of four homes is heated by one condensing, ultra-efficient gas condensing boiler and a mini-district heating system runs through the cellars. This approach saved on capital and running costs. With this peak heat demand one could heat a housing estate of 25 dwellings from one domestic boiler!

The monitoring work, with several hundred sensors per house, validated the earlier predictions. The calculated energy consumption was 31 kWh/m^2yr. The measured consumption in the period 1991-95, the first four years after they were built, was 32 kWh/m^2yr.

Thanks to continuous improvement and launch of new products, the cost of building to Passive House Standards has been reduced from +25% to +4%. Features which were experimental then are now regarded as applicable to volume housing. By February 2001, 800 low-rise houses had been built to the standard along with a three-storey office block and two blocks of flats. The most common wall construction is externally-insulated calcium silicate masonry or storey-height elements, followed by timber-frame and poured concrete.

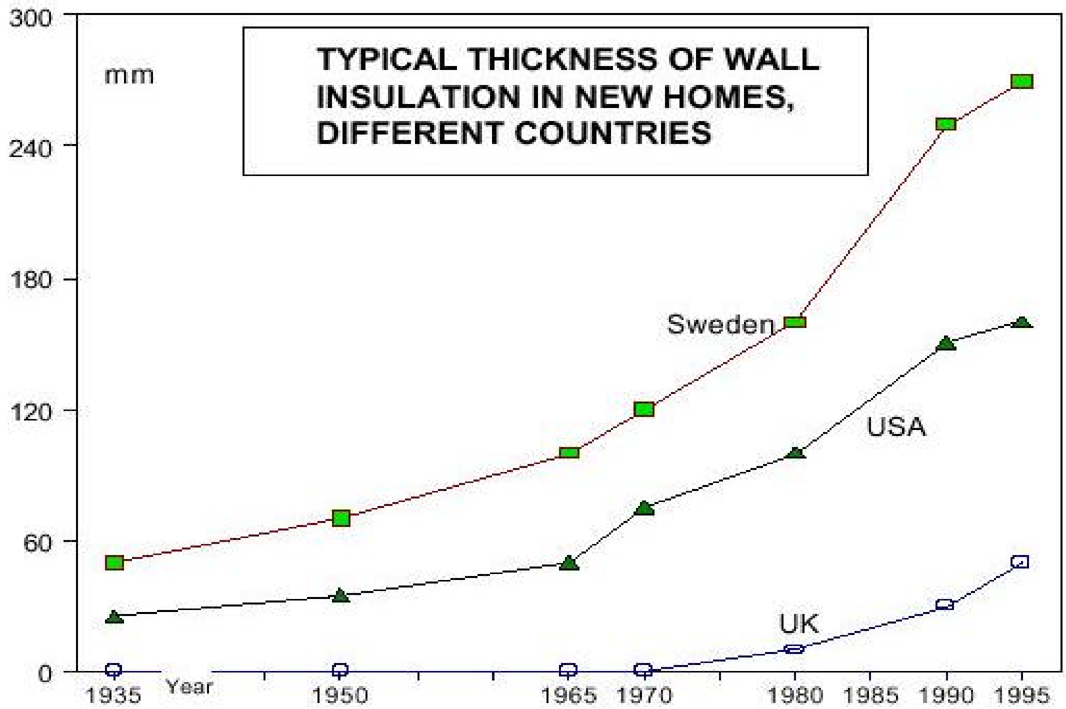
Photo: Wolfgang Feist

Standards here and there: mainland Europe and beyond

3.3 One of the most startling differences between the UK and other countries is the sheer standard of insulation and draughtproofing used elsewhere. Both features, the insulation and the reduced air leakage, contribute to reduced heat loss.

3.4 Figure 5 shows the wall insulation thicknesses in new dwellings in the UK, the USA and Sweden over the years. Figure 6 shows the air leakage of new homes in the UK and three other countries over the 20th century. Measurements on modern houses are in red, figures from the older dwelling stock are in blue.

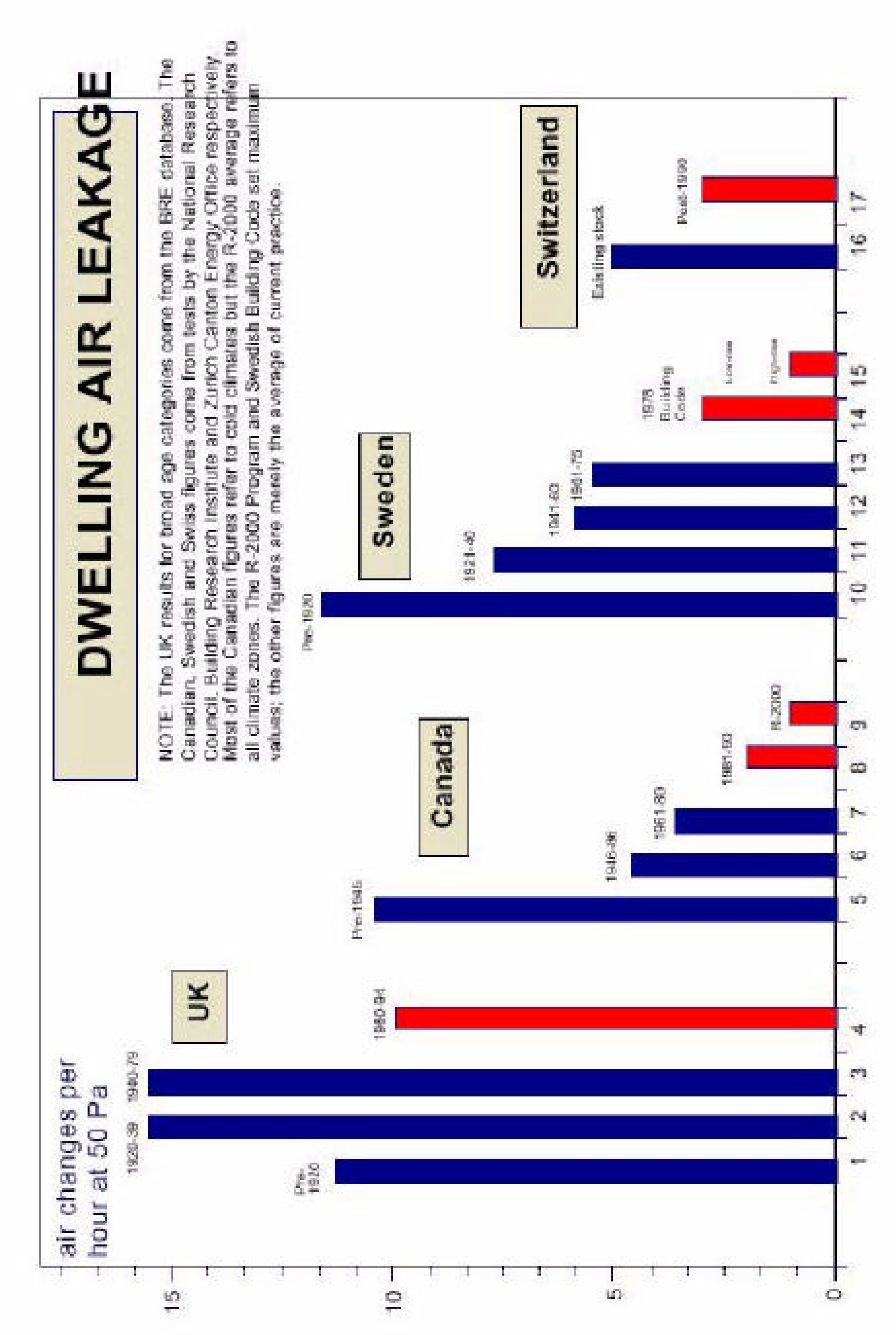
Figure 5 - Wall insulation thicknesses over time in Sweden, USA and UK



NOTE:

The figures for the USA refer to moderately cold climates, such as New York and Seattle

Figure 6 - Air leakage data for UK, Canada, Sweden and Switzerland.



3.5 All in all, many new UK houses keep the heat in less effectively than houses built in Scandinavia before the Second World War. Our homes have less wall insulation, inferior glazing[26] and they are draughtier[27]. Table 3 shows current standards in the UK, the 2002 proposals for England and Wales and standards in six other developed countries.

Table 3 - Relative Standards

ELEMENT	U-VALUE				1	2	3	4	5	6	7
	UK[1] 1995	England and Wales, proposed 2001-02	Trade-offs	Ratio, England & Wales to regions 1-6	Sweden	Norway	Denmark	Switzerland[5]	Germany[6]	USA: Seattle	USA: Los Angeles
Roofs	0.36	0.20	0.35 [2,3]	2.41	0.12	0.15	0.15	0.15	0.16	0.14	0.18
External walls	0.62	0.35	0.45	1.88	0.17	0.22	0.25[4]	0.20	0.30	0.30	0.43 [8]
Ground floor slabs	0.61	0.30	0.45	2.45	0.15	0.20	0.20	[7]	[7]	[7]	0.50
Windows	3.3	2.2	2.7	1.67	1.3	1.3	1.8	1.5	1.8	2.0	3.0
AIR LEAKAGE [9]							ac/h at 50 Pa				
	8	<10			<2	<3	6 [9]	3 [9]	<3/1.5	6 [9]	[10]

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26 Most Scandinavian buildings of this age have linked-casement wood windows, with a typical U-value of some 2.6 W/m^2K.

27 Adalberth, Karin, "Good Airtightness". T5:1998 Prepared by AB Jacobson & Widmark for Swedish Council for Building Research, Stockholm (in Swedish) (February 1998).

Lowe, R J et al, "Airtightness in Masonry Dwellings: Laboratory and Field Experience", Bldg. Serv. Eng. Res. Technol., 15(3), 149-155 (1994).

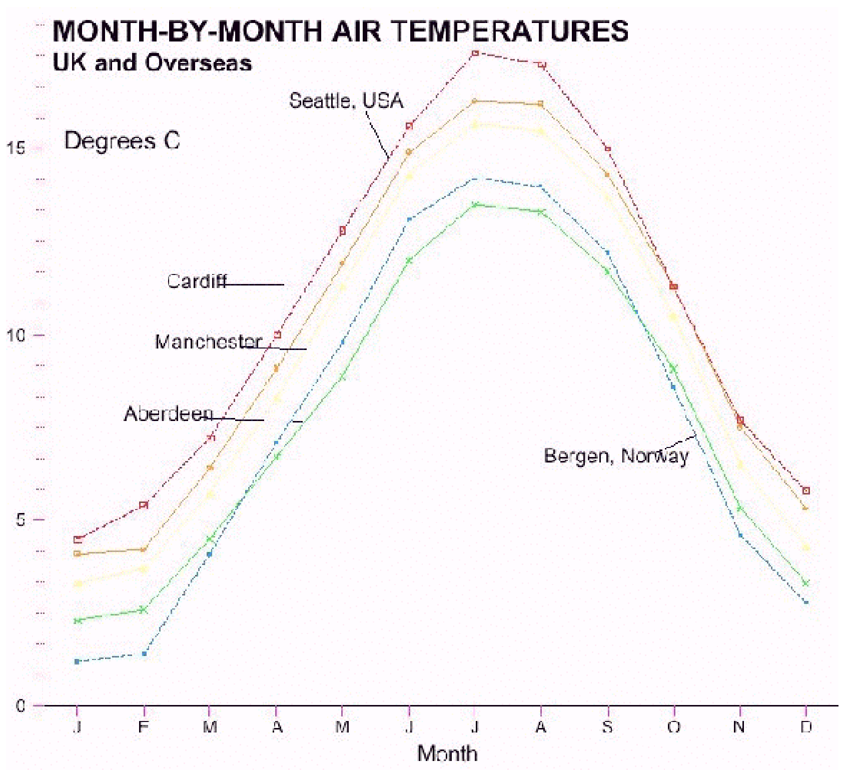
Uvslokk, S and Bjorn Vik, "A Consequence Analysis of New Building Regulations on Air Infiltration", Proc. 5th. AIC Conf., Nevada, USA (October 1984).

NOTES:

1. Estimated U-values actually achieved. More precise calculations are required in regions 1-6 and will probably be required here in the future.
2. Trade-offs refer to a 100 m^2 semi-detached house with glazing equal to 12% of floor area.
3. Assumes that insulation goes on the attic floor. The other European countries assume that it goes between the rafters. The UK plans to allow higher U-values here.
4. Average of timber-frame and masonry walls - maxima are U0.20 W/m^2K and U0.30 W/m^2K respectively but are now under revision again.
5. Zurich Canton.
6. The 2002 Building Code will require these U-values and set a limit to air leakage of <1.5(3) ac/h @ 50 Pa for dwellings with mechanical (natural) ventilation.
7. Ground floor slabs are uncommon; most houses in these regions have basements.
8. The mildest of California's 16 climate zones. This wall U-value is the maximum for timber-frame construction. Higher wall U-values are permitted in high thermal capacity buildings; e.g., those with poured concrete or masonry walls.
9. Where air leakage is unregulated, current practice is quoted.
10. Unknown.

3.6 According to advocates of current building standards, apart from Los Angeles all these places are colder than the UK, so higher standards here are not justified. However, the climatic data in Figure 7 is a clear indication that a priori, English and Welsh standards should lie midway between those of the north-west USA and Norway. On the same basis, north-east Scotland should be keeping up with Norway.

Figure 7 - Annual air temperatures for Seattle in USA, Cardiff, Manchester, and Aberdeen in UK and Bergen in Norway.



3.7 With trade-offs, even the minimum standards proposed for 2004 would still lag building practice in most other cold and temperate countries – see Table 3 - Relative Standards. The DTLR emphasised to the House of Commons Environmental Audit Committee in August 1999 that UK standards were on a par with Belgium, France and Ireland, but this claim seems a little optimistic. All new Belgian homes are overseen from start to finish by an architect, who has a duty of care to the owner to ensure that design and build quality meet the state's legal minimum energy efficiency standards. There is a ten-year liability period.

3.8 Most Belgian houses have fully-filled or partly-filled cavity walls and in situ concrete upper floors. It is evident from the drawings that, de facto, their thermal envelopes are superior in design to much practice in England and Wales. Belgian and French dwellings are likely to have better agreement between predicted and actual U-values than the poorer forms of construction used in mass UK housing.

Recent research[28] also shows that new French homes are markedly less draughty than new UK homes.

3.9 Ireland has a significant self-build market. Like their UK counterparts, Irish builders of single houses often meet higher standards than volume developers. Most new Irish houses have cavity walls with dense block inner leafs and rely on 50 mm expanded polystyrene or polyurethane foam partial fill for their insulating value. The inner leafs are plastered, not dry-lined. Since plastering improves airtightness, and since Irish walls also have rendered outer leafs, one might expect better agreement between calculated and actual U-values than with some UK construction techniques.

Goals: less CO_2 to 2020

3.10 Technically, new buildings are the easiest sector of the economy to make large CO_2 reductions. Given the scale of the climate change problem, the DTLR's predicted 23% saving in new dwellings by 2004 is too little, too late. A more appropriate response would be to set stringent targets. We suggest that a reasonable interpretation of stringent targets would be to recommend that new dwellings should soon deliver 50% energy and carbon savings compared to current practice, followed by 75%, then 85-90%, with perhaps a five- to eight-year interval between each major phase. Table 4 sets this out.

Table 4 - Overall Energy and Carbon Savings, New Dwellings

2002	2005	2010	2015	2020
50%	65%	75%	85%	90%

NOTE:

Proposed reductions in primary energy vs. practice under 1995 Building Regulations. The reduction in CO_2 would be slightly larger than these if a significant fraction of energy supplies by 2020 comes from renewables.

28 Litvak, Andrés et al, "Airtightness of French Dwellings: Results from Field Measurement Studies", Proc. 21st. Air Infiltration and Ventilation Centre Conf., The Hague, Netherlands, Sep. 2000.

Barles P and X Boulanger, "Airtightness and Underpressures: Measurements in French Apartments", Proc. 21st. Air Infiltration and Ventilation Centre Conf., The Hague, Netherlands, Sep. 2000. The leakage of these concrete and masonry dwellings ranged from 0.3 to 5.0 ac/h @ 50 Pa. This is of the order of 25% of the mean air leakage one could expect from a UK sample.

3.11 Eventually, we must be building new dwellings which use negligible non-renewable energy when they are occupied by normal users, are as comfortable as any other, and cost little extra to build. This would be because the relevant technology has been brought into mass production and the industry is familiar with its use.

3.12 To illustrate the feasibility of very high energy performance, the sort of standard which we might need to implement by or before 2020, Table 5 contains examples of some regions' minimum building standards and about 50 separate building development programmes or projects which have already been implemented, right across the northern hemisphere. The estimated energy savings are given, compared to current practice under our 1995 Building Regulations.

Table 5 - Examples of Advanced Building Practice

STANDARD	SPACE HEATING ENERGY kWh/m^{2}yr	TOTAL ENERGY kWh/m^{2}yr	REDUCTION ON UK NORM
1995 Building Regulations, England and Wales [1]	150-180	220-250	0%
Proposed 2002 Building Regulations [2]			23%
Survey of "ultra-low energy homes" in GIR 38-39, weighted average	120	160	45%
Ten best-performing schemes in GIR 38-39, typically	40	70	70-75%
Building Codes in Germany (imminent), Denmark 1985, north-west USA 1994	60-70	110	50%
Building Codes in Sweden 1984/89, Norway 1995, Switzerland 1995, Hjortakaer House G 1985, US Energy Star/PATH, R-2000 [3,4]	25-40	60-80	65-75%
Swiss MINERGIE 1993, NW USA Long-Term Super Good Cents 1989, IEA Task 13 1989-1992 [Canada, Denmark, Finland, Norway, Netherlands, Sweden, Switzerland & USA] Californian ACT[3] 1990, Canada Advanced Houses 1989-96 [3], Kranichstein Passive Houses 1991, CEPHEUS 1998-2002[1] [Germany, Sweden, France, Switzerland, Austria], Wadenswil Ultra-Low Energy 1990	10-15	30-45	88 %
Wadenswil Zero Energy 1990, Hanover Solar House, New Hampshire, USA 1994, Minergy House, Boulder, USA 1983, Rocky Mt. Inst., USA 1983	5	15-25	92%
Freiburg SSSH 1992, Boyne River Ecology Centre 1993, Toronto Healthy Houses 1995-96	0-2	15	95-100%

NOTES:

1. Consumption calculated, not measured. Space heating energy assumes that U-values are actually achieved.
2. Saving predicted by DTLR Consultation Paper.
3. Most R-2000 and Advanced Houses were in severe climates; the figures quoted here were measured for these houses when they were built in the temperate climate of coastal British Columbia.
4. Assumes that tighter thermal standards are accompanied by progressively tighter standards on lighting and electrical appliances too. This is generally outside the scope of the Building Regulations and needs separate policy initiatives.

The leaders: give them a chance

3.13 In the last five years, 15% of UK dwellings were self-build. The term generally means dwellings built by or for a particular household. In this report the definition is used to include cases where a family buys a plot of land and simply commissions an architect and/or contractor to design and build a house to their requirements, without playing an active role; and also houses which are partly constructed in the course of running a business, such as farming.

3.14 At the latest count, the self-build proportion has risen to about 18%. It could soon go higher still; it exceeds 20% in most developed countries. In some countries, including Austria, Germany and Belgium, it exceeds 50%.

3.15 Of the top ten UK housing projects for energy performance in BRECSU's Review of Ultra-Low Energy Homes[29], nine were self-build houses. Only one was speculative. All projects, including this speculative house, clearly received attention to detail from start to finish. This seems to be the main factor which unites them and separates them from speculative and social housing projects, both of which produced far fewer cases of outstanding energy performance although they actually account for 82% of new housing starts.

3.16 Self-builders are clearly the main sector of the housing market who at present are prepared to spend some of their money on careful design and construction of innovative dwellings, with markedly better energy performance than the English and Welsh norm. Accordingly, we perhaps ought to be looking at ways of encouraging more self-builders. Operating the English and Welsh planning system in a way which is more supportive of one-off houses would clearly be a good way of promoting higher energy efficiency standards.

3.17 The DTLR needs to draw attention to the point about energy efficiency in guidance to local planning authorities and emphasise the need to be even-handed.

[29] Olivier, David, John Willoughby et al, "REVIEW OF ULTRA-LOW ENERGY HOMES", Best Practice General Information Reports 18 and 19. BRECSU, Garston, Watford, 1996.

One way to level the playing field is to release many more one-off plots for development within either existing settlements or housing clusters.

3.18 According to articles in the self-build press, councils in south-east England - the region of the UK which is under most development pressure - have defined as 'greenbelt' about 2,000 plots which have been developed in the past, have roads and services laid on and would suit individual self-build homes. They are banning redevelopment of these plots, yet they are allowing mass housebuilders to build estates on greenfield sites in the same districts[30].

3.19 Another positive way forward would be to replace the detailed planning permission procedure for single houses by broad requirements for setbacks, maximum building heights, maximum areas and lists of approved materials. Only exceptions to the broad rules would need permission. Within designated landscape areas such as Green Belts and National Parks, more detailed requirements would continue.

3.20 Terms and conditions in government initiatives like the DTI's 100 Roof PV Programme are not all-inclusive, and unintentionally seem to create a bias against support of self-build housing. These should be revised to ensure they take proper account of self-builders. To further level the playing field, self-builders who provide all their own management, using sub-contractors, should be allowed to re-claim VAT as frequently and on as many items as speculative developers can.

3.21 Bodies such as the Association of Self-Builders[31] do not seem to be represented on the DTLR's consultative committees, which have an input to new building standards at an early stage. Yet, taking account of the fact that they build larger dwellings than the average, self-builders may be responsible for about 30% of new domestic floorspace. This amounts to several times more output than any of the members of the Housebuilders' Federation. The DTLR should seek a formal input into new housing energy efficiency standards from this market sector.

Education, training and research: cheaper than ignorance

3.22 At the time that the projects listed in Table 5 went ahead, UK work on the area of whole-system performance of buildings, into the problems and benefits of integration and synthesis, technology transfer, builder training and education was small and falling. To quote the RCEP:

> "Government spending on energy-related R&D has fallen sharply - the UK spends less as a proportion of GDP than almost any other developed nation[32]. This trend must be reversed if we are to develop new energy systems to counter the threat of climate change."

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30 David Snell, "Green Belt Madness", *Homebuilding and Renovating* pp. 22-27, November 2000.

31 The Association of Self-Builders, Room 23, The Rufus Centre, Steppingley Road, Flitwick, Beds. MK45 1AH. Secretary Fran Adamson.

32 Chapter 5, paras 5.61-5.62.

3.23 In addition the RCEP notes that the USA spends more than 50 times as much as we do on non-nuclear energy R&D. This translates to an overall expenditure on energy efficiency and renewables more than ten times more per capita, and seven times higher in relation to GDP.

3.24 The UK seldom enters into international collaborative projects to disseminate state-of-the-art technology. One of the latest of these valuable exercises in spreading international best practice is IEA Task 28, 'Sustainable Solar Housing'[33]. This formally began with a meeting in Switzerland in April 2000 but it has still attracted no formal support in this country - support which would permit UK experts to take part in the work.

3.25 The prevailing view is that industry will initiate and fund worthwhile research and development. However, the necessary CO_2 reduction, which is arguably of the order of 90% over a 50-year period, is totally unrelated to the timescale on which private companies undertake R&D, plan their cash flow and deliver returns to investors. Most people in the construction industry admit that they do not know of the new approaches to building design which are being tested and commercialised abroad. When these projects are described, at worst they dismiss them. At best they see them as unfamiliar, long-term and speculative.

3.26 Accordingly, the public sector must underpin moves forward by funding education, training and research on more energy-efficient buildings at a higher level. We need a suite of government-led programmes which stress the correct integration of technologies into buildings, change the design process in ways which are known to deliver better value-for-money, and extend the process of education and training to correct commissioning and management of new or refurbished buildings.

The R-2000 Program - A Case Study:

3.27 A good example of a technology transfer and builder training initiative is Canada's R-2000 Program. By 1983, several hundred earlier research and experimental houses in the prairies had demonstrated the possibilities for huge energy savings. The main energy efficiency principles were simplified and incorporated into a mainstream initiative, which was initially led and funded by the federal government, and later managed by the Canadian Association of Homebuilders.

3.28 R-2000 became the world's biggest builder training programme. In the years 1983-93, many Canadian housebuilders from the Pacific coast to the Atlantic coast attended training courses on how to build an energy-efficient home. Initially, the government paid the trainers and reimbursed builders for the costs to their business. Later registrants had to pay to be trained.

3.29 With government backing, the market would bear a premium for R-2000 Homes. By 1995, about 5,000 registered R-2000 Homes had been built. A larger number

[33] Operating agent (on behalf of the Swiss Federal Office of Energy): Architecture, Energy & Environment GmbH, Kirchstrasse 1, CH 8304 Wallisellen Switzerland. Tel. +41 1 883 1717 or 16. Fax. +41 1 883 1713.

of unregistered homes were built to similar specifications, although these copies lacked the formal R-2000 quality assurance. By 2000, most provinces had introduced some R-2000 requirements into their Building Code.

3.30 R-2000 dealt with what Canada classifies as 'low-rise' timber-frame housing, ranging from detached bungalows to four-storey blocks of flats. Canada's more recent IDEAS Challenge and C-2000 Programs have dealt with medium- and high-rise residential buildings, public and commercial buildings, built in other materials. The history vividly shows the scope for similar initiatives in other countries.

3.31 R-2000 has cost approximately £30M over 20 years[34]. The bulk of the government expenditure occurred in the 1980s. Up to 1996, the input of federal government and publicly-owned utility funds to IDEAS Challenge and C-2000 was about £200,000 for each of the first three projects built, including an architectural competition which paid the runners-up for their time.

3.32 After 1996, C-2000 marginal costs declined drastically to about £10,000 per project as important lessons from the first three projects were absorbed. Currently, about 90 non-domestic projects per year in Canada receive financial support and save 25-60% of energy use versus current minimum practice, as required by the standard ASHRAE[35] 90.1-1999.

3.33 These costs exclude federal government overheads but for the lessons learned, they seem like money very well spent. Officials in the Canadian government say that the three key ingredients for such programmes to succeed and deliver results are:

- a clear vision;
- a champion; and
- a very long-term commitment.

3.34 Similar UK initiatives would need close policy co-ordination between government departments. There must be political support at the highest levels. This is seen in the USA, where three government departments and two specialist agencies joined forces with progressive builders in 1998 to spread 'good practice' housing technology:

"President Clinton visited California's San Fernando Valley to see first-hand how home builders are embracing advanced construction technologies and materials under the Partnership for Advancing Technologies in Housing (PATH). PATH is a partnership

34 Mayo, Tim, CANMET, personal communication, 2001.

35 ASHRAE/IESNA 90.1-1999 Standard, Energy Standard for Buildings Except Low-Rise Residential. American Society of Heating, Refrigeration and Air-conditioning Engineers, Atlanta, USA, 1999. www.ashrae.org. These documents are designed for direct use by provinces, states and municipalities who in North America set their own Building Codes. 90.1-1999 has higher minimum energy efficiency levels than its predecessor 90.1-1989.

between the White House and leaders in the private sector designed to improve the quality, durability, environmental efficiency and affordability of the new and existing housing stock.

... President Clinton praised the PATH Project as "the most ambitious effort ever to help private home builders and home-owners make cost-effective energy-saving decisions' that will cut energy use by an estimated 50% in the estimated 15 million homes to be built over the next decade and by 30 percent in existing homes.

... Partners in the PATH Project include the Dept. of Housing and Urban Development, the Dept. of Energy, the Dept. of Commerce, the Environmental Protection Agency and the Federal Emergency Management Association."

Source: Press release from US National Association of Home Builders, 5 May 1998.

The road forward: Reforming the construction industry

3.35 Present UK policies will not overcome the institutional barriers to better buildings. In the UK, the state and the private sector have a joint responsibility to move from current building practice towards sustainability. Neither can do it alone. Only the private sector can implement the detail, but until the state provides the right background conditions and signals, achieving exemplary practice in more than a tiny minority of buildings is likely to prove impossible.

3.36 The threat to world climate completely transcends narrow sectoral interests. From where we are now, we need nothing less than a complete political commitment to catch up the energy efficiency of housing in other industrial countries and start to build homes fit for the 21st century - the post-fossil fuel era.

3.37 The UK government needs to apply the same vision as authorities in Germany, Sweden, Switzerland and Canada, which expect to deliver mass housing which consumes no fossil fuel, at no extra cost, from 2020 onwards. Viewing the present UK construction industry, this idea may seem utopian, but it should be achievable here within a generation; i.e., 20-25 years, if we take the problem seriously now. To believe otherwise is a policy of defeatism.

3.38 With a typical budget of 2,000 DM per m^2, or 1,700 DM excluding VAT, the construction cost of a one-off German home is if anything lower than UK homes on the same size of development - small social housing schemes and self-build housing. German houses come with built-in energy efficiency compared to ours[36]. However, it is not generally economic to import German heavyweight building systems because of excessive transport costs. Were it economic, given the existence of the single European market one presumes that the UK construction industry would already face fierce competition from German imports.

3.39 The appropriate response is to accept that much of the UK construction industry is delivering a energy-inefficient and poor-quality end product, compared to our international competitors. Government must then take responsibility, at national

36 See Table 5.

level, for changing the processes involved and turning round the prevailing culture of the industry so that it delivers a quality product.

3.40 The 1998 Egan Report 'Rethinking Construction' addressed ways forward, but Egan focussed on the process leading to finished buildings at handover and finished there. This is not a full picture. Indeed, Egan placed far too little emphasis on life-cycle costing and long-term sustainability. The majority of a building's environmental impact is not in its construction but in its energy use over time, its maintenance and, eventually, its re-construction. Were UK dwellings to become shorter-lived, from using less durable materials, this could even increase their impact on the environment.

3.41 The agencies for implementation of 'Rethinking Construction' ideals (The Movement for Innovation, The Housing Forum and Construction Best Practice Programme) are writing reports to fill the gaps left by Egan but they have not yet been fully published. Pending their publication, we suggest that substantive progress in reforming the construction industry will require the UK to study and emulate practice in other mature developed countries, whose construction industries often seem to deliver new housing with the following merits relative to the UK's output:

- more durable;
- more energy-efficient;
- more quickly;
- at lower initial cost.

3.42 Three of these characteristics could be a compelling combination. To deliver all four should really make us stand up and take notice. General discussions with workers in the UK construction industry who also appreciate the problem suggest that improving matters needs at least six initiatives:

- restore the tradition of trained, apprenticed, skilled and highly-paid labour which continues successfully in most countries. The UK has let this infrastructure disintegrate and has paid a huge price in declining levels of technical knowledge and competence;
- stop using construction as a buffer in managing the UK economy. Fluctuations from over-demand to recession and back again have had highly damaging effects;
- mechanise sites further and use highly labour-saving plant and equipment to the maximum. For the potential for this we need only look across the English Channel;
- further rationalise designs to reduce the number of trade operations and the total person-hours;
- train architects more fully in construction practice and require the same levels of numeracy as their peers on the European mainland;
- raise the level of management skills.

3.43 Success is not necessarily dependent on prefabrication. At best, claims of large savings from this route remain unproven. There have been well-informed press articles making a contrary point - that some countries achieve reduced construction costs because, with a skilled workforce, people can carry out assembly operations on site or in small workshops. These have much lower overheads than factories.

3.44 In truth, a single panacea for the industry's ills seems an illusion. There is no reason why diverse solutions should not be adopted on different sites and building types in different regions of the UK. However, progress towards better-constructed, less expensive, more energy-efficient buildings requires us to pay attention to factors 1-6 and more.

Guaranteed performance: why not?

3.45 In the UK there exists a Standard Assessment of Performance (SAP) for all new homes and a voluntary National Home Energy Rating Scheme (NHER). In theory, energy labels are a valuable tool, enabling house-buyers to distinguish between competing dwellings. However, the weakness is that they are based on designers' predictions of how much energy a building will use. Inaccurate calculations, poor design or poor workmanship can completely defeat the predictions, leading to actual bills which are totally at variance with what the calculations say they should be.

3.46 And yet, why shouldn't the measured gas or oil bills for space and water heating equal the calculated bills? Looking beyond these shores, this is quite a reasonable expectation. The Bigelow Group in Chicago, USA has guaranteed the maximum heating bills of the speculative houses which it sells since the early 1980s. It seldom has to pay out. In many countries on mainland Europe, the Building Code says how much energy a new building may use for space and water heating under standard occupancy conditions. The U-value calculations take into account exactly how the walls, roofs and floors of the proposed building are constructed. Ultimately, if the expected bills do not materialise, in principle the owner or tenant has legal recourse against whoever is responsible for the failure.

3.47 The UK situation is viewed with surprise by an architect who works in both the UK and the USA and sees the construction industry equally in both countries:

> "Will your builder [guarantee your bills]? Why not? ... We can reckon an engine's rated performance to give us reliable fuel costs for motoring, so assuming that U-values, SAP ratings and so on aren't just another score at Scrabble, surely we should be able to focus household fuel costs just the same for a given size of box? Yes I know there are variables, but those anoraks that witter on about kids never shutting the back door, or about leaving a window ajar at night for the cat, llama or pot-bellied pig are just sweating the small stuff, because it's already happening.
>
> The Energy Star Program is a serious US initiative that has spread worldwide ... [It] also applies to housebuilding - but not here in the UK ... In contrast ... the US Federal Housing Administration is engineering a sea-change in the housebuilding industry, specifically to manage their huge domestic energy drain more efficiently. It is incentivising builders to use rated materials and building systems that reliably produce highly desirable capped running costs. Westminster, please take note ...
>
> Whether we get to a similar place here depends on just how hard our builders feel like searching. If they don't find it, I hope someone has the intelligence to realise that maybe it is actually [the builders] who are lost, not what they are looking for".
>
> SOURCE: Raymond Durber, column in Homebuilding & Renovating, June 2000 issue.

4. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

4.1 The previous sections of this report have discussed the proposed new UK Building Regulations. They have set out reasons for believing that, if implemented as planned, they will not deliver upon their promise, and do not form a strategy for improvements that would deliver the required savings.

4.2 Those reasons are:

- the standards themselves are too low, particularly given the urgent need to meet the challenge of climate change robustly and cost-effectively.
- they are overly bureaucratic and allow too much flexibility to developers to make trade-offs which undermine the central energy efficiency objectives.
- what little evidence there is suggests that the energy-saving measures in the last three improvements to the Building Regulations failed to deliver against their targets by a very wide margin.
- no individual or body is legally responsible for ensuring that each finished building meets a particular energy performance.
- without a coherent strategy of monitoring, verification, education and training, the experience this time will be just the same.

4.3 There is no time to wait. The following actions need to be taken now. What follows are our recommendations for a comprehensive package of measures to deliver real reductions in energy use and carbon dioxide emissions which will last for the rest of this century. All it needs is the political will to enact the required changes.

Recommendations

4.4 This report has highlighted numerous weaknesses in the proposed new standards in Part L of the Building Regulations. Dealing with those weaknesses can be grouped under five main policy areas:

- Establishing the energy performance of new buildings under the existing regulations
- Setting higher, yet simpler, standards
- Providing more detailed guidance to the industry on implementing higher standards
- Introducing random testing of new dwellings
- Investing in a programme of training and education for the industry as a whole.

a) Establishing the energy performance of new buildings under the existing regulations

4.5 Current policy is based on theoretical calculations. We do not know how well the 1982, 1990 or 1995 Building Regulations actually worked. We must quickly measure the energy use and internal temperatures of a random sample of homes which were built to at least the 1990 and 1995 Regulations, followed by homes to the 2002 and later Regulations.

b) Setting higher standards - proposed regulations 2002-2015

4.6 In place of the complexity of current policy, outlined in this report, we propose a simplification of the energy performance standards for new domestic buildings which can be summarised as:

- maximum elemental U-values which cannot be exceeded;
- a reduction of trade-offs to ensure good envelope performance with minimal enforcement costs.
- simple requirements for heating system controls and commissioning;

4.7 These are set out in further detail below.

4.8 Table 6 contains our proposals for maximum elemental U-values up to 2015, with a return to changes at five-year intervals. The suggestion is for one improvement only in elemental U-values before 2005. The proposed 2002 requirement would be accompanied by much more precise U-value calculation methods and would seek to establish a level playing field for competing materials and construction systems.

4.9 The U-values in 2002 would, however, still omit thermal bridging at the corners of the building and at the junction of different opaque elements - such as the roof and wall, and the wall and the ground floor. By 2005, real U-values would be in use and all these effects would have to be taken into account.

Table 6 - Required Thermal Performance, New Dwellings

	ELEMENTAL U-VALUES (W/m^2)				
	1995	2001	2005	2010	2015
Pitched roofs (if insulated in slope)	0.36 [1]	0.25	0.18	0.15	0.12
External walls	0.62	0.35	0.25	0.20	0.17
Ground floor slabs	0.61	0.30	0.25	0.20	0.17
Opaque doors	-	1.00	0.80	0.65	0.55
Windows	3.30	2.00	1.60	1.00	0.80
AIR LEAKAGE (m^3/m^2hr @ 50 Pa)	-	10	5 [2]	3 [3]	2 [3]

NOTES:

1. Approximate U-values achieved in 1995 - not those required. See Table 3. From 2002, calculations would be greatly tightened-up. By 2005, they would have to reflect the full physical reality of the situation.
2. Requires exhaust-only mechanical ventilation.
3. Requires exhaust ventilation or balanced ventilation with some form of heat recovery.

4.10 The minimum requirements should be simplified, with just two ways to obtain approval:

- meet the elemental U-values in Table 5 with minor tradeoffs; or
- prove that the proposed dwelling emits CO_2 at a rate of no more than X, still with upper limits on U-values. Such calculations to be carried out by a competent, independent person.

4.11 Passive solar design could be catered for as the DTLR's Paper proposes but a more concise approach is to set maximum elemental U-values for windows of all three principal orientations; i.e., south within 30 or within 45 degrees, east/west and north. From 2005, if designers are following the elemental approach, a minimum average whole house window energy rating would replace a maximum U-value.

4.12 From 2002, the Regulations should require the installation of a space heating system which is based on distributed low-temperature heat. Systems such as electric resistance heating, both direct and storage heaters, are inflexible. They cannot be modified later to use another source of energy except at great expense.

4.13 Our proposal permits electric heat pumps which feed a warm air, radiator or underfloor heating system, or electric boilers charged up by off-peak electricity, connected to these same systems. So long as these systems can meet the peak demand without electric resistance backup, they preserve the desired long-term flexibility in energy source.

c) Providing more detailed guidance to the industry on implementing higher standards

4.14 Standard design details should be published covering a vast majority of the industry, along with published illustrations of minimum acceptable build quality, such as thermal insulation work in ground floors, external walls and roof. Failure to meet these minima would mean that work could be condemned, and would have to be re-done.

4.15 If designers do not use 'robust' details from the proposed DTLR publication(s), they could use non-standard details. These must also meet a set of published requirements which are designed to ensure adequate thermal performance. Such clauses have appeared in the Canadian, Danish and other Building Codes for many years. The most important item is a reasonably continuous air barrier in contact with the thermal insulation layer, with no gap between the two to allow unwanted air circulation.

d) Introducing random testing of new dwellings

4.16 Random testing of air leakage and thermal insulation continuity should be immediately introduced on all homes built under the new proposed standards. For twelve months; i.e., until 2003, test results should be advisory. Thereafter, dwellings which fail should have to undergo remedial work.

4.17 Air leakage tests on new dwellings and occasional tests with infra-red cameras, etc should be funded out of building control charges. The cost is then spread uniformly over all dwellings. Relative to ad hoc arrangements, charges could be markedly reduced by councils awarding bulk testing contracts after a competitive tendering process and the test results from building control departments would allow us to build up an independent national database. This is urgently needed.

4.18 After 2002, DTLR should ask building control departments to check doubtful cases of non-standard details - by outside experts if necessary, like they ask independent consulting engineers to check "non-standard" building structures. The DTLR should monitor a sample of structures using standard and non-standard details to assess whether practice is improving over time as it needs to.

e) Investing in a programme of training and education for the industry as a whole

4.19 It is pointless to make a radical shift in emphasis, to guaranteed energy bills, until we have improved design and construction quality, with reliably low air leakage, and calculation methods and construction systems which give us known U-values. Average energy consumption would then equal what we predict from the drawings and specifications. To achieve this over a decade needs substantial investment in training and education directed at actors who range from sub-contractors and builders to architects, surveyors, mechanical and electrical engineers and structural engineers. Building control officials, on whom falls the burden of ensuring that standards are met on site, must also be included.

4.20 Within three years, we should bring expenditure on research, development and deployment and all aspects of education, training and technology transfer concerned with energy-efficient buildings up to the OECD average. Within five years, we should match the expenditure levels of the better-performing regions. These are broadly: North America, Scandinavia, the Netherlands and the German-speaking countries of central Europe.

4.21 Within this available funding, programmes should be drawn up to support innovative buildings which reach the different levels of energy performance set out in Table 5, earlier. The least ambitious of them still represent significant improvements on current practice; the most ambitious of them lead to zero fossil-fuel houses.

4.22 The focus of such programmes should be on results - improved building energy performance and useful lessons for the future. It should not be not on applying specific measures per se but without checks on performance and feedback. The positive lessons must be applied immediately and systematically to subsequent projects, not ignored in the way that the vital lessons of the 1970s were ignored.

Dwellings involving the public sector or public funds

4.23 The public sector could be used to spearhead advances in new dwelling energy performance standards. According to the Paper, the Building Regulations Advisory Committee has ruled out explicit reference to 'Good Practice' standards in parallel to the Approved Document L. If defined separately, however, these could be adopted immediately by housing developers or authorities in the public sector who wish to be a stage closer to the leading edge. They might then become the legal minimum standards five years hence.

4.24 The indicative figures in paragraph 12 of the Paper are a very broad proposal for future Part L requirements. The government should make firmer proposals for minimum standards ten years ahead. Having set them out in detail, it could then obtain undertakings from the public sector, including all local authorities and housing associations, that for the foreseeable future they will meet standards five years in advance of the Building Regulations.

4.25 Whenever a public sector body sells land, it could be required to impose higher energy efficiency standards on the developer. These specifications should also be published in detail in the journals read by self-builders. As with housing associations, these groups are far more likely than speculative developers to exceed legal minimum requirements.

4.26 Average practice in a large minority of the industry - indeed, most new dwellings except typical large speculative housing estates - would then be more energy-efficient than the Regulations require. This matches the situation in many other developed countries. Prior experience of higher standards on this scale should markedly reduce the opposition by large-scale builders to requiring the same measures in all new homes five years later.

Final thought

4.27 Judgement on such programmes will be hard to make before 2020-2025. If a timewarp can still be identified, the new policies will have partly failed. If by then the UK is level with the countries which lead the world in more energy-efficient, solar buildings, they will have succeeded and the omens for world climate may be brighter.

APPENDIX

EXAMPLES OF TYPICAL WALL CONSTRUCTIONS

These show examples of the two most common wall construction methods in low-rise housing which would normally meet a standard elemental U-value of 0.35 in 2001. This assumes that an elemental U-value •0.25 is required from 2005. With tradeoffs, U•0.30 might be used even after 2005 and the insulation thickness can be interpolated.

<table>
<tr><th colspan="3">MASONRY</th><th colspan="2">TIMBER-FRAME</th></tr>
<tr><td>2001</td><td colspan="2">2005</td><td>2001</td><td>2005</td></tr>
<tr><td>U•0.35</td><td colspan="2">U•0.25</td><td>U•0.35</td><td>U•0.25</td></tr>
<tr><td>13 mm plaster</td><td>ditto</td><td>ditto</td><td>12 mm plasterboard</td><td>ditto</td></tr>
<tr><td>100 mm dense concrete blockwork or brick</td><td>ditto</td><td>100 mm aerated concrete blocks</td><td>Polyethylene air-vapour barrier</td><td>ditto</td></tr>
<tr><td rowspan="2">100 mm full fill mineral fibre batts (• =0.036)</td><td rowspan="2">150 mm full fill mineral fibre batts (• =0.036)</td><td>80 mm polyurethane foam (ZODP)</td><td rowspan="2">140 mm mineral or cellulose fibre (• =0.037) between softwood studs (• =0.13)</td><td>140 mm mineral or cellulose fibre (• =0.037) between softwood studs (• =0.13)</td></tr>
<tr><td>50 mm residual low-emissivity cavity</td><td>50 mm insulated sheathing (• =0.037)</td></tr>
<tr><td rowspan="3">102 mm clay brickwork (or other outer leaf)</td><td rowspan="3">ditto</td><td rowspan="3">ditto</td><td>12 mm plywood sheathing</td><td>ditto</td></tr>
<tr><td>Breather paper</td><td>ditto</td></tr>
<tr><td>50 mm cavity</td><td>ditto</td></tr>
<tr><td></td><td></td><td></td><td>102 mm clay brickwork (or other cladding)</td><td>ditto</td></tr>
<tr><td>Thickness 315 mm</td><td>365 mm</td><td>345 mm</td><td>316 mm</td><td>366 mm</td></tr>
</table>

NOTES:

1. Indicative only. Not a full study of ways to meet the new U-value requirements, not precise to ±1%.
2. 1mm is within normal building design and construction tolerances. There may be no major difference in thickness between an average timber-frame wall and a masonry wall; there may be more variation between different types of masonry walls or different types of timber wall.
3. MASONRY. Typical constructions derived mostly from the 1977, 1982 and 1985 Danish Building Regulations. Would require the area of twist-type stainless steel ties to be below a specified limit and only approved window reveal details to be used.
4. TIMBER. Based mostly on information in 1993 and 1997 ASHRAE Handbooks of Fundamentals. Refers to a platform-framed building where the fraction of solid timber in the entire wall from top to bottom, including the area occupied by intermediate timber floors, equals 25%.
5. UK research indicates that the timber fraction here may be higher than in the USA; in the USA, most timber-frame houses are site-built. If so, thicker studs than 140 mm might be needed.