Developing Future UK Energy Performance Standards

St Nicholas Court Project

Executive Summary

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CeBE
Centre for the Built Environment
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It does not diminish the contribution of any of the above to affirm that the responsibility for any remaining errors or omissions in this report lies with the authors and that the contents of this report do not necessarily reflect the views or policies of the project's funders or partners.

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Executive Summary

Introduction
The St Nicholas Court Project was set up to explore the implications of an enhanced energy performance standard for new housing for the design, construction and performance of timber framed dwellings. The energy performance standard, EPS08, is modelled on proposals made by the DETR in June 2000 for a possible review of Part L of the Building Regulations in the second half of the present decade. The overall goal of the project was to support the next revision of Part L through an enhanced body of qualitative and quantitative evidence on options and impacts.

The seeds of the project were contained in a report – *Towards Sustainable Housing* - commissioned by Joseph Rowntree Foundation at the start of the last review of this part of the Building Regulations. The project itself has been based on the St Nicholas Court Development which involves the design and construction of a group of 18 low energy and affordable dwellings on a brown field site in York (see site plan below). The research project was established in two stages. Initial funding was provided by the Joseph Rowntree Foundation in the spring of 1999. This ensured the involvement of the research team from the outset of the development process. Additional funding was provided from late 2000 by the Housing Corporation and by the DETR through the *Partners in Innovation* programme (responsibility for which now lies with the DTI).

The research project was originally divided into five phases – project definition, design, construction, occupation, and communication and dissemination. Delays in site acquisition initially allowed the design phase to be extended, but ultimately forced the abandonment of the construction and occupation phases, and the scaling down of the communication and dissemination phase. Despite the delays, the development itself will now go ahead, with construction starting in mid-2003.

The Partnership
The St Nicholas Court Project was based on a partnership that included all those involved in the design process. The following organisations contributed directly throughout the design phase:

York Housing Association
Constructive Individuals
RWS Partnership
Wates Construction Ltd
Oregon Timber
Baxi Air Management
City of York Council
LEDA

Support for the project's advisory group was also provided by NHBC, CITB, BRECSU and the Hastoe Housing Association Ltd.

Figure 0.1: Layout of houses at St Nicholas Court

Summary of EPS08

The St Nicholas Court Project was conceived from the outset as revolving round a clearly defined energy performance standard, used in place of the then current version of Part L (ADL95). The first version of the *Energy and Ventilation Performance Standard*, written in 1999, was based on an expansion and revision of the proposals for 2005 contained in *Towards Sustainable Housing*. The opportunity was taken to review the elemental U values that had been proposed in 1998, to provide a much clearer indication of the relationship between three compliance modes - elemental, target or mean U value and carbon index and to define, more precisely and procedurally, in terms of the raft of CEN standards that had by then emerged, what was meant by U value. The opportunity was also taken to begin to explore approaches for integrating other contemporary developments – such as the BFRC window energy rating system – into the standard, and to outline a possible format for the ventilation provisions of Part F which would be consistent with the proposals for Part L.

The elemental requirements of EPS08 are presented in Table 0.1 below:

Table 0.1: EPS08 elemental performance requirements	
exposed walls	0.25 W/m^2K
roofs	0.16 W/m^2K
floors	0.22 W/m^2K
windows, outer doors & rooflights (no more than 25% of gross floor area)	1.3 W/m^2K (or window energy rating $\geq$ 70)
air permeability at 50 Pa	5 m/h
maximum carbon intensity for space and water heating	70 kg/GJ

U values in the above table are defined as whole element values. They include contributions to total heat loss from all linear thermal bridges. U values calculated on this basis are more difficult to achieve than those calculated according to procedures laid out in the current Part L Approved Document. Crudely, a wall with a U value of 0.25 W/m^2K calculated according to EPS08 requires 10-15% more thermal insulation than one calculated according to ADL02. The precise amount depends on the care taken to reduce thermal bridging, both within the wall, and at junctions between it and other elements of the building thermal envelope.

The predicted impact of these elemental performance requirements on CO_2 emissions and carbon index is shown in Figures 0.2 and 0.3 below:

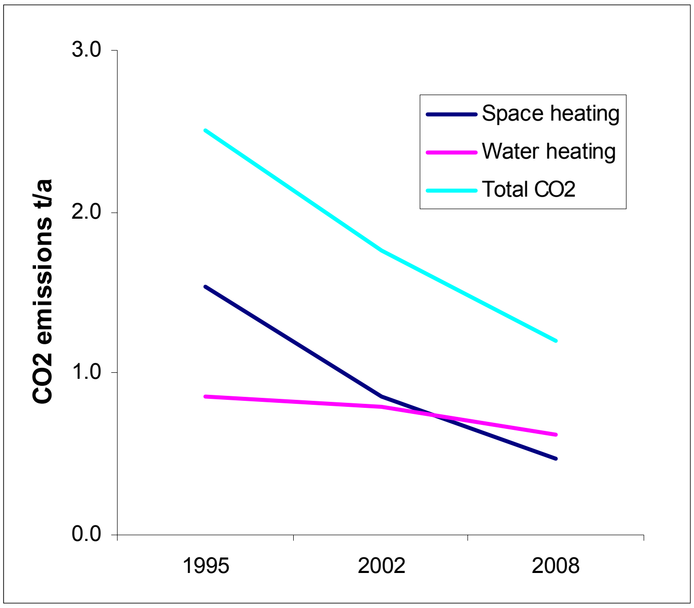

Figure 0.2: Comparisons of carbon emissions under ADL95, ADL02 and EPS08, for an $80m^2$ gas heated semi-detached dwelling.

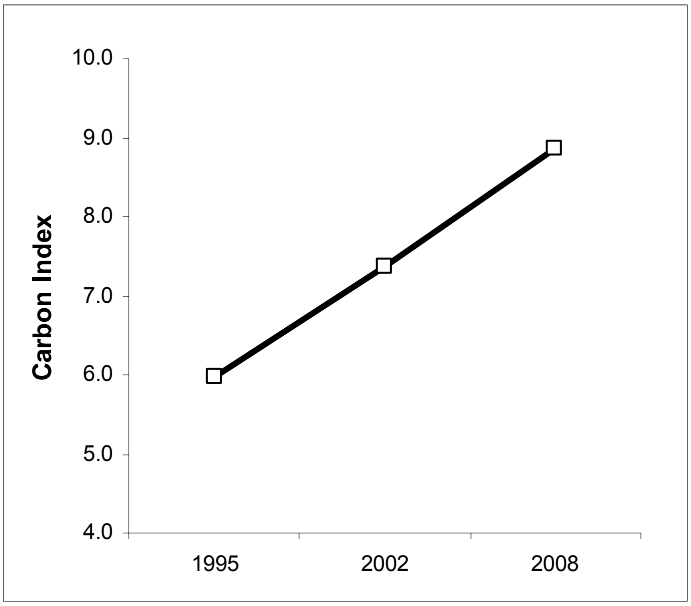

Figure 0.3: Comparisons of carbon index under ADL95, ADL02 and EPS08, for an $80m^2$ gas heated semi-detached dwelling.

In brief, EPS08 is expected to reduce CO_2 emissions and gas consumption for a typical 80 m^2 semi-detached dwelling by approximately one third compared with ADL02 and by more than one half compared with ADL95. At this level of performance, annual energy requirement for domestic hot water is greater than for space heating.

Research methodology

The research project was conducted using an action research approach. The appeal of action research stemmed, to paraphrase Greenwood et al (1993), from the fact that it:

- addresses real-life problems;
- is change-oriented;
- emphasises a participatory approach in which participants and researchers generate knowledge and understanding through collaborative processes in which all participant's contributions are valued;
- is an eclectic approach that embraces ideas, knowledge and theory from any source that is able to contribute to the goal of addressing the research problem;
- does not insist on classical experimental methods as the only way of establishing truth, particularly in the social domain;
- maintains the validity of meanings negotiated by free agents in the course of undertaking and reflecting upon a shared task.

This approach worked well with the partnering approach to design and construction, which was laid down as a requirement, from the outset, in York Housing Association's Innovations Brief (Gilham 1999). This in turn drew on the Egan Report, *Rethinking Construction* (Construction Industry Task force 1998).

The key features of the research process were:

- the acceptance by all partners of the performance standard EPS08, which defined the performance target to which the dwellings and their sub-systems were ultimately designed.

- reflection on and evaluation of the design process and the performance standard throughout the design process and through a series of group and individual interviews conducted by the research team.

The research team participated throughout the design process and provided technical support to the design team though a series of workshops, informal meetings, demonstrations, email exchanges and working papers. Wherever possible, exchanges between partners were minuted and minutes circulated to support processes of individual and collective reflection. In many cases, meetings were tape-recorded and, in a small number of cases, video recorded to provide additional material for subsequent reflection. Although in most cases workshops were proposed by the research team, the ultimate decision to hold a major workshop on any particular subject was taken by the team as a whole. The whole process of design was managed and punctuated by a series of Design Team meetings, involving essentially all those with a professional interest in design and construction of the St Nicholas Court project: client, architect, main contractor, up-stream suppliers, building services engineer.

The design process

York Housing Association's decision to adopt the partnering approach was perhaps the most important determinant of the design process. As a result of this decision, up-stream suppliers – in particular Oregon and Baxi - were involved from the start of the design process. Within the design team, the primary role of the architect was information broker. Within this structure, the prototype standard provided a very clear focus for the design process and was used, in place of ADL95, continuously to assess emerging design solutions. The research team acted partly as the guardian of the standard and partly as a facilitator of training and provider of technical support. The atmosphere within the design team was characterised by open debate and a positive attitude to the achievement of the standard. This atmosphere was the result of clarity of purpose, reinforced by the client, and the partnering approach.

Early design discussions focused on conceptual reorientation as the design team grappled with the changes required by the new standard. Thermal bridging, airtightness and the need for a whole house ventilation system were key areas to be addressed. Initial attempts at solutions for the dwelling envelope tended to seek the achievement of the required U values using conventional approaches that did not take account of thermal bridging and with little appreciation of the implications for airtightness. This was to be expected and these early attempts provided an essential starting point for raising awareness of the practical significance of the issues. The conceptual principles involved were grasped very quickly - in the case of the wall design bridging through the studs and at openings and junctions was illustrated at a single meeting, leading to a rapid redesign. The resulting solution, an 89 mm stud externally insulated frame, remained largely unchanged through subsequent design iterations. Airtightness was addressed in a general way by raising awareness of the importance of continuity of the primary air barrier, and of the need to minimise service penetrations. Practical impacts of this on the design included the choice of roof construction, the decision to use a combi-boiler, the incorporation of a polythene vapour barrier in the wall construction and the provision of a service-space between it and the plasterboard.

Considerable effort was centred on the design of the roof. Initially, a low pitch, trussed rafter roof with insulation at ceiling level was designed. This was challenged both by the research team and ventilation designer/supplier and an I-beam warm roof was proposed. Despite an acceptance that such a solution was technically superior and provided an opportunity for additional living space, it was rejected on cost grounds. Considerable effort was then put into making the trussed rafter solution work, a process that promised to produce some complicated details. The delay in the project programme coupled with the client's desire to realise the benefits of additional habitable volume resulted in a review of this decision and the adoption of the warm roof design.

The issue of the roof design illustrates the problems that are likely to arise when standards begin to push the boundaries of conventional technology. Although the trussed rafter solution could be made to work, improved performance standards appear progressively to erode the advantages of this form of construction. The technical and environmental merits of I-beam construction coupled with evidence of falling costs are likely to make this an increasingly common choice for timber frame construction.

The proposed airtightness standard requires the adoption of a continuous whole house ventilation system. Early hopes that the levels of insulation envisaged by EPS08 would enable heating and ventilation systems to be combined proved infeasible and separate systems were designed. However improved insulation enabled a reduction in the size of heating systems, particularly in dwellings ventilated using MVHR where the omission of bedroom radiators was considered to be a viable option.

The training support facilitated by the research team ranged from formal seminars and workshop discussions to the provision of feedback as design solutions emerged. The two approaches proved to be complimentary with the seminars covering a wide range of principles that were reinforced by discussion during design development. Although it would be prohibitively expensive to replicate this approach in full, there are lessons that can be learned. As far as possible, training programmes should be participatory and based on "real" cases with design and feedback cycles built into the process. The role of building control staff as a dissemination tool should be exploited much more than in the past, backed up by investment in building control training, again, based on a participatory approach.

The proposed requirements for the comprehensive treatment of thermal bridging require efficient mechanisms for accounting for thermal bridges. In this project the calculations were done by the research team and the resulting values provided to the design team through a modified SAP spreadsheet. This was designed to simulate an approach based on a catalogue of pre-calculated values or on certified values provided by suppliers for standard construction details. This approach demonstrated considerable promise with the architect reporting that the modified SAP spreadsheet was easy to use. However any system that relied on the use by designers of thermal modelling software to calculate their own values, is unlikely to meet with widespread success.

The design solution

It appears that the design that emerged from this process will meet the U value and airtightness requirements of the EPS08 performance standard with relatively minor modifications. The specifications of the main elements of the dwellings are:

Wall construction: The construction of the proposed St Nicholas Court dwellings is shown in Figure 0.4. The most obvious change is to the wall construction, which is to consist of conventional 89mm studwork clad externally with 40 mm of rigid polyurethane insulation. This construction:

- significantly reduces thermal bridging through studwork and at junctions
- makes the overall thermal performance less sensitive to detailed design of the timber frame
- achieves the required whole wall U value of approximately 0.25 W/m^2K.

An alternative construction using timber I beams in place of conventional studwork was considered, but was rejected mainly on grounds of practicality and lack of familiarity on the part of the timber frame supplier. Cost was an important secondary factor in this decision.

Roof construction: Two roof constructions were developed for the scheme – a cold roof variant using a conventional timber truss structure and a warm roof variant using an I-beam structure with 200 mm of insulant (mineral or cellulose fibre). The costing exercise also explored the option of a warm roof design using conventional 150mm rafters, over-clad with approximately 50 mm of rigid insulation board. This option was found to be more expensive than the I-beam option.

Ground floor construction: The U value requirement for the ground floor is to be met through a modest increase in insulation thickness coupled with improved edge detailing. The method chosen is beam-and-block construction, insulated with approximately 60 mm of polyurethane insulation. Incremental reductions in ground floor U value can be achieved, without qualitative changes in construction, by increasing the thickness of the insulation board.

Windows: Windows are to be double glazed in softwood timber frames from a UK supplier. Sealed units are to incorporate a high performance low emissivity coating and argon filled gas space. Currently it is not intended to use insulating glazing spacers. The resulting window U value is estimated to be in excess of 1.6 W/m^2K – failing to meet the elemental requirement of EPS08 and falling just outside the acceptable range for trade-off. Clearly further design iterations will need to be carried out with the manufacture to seek to achieve the required values. Work with a second, European manufacturer, undertaken as part of the companion Brookside Farm project, has led to the development of a specification for a double glazed window in a softwood timber frame which appears to achieve the elemental target U value of 1.3 W/m^2K. The absence of certified window performance data made it significantly more difficult to confirm window performance claims and impeded the process of window selection.

Costs and cost effectiveness

The termination of the research project at the end of the design phase has restricted the cost assessment to design estimates. The lack of actual construction costs means that conclusions in this area must remain tentative. The cost increase stems from 5 areas - ground floor, walls, roof, windows & doors and services.

In the 3 bed 5 person dwelling (warm roof - as designed), the change in standard from 1995 to 2002 adds just over £1,470 to cost. The step from 2002 to EPS08 adds a further sum, either £1,130 or £1,900 depending on whether the cost of the internal service-space is taken into account[1]. In percentage terms, the 2002 standard adds some 2.6% to construction cost. EPS08 adds a further 1.9% if the cost of the service space is not counted, rising to 3.3% if it is.

Annual energy cost savings of just under £70 were calculated for the shift from 1995 to 2002 and a further £50 from 2002 to 2008. If the value of the carbon saved is added, the figures increase to £93 and £67 respectively. Simple pay back times (based on energy cost savings) are:

1995 → 2002 22 years
2002 → EPS08 23 years (excluding cost of services space) to 39 years

The discount rate currently recommended for long term investment in such areas as building regulations is 3%. The economic benefit of moving to EPS08 from ADL02, expressed as an average annual equivalent saving over a 60 year life, and including the value of carbon saved, ranges from +£26 to -£2, depending on whether the cost of the service space is included or not. The former case comfortably passes the economic test and the latter is on the margin.

Our general observations and analysis of costs in this project lead us to the conclusion that the uncertainties that exist during the design phase of any project are likely to impact much more on estimates of cost for novel constructions and untried standards of performance than on those that are well tried and tested. This leads to the general conclusion that the costs of achieving improved standards are likely to be over estimated. Empirical evidence for this is provided by the trajectory of over-cost for an I-beam warm roof, which fell from an initial value of approximately £2,000 per dwelling reduced to something close to zero as the design was firmed up and more definitive cost estimates were obtained. This tendency to over-estimate in the face of uncertainty is understandable, but unless it is allowed for, it may have the unfortunate effect of inhibiting the development of both housing energy standards and the technology required to support them.

[1] It is not clear that the whole cost of the services space should be set against the airtightness standard. As well as reducing the risk of air leakage through service penetrations of the air barrier the services space was provided in the final design to enable flexibility of services routing. It could be argued that this space is a matter of good design rather than compliance with any given airtightness standard.

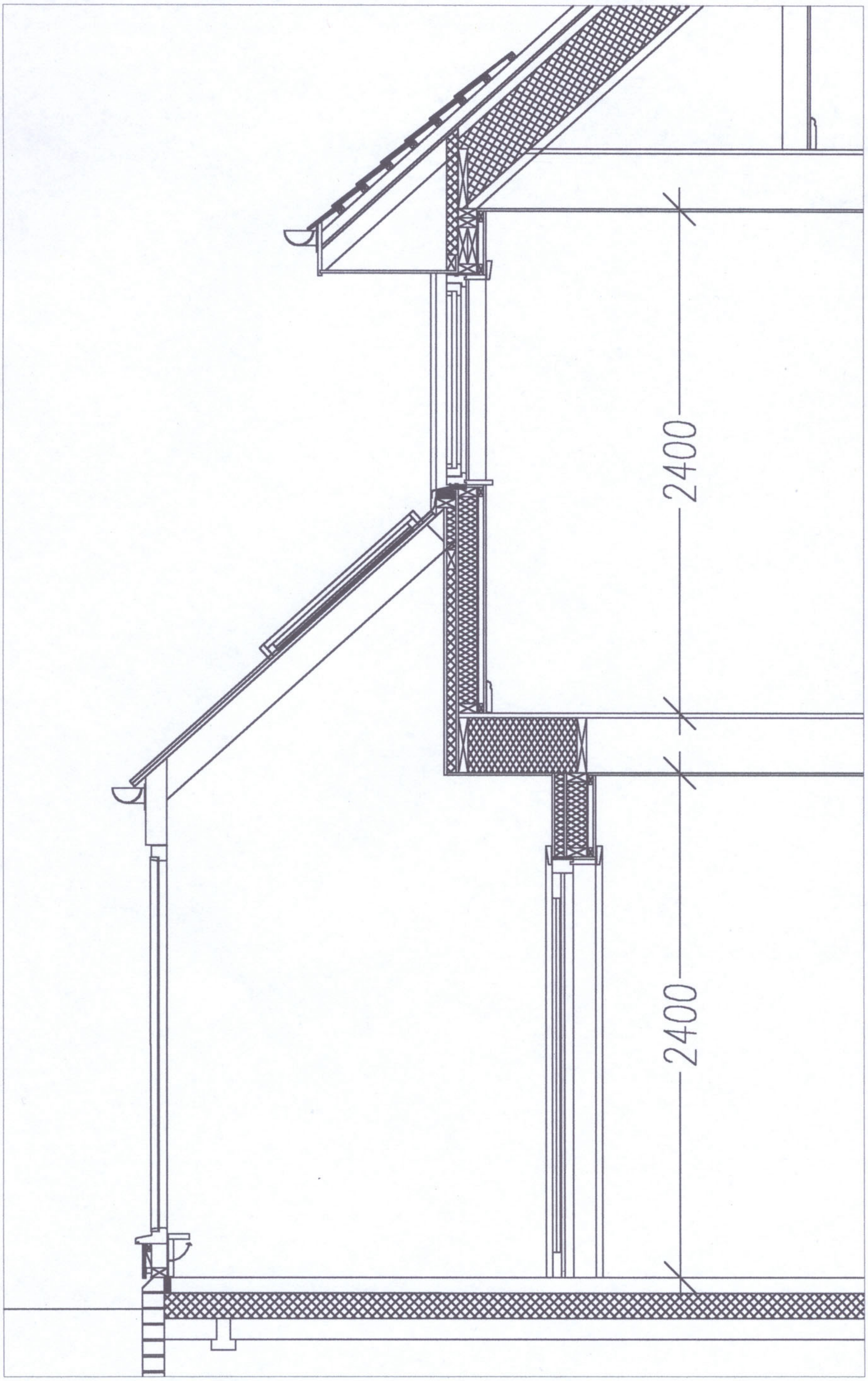

Figure 0.4: Construction section through 3-bed 5-person house at St Nicholas Court.

Principal conclusions and recommendations

The wide-ranging discussion contained in the full report is summarised here, with key recommendations emphasised.

(i) It appears that with the exception of windows, the envelope requirements of EPS08 are relatively straightforward to meet in timber-framed housing. The standard appears to be economic when tested against current Treasury guidelines, provided that account is taken of the value of carbon saved by the improved standard.

(ii) With the support of the research team, the design team found the thermal bridging and airtightness requirements of the standard conceptually straightforward. However few, if any, of the design team or York Building Control achieved familiarity with the quantification of thermal bridging. *This suggests that a prescriptive standard, based on the current Robust Details approach, would be an important part of the implementation of EPS08 or similar standards. There is a need to extend Robust Details to include numerical information on thermal bridging, and a need to ensure that this information is interfaced to a modified version of SAP.*

(iii) The approach taken by the project to training appears to have been effective. The key features were a workshop-based approach, with use of graphical techniques and on-site demonstrations, in the context of real design problems. Training was facilitated by the partnering approach. Training of this nature is needed throughout the supply chain and in organisations responsible for building control.

(iv) Absence of reliable information on air leakage led to uncertainty in a number of areas, e.g., as to whether a services void on the inside of the timber frame would be needed to achieve the air leakage target of 5 m/h at 50 Pa. *The introduction of mandatory pressurisation testing of a proportion of new dwellings may be the most effective way to ensure the rapid diffusion of knowledge about airtightness and the rapid generation of a large database of experience on both effective and ineffective design and construction solutions.*

(v) For double glazed windows with current framing systems, the performance target of 1.3 W/m^2K or a window energy rating of 70 is, as intended, on the margin of what is achievable. However, a number of continental manufacturers can achieve this performance with triple glazed windows at modest over-costs, and the Passivhaus window standard – a whole window U value of 0.8 - exceeds the EPS08 U value requirement by a factor of 1.6. The key areas for technical improvement are edge spacers, improved coatings, inert gas filling of sealed units and improved frame designs. *It would appear justifiable for the ODPM to signal window performance standards for 2005 that would require the use of warm edge in all windows. In our view, inert gas filling of sealed units comes into the same category, if not by 2005 then certainly by 2008. We view the commercialisation of a range of high performance windows with these features as urgent and of strategic importance. There is also a need to demonstrate and commercialise a range of superwindows with performance at the level of the Passivhaus standard.*

(vi) The development of performance-based ventilation standards for dwellings is a key task. We have developed a possible model, but consider that further work is needed to develop both the conceptual and empirical foundations of such standards in the UK context. *More work is needed to commercialise a wider range of continuous ventilation systems, particularly single point extraction systems (MEV) and balanced heat recovery ventilation (MVHR).*

(vii) *There is a powerful case for requiring, from 2005, the use of condensing boilers wherever gas is used for heating*. However, the thermal performance of the condensing boiler has essentially reached its physical limit. *There is therefore a pressing need to define and commercialise a range of successor technologies to the condensing boiler*. These are likely to include some or all of (micro-) CHP, fuel cells, district heating and heat pumps supplemented with solar hot water heating. It is clear from our work both at St Nicholas Court and at Brookside Farm that the integration of any of these technologies into the UK construction industry will be a major, probably decade-long, task.

(viii) Innovation in the construction industry requires empirical information on actual in-use performance, if it is to achieve the objectives of raising building performance and reducing environmental impact. *There is therefore a need for measurement programmes capable of detecting long-term trends in energy use in the whole stock, and in the performance of new homes*. This would require performance data from significant numbers of existing and new dwellings, based on stratified random samples and measured on a rolling, cohort-by-cohort basis.

(ix) The St Nicholas Court project has helped us to identify a number of areas of technology in which the UK lags behind developments elsewhere. These include condensing boilers, high performance windows and construction systems. We suspect that a significant contribution to this situation was made by the view, which prevailed through the 1980s and much of the 1990s, that regulation is a burden on industry. It appears that under certain conditions the opposite may be the case, and that a challenging regulatory environment can become a stimulus to innovation.

(x) Finally, *there is now an urgent need to begin to conceptualise and demonstrate a performance standard to follow EPS08*. Such a standard, which would need to be consistent with the demanding sustainability goals of the white paper *Our Energy Future*, would bring together many of the proposals that we have made in this report. It would help to provide the construction and up-stream industries and the research community with long-term performance goals well into the next decade. The German Passivhaus standard (www.passivehouse.com) may well provide an appropriate model for a long-term UK energy performance standard.

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