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Regulatory standards and barriers to improved performance for housing ☆

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ABSTRACT

This paper argues that energy efficiency in dwellings probably needs to improve more rapidly, and to higher levels, than is likely to be achieved by current policy if global mean temperature rise is to be held to 2 K. History suggests that achieving real reductions in carbon emissions is not easy in this sector. Future progress will require significant changes in the way policy is formulated and implemented.

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"The mountains are high and the emperor is far away"

1. Introduction

The key goals of current energy and environmental policy are to achieve rapid and deep reductions in CO_2 emissions, and to ensure that the resilience of the energy supply system is retained and enhanced. These are radical goals, which go far beyond anything that has been attempted historically by technology policy in the UK.

This paper, which should be read as a work in progress, reflects on the policy tools available to achieve these goals in the housing sector, on barriers that any policy will need to overcome in order to achieve improved performance in housing and on the broader context within which construction industry policy is formulated.[1]

The paper is written on the basis of a total of 50 years of experience working on energy use in buildings, four major field trials of low-energy housing, numerous desk and laboratory studies, and more than 4 years involvement in the development of energy performance standards for new housing. We argue that energy efficiency in dwellings probably needs to improve more rapidly, and to higher levels, than is likely to be achieved by current policy if global mean temperature rise is to be held to 2 K. History suggests that achieving real reductions in carbon emissions in this sector is not easy, and that delivering them will require significant changes in the way policy is formulated and implemented. The main barriers to progress are located in policy, process and availability of human resources, rather than in technology as narrowly defined.

2. Unclarity around goals of climate change policy

Had this paper been prepared even 5 years ago, it would have focused on the necessity of establishing challenging strategic policy goals and on a programme of regulatory development designed to achieve them. On the surface this battle might appear to have been won through European Union energy and environment policy, specifically the EPBD and Action Plan for Energy Efficiency (European Parliament and Council, 2003; Commission of the European Communities, 2006), and the UK Government's proposed carbon targets for 2020 and 2050 (DTI, 2003; DEFRA, 2007).[2]

Both the EU and the UK Government have stated that the goal of climate change policy should be to prevent global mean temperatures rising by more than 2 K. Given that, in the long run, a 3 K temperature rise places the Greenland ice cap at risk, it is

☆ While the Government Office for Science commissioned this review, the views are those of the author(s), are independent of Government, and do not constitute Government policy.

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[1] While we have limited this paper to housing, many of the issues that we raise will also apply in general terms to non-domestic stock. This is, however, significantly more complex and difficult to deal with. Over the last 30 years, many conceptual and technological advances in energy saving have come first in the domestic sector. It is sometimes assumed that such advances can be unproblematically and rapidly transferred to the non-domestic sector. The most extreme example of this is energy rating. In the domestic sector, algorithms for energy rating were developed, published, tested and refined over more than 20 years before SAP became mandatory. In 2006, within a year of its development, with minimal testing and little possibility of peer review, SBEM became the primary tool for demonstrating compliance with Part L in the much more complex non-domestic setting.

[2] The Departments of State referred to in this paper are DTI, DEFRA, (D)CLG and the Treasury. Readers not familiar with the situation in the UK should be aware that names of these departments are subject to change. In May 2007, DTI (Department of Trade and Industry) became briefly DBERR and then BERR (Department for Business, Enterprise & Regulatory Reform). DETR became DTLR in 2001, ODPM in 2002 and, from May 2007, briefly DCLG (the Department of Communities and Local Government) and then CLG. DEFRA (the Department for Environment, Food and Rural Affairs) has remained unchanged in name (and has retained its "D") since its creation in 2001. In October 2008, the creation of a new Department for Energy and Climate Change (DECC) was announced, which combines the climate change group of DEFRA and the energy policy group of BERR.

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hard to argue that this warming limit is too low. Recent scientific work (Meinshausen, 2006; den Elzen and Meinshausen, 2006) suggests that to have a better than 50 per cent chance of achieving this, a ceiling on greenhouse gas concentrations of 450 ppm CO_2 equivalent would need to be enforced. Since the atmospheric concentration of greenhouse gases is currently around 427 ppm CO_2 equivalent and is growing at 2–2.5 ppm/year (EEA, 2006), this ceiling is likely to be reached in the next decade.

There is an emerging view that a 450 ppm CO_2-equivalent ceiling would require industrialised countries such as the UK to reduce their emissions by around 80 per cent by 2050. In this light, the 2050 reduction target of 60 per cent advanced in the White Paper, Our Energy Future and again in the Draft Climate Change Bill (DTI, 2003; DEFRA, 2007) appears insufficient. One is therefore forced to conclude either that reductions in CO_2 emissions will need to be significantly deeper and quicker than envisaged in Our Energy Future, or that the goal of a 2 K warming limit will need to be relaxed.[3]

Regardless of the reduction targets set for the UK as a whole, there remains the problem of setting robust sectoral targets. Given the widespread view that many of the easiest wins using existing technology are in the built environment, one might expect reductions in this sector to be deeper and quicker than in the economy generally. The problem is that the potential for long-run reduction in emissions is linked only weakly to the scope for short-run reductions. The crucial factor determining short-run reduction targets is the rate of turnover of infrastructure. Much of the infrastructure in the housing sector is long lived. While deep reductions are possible over a period of several decades, costs will rise significantly if timescales are foreshortened.

The practical consequences of this unclarity in the short to medium term are significant. UK climate change policy goals as currently stated provide an insufficiently clear basis for developing concrete short- and medium-term policies for the housing sector.

3. Regulatory confusion

In an ideal world, one of the main functions of regulation would be to provide the domestic construction industry and its suppliers with a clear, coherent and credible long-term route map towards low-carbon, energy-efficient housing. At first sight it would appear that the proposals in *Building a Greener Future* (DCLG, 2006) provide a route to zero-carbon new housing by 2016. However, this route map suffers from significant deficiencies.

First, it is not clear that a "zero-carbon" goal is likely to be more effective than a more practically achievable goal such as an 85 or 90 per cent carbon reduction target.[4] The zero-carbon target is, in our view, likely to divert scarce financial and human resources from the crucial task of minimising energy use in new and existing housing, and in particular of improving the performance of the dwelling envelope and towards renewable energy in housing. Our experience, most recently through the Stamford Brook field trial (Wingfield et al., 2008), suggests that achieving significant advances in building envelope performance will, on its own, present the industry with a very difficult task whose success cannot be taken for granted.

Any insistence on on-site renewables is likely to increase significantly the total cost of the renewable energy delivered in conjunction with new housing. Like most technologies, many renewables display strong economies of scale. In the case of wind, these are compounded by differences of more than an order of magnitude in the density of the wind resource between typical urban locations, and offshore and good rural onshore sites. A preliminary analysis suggests that the additional cost of making all new homes zero carbon by using on-site renewables would be sufficient to upgrade all existing homes to something like Code Level 3 by 2050. This would make it possible to reduce carbon emissions by almost 80 per cent (a factor 4 reduction), depending on the extent of decarbonisation of electricity generation (Lowe, 2007b).

There are also potential inconsistencies in the definition of on-site renewables. For example, biomass can count as on-site if burnt in individual buildings or developments. However, very few buildings or developments will produce their own biomass. Most will be imported from other parts of the UK, Europe or elsewhere. In many cases, imported biomass, which would comply with the definition of on-site renewables, will come from further afield than remote grid-linked renewables such as offshore wind, which would not comply. Distinctions such as that between biomass-by-lorry and wind-by-wire appear to have been insufficiently considered in framing the definition of on-site renewables.

This problem could be overcome by extending the definition of the zero-carbon target to include remote off-site renewables such as offshore wind. This would, however, reduce the zero-carbon target to little more than an accounting exercise. It is not obvious that the best way to fund large-scale deployment of renewables is by tying it to new house construction. The rate of construction of renewable generation capacity needed to approach the UK's 15 per cent target for 2020 exceeds by roughly an order of magnitude what would be realised though a connection with new house construction.[5]

In addition, there is a risk that the zero-carbon target will result in limited domestic biomass resources being used for heating, rather than for strategically and thermodynamically more valuable uses such as transport fuels and combined heat and power, and a possibility that the target will further stimulate the already deeply problematic global trade in biomass (Zah et al., 2007).

A perceived general failure to achieve the zero-carbon target may have a number of unfortunate results. Both Government and industry might be tempted not to acknowledge the problem, and instead to redefine the target. Both perceived failure and attempts to define it away could lead to a loss of political capital. For all of these reasons, we consider that zero carbon makes a very good aspirational target but a poor goal for regulation.

Separate from our concerns about the zero-carbon target, there appears to be a significant problem with the system for calculating carbon targets in the Code for Sustainable Homes. This particularly affects targets for Code Levels 3 and 4, where its effect is to make it easier to achieve compliance with the CO_2 emissions thresholds for buildings heated with electricity than with the less carbon-intensive direct combustion of gas. As a result, Code Levels 3 and 4, which are supposed to represent significant intermediate steps on the road to zero carbon, are likely to push designers towards all-electric solutions, with reduced overall CO_2 savings compared to gas-heated designs, which comply with the 2006 edition of Part L of the Building Regulations (ODPM, 2006). This problem has already caused consternation among designers of low-energy dwellings, and

[3] As this paper was being finalised, the Climate Change Commission announced that it would advise the UK Government that Britain should adopt an 80 per cent emissions reduction target for 2050.

[4] In approximate terms, such a reduction would be equivalent to Code Level 4 and to the Passivhaus standard.

[5] Roughly 400 MW of high-quality offshore wind capacity would be needed to offset the carbon emissions from a year's production of 200,000 new dwellings built to Code Level 4 or the roughly comparable Passivhaus standard. To meet the UK's 15 per cent renewables target through the deployment of renewable electricity generation might require some 40 GW of offshore wind capacity, implying an installation rate of around 4 GW/year from 2010 onward.

unless corrected quickly could undermine the Code. Although this may appear a narrowly technical point, in practice it is important. During a period of rapid innovation, it is vital that the Government sends consistent and credible signals to the construction industry.

It is interesting to reflect on how it is that we have ended up in such a situation, and on the lessons that might be learnt. Responsibility for developing and implementing policy for energy and environmental performance of housing is split between four different government departments: CLG, DEFRA, BERR and the Treasury. CLG is responsible for the Building Regulations. DEFRA is responsible for the Standard Assessment Procedure for Energy Rating of Dwellings (SAP; Anon, 2006) and is the primary source of information on matters such as carbon intensities of energy vectors. BERR has been responsible for the main programme of construction industry research, Partners in Innovation, while the Treasury is responsible for matters such as the shadow price of carbon used to develop regulation. Despite the fact that the bulk of building science and energy expertise in the Government resides in other departments, the Treasury was responsible for the announcement, late in 2006, of plans to move towards zero-carbon new housing, and for the policy of not allowing off-site renewables to contribute towards carbon budgets for new dwellings.

Communication between the teams responsible for policy in the different departments is imperfect. Even within departments, different teams pursue different agendas. Within CLG the teams responsible for Building Regulations (particularly Parts L and F) on the one hand, and for the Code for Sustainable Housing on the other are largely separate. Each of these teams has its own separate team of technical advisors. While these teams have been aware of each other, effective communication has proved problematic, in part because of tensions between the different principal stakeholders and between the teams themselves.[6]

Regulatory confusion is enhanced by inadequate resources for regulatory development and enforcement. Although it is the most important and far-reaching change in energy performance standards for new housing to date, the 2006 revision of Part L is still not complete. Work on the 2010 revision has only just begun. The budget for the departmental team responsible for Building Regulations has been cut and key members of the team are being lost. The parlous state of Building Control is consistent with the view widely accepted within the Government and Civil Service that the regulatory burden on industry needs to be reduced. But it is at odds with the view widespread in the construction industry that Building Regulations need to be vigorously and rigorously enforced to ensure a level playing field (Lovell, 2008).

4. Absence of coherent energy supply policy for housing

The confusion around carbon targets described above is symptomatic of, and compounds, the absence of a clear medium-to-long-term energy supply policy for the UK domestic sector, despite the commissioning of work in 2004 that clearly indicated the importance of interactions between dwelling energy performance, energy infrastructure and overall carbon emissions.

In addition to carbon emissions, the central question that such policy would need to address would be "what after gas?". The present answer, as far as it can be interpreted, appears to be a mix of micro-generation, all-electric heating with CO_2 emissions offset by photovoltaics, and combustion of biomass. Problems with this policy include:

- the poor performance and high costs of most forms of micro-generation (Carbon Trust, 2007; BRE, 2007; Rhodes et al., 2007; see also earlier comments),
- the inappropriateness of encouraging electric resistance heating when marginal plant is likely to be fossil fired for at least another decade, and when generation and transmission capacity are both likely to be under pressure as a result of growing demand and retirement of significant tranches of existing capacity,[7]
- the likelihood of local air quality problems from large numbers of small biomass installations (Anon, 2007),
- the diversion (as noted previously) of a large fraction of available biomass into direct provision of low-temperature heating as opposed to the thermodynamically more valuable conversion routes through CHP[8] or to liquid fuels for transport and
- the absence of clear policy for urban-scale energy systems such as District Heating.

Our conclusion is that the development of effective policies for energy use in buildings cannot be undertaken in the absence of explicit policies for energy supply, and specifically heat supply.[9]

5. Lack of data on energy performance of new and existing housing

A major problem with energy performance standards is that there is little empirical evidence on their actual impact. Work on individual developments shows that actual energy use can significantly exceed predictions (Carbon Trust, 2007; Lowe et al., 2007; Sanders and Phillipson, 2006). The causes can include poor airtightness, poorly installed insulation, poor boiler efficiency and high heat losses from storage and distribution systems for hot water.

The closest to a statistically rigorous exploration of the impact of successive revisions to Part L of the Building Regulations that we are aware of is presented in Fig. 1 below. This suggests that newer dwellings do consume significantly less gas. We are unable to say what proportion of the effect is due to the requirements of the Building Regulations and what to concurrent changes in variables such as dwelling size.

Fig. 1 suggests that measures up to 1990 and possibly up to 1995 may have reduced gas consumption by just over 20 per cent. The data is, however, noisy, and there is currently no data for dwellings built after 2000. So it is not possible to confirm the impact of the 2002 and 2006 revisions to Part L. This is unfortunate, because we would expect to see the steepest decline in gas use in this period. The projected decline (dashed line) over the period from 2006 to 2016 can be described only as precipitate.

The methodology behind Fig. 1 is crude. Significantly better information on the impacts of improved dwellings construction standards could be achieved if researchers had better access to data. The ability to undertake such analysis, in as close to real time as possible, will be of strategic importance for policy development and for improving the energy performance of housing over the coming decade. Evidence on the actual performance of buildings

[6] Support for the Code for Sustainable Homes has been provided by BRE, while support for Building Regulations has been provided by the FMnectar Consortium, of which the authors were members, led by Faber Maunsell. The wording of this section is based primarily on personal observation of the process.

[7] We note that the carbon intensity for grid electricity used in SAP and Part L of the Building Regulations (0.422 kg/kWh) underestimates by around 30 per cent the 0.5–0.6 kg/kWh range likely over the next decade.

[8] If designed to operate flexibly, such CHP capacity can complement generation from intermittent renewables.

[9] We note and have responded to BERR's very recent call for evidence on "Heat" (BERR, 2008; Lowe and Oreszczyn, 2008).

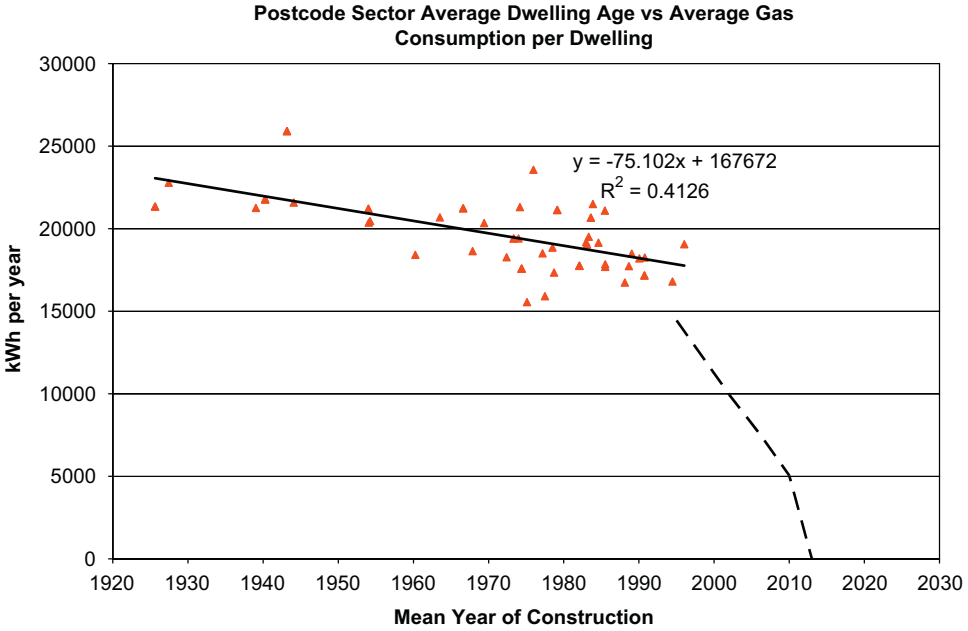

Fig. 1. Annual gas consumption versus age of dwellings in Milton Keynes (courtesy of Alex Summerfield, Bartlett School of Graduate Studies). Raw data from the DTI online database of energy use by postcode sector. Each point represents between several hundred and 2000 dwellings. Milton Keynes was chosen for this study because of its homogeneity compared with other UK connurbations plus the access to mains gas for all dwellings. The dashed line indicates the expected trajectory of performance based on implementation of the 2002 and 2006 revisions of Part L and the proposals in *Building a Greener Future*.

would reduce the current tendency throughout the Government to confuse rhetoric with action, and to view energy policy primarily as a problem of market organisation, rather than as a complex socio-economic-technical problem whose ultimate solution must revolve around engineering and infrastructure.

6. Weak research base

The lack of data on energy performance of new and existing housing is symptomatic of a long-term lack of UK research into low-energy buildings. It has been compounded by a recent steep decline in funding for all applied construction research, public support for which fell by 69 per cent between 1997/1998 and 2004/2005 (House of Lords Science and Technology Committee, 2005). This decline has been compounded by a mismatch between the research culture and objectives promoted by the EPSRC, historically the main funding body for engineering and physical science, and the nature and requirements of applied research in construction. This mismatch has made it difficult if not quite impossible for the EPSRC to engage with detailed, context- and process-bound problems that arise from the deployment, as opposed to the initial development of technology.

Buildings and energy research has for many years more closely resembled a cottage industry than a mature academic sector, with few large-scale or rigorous investigations, and limited high-quality science. The increases in overall funding and new funding mechanisms for science and engineering that were announced in 2006 and 2007 will begin to address the problem, but the new money cannot immediately overcome a deficit of human capital that has accrued over the last quarter century.

7. Lack of preparedness in the construction industry

From the mid 1960s to the end of the century, it has been possible for the construction industry to meet the demands of successive revisions to Part L by making incremental improvements to construction practices. The proposed standards for 2010 and 2013 can no longer be met in this way. The UK house building industry is, in our view, almost completely unprepared for the challenges posed by these standards. It neither has the technology to deliver on them, nor knows what would be required to do so—to the extent that the initial response of senior industry figures to the targets and timetable set out in the consultation document *Building a Greener Future* (DCLG, 2006) is reported to have been overwhelmingly positive.

Public support and rhetoric over the last 15 years have focused on support for large construction firms, ignoring the fact that a disproportionate fraction of effective innovation has been undertaken by small companies. The way forward here is probably not to try to turn large companies into small ones, but to identify those structural features of large companies that impede rather than facilitate training, education and learning from experience. The most important appear to relate to high rates of sub-contracting (Clarke, 2006), and the dominance among directly employed staff of backgrounds in management and cost control as opposed to the technical aspects of house design and construction. The present situation appears to stem in large part from decisions taken by the Government in the 1960s and 1970s to relax the definition of self-employment for workers in the construction industry. The Government has recently begun to reverse the process (Clarke, 2006), but more may need to be done.

8. Appropriate understanding of the complexity and difficulty of the problem

There is a perception in the Government that energy efficiency in buildings is straightforward and requires minimal investment. However, empirical evidence and experience suggest that it will be neither particularly easy nor particularly cheap to reduce heat demand in buildings.[10]

[10] It remains the case that significant reductions in electricity use are achievable by replacing existing electrical appliances by the most efficient available, but the operation of the market for efficient appliances is obscured by

A full justification of this statement would be as long as, if not longer than, the rest of this paper. We will nevertheless attempt to give a brief indication of its basis here. Sanders and Phillipson (2006) have suggested that the real energy saving achieved by one of the most important short-term energy conservation measures available to the UK—filling wall cavities and insulating roofs in existing dwellings—is approximately half as effective as previously thought. Most of the reduction in performance arises from the practical impossibility of achieving continuity of insulation and dealing with thermal bridges in both situations. Lowe et al. (2007) have confirmed that a previously ignored heat loss mechanism associated with party wall cavities approximately doubles the fabric heat loss of terraced houses built to a standard slightly more stringent than the 2006 Building Regulations (Part L). Two major recent studies conducted by the Carbon Trust and the EST, have established that the *in situ* efficiency of condensing boilers in UK dwellings is around 7 percentage points less than expected on the basis of the SEDBUK test (Carbon Trust, 2007). The capital cost of heat saved by external insulation of solid walls is of the order of 1500 £/kW, around an order of magnitude higher than the capital cost of heat saved by insulating uninsulated roofs. Analysis of the cost-effectiveness of envelope insulation measures reported in the Regulatory Impact Assessment of the 2006 revision of Part L of the Building Regulations was conducted using a 3.0–3.5 per cent discount rate evaluated over 60 years, and with an assumed social cost of carbon equal to more than 70 £(2000)/t.

Again it is interesting to reflect on how the sector has got itself into this situation. The technology to reduce heat loss in buildings has been available for over 30 years. Theoretical understanding of energy flows in buildings has been developed to a very high level of sophistication over this period. Modest levels of building insulation are very cost-effective compared to renewables or other low-energy technologies, and the UK has some of the least-energy-efficient buildings and until recently, had some of the most lenient regulations in northern Europe. However, a large proportion of the most cost-effective measures in existing and new UK housing have already been undertaken.

Prompted initially by the large economic and social benefits of insulating uninsulated dwellings, researchers and campaigners have spent the last 30 years urging the Government to take action to improve energy efficiency in this sector. In the process they may have oversold the long-run performance of available technologies. The Government has finally bought the message, and assumes that radical targets can be achieved quickly.

What has been largely absent from the debate to date has been high-quality empirical evidence on the actual performance of low-energy housing, on technical and procedural difficulties faced by designers and builders of energy-efficient housing, and on where and how these difficulties have been overcome. A continued dearth of such data is likely to lead to a progressive widening of the gap between theory and practice, and ultimately to failure to achieve difficult but essential strategic goals.

9. The way forward

In writing this final section, we have drawn heavily on a report written for Building Regulations Division of CLG (Lowe, 2007a).

In our view, achieving the goals implicit in *Building a Greener Future* and the *Code for Sustainable Homes*, will require:

- building human capital,
- building knowledge,
- building institutions and systems,
- building the supply chain, and, perhaps most importantly,
- clear leadership and appropriate resourcing for change.

9.1. Building human capital

It appears that education and skills are particularly important during times of rapid technological change. The implication is that the historical trend towards lower levels of skill in the UK construction industry will need to be reversed to give the industry as a whole a reasonable chance of achieving Code Level 4 within 6 years.

There are nearly 200,000 employees in the housebuilding industry. A significant proportion of these will have a part to play in the construction of houses to Code Level 4 of the Code for Sustainable Homes. All, except those retiring in the interim, will need to be trained over the next 5 years in the fundamentals of energy-efficient house construction.

Systems for training recruits to the industry need to be re-appraised. The construction industry, which with the demise of traditional apprenticeships became a consumer of human capital, needs, once again, to become a producer.

9.2. Building knowledge

A strategic and structured approach to the gathering of evidence on construction systems, materials, heating and ventilating systems, and crucially on the overall impact of such systems on actual CO_2 emissions from occupied dwellings, will need to be put in place to support the development and implementation of the proposed 2010 and 2013 standards. It is needed to provide CLG with the confidence to regulate, and to give the industry a firm footing to make onerous targets a reality. If the drive towards Code Level 4 is not evidence based, it is likely to fail.

Much expertise already exists in detailing and constructing low-energy housing. Much of this expertise is on the fringes of the mainstream construction industry in organisations such as the Association for Environmentally Conscious Building (AECB). Ways need to be found to make this expertise available to the wider construction industry.

A substantial fund of experience now exists in Germany, Austria and Switzerland on how to build to the Passivhaus standard (broadly equivalent to Code Level 4). It will be necessary to fund a major programme to transfer the fruits of this experience to the UK construction industry.

The most important means of building knowledge is likely to be a demonstration programme. It needs to be large enough to provide an exemplar development in every community, to cover all main dwelling types and to demonstrate a wide range of construction systems. It should ensure that by 2013, a large proportion of construction industry employees have been involved in a Code Level 3 or 4 project,[11] or know colleagues who have.

The poor availability of expertise capable of delivering dwellings to this level probably limits the first round of such a programme to about 100 dwellings. They need to be commissioned in 2008 for

(*footnote continued*)
absence of energy information, by energy-rating systems that, through being based on scale-independent metrics such as energy use per unit volume, systematically reward large appliances (refrigerators and freezers), and by continuous exposure of the public to advertising and para-advertising that emphasise style at the cost of energy performance in areas ranging from lighting to televisions. Technical developments in infotainment have, in the last decade, made possible the fitting of television sets of previously undreamt-of sizes into ordinary houses.

[11] …assuming that the problems with the Code for Sustainable Homes, described earlier, are addressed in the meantime.

completion in 2009 or 2010. The programme as a whole needs to deliver tens of thousands of exemplars by 2013.

9.3. Building institutions and systems

It is impossible to envisage the successful implementation of a CO_2 standard as demanding as that outlined in *Building a Greener Future* in the absence of enforcement. Ways must be found to breathe new life into Local Authority Building Control Organisations, and to address the conflicts that arise from competition between public sector and private sector Building Control Bodies (BCBs). Ways must be found to ensure that all BCBs can recruit, train and retain good staff and that they have sufficient time to assess and control the energy performance of new and refurbished buildings. Consideration should be given to reorganising Building Control on a national basis, with clear terms of reference and an independent stream of funding.

It is hard to envisage significant progress in the absence of a strong, well-funded Building Regulations Division, staffed by exceptional individuals. Recent reductions in the strength of Building Regulations Division are in our view a mistake.

9.4. Building the supply chain

CLG and BERR need to take a view on the importance of a domestic supply chain capable of delivering Passivhaus components and systems to the UK housebuilding industry. The goals of *Building a Greener Future* will render a large part of the existing construction supply chain obsolete.[12] The political problems that may stem from this should not be underestimated. The industry may well take the view that its difficulties stem from a failure on the part of the Government to provide adequate support for research and development and to signal sufficiently far in advance what would be needed in the second decade of the 21st century. If the view is taken that a domestic supply chain is essential, a programme has to be initiated immediately to convert the existing supply chain. The form of such a programme requires further development, but one component might be a series of "golden carrot" competitions.

10. List of immediate actions for government

It will be clear from the foregoing that the Government has a key role to play in setting strategic goals in this area and implementing policies to achieve them. In this final section of the paper, we draw together a short list of immediate actions that we consider necessary for progress. We suggest that Government should:

- Undertake a strategic review of carbon targets, policies and technologies for new and existing housing over the next 50 years.
- Consider rebranding the "zero-carbon" target for dwellings as aspirational and adopting a revised regulatory target of 85–90 per cent reduction in carbon emissions by 2016.
- Undertake a critical technical and economic comparison of on-site and off-site renewable energy.
- Address problems with CO_2 targets in the Code for Sustainable Homes and ensure better integration between the Code and Building Regulations.
- Improve cooperation within the Government, for example by establishing one well-resourced cross-government team that helps define policy and coordinates implementation. This team should commission and use the evidence base required to develop policy and meet targets in this area.
- Integrate demand-side and supply-side policies for energy performance in housing.
- Improve the research community's access to energy and building data to provide the evidence base for policy and to help meet carbon targets.
- Encourage more rapid and better quality research on energy use in buildings to support policy.
- Review the impact of the patterns of sub-contracting and self-employment of construction workers on the industry's capacity for innovation.
- Reappraise the training of construction workers in the light of the need to develop a capacity for construction to Passive House standard and Code for Sustainable Homes Level 4 within 5 years.
- Develop improved mechanisms to transfer knowledge between the UK and other northern European countries.
- Carry out a large-scale UK demonstration programme of Code Level 3 and 4 dwellings.
- Reorganise and restructure Building Control and ensure appropriate funding and staffing for the Building Regulations Division of CLG.
- Work to transform the construction industry supply chain through actions such as a programme of "golden carrot" competitions.

[12] Windows provide an obvious example. Mass-produced and cost-effective Passivhaus windows are now available from a number of continental suppliers, but with the possible exception of a range of windows supplied by the Green Building Store, the authors are unaware of comparable UK production. When, in 2010 or shortly after, such components become unavoidable in new housing, a large part of the domestic window industry will be at risk.

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