ZERO CARBON HUB

CARBON COMPLIANCE

SETTING AN APPROPRIATE LIMIT FOR ZERO CARBON NEW HOMES

FINDINGS AND RECOMMENDATIONS

February 2011

Zero Carbon Hub

The Zero Carbon Hub was established in the summer of 2008 to support the delivery of zero carbon homes from 2016. It is a public/private partnership drawing support from both Government and the industry and reports directly to the 2016 Taskforce.

The Zero Carbon Hub has developed five workstreams to provide a focus for industry engagement with key issues and challenges:

- Energy Efficiency
- Energy Supply
- Examples and Scale Up
- Skills and Training
- Consumer Engagement

To find out more about these workstreams, please visit www.zerocarbonhub.org.

If you would like to contribute to the work of the Zero Carbon Hub, please contact info@zerocarbonhub.org.

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London Office
62-68 Rosebery Avenue
London EC1R 4RR

Milton Keynes Office
NHBC House, Davy Avenue
Milton Keynes MK5 8FP

T 0845 888 7620
F 0871 813 0569
info@zerocarbonhub.org
www.zerocarbonhub.org

Supporters

The Zero Carbon Hub is very grateful to the following organisations who kindly supported the publication of this report:

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it's time to save energy

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NHBC Foundation
Housing research in partnership with BRE Trust

WILLMOTT DIXON

PREFACE

This report represents the next step along the road towards zero carbon homes. The report builds on the work which has already been undertaken, on the energy efficiency of the building fabric. It answers a key question: how much of the zero carbon objective can and should be delivered on-site?

The Zero Carbon Hub specialist Task Group was commissioned by the Housing Minister to recommend an appropriate national Carbon Compliance limit, to form part of the overall definition of a zero carbon home which will apply in regulations from 2016. The Group was asked to develop an evidence base and consider options which would represent a reduction of between 44% and 100% in carbon dioxide emissions permitted by 2006 Building Regulations.

The report sets out key results from an extensive exercise in modelling and reality checking which indicates the limits of what is generally feasible using today's knowledge of design and technology. It does not rely on the hope that new technologies will arrive to solve every problem, although it does recognise that new investment and innovation will be stimulated.

The report also highlights that zero carbon in general, and Carbon Compliance in particular, will come at a price. Someone will have to pay, so the costs are considered from a range of perspectives including society, the householder and the developer. The Group recognises that the cost of zero carbon new homes, together with other regulatory burdens, must not be so high that either the price of land or the selling price for new homes becomes uncompetitive with impact on housing supply.

On the other hand the intention of the zero carbon policy is to challenge the broader industry to make a full contribution to our low carbon, low energy future. It is equally important that this challenge be maintained.

To their great credit, the members of the expert Task Group who undertook this work have not ducked these and other difficult issues. Starting from a wide range of different viewpoints, they have recognised the strength of agreeing on a way forward. Their recommendations balance challenge with achievability. They have also highlighted some areas in which further work, and decisions, are now urgent.

The Zero Carbon Hub and I are very grateful to the individuals involved who invested so much time, energy and thought. Sincere thanks are also extended to their organisations – such a complex subject could not have been tackled without their full support.

I believe this report represents a real advance and I am confident that it will command support from a wide range of stakeholders. While the 2016 Regulations to which it mainly relates are still some way off, an early statement by Ministers in response to these recommendations will further build confidence that investment of time and money in developing solutions is soundly based and that the zero carbon objective is achievable and on track to be delivered.

David Adams
Director, Zero Carbon Hub and Carbon Compliance Task Group Chair

TASK GROUP TERMS OF REFERENCE AND REPORT STRUCTURE

At the end of July 2010 the Minister for Housing and Local Government commissioned the Zero Carbon Hub to establish a Task Group to test an appropriate level for Carbon Compliance within the context of zero carbon homes policy. To provide a framework for the group a Terms of Reference was developed which described: the policy aims of the Zero Carbon Homes initiative, the Task Group objectives, the Task Group considerations and the deliverables expected.

The Terms of Reference is available on the Zero Carbon Hub website www.zerocarbonhub.org.

The Zero Carbon Homes policy aims to:

- Reduce the energy demand of new homes.
- Support behaviour change through driving local/individual ownership and engagement with energy efficiency and carbon reduction.
- Remove barriers to delivery of new homes, by providing clear forward look on regulatory environment.
- Support localism through an increased role for localities in low-carbon energy planning and delivery.
- Help Government to meet renewable energy targets.
- Support energy security via support for renewable and decentralised energy.
- Push forward innovation in construction and affected sectors by requiring high technical standards.
- Future proof new homes, reducing need for retrofit later on.
- Economic spill overs to retrofit of existing stock.

The report comprises:

1) An Overview Report (this report, published in hard copy and on the Zero Carbon Hub website)
2) Supporting documentation (available on the Zero Carbon Hub website)
    - Terms of Reference
    - Carbon Compliance commercial overview
    - Carbon emission factors for fuels – methodology and values for 2013 & 2016
    - National or Regional weather: implications for Carbon Compliance
    - Building services options for 2016 (CIBSE Technical Think Tank paper)
    - Carbon Compliance policy considerations summary matrix
    - Carbon Compliance technical modelling assumptions
    - Technical summaries:
        - Carbon Compliance technical feasibility charts
        - Carbon Compliance technical feasibility slides
        - Carbon Compliance technical feasibility sensitivities
    - Modelling 2016 using SAP 2009 - Technical Guide

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ACKNOWLEDGEMENTS

The Zero Carbon Hub is grateful to all Task Group members and Work Group members for their contribution to this work.

The Task Group consisted of the following members:

Task Group Members:

Neil Cutland	AECB / Passivhaus Trust
David Ross	AECOM
Oliver Novakovic	BRE
Hywel Davies	CIBSE - Tech WG Chair
Ian Manders	Combined Heat & Power Association
John Tebbit	Construction Products Association
Liz Laine	Consumer Focus
Chris Baker	Davies Arnold Cooper
Steven Harris	Energy Saving Trust
Peter O'Connell	Federation of Master Builders
Melissa Taylor	Good Homes Alliance
Dave Mitchell	Home Builders Federation (HBF)
Jacqueline Fox	HBF / Barratt Developments
Derric Heyden	HBF / Barratt Developments
Michael Black	HBF / Bovis Homes
Dale Saunders	HBF / Taylor Wimpey
Jayne Lomas	Homes & Communities Agency
Roger Humber	House Builders Association (HBA)
Andrew Day	HBA / Countryside
Kirk Archibald	HBA / Fairview
Nigel Banks	Keepmoat
Paul Everall	Local Authority Building Control
Russell Reefer	Local Government Association
Robert Tudway	London Development Agency - Policy WG Chair
Neil Smith	NHBC
Stuart Pocock	Renewable Energy Association
Bill Gething	Royal Institute of British Architects
Richard Partington	Royal Institute of British Architects
Peter Rickaby	Royal Institute of British Architects
Anna Surgenor	UKGBC
Mark Driscoll	WWF
Zoe Leader	WWF

David Adams	ZCH - Task Group Chair
Ian Butterss	ZCH - Technical Lead (Comm WG)
Ted Chandler	ZCH
Mark Coulshed	ZCH - Report Author
Sarah Downes	ZCH
Ross Holleron	ZCH - Technical lead (Task Group)
Neil Jefferson	ZCH
Robert Macdonald	ZCH
Marco Marijewycz	ZCH - Technical Lead (Policy WG)
Rob Pannell	ZCH - Strategic Lead & Comm WG Chair
Tessa Parnell	ZCH - Technical Lead (Tech WG)
Clive Turner	ZCH
Alex Uregian	ZCH

Observers:

Nick Scott	BIS
Peter Whittington	BIS
Simon Brown	CLG
David Craine	CLG
Paul Decort	CLG
Henry Demaria	CLG
Rosie Smith	CLG
Alan Christie	DECC
Paul McCloghrie	DECC
Steven Scott	Scottish Government
Francois Samuel	Welsh Assembly Government

EXECUTIVE SUMMARY

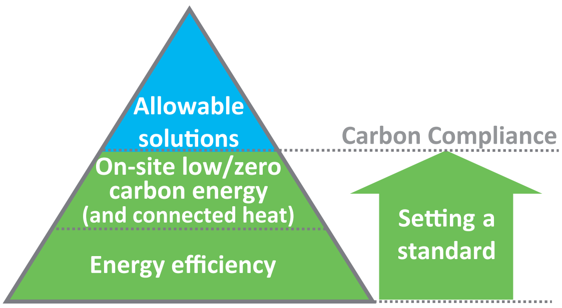
In July 2010 the Government confirmed its commitment to ensure that from 2016 new homes can be zero carbon. This ambition is very challenging. These homes are not simply the homes we build today with extra insulation. A low energy, zero carbon home is a complex combination of systems and products which must perform as expected.

Zero carbon homes are achieved by a combination of:

- Ensuring an energy efficient approach to building design
- Reducing CO_2 emissions on-site through low and zero carbon technologies and connected heat networks.

These first two steps are together referred to as **Carbon Compliance**. In addition, there is a third step:

- Mitigating the remaining carbon emissions through **Allowable Solutions**, which secure carbon savings away from the site.



This report is concerned with the limit which should apply to new homes from 2016. We were asked to consider a range of dwelling and development types and technologies, and to look at options for tightening the Carbon Compliance limit by between 44% and 100% compared with 2006 Building Regulations. As our starting point we have taken the Fabric Energy Efficiency Standard (FEES) for energy efficiency, which was the subject of a previous report[1], and focused on what overall level of Carbon Compliance can be achieved with various on-site energy generation technologies and further improvements to energy efficiency.

The report represents five months of effort by an expert Task Group which, together with associated work groups, comprised some 100 people from 50 different organisations. Members were drawn from the house building and supply industries, related professional bodies, trade associations, consumer representatives and bodies with a specific interest in environmental objectives.

Factors which have a bearing on the Carbon Compliance limit fall in three broad groups:

- Technical considerations – what is feasible with current technology and not dependent on site specific considerations;
- Commercial factors – what are the costs and benefits and their sensitivity to different Carbon Compliance levels;
- Policy issues – how Carbon Compliance contributes to, or is constrained by, other policies and external factors.

We have also noted some wider considerations which we believe should be reflected in the Carbon Compliance limit.

Technical feasibility

Technical feasibility has been modelled for a range of standard house types and sizes, using a variety of existing energy technologies and two fabric standards, FEES and a more demanding standard. Sensitivity tests have been undertaken for other technologies, house types and sizes. In total about 14,000 combinations of dwelling type, fabric standard, mix of technologies and carbon limits were modelled.

An earlier Zero Carbon Hub Task Group found[2] that setting Carbon Compliance standards as a percentage improvement over a previous standard is increasingly difficult to understand and at risk of causing perverse outcomes. In this report, therefore, we refer to Carbon Compliance in terms of an absolute limit on the predicted emissions of carbon dioxide (and other greenhouse gases expressed as equivalents) per square metre of internal floor space. This is measured as an amount in kilograms per square metre per year (kg $CO_{2(eq)}$ /m^2/year).

Modelling shows that most of the Carbon Compliance limits within the range we have been asked to consider cannot be achieved using current mainstream low and zero carbon (LZC) heat technologies alone. On-site LZC electricity generation is also required.

The mainstream technology for on-site LZC electricity generation is photovoltaic (PV) panels, which are usually installed on the roof and convert light to electricity. Other current technologies have limitations which mean they are not appropriate in many cases. They therefore cannot be used as the basis for national regulation, although where they are available they may offer significant benefits.

[1] *Defining a Fabric Energy Efficiency Standard*, Zero Carbon Hub, November 2009 [2] *Carbon Compliance for Tomorrow's New Homes*, Zero Carbon Hub, July 2010, recommendation C1

The model calculates the amount of PV required to achieve different levels of Carbon Compliance. The assumption applied was that if this amount exceeds 40% of total ground floor area of the building, it may be necessary to design homes to maximise solar benefits, which may not be technically feasible on every site. We have therefore taken 40% of total ground floor area as a proxy indicator for feasibility. It is not intended to suggest any preference for PV; developers would be free to choose any other approach which achieves the same performance.

Low carbon emissions may be achieved using shared or communal solutions which supply on-site heat and/or electricity to a whole development or by connecting to a local low carbon heat main. However, such solutions are not always available, for instance for small sites, and therefore cannot be used as the basis for national regulation.

Modelling shows that, using this indicator:

- the previous proposal for 2016 of a 70% reduction in carbon emissions (equivalent to a Carbon Compliance limit of 6 kg $CO_{2(eq)}$ /m^2/year) is not feasible in all cases;
- the performance of detached houses, attached houses, low-rise and high-rise apartments are different, so they should be subject to different limits.

Even where we have determined that an option is feasible, we recognise that the challenge to the industry may be substantial. Moreover, our modelling is not able to reflect the additional difficulties which may arise on specific sites, so a level of 'headroom' is also required. Whilst extensive modelling has been undertaken around relatively standard house types, we recommend that further modelling is undertaken on a wider range of types prior to formal consultation to determine if there are particular difficulties for some sub-categories of dwellings, including very small houses and those on particularly difficult small sites.

Cost

The additional cost of delivering zero carbon homes will comprise Carbon Compliance measures plus Allowable Solutions. The price for Allowable Solutions is not yet known. The analysis in this report uses an illustrative figure of £75 per tonne of CO_2 over 30 years[3]. Sensitivity analysis has also been undertaken for prices in the range of £50 to £200 per tonne[4].

If Allowable Solutions are priced at £75 per tonne, the capital cost of achieving zero carbon is higher when the Carbon Compliance limit is more stringent. The marginal additional cost of moving the Carbon Compliance limit by 1 kg is relatively small: between £80 and £175 per dwelling using 2016 projected costs[5].

By way of reference, the modelling suggests the following for a typical semi-detached house at a Carbon Compliance level of 11 kg $CO_{2(eq)}$ /m^2/year and a detached house at 10 kg $CO_{2(eq)}$ /m^2/year both using a gas boiler and PV:

Cost of Carbon Compliance:	Semi Detached		Detached	
	2010 prices	2016 prices	2010 prices	2016 prices
Capital cost over 2006 Regulations	£8,500	£4,800	£12,900	£7,600
Capital cost over 2010 Regulations	£6,700	£3,500	£9,700	£5,400

Total cost of Zero Carbon:	Semi Detached		Detached	
	2010 prices	2016 prices	2010 prices	2016 prices
Total cost over 2006 Regulations	£13,700	£10,000	£19,800	£14,500
Total cost over 2010 Regulations	£11,900	£8,700	£16,600	£12,300

Where Allowable Solutions represent £5,200[6] for the semi detached and £6,900 for the detached.

For a semi detached dwelling without access to a gas supply for heating, using an air source heat pump and PV the net additional cost of zero carbon, beyond what is required by 2010 Regulations (assuming an electric panel heater), would be £10,300 at 2010 prices (£4,900 at 2016 prices).

Any additional costs imposed on a house building scheme may make it commercially unviable. In practice, house builders already face a range of regulatory costs, including the requirements of the local authorities for affordable housing and for contributions under section 106 or the Community Infrastructure Levy in addition to other national regulations. They cannot recover such costs directly through the sale price, as that is determined by the wider market, so these additional burdens have historically been absorbed either through house price inflation and / or reflected in the price they paid for land. Achieving zero carbon will require either a reduction in land price, moderation of the local authority requirements, reduction in the burden / costs of other regulations, the willingness (and ability) of house purchasers to pay more or a combination of these responses. Failing this, there will be an impact on the

[3] As adopted in DCLG *Zero Carbon Homes: Impact Assessment (December 2009)* [4] The range used in the *Zero Carbon Homes: Impact Assessment (December 2009)*
[5] Based on PV. At 2010 prices the costs range between £280 and £610 [6] Assuming Allowable Solutions cost of £75 per tonne over 30 years

viability of house building schemes and the delivery of new homes, noting that in some areas of the country land value is currently such that schemes are already not commercially viable.

Within this context, however, our modelling shows that tightening the Carbon Compliance limit (within the range we were asked to consider) has only a minor impact.

Policy issues

Whatever limit is set for Carbon Compliance, the target of zero carbon is still achieved as the balance being made up through Allowable Solutions. However, the wider context needs also to be reflected. We sought a wide range of advice on other policies and external factors which may be relevant. Our analysis suggests that a more stringent Carbon Compliance limit delivers modest benefits:

- to householders in terms of reduced energy bills over time even when maintenance and replacement costs are taken into account.
- at a society level, the carbon cost effectiveness is similar to the Governments carbon price projections[7].

Carbon compliance measures are also seen by some to offer a stronger assurance of true carbon savings than off-site measures such as Allowable Solutions, where it is harder to be sure that the benefits are truly additional to what would have occurred anyway. The benefits may also not accrue to the householder. Addressing this risk should be an important feature of how Allowable Solutions are defined.

For a range of other issues our general conclusion is that, while many of these are very significant in their own right, their impact on the specific question of where the Carbon Compliance limit should be set is negligible. Among these are:

- Householder health and well-being
- The need for desirable homes on a mass scale
- Deliverability of new homes
- Energy efficiency and energy security
- Monitoring and enforcement
- Consumer behaviour and perceptions
- The impact of UK targets for renewable energy and CO_2 emissions

Wider considerations

Design v built performance A previous Zero Carbon Hub report[8] drew attention to the potential gap between the calculated (designed) performance of new homes and how they perform when built. This issue is potentially crucial. If the gap exists, then low energy homes will not meet expectations; and by closing the gap we can achieve significant carbon savings. We therefore agree with the earlier report that the Carbon Compliance limit should apply to **built** performance (post construction), not **designed** performance[9].

Averaging across a development It should not be necessary for each individual dwelling on a development site to achieve the Carbon Compliance limit, so long as the aggregate limit is achieved by the development as a whole. This will help to provide flexibility, and avoid unnecessary restrictions on design and place-making. The specific details need to ensure that anomalies are avoided such as from development phasing. Implications for house purchasers should also be considered.

National v regional weather Our modelling shows that differences in regional weather patterns make a significant difference to actual carbon emissions from otherwise identical homes. At present a standard national weather assumption is used to demonstrate compliance. A range of options exists for matching carbon performance region by region more closely to whatever national standard is set. There are significant consequences for some options and we are not recommending any particular approach. However, it is important that the basis for the weather assumption is confirmed by Government when the Carbon Compliance limit is announced.

Localism While we recognise the interest and support given by local authorities to the wider objective of reducing carbon emissions, we consider that there should be no local power to set a different limit for Carbon Compliance, or to make other related stipulations. However, we recognise the weight attached by Government to localism, and have made some specific recommendations in case Ministers wish to allow local authorities some flexibility in this area[10].

[7] *Referencing the DECC Traded and Non traded carbon prices* [8] *Carbon Compliance for Tomorrow's New Homes*, Zero Carbon Hub, July 2010, pages 40-44
[9] See also *Carbon Compliance for Tomorrow New Homes Report available at www.zerocarbonhub.org* [10] *The LGA do not support the Task Groups call for there to be no local powers to set a different Carbon Compliance limit. However, they do support the specific recommendations made 9a – d on page 9*

Carbon intensity of the grid We note that over the years following 2016 the carbon emission factors for gas and grid electricity are likely to change and, at some point, the relative attractiveness of gas and electrical options (in terms of Carbon Compliance) may reverse. These effects are too speculative to steer our recommendations for 2016, but they are worth noting as they may feature strongly when regulations are revised again in 2019.

Determining the Carbon Compliance limit

We have not found any single consideration so weighty that it leads the Task Group immediately to a clear conclusion on the Carbon Compliance limit. We recognise that there is a range of arguments for setting a limit that is more, or less, stringent.

Different members of the Task Group attach different weights to the various considerations. However, we recognise that from any viewpoint there is considerable strength in an agreed set of recommendations to Government. Following much debate the following recommendations were agreed[11], to apply to 'built' performance within 2016 Building Regulations[12]:

10 kg $CO_{2(eq)}$ /m^2/year for detached houses

11 kg $CO_{2(eq)}$ /m^2/year for attached houses

14 kg $CO_{2(eq)}$ /m^2/year for low rise apartment blocks (four storeys and below).

We consider that further specialised work is needed before a limit can be set for high rise apartment blocks of five or more storeys.

These recommendations apply to **built** performance. For this reason the recommendations *cannot* be directly compared with current standards. However, in *addition* to any potential carbon savings achieved by moving from designed to built performance, the % improvements on the 2006 standard would be:

- 60% for detached houses
- 56% for attached houses
- 44% for low rise apartment blocks

Rebasing

Our analysis in this report is based on current assumptions for a range of factors: these include the assessment methodology (for which we have used a modified version of SAP 2009), carbon emissions factors, and other parameters. These and other factors will have changed by 2016. Our modelling and calculations will need to be revisited (rebased) in due course to reflect these changes. This may mean that the particular recommended Carbon Compliance limits also need to be adjusted to ensure that the standard dwellings that 'complied' under the old assumptions do so when the new assumptions are applied. This may also be the opportunity to accommodate any findings from more extensive modelling of specific house types and work on closing the potential performance gap.

Implications

These recommendations represent a very challenging, but we believe a deliverable, national minimum standard for 2016 Building Regulations. The level of this challenge should not be underestimated especially for some very small or infill sites where options may be more limited.

The effect of introducing the Carbon Compliance standard in 2016 Regulations will not be seen immediately, since sites which are already in the process of being built will not be subject to the new requirements. Over time the proportion of new homes completed to this standard will increase and, by 2020, it is likely that most new homes will be zero carbon.

To absorb the additional cost of zero carbon (see page 6) will require either a reduction in land prices, reduction of the requirements of local authorities, reduction in the burden / costs of other regulations, the willingness (and ability) of house purchasers to pay more or a combination of these responses. Failing this, there is likely to be an impact on the viability of house building schemes and the delivery of new homes.

House builders will need to be fully aware of these costs when purchasing land and the energy (and hence carbon) strategy for a site will also become one of the primary design factors. Planners will also need to recognise this when considering applications.

This report highlights the need for the wider house building industry to change significantly in order to achieve the standards, not least to ensure that built performance is in line with designed performance. This will have an impact on every aspect of the housebuilding process including master planning, detail planning, design, modelling tools, construction/energy products, construction methods / skills and quality assurance. The challenge may be greatest for smaller house builders. For this reason, Government needs to make its decisions promptly to stimulate innovation and give the wider industry the time to respond.

[11] Although agreed by all at the time the HBA subsequently withdrew their support for the recommended levels for houses

[12] Based on a modified version of SAP 2009. A technical paper is available on the Zero Carbon Hub website to allow modelling with standard industry SAP tools

RECOMMENDATIONS

Carbon Compliance Limits

1. The Carbon Compliance limit should apply to 'built' performance. See page 36

2a. The Carbon Compliance limits for built performance from 2016 should be[13]:

- 10 kg CO2(eq) /m²/year for detached houses
- 11 kg CO2(eq) /m²/year for attached houses
- 14 kg CO2(eq) /m²/year for low rise apartment blocks (four storeys and below).

See page 46

2b. Further modelling should be undertaken on a wider set of dwellings including very small houses and those on particularly difficult small sites, prior to formal consultation. See page 47

Regional weather

3a. The weather assumption for compliance calculations should be further considered by Government and a provisional view should be expressed when the Carbon Compliance levels for 2016 are announced, and full consultation undertaken with the 2013 regulations. See page 41

3b. A mechanism should be implemented to ensure that Allowable Solutions does not over calculate residual emissions nationally. See page 41

3c. Should a regional approach to weather be implemented, a review of the number of, and appropriate drawing of boundaries between, 'regions' should be undertaken. See page 41

Designed vs built performance

4a. From 2020 the test results distribution should demonstrate that at least 90% of all dwellings would meet or perform better than the designed energy / carbon performance. See page 36

4b. An industry / government group should be established to oversee the process of measuring and addressing the potential gap between designed and built performance as described in the Carbon Compliance Task Group file note (see Appendix). See page 36

Development averaging

5a. There should be an option to achieve compliance on a development by reference to the aggregate of the limits which would otherwise apply to the individual dwellings on that development. See page 37

5b. Rules should be developed to ensure that this option provides appropriate flexibility yet delivers overall compliance. See page 37

CO2 emission factors

6. The methodology for determining carbon emission factors set out in the Zero Carbon Hub's previous report Carbon Compliance for Tomorrow's New Homes, published in July 2010, should be adopted in the next revision of Building Regulations. See page 13

High-rise

7a. Further work should be undertaken, by a specialist group with expertise in the development of high rise and non-domestic buildings, in order to develop proposals for appropriate Carbon Compliance levels for high rise blocks. See page 20

7b. The high rise specialist group should also develop a practical definition to distinguish between low and high rise apartments. See page 20

Localism

8. There should be no local power to set a different limit for Carbon Compliance, or to make other related stipulations[14]. See page 41

Should the Government wish local authorities to be able to set a more stringent Carbon Compliance level or make additional stipulations for new dwellings (See page 42):

9a. local authorities should be required to set out this intention in local plans whose soundness will be independently tested at examination as per current procedures and should not be able to introduce planning conditions in relation to Carbon Compliance if not covered by the local plan;

9b. local plans and specific planning conditions should be underpinned by a rigorous technical analysis (utilising the extensive analysis undertaken for this Task Group), and should use the same metric as in Building Regulations;

9c. house builders should be given flexibility in how they deliver the local derived Carbon Compliance level, subject to any conditions in the local plan;

9d. both local plans and specific consents should be subject to whatever new arrangements the Government introduces to constrain the total regulatory burden such as a commercial viability test.

Allowable Solutions

10. The Government should commission whatever further work is necessary in order to set the price and other parameters for Allowable Solutions with the least possible delay. See page 27

Rebasing

11. The Carbon Compliance limits should be rebased whenever there is a substantive change to the assumptions on which the levels were based. See page 43

[13] Although agreed by all at the time the HBA subsequently withdrew their support for the recommended levels for houses

[14] The LGA do not support the Task Groups call for there to be no local powers to set a different Carbon Compliance limit. However, they do support the specific recommendations made 9a – d

INTRODUCTION

Steps towards zero carbon

In July 2010 the Government made clear its commitment to ensure that from 2016 new homes can be zero carbon. This commitment is based on a hierarchical approach to achieving "zero carbon" (see Figure 1), which comprises:

- Ensuring an energy efficient approach to building design
- Reducing CO_2 emissions on-site through low and zero carbon technologies and connected heat networks.

These first two steps are together referred to as **Carbon Compliance**. In addition, there is a third step:

- Mitigating the remaining carbon emissions through **Allowable Solutions**, which secure carbon savings away from the site.

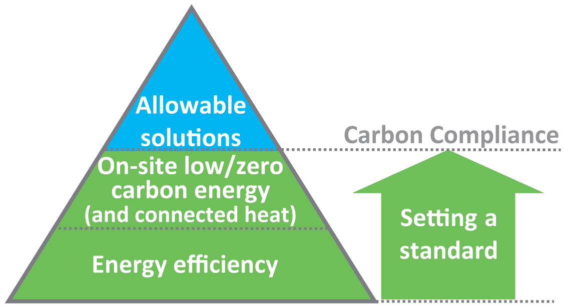


Figure 1 The Zero Carbon policy

The Government has already tightened the Carbon Compliance requirements in Building Regulations, and has made a commitment to tighten them further when they are next reviewed in 2013.

In July 2009 the then Housing Minister announced that, consistent with the zero carbon objective, the Carbon Compliance limit from 2016 would be set to require (broadly) a 70% reduction in carbon emissions when compared with the requirement in the 2006 Building Regulations. However, the Government is concerned that this may not be achievable in all cases. It has therefore commissioned the Zero Carbon Hub to research and examine the evidence and to recommend an appropriate national Carbon Compliance limit for 2016, consistent with the overarching zero carbon objective, which will be applicable to all new homes. This report represents the outcome of that work.

In a previous report, the Zero Carbon Hub made recommendations for ensuring an energy efficient approach to designing new homes. The current report takes these recommendations as its starting point. It is thus in effect concerned with what further improvements in Carbon Compliance may be achieved through the use of low and zero carbon technologies and additional fabric measures, and what are the costs and other implications of doing so. The report offers specific recommendations for the Carbon Compliance limits which should be set in Building Regulations for 2016, and some other related recommendations.

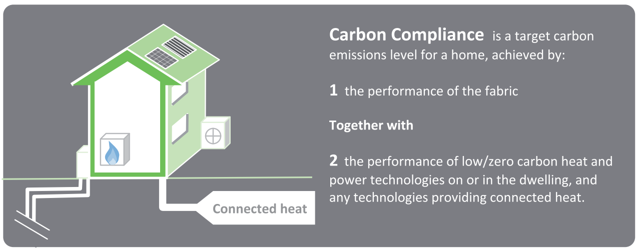


Figure 2 Scope of Carbon Compliance

Any changes made in 2016 Building Regulations will also need to be considered by the Building Regulations Advisory Committee (BRAC) and be subject to public consultation before they can be implemented.

The effect of new requirements for Carbon Compliance introduced by Regulations in 2016 will not be seen immediately, since sites which are already being built when the Regulations are changed will not be subject to the new requirements. However, the proportion of new homes which are subject to the new Regulations will grow over time, and by 2020 it is likely that most newly completed homes will meet the 2016 Carbon Compliance standard.

Task Group structure and process

The Zero Carbon Hub has convened an expert Task Group to undertake this work. Members of the Task Group have been drawn from the house building and supply industries, related professional bodies, trade associations, consumer representatives and bodies with a specific interest in environmental objectives. A number of public sector organisations are members of the Task Group and representatives from interested Government departments have attended as observers. A full list of participating members and organisations is set out at the start of this report.

The Task Group has met on seven occasions from September 2010 to January 2011. Three working groups were established by the Task Group to address technical, commercial and policy issues, and sections of this report are based on their work. The technical working group has also been assisted by a "think tank" assembled by CIBSE to review the assumptions about future technology made by the Working Group.

During November and December 2010 the Zero Carbon Hub also convened three Have Your Say events, in Manchester, Milton Keynes and London, at which the Task Group was able to test its emerging conclusions with a wider range of interested parties. Participants at these events expressed a range of views, and were supportive of the Task Group's approach.

This report sets out the analysis, recommendations and conclusions of the Task Group.

Prior considerations

The Task Group has identified a number of prior considerations which need to be taken into account in order to ensure that the Carbon Compliance limit is realistic and achievable. These prior considerations informed the technical analysis and are reflected in the Task Group's recommendations.

- The Carbon Compliance limit should allow for a range of technical approaches. This is necessary in order to leave scope for future innovation and in order to minimise technical risk. It is also highly desirable in order to avoid distorting the market for new technologies. The limit should not be achieved at the expense of good place-making or by imposing house designs that look out of place.
- The Carbon Compliance limit should be technically achievable in the vast majority of situations where homes may be brought forward for development. This does not mean it needs to be the lowest common denominator across all dwelling types – different limits may be appropriate for different types of dwellings or in different circumstances.
- The limit should be achievable using current technologies, not dependent on speculative future developments. However, where the use of specific current technologies is likely to become more widespread, both within and beyond the housebuilding industry, allowance should be made for improvements in their cost and efficiency. While the impact of such improvements can only be estimated, it would be misleading to ignore them.
- As the findings of the report relate to regulatory changes anticipated for 2016, modelling and analysis should so far as possible use projected values for 2016. This applies in particular to costs, technology efficiencies and carbon emission factors.

TECHNICAL ISSUES

Investigation methodology

The Task Group established a working group to analyse the technical feasibility of different levels of Carbon Compliance in different types of dwellings. The working group has commissioned a large amount of computer modelling to inform its analysis.

The modelling uses a modified version of SAP2009[15], provided by National Energy Services (NES). The modifications allow use of 2016 carbon emission factors and regional weather (temperature, solar radiation, solar irradiation, wind speed). Fuel Factors[16] have not been used.

The 2016 carbon emission factors used in the modelling have been derived from best available information, at August 2010, following the methodology recommended in the Zero Carbon Hub's previous report on the assessment of Carbon Compliance[17]. This methodology differs from that used for 2010 Building Regulations: it is based on a 15-year forward-looking average of marginal emissions, including upstream emissions and the equivalent effect of other greenhouse gases produced[18]. **The Task Group recommends that the methodology for determining carbon emission factors set out in the Zero Carbon Hub's previous report *Carbon Compliance for Tomorrow's New Homes* should be adopted in the next revision of Building Regulations.** A list of the emission factors used can be found in Appendix A.

An earlier Zero Carbon Hub report[19] found that setting Carbon Compliance standards as a percentage improvement over a previous standard is increasingly difficult to understand and at risk of causing perverse outcomes. It recommended that the standard should be expressed in absolute terms. The Task Group agrees with this recommendation.

This report, accordingly, refers to Carbon Compliance in terms of an absolute limit on the emissions of carbon dioxide (and other greenhouse gases expressed as equivalents) per square metre of internal floor space. This is measured as an amount in kilograms per square metre per year (kg $CO_{2(eq)}$ /m^2/year).

Assessing feasibility

Modelling cannot possibly reproduce all the opportunities and challenges which arise on each individual development site. Instead, it is necessary to develop a standard benchmark which can be used as a proxy for feasibility.

Heat generation (for space and water heating) is currently the most significant use of regulated energy in the home. Various technologies are available to provide low and zero carbon (LZC) heat.

However, as the Carbon Compliance limit is tightened it becomes increasingly difficult to achieve simply through LZC heat generation. LZC electricity generation may also be needed, for which there is a smaller range of options. In practice, the mainstream technology currently usable for a wide variety of individual dwelling types and locations is photovoltaic (PV) panels, which are usually installed on the roof and convert light to electricity. Other options, such as wind turbines and CHP, are only

Members of the Technical Working Group

Hywel Davies, Chair (CIBSE)
Tessa Parnell, Technical lead (ZCH)

Gordon Andrews (HBF / Crest Nicholson)
Kirk Archibald (HBA / Fairview)
Michael Black (HBF / Bovis Homes)
Craig Dennett (CHPA)
Craig Ferrans (Miller Homes)
Steven Harris, (EST)
Derric Heyden, part time (HBF / Barratt Dev)
Kevin Knapp (REA)
Tom Lelyveld (AECOM)
Richard Partington (RIBA)
Matthew Prowse (Knauf Insulation)
Peter Rickaby (RIBA)
Steven Stenlund (BRE)
Saryu Vatal (RPA)
Michelle Wangusi (NHBC)
Stephen Wooldridge, part time (HBF / Barratt Dev)
Dave Worthington (Camco)

[15] To allow currently available industry tools to calculate '2016' **design** performance see Modelling 2016 using SAP 2009 – Technical Guide at www.zerocarbonhub.org

[16] In current (2010) compliance methodology, Fuel Factors are applied to the calculation of Target CO_2 Emission Rate (TER) depending on the fuel used to provide heat to the dwelling. The effect of this is that, for example, electrically heated dwellings are allowed to emit more CO_2 than an equivalent gas heated dwelling.

[17] *Carbon Compliance for Tomorrow's New Homes*, Zero Carbon Hub, July 2010

[18] Further details of how the 2016 value was derived for this work can be found on the Zero Carbon Hub website: *Carbon Emission Factors for Fuels – Methodology and Values for 2013 and 2016*, AECOM, October 2010

[19] *Carbon Compliance for Tomorrow's New Homes*, Zero Carbon Hub, July 2010, recommendation C1

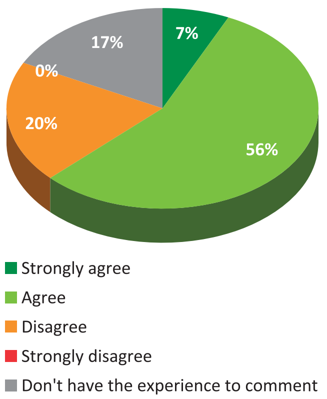


Figure 3 Do you feel it is a reasonable assumption to use 40% ground floor area as the maximum area available for solar technologies when setting a Carbon Compliance limit? *Views from the Have Your Say events*

appropriate in some situations and their use should not therefore be the basis for setting a national regulatory limit.

The Task Group has agreed, therefore, that feasibility should be assessed by reference to the amount of PV required, taking this as a proxy for all LZC electricity generation technologies. If the area of roof-mounted solar technologies required, of which PV is one, exceeds a certain proportion of ground floor area, it indicates that specific "solar design" features such as orientation or roof type and pitch may also be required, and other features such as dormer windows or vernacular design may become impractical. This is contrary to the Task Group's general view that the Carbon Compliance standard should not be achieved at the expense of good place-making or by requiring house designs that look out of place.

The Task Group considers that a requirement for roof-mounted solar technologies equivalent to 40% of ground floor area is the appropriate reference point for feasibility. If the area required exceeds this amount, other measures may be necessary which are not feasible or desirable in every case. The majority of participants at the Have Your Say events who commented on this issue agreed that this was an appropriate reference point.

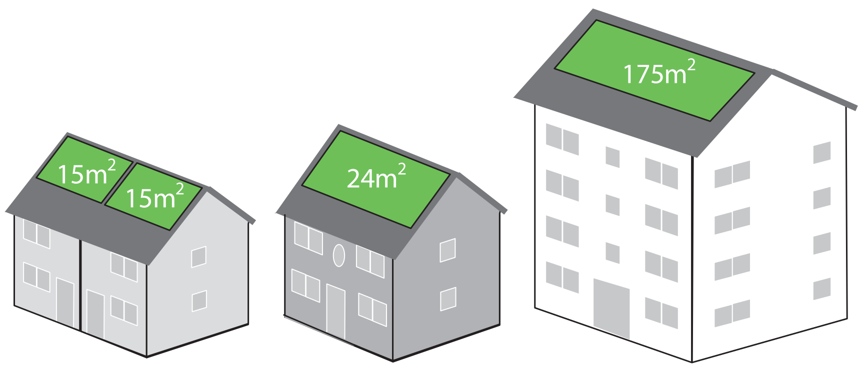


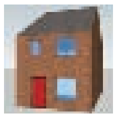
Figure 4 Feasibility: How the 40% Ground Floor Area threshold translates into PV area on typical roofs

PV is used in this model simply as a proxy for feasibility. It does not assume that all sites are the same, nor does it imply reliance on PV. Developers would be free to choose any other approach which achieves the same performance and the Task Group would expect a broad range of technologies to be employed.

Dwelling types

A number of different dwelling types have been modelled, as illustrated below. They were selected as being generally representative of the range of new dwellings being built. The dimensions of the dwellings modelled are the same as in the Zero Carbon Hub's earlier report on the Fabric Energy Efficiency Standard[20].

A range of other dwellings of different types and sizes was modelled in order to test the sensitivity of the core assumptions, including the dwelling types. It would not have been feasible to undertake equally extensive modelling of technical options and compliance limits for every one of these dwellings. However, the sensitivity analysis shows that, in each case, there is a suitable proxy for performance within the range of core types that were modelled.

	Small Apartment	Large Apartment	Mid Terrace House	End Terrace / Semi Detached House	Detached House
	 Top floor Mid floor Ground floor	 Top floor Mid floor Ground floor			
TFA (m²)	43	66	76	76	118

Apartment blocks
3, 4, 8 & 20 storey
(4x small & 4x large per floor)

Other house types looked at for sensitivity

- Large detached
- Detached bungalow
- Small mid terrace
- Life Time Homes mid terrace
- 3st int. garage mid terrace
- Room in roof mid terrace
- Modest passive solar design dwelling

Figure 5 Dwelling types modelled

Fabric efficiency

Two sets of assumptions for the energy efficiency of the building fabric have been modelled, taken from the same report: FEES, which is the standard recommended in that report, and Spec C, which is a more demanding standard approaching PassivHaus. The exact specifications used can be found in Appendix A.

Technology types

Modelling was initially undertaken of eight core technology options, as shown in Figures 6 and 7. Other technologies/technology combinations were modelled as sensitivities (see Appendix A for full list). The results of this additional modelling broadly fall in the range illustrated by the core technology options and these other technologies have therefore not been modelled further.

The core technologies modelled include both individual and shared/communal options. The modelling shows that where feasible, shared/communal heating schemes can be an effective means of achieving Carbon Compliance. However, they are not always available for small or in-fill developments or individual houses. This being so, the Task Group has concluded that the national minimum standard for Carbon Compliance cannot assume that communal systems will be available, and so should not be based on their technical performance. Developers will still of course be free to adopt communal solutions or plug into an existing network where feasible and take advantage of the benefits.

[20] *Defining a Fabric Energy Efficiency Standard*, Zero Carbon Hub, November 2009

The Task Group felt that if a particular Carbon Compliance level is to be considered technically achievable, at least one gas and one electric option should be available. For houses these must be individual options, not shared/communal systems. For apartments, shared (in-block) options should also be considered.

The electric option used is air source heat pump (ASHP) as it is a more efficient use of electricity than instantaneous electric and more widely deployable than ground source heat pump (GSHP). The gas options used are gas condensing boiler for houses and gas condensing combi boiler for apartments. Technologies utilising very low carbon fuels such as biomass may also be an option at the levels being considered, but for reasons discussed later should not be relied upon as the basis for setting a Carbon Compliance limit (see page 32).

Houses

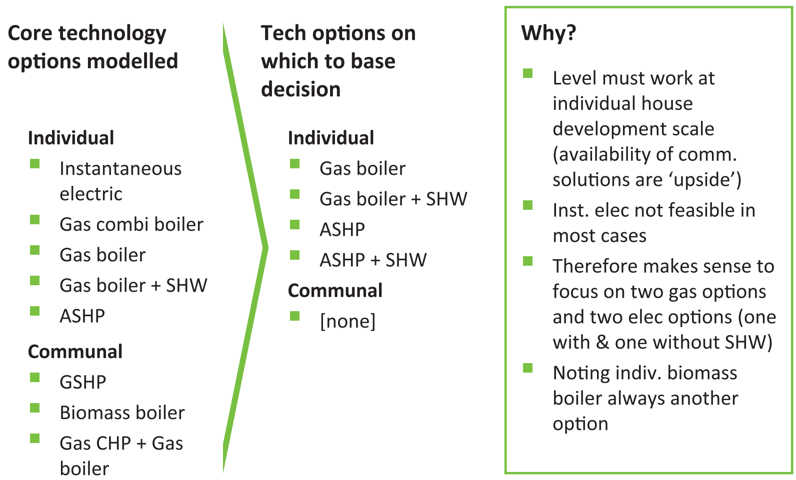


Figure 6 Technology scenarios - Houses

Apartments

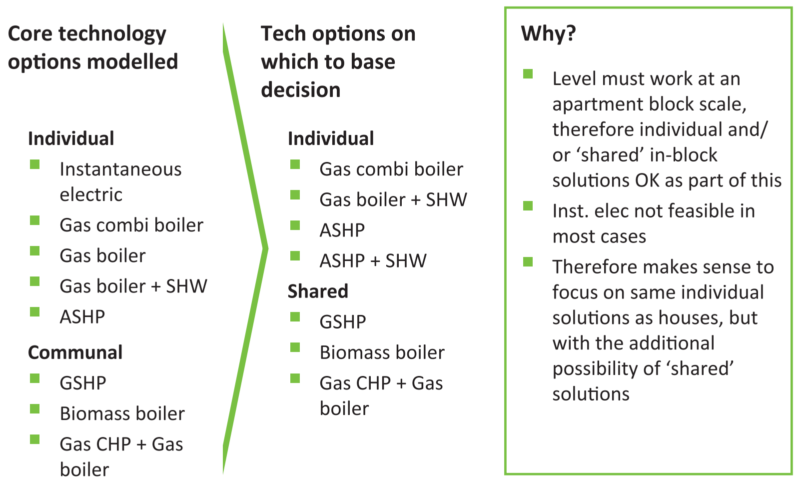


Figure 7 Technology scenarios - Apartments

To check that the choice of core technologies was valid, the technical working group asked the CIBSE Energy Performance Group to create a 'think tank' to review the assumptions, recommend any additional core technologies required, and identify any technologies likely to emerge as major sources of domestic heat or electricity before 2016. Whilst they offered a number of comments on future developments, the CIBSE Group supported the choice of core technologies. The great majority of participants at the Have Your Say events also agreed with the choice of technology options to be modelled and the reasons why they were chosen.

In line with the general principles outlined by the Task Group, the modelling assumes that current best practice in 2010 will be mainstream by 2016 onwards. This is reflected in the technology efficiency assumptions built into the model. However, if there is evidence that a specific technology is known to be facing challenges in achieving its expected performance today, the model assumes no improvement in performance from 2010. Appendix A includes a list of performance efficiencies used within the modelling.

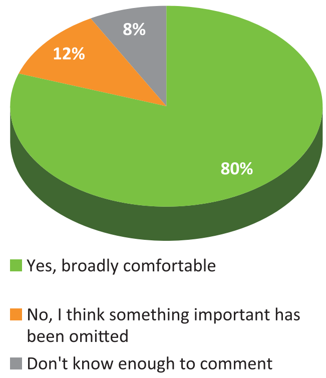


Figure 8 Are you broadly comfortable with the range of technologies that were explored and why they were chosen?
Views from the Have Your Say events

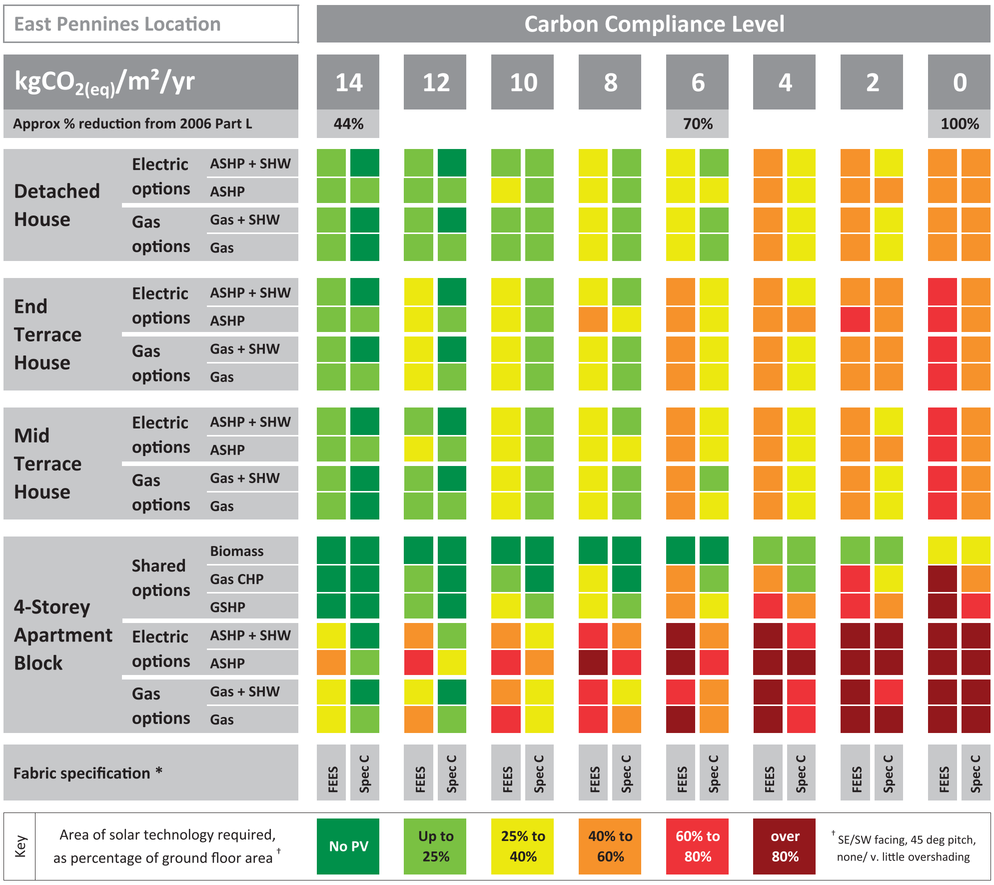
Modelling results and conclusions

Selected outcomes from the modelling work are presented in Figure 9. The results shown are for detached, end-terrace/semi-detached and mid-terrace houses, and for a 4-storey apartment block, using the two selected fabric specification.

At the side of the table are the chosen dwelling / technology options (see Figures 6 and 7 above) and across the top are the range of potential Carbon Compliance levels. For each dwelling / technology option PV (as a proxy) is used to the extent required to meet the particular carbon emissions limit.

The results are colour-coded to indicate degrees of feasibility, based on the proportion of space required for solar technologies. Green indicates that the requirement can be comfortably met (dark green shows that no PV is needed at all). Yellow shows that the 40% reference point, as described above, is being approached. Orange, red and deep red show that it has been exceeded, by increasingly large margins. Thus, green and yellow show that an option is unlikely to require 'solar design'; where as orange and red show that 'solar design' is likely to be needed.

A fuller set of results, using the same colour codings, is available in Appendix C.



* FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

Figure 9 Technical feasibility, expressed as function of solar technology area required to achieve various Carbon Compliance levels

The progressive change in colour across the chart from left to right shows how technical feasibility reduces (due to the proportion of space required for solar technologies increasing) as the Carbon Compliance limit is tightened. Clear differences can also be seen between houses and apartments, and (though less pronounced) between detached and other types of houses.

On this basis the Task Group concludes that it would be appropriate to set different Carbon Compliance limits for different dwelling types. The Task Group has taken these results into account in arriving at its recommendations.

In the light of the technical evidence, the Task Group has concluded that the currently proposed 70% improvement in Carbon Compliance from 2016, over the limit which was applied in 2006, is not deliverable as a national minimum standard for all dwellings, as it could significantly constrain the range of house types (and designs) which could be built. In particular, it may inhibit the building of apartments. This would be a perverse outcome, since apartments in other ways are beneficial for facilitating a low carbon lifestyle and are inherently energy efficient.

Smaller homes

As part of its sensitivity analysis, the Task Group has specifically considered the effect if dwellings are a different size from those used in the core modelling. Figure 10 shows the results for small and large mid terrace houses with the Carbon Compliance limit set at 11 kg $CO_{2(eq)}$ /m^2/year, using the FEES standard for energy efficiency. For purposes of comparison the results for the standard mid terrace house modelled ('ZCH Mid Terrace') is also shown.

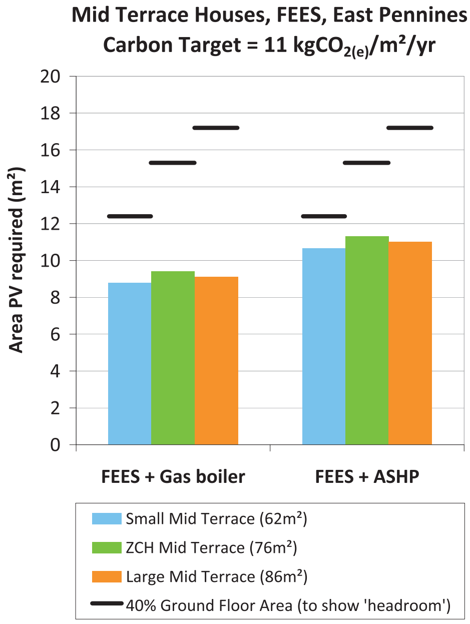


Figure 10 Area of PV for different sized houses

Implications for other dwelling types at other Carbon Compliance levels have also been modelled. However, industry representatives have expressed particular concern in relation to small houses whose roof area is correspondingly limited.

Figure 10 shows that for the small dwelling the amount of PV required still falls within the 40% feasibility benchmark, although there is considerably less headroom. A developer building homes to this size might consider other options such as a further improvement in the energy efficiency of the building fabric. However, the nature of these challenges represents a matter of degree; it is similar to the additional challenge of building on constrained sites or in order to incorporate vernacular design features, and needs to be taken into account in the same way when setting an appropriate Carbon Compliance limit. See also the section on Implications on page 47.

Treatment of high rise dwellings

Figure 11 shows modelling results for a higher rise (specifically, 8 storey) apartment block, using both individual and shared solutions. This is illustrative of higher rise blocks generally.

A set of results for 20-storey apartment blocks is available in Appendix C.

In broad terms, using the Task Group's methodology, the higher the block, the more challenging it will become to achieve any given Carbon Compliance level, since there is proportionately less roof space available per apartment in the block and therefore an increasing need for other solutions. While this is partly a reflection of the Task Group's methodology, it also reflects a real practical constraint.

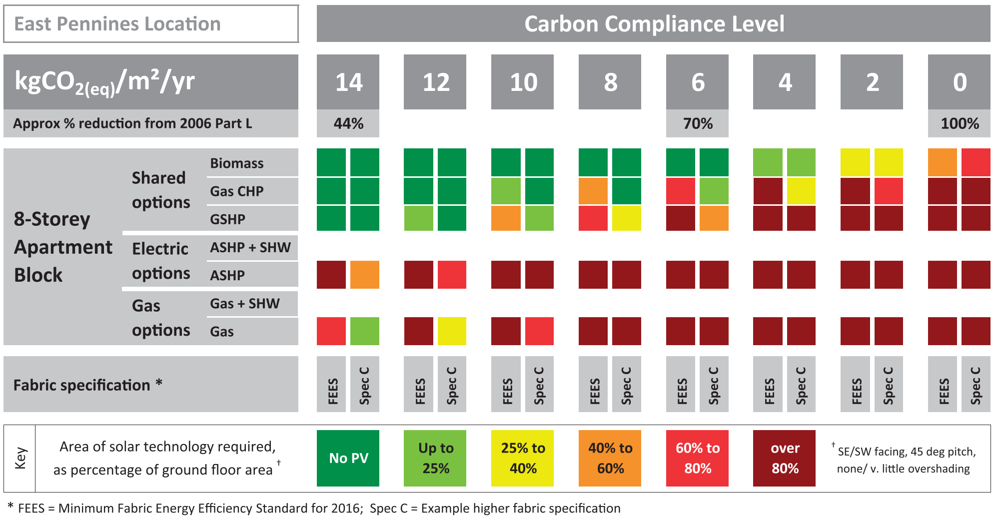


Figure 11 Technical feasibility, expressed as function of solar technology area required to achieve various Carbon Compliance levels – 8 Storey Apartments

For higher rise blocks, it is clear that a Carbon Compliance limit set within the 14 to 0 kg $CO_{2(eq)}$ /m²/yr range would effectively require the use of shared solutions such as CHP, biomass or linkage to a low carbon district heating scheme.

At the same time, high rise blocks are particularly diverse in their structural design. They often incorporate more complex building services than are used in houses or low-rise developments, requiring specialised installation and maintenance. In some respects they have more in common with certain types of non-domestic buildings, and offer the opportunity for the use of technologies and design features being developed for the non-domestic sector. Indeed, many high rise apartment blocks are part of mixed use developments, also including retail or other uses which create specific demands (and opportunities) for infrastructure and services. Work is currently under way by others to take forward the delivery of zero carbon in new non-domestic buildings.

From the Task Group's own analysis it has concluded that the particular nature of high rise dwellings needs more detailed consideration. **The Task Group recommends that further work should be undertaken, by a specialist group with expertise in the development of high rise and non-domestic buildings, in order to develop proposals for appropriate Carbon Compliance levels for high rise blocks.** This group should be able to draw upon the growing body of experience of the design and construction of high rise blocks to achieve higher standards under the Code for Sustainable Homes, and where available their performance in use. The work should be completed in time to inform the planned consultation on Building Regulations Part L 2013.

The Task Group has recommended a Carbon Compliance level for low rise apartments (4 storey and below). It is recognised that the definition of this interface may be important dependent on the recommendation made for high rise and in cases such as mixed height medium rise apartments or those above shops. **The Task Group recommends that the high rise specialist group also develop a practical definition to distinguish between low and high rise apartments.**

COMMERCIAL ISSUES

Achieving a zero carbon standard is not cost free. The additional cost will comprise Carbon Compliance measures and Allowable Solutions.

The Task Group established a working group to analyse the costs of Carbon Compliance. The Zero Carbon Hub commissioned Cyril Sweett to provide capital and lifecycle cost analysis for the commercial working group. The Group has also drawn on Cyril Sweett's analysis of the costs and benefits to households (see page 28) and the cost effectiveness of carbon reductions (see page 31).

The price for Allowable Solutions (see page 10) is not yet known. The analysis in this report uses an illustrative figure of £75 per tonne of CO_2 over 30 years[21]. Sensitivity analysis has also been undertaken for prices in the range of £50 to £200 per tonne. If Allowable Solutions are defined on a basis substantially different from the Task Group's assumptions, or beyond the range of sensitivities modelled, it may be necessary to extend the Group's analysis, and consider whether the recommendations are affected.

Investigation methodology

The analysis of costs is based on market costs for Q3 2010 for both building fabric and services. Cost models have been developed for each of the core dwelling types considered by the technical working group. Additional analysis on regulatory burdens has been undertaken using a modified version of the Three Dragons viability assessment tool[22].

A full account of the assumptions and methodology used by Cyril Sweett is available at www.zerocarbonhub.org.

Cost projections for 2016 and beyond

Future costs of different technologies have been estimated using "learning rates" which provide a means of estimating the impact of industry-wide learning on the costs of a technology or service. Learning may have the effect of reducing costs through increased efficiency in (for example) production, supply and installation of a new product, and in the performance of the product.

Cyril Sweett drew on a wide range of sources in order to estimate learning rates for the technologies covered by this report and compared this with the best costs identified today. Details are available in the paper by Cyril Sweett.

Figure 12 shows the average projected future costs of two technology options, PV and the advanced energy efficiency specification (Spec C). The analysis suggests significant reductions in these costs between now and 2016. It also shows the lowest cost identified for these technologies in a market survey from 2010. There is no formal link between the lowest 2010 costs and the forecast central cost in 2016. However, their relative similarity suggests that the scale of cost reduction projected is not unrealistic.

Members of the Commercial Working Group

Rob Pannell, Chair (ZCH)
Ian Butterss, Technical lead (ZCH)

Kirk Archibald (HBA / Fairview)
Phil Birch (Cyril Sweett)
Michael Black (HBF / Bovis Homes)
Jeremy Bungey (E.on)
Marcello Burbante, part time (HBF / Taylor Wimpey)
Ian Chilcott (HBF / Persimmon)
Kathleen Dunmore (Three Dragons)
Simon Harris (Cyril Sweett)
Kevin Knapp (REA)
Jayne Lomas (HCA)
Adam Mactavish (Cyril Sweett)
Richard Partington (RIBA)
Robert Tudway (LDA)
Alex Uregian (ZCH)
Sarah White (Saint Gobain)
Peter Willis, part time (HBF / Taylor Wimpey)

[21] As adopted in DCLG *Zero Carbon Homes: Impact Assessment (December 2009)*
[22] See www.three-dragons.co.uk

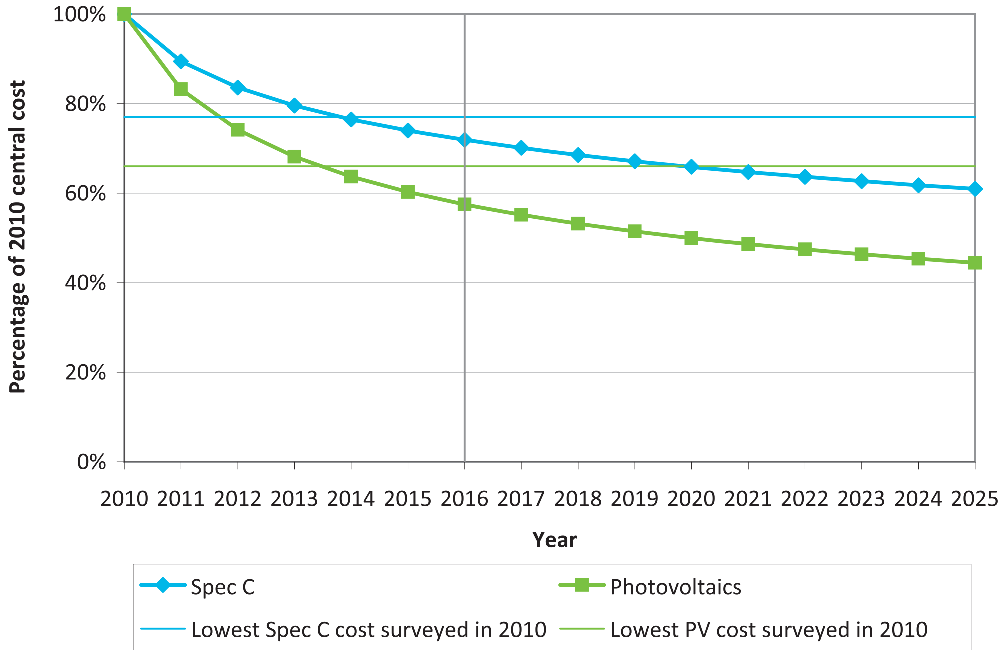


Figure 12 Projections of the future cost of PV and the advanced fabric specification (Spec C)

Capital costs

Figures 13 to 17 illustrate the projected 2010 and 2016 capital costs of achieving a zero carbon home where the Carbon Compliance limit is set between 14 and 0 kg $CO_{2(eq)}$ /m^2/year and Allowable Solutions are calculated using a figure of £75 per tonne of CO_2 over 30 years. The graphs show the additional cost beyond the baseline cost of a similar home, using a gas boiler and compliant with 2010 regulations.

The analysis includes only those technologies considered to be widely applicable for each house type, i.e. individual systems for housing and individual and shared systems for apartments. No costs are shown where an option would require an area of roof-mounted solar technologies that is greater than 40% of the building's ground floor area.

In each case, the **total** additional cost of a technology option is indicated by the coloured line. This includes the cost of the technology and the Allowable Solutions costs to achieve zero carbon. The purple wedge indicates the proportion of the total cost which is attributable to Allowable Solutions.

Where the technology lines stop, this represents the limit achievable using that particular technology combination with PV without exceeding the solar technology area limit determined by the Task Group. If a developer reaches one of these limits but still needs to achieve further improvement in Carbon Compliance, they have a range of options: to improve the dwelling fabric, to choose an additional (or replacement) technology, or a combination of these.

The tightening of the Regulations in 2010 has already led to some additional cost over 2006. The amount of this increase is noted on the graphs; the amount varies by type of home.

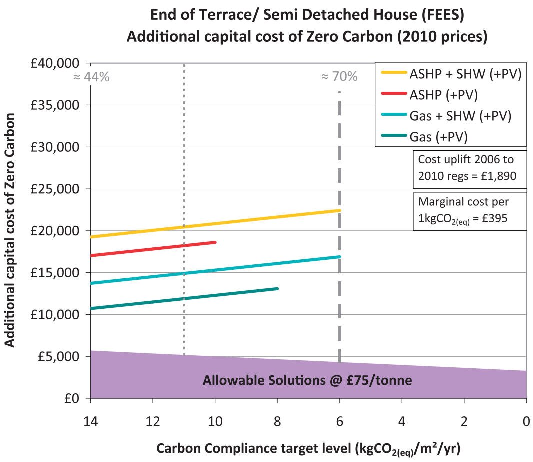


Figure 13a Additional capital cost in 2010 of a zero carbon end terrace house, for different levels of Carbon Compliance (FEES)

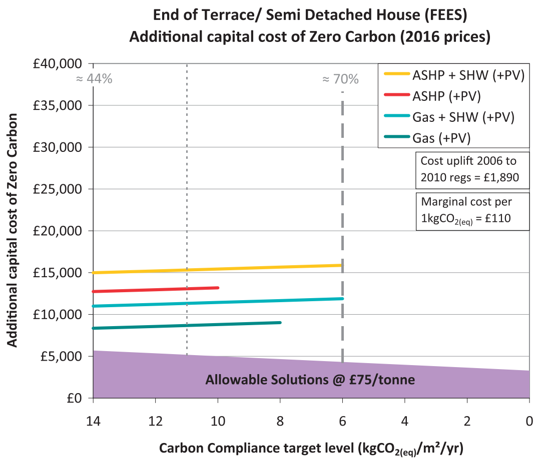


Figure 13b Additional capital cost in 2016 of a zero carbon end terrace house, for different levels of Carbon Compliance (FEES)

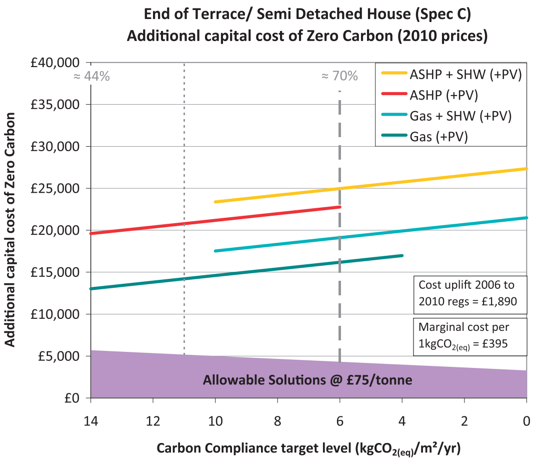


Figure 14a Additional capital cost in 2010 of a zero carbon end terrace house, for different levels of Carbon Compliance (Spec C)

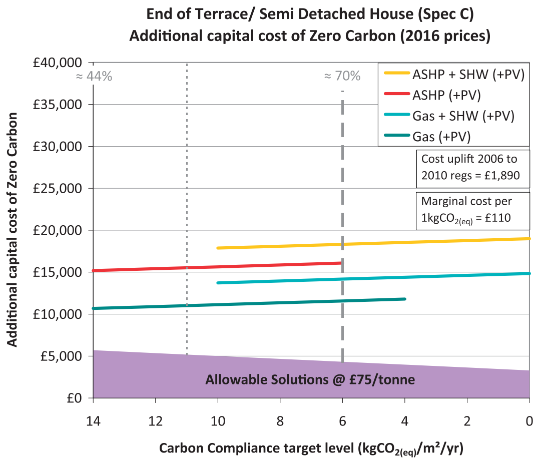


Figure 14b Additional capital cost in 2016 of a zero carbon end terrace house, for different levels of Carbon Compliance (Spec C)

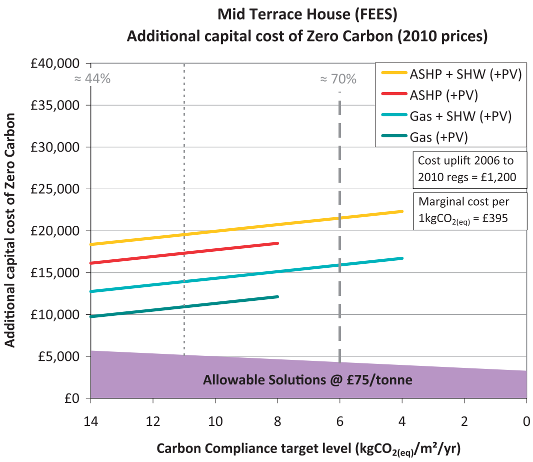


Figure 15a Additional capital cost in 2010 of a zero carbon mid terrace house, for different levels of Carbon Compliance (FEES)

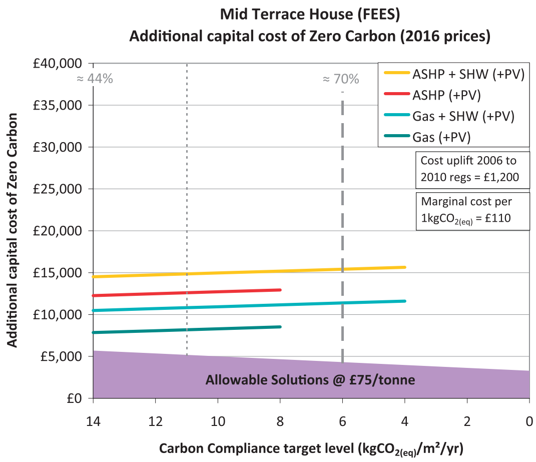


Figure 15b Additional capital cost in 2016 of a zero carbon mid terrace house, for different levels of Carbon Compliance (FEES)

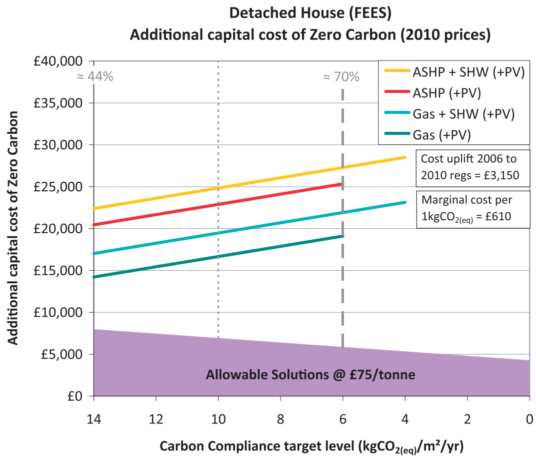


Figure 16a Additional capital cost in 2010 of a zero carbon detached house, for different levels of Carbon Compliance (FEES)

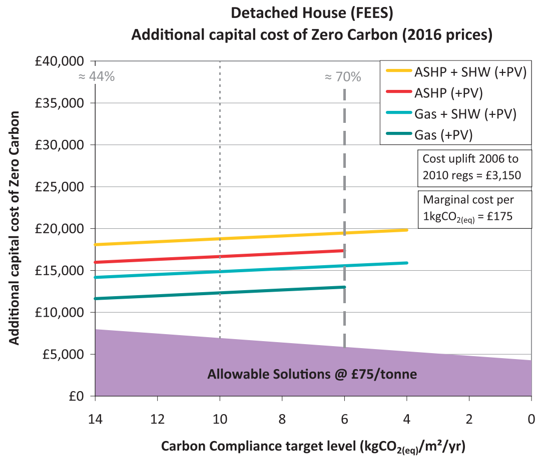


Figure 16b Additional capital cost in 2016 of a zero carbon detached house, for different levels of Carbon Compliance (FEES)

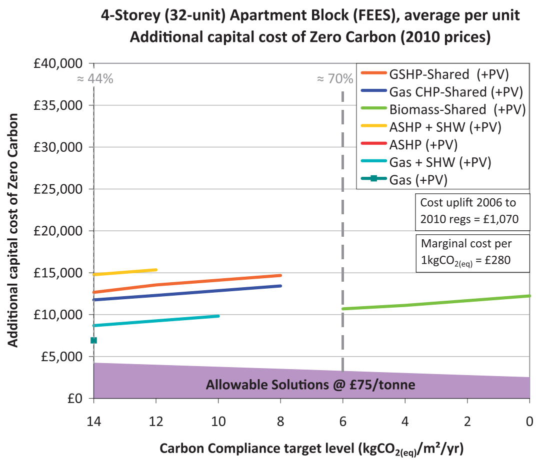


Figure 17a Additional capital cost in 2010 of a zero carbon 4-storey apartment block (per unit), for different levels of Carbon Compliance (FEES)

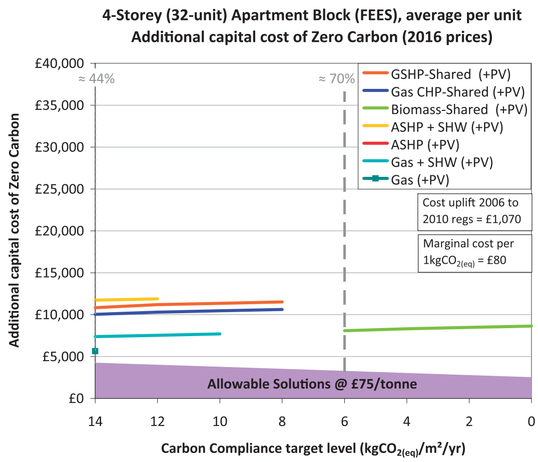


Figure 17b Additional capital cost in 2016 of a zero carbon 4-storey apartment block (per unit), for different levels of Carbon Compliance (FEES)

If Allowable Solutions are priced at £75 per tonne, the cost of achieving zero carbon status is higher when the Carbon Compliance limit is more stringent.

Within each core heat technology group (eg gas boiler or ASHP) the incremental cost of moving to a more stringent level of Carbon Compliance is a function of the cost of the additional PV required, less the reduction in the cost of Allowable Solutions. For example, for a semi detached property the marginal cost for moving the Carbon Compliance limit by 1Kg is £110 per dwelling (2016 prices; £395 using 2010 prices). These marginal costs are stated on the graphs (Figures 13 to 17)

Regulatory burden

In practice, total costs include not only land purchase and construction costs but also a range of regulatory costs, including the requirements of local authorities for affordable housing, contributions under Section 106 and or the Community Infrastructure Levy, and other national regulation.

It is not the purpose of this study to attach specific figures to these other regulatory costs, which in any event may vary greatly from one scheme to the next, depending on the area of the country, the local authority and indeed the individual site.

In order to illustrate how Carbon Compliance and the achievement of zero carbon may interact with wider pressures, a number of indicative scenarios were developed based upon guidance and evidence provided by developers within the commercial working group. Each of the scenarios used the same illustrative site plan (see Figure 18), comprising 74 dwellings on a 1.2 hectare site. The costings were developed for four different locations: Borders, East Pennines, South West and Islington in London. They illustrate the impact of Carbon Compliance alongside a wide range of other regulatory costs.

Figure 18 Illustrative site plan

In brief, what the illustrations (Figures 19 to 21) show is that where affordable housing or section106 contributions are not required, the additional cost of zero carbon may form a significant part of the total regulatory burden; but where these other requirements are made, the additional cost of zero carbon may well represent only a comparatively small proportion of the total regulatory cost.

Figure 19 is an illustration of the scale of costs of developments in the Borders region where land and house prices are relatively low, and assumes typically modest requirements for affordable housing and under section 106. This illustrates the impact of Carbon Compliance costs in a case where other costs are low. As can be seen, the overall cost of achieving zero carbon (Carbon Compliance measures plus Allowable Solutions) forms a significant part of the total burden. The cost of Carbon Compliance illustrated represents about 17% of the total. But even here the additional cost from tightening the Carbon Compliance limit, after taking account of the corresponding reduction in the cost of Allowable Solutions, is small.

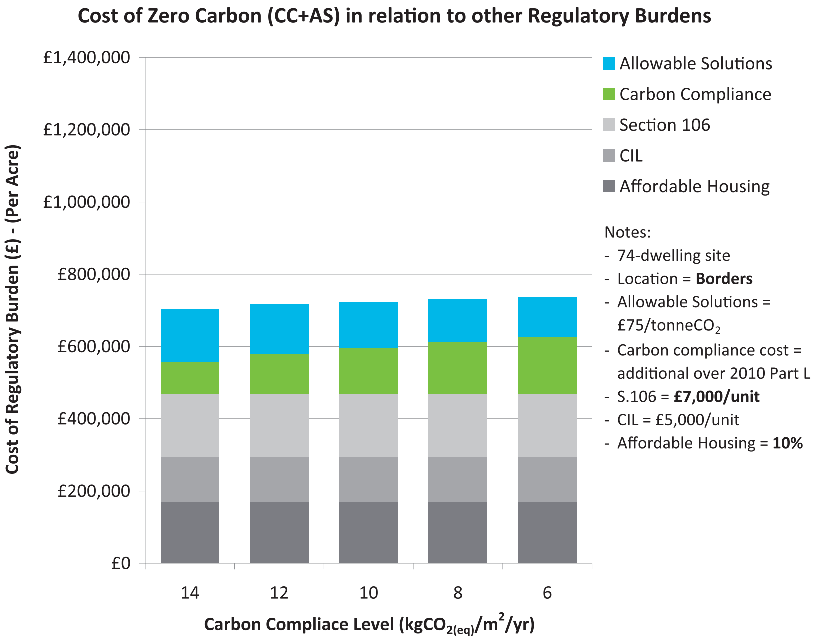


Figure 19 Cost of zero carbon in relation to other regulatory burdens, Borders

Figure 20 is an illustration of the scale of costs in the East Pennines region, where house prices are somewhat higher. It also assumes a greater requirement for affordable housing. In this case the overall regulatory burden is significant and the proportion represented by Carbon Compliance is correspondingly smaller at about 8%. Relative to the overall burden, the difference between Carbon Compliance levels is very small.

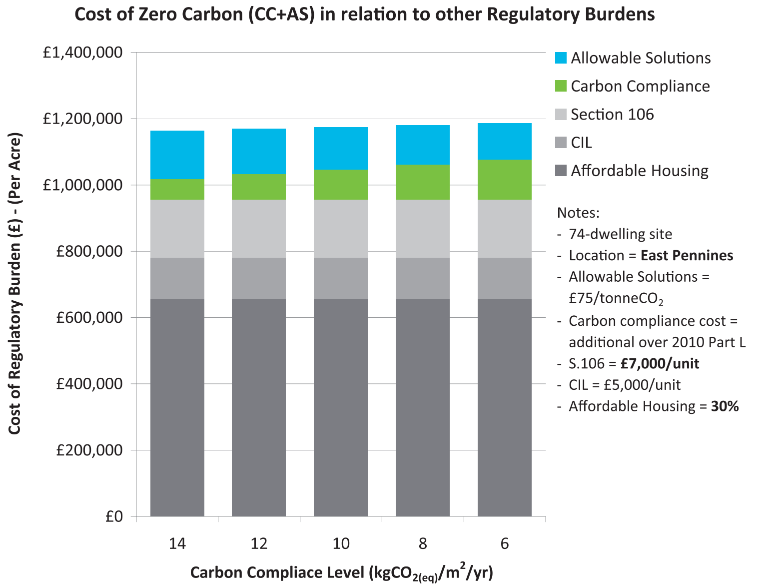


Figure 20 Cost of zero carbon in relation to other regulatory burdens, East Pennines

By comparison, Figure 21 (note the change in scale) illustrates the corresponding costs in Islington. In this case land values and house prices are high, and typically higher requirements are assumed for affordable housing and section 106. Here the total cost of zero carbon forms only a small proportion (around 6%) of the total regulatory burden. Carbon Compliance in this illustration accounts for around 2% of the total, and the incremental cost from tightening the Carbon Compliance limit is marginal.

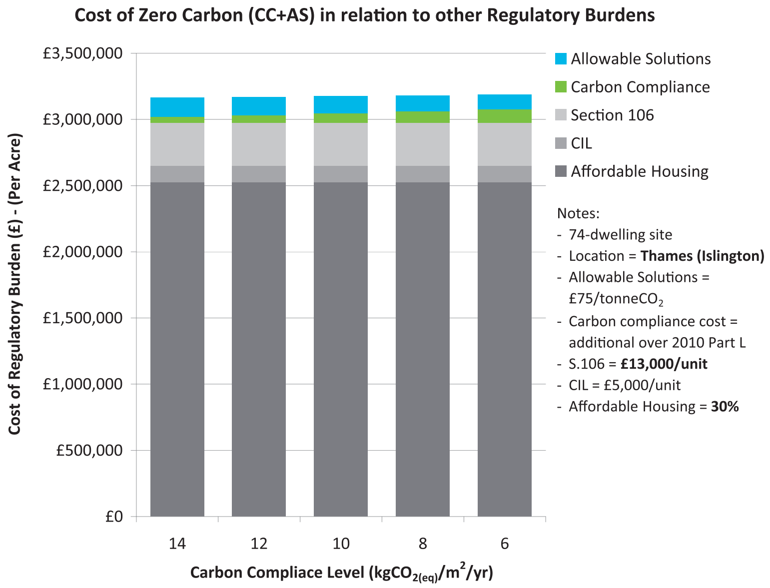


Figure 21 Cost of zero carbon in relation to other regulatory burdens, Thames (Islington)

The marginal cost of each 1 kg change in the Carbon Compliance limit, within the narrowed range considered by the Task Group, is relatively small.

This said, any additional cost imposed on a housebuilding scheme may make it not commercially viable. Housebuilders cannot recover such costs directly through the sale price, as that is determined by the wider market, so these additional burdens have historically been absorbed either through house price inflation and / or reflected in the price they paid for land. Achieving zero carbon will require either a reduction in land price, moderation of the local authority requirements, reduction in the burden / costs of other regulations, the willingness (and ability) of house purchasers to pay more or a combination of these responses. Failing this, there will be an impact on the viability of house building schemes and the delivery of new homes; noting that today, in some areas of the country, low land value is affecting the commercially viability of schemes.

The Task Group recognises that site viability is affected by the costs of the zero carbon policy as a whole. It is noted that the difference in Carbon Compliance costs between levels is significantly less than the total cost of Allowable Solutions, yet to be set, which may have a larger impact on viability.

Sensitivity to Allowable Solutions

The Government has not as yet made any decisions about the scope or price of Allowable Solutions, or how they are to be delivered. The analysis in this report uses an illustrative figure of £75 per tonne of CO_2 over 30 years[23]. However, the Task Group has also considered whether its recommendations might be different if a different price was set.

Figure 22 illustrates the impact for three different levels of Carbon Compliance if the Allowable Solutions price is set at £50, £75, £125 or £200 per tonne of CO_2 over 30 years. The illustration is for an end-terrace or semi-detached house and uses 2016 costs.

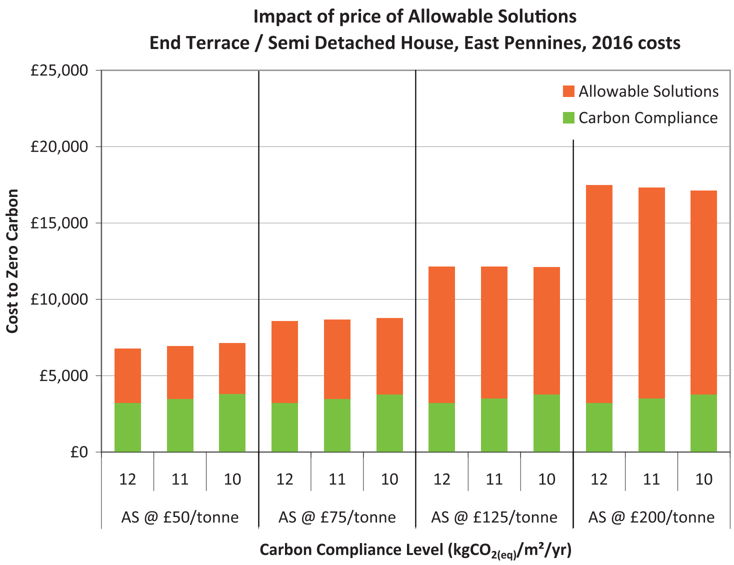


Figure 22 Impact of price of Allowable Solutions, 2016 Carbon Compliance costs

As can be seen, the cost of Allowable Solutions makes a considerable difference to the total cost of zero carbon and therefore is a very important factor in site viability. By contrast, the difference in costs at different Carbon Compliance levels is very marginal. On this basis, the Task Group does not consider that its recommendations will need to be revisited if the price for Allowable Solutions is set, not at £75 as the Group has used in its analysis, but at some other level within the range specified in the terms of reference: £50 to £200.

The Task Group is acutely aware of the impact on overall costs from Allowable Solutions, and **recommends that the Government commission whatever further work is necessary in order to set the price and other parameters for Allowable Solutions with the least possible delay.**

[23] As adopted in DCLG *Zero Carbon Homes: Impact Assessment (December 2009)*

POLICY ISSUES

Members of the Policy Working Group

Robert Tudway, Chair (LDA)
Marco Marijewycz, Technical lead (ZCH)
Chris Baker (DAC)
Andrew Day (HBA / Countryside)
Craig Dennett, part (CHPA)
Paul Everall (LABC)
Steven Harris (EST)
Roger Humber (HBA)
Zoe Leader (WWF)
Jayne Lomas (HCA)
Ian Manders (CHPA)
Russell Reefer (LGA)
John Slaughter (HBF)
Nick Small (HBA / Appletree)
Neil Smith (NHBC)
John Stewart (HBF)
Anna Surgenor (UK-GBC)
Stephen Tapper (POS)

Investigation methodology

The Task Group identified a range of other issues which have a bearing on Carbon Compliance. These issues may affect industry (housebuilders, designers and suppliers including the energy industry), householders or government at any level. The Task Group accordingly established a working group to examine the evidence in each case, focusing on the specific question of the implications for Carbon Compliance levels.

Many of these issues are very significant in their own right. But, for the purposes of this report, the key question is how great an impact these issues have on where exactly the Carbon Compliance limit should be set. The Task Group has found that in some cases there is a definite impact, but it is small. In others, the impact is negligible, or there is insufficient evidence to predict what it will be (in particular, this is true of behavioural issues).

Further details of the analysis by the policy working group can be found on the Zero Carbon Hub website www.zerocarbonhub.org.

Issues with an impact

Benefits to householders

Householder benefits resulting from Carbon Compliance measures may be measured in terms of lower energy costs. These are described as present values, weighing running costs (operation, maintenance and replacement costs, but not initial installation cost) against fuel cost savings.

Figures 23 to 25 show the impact of different Carbon Compliance standards on the present value of running costs over 60 years. Three different Carbon Compliance technologies, and Carbon Compliance limits from 14 to 0 kg $CO_{2(eq)}$ /m^2/year, are illustrated. Figures 23 and 25 compare the running costs with those for a corresponding dwelling built to 2010 standards using a gas boiler. Figure 24 compares these costs with those for a corresponding off-gas-grid dwelling built to 2010 standards using either a panel heater or an ASHP.

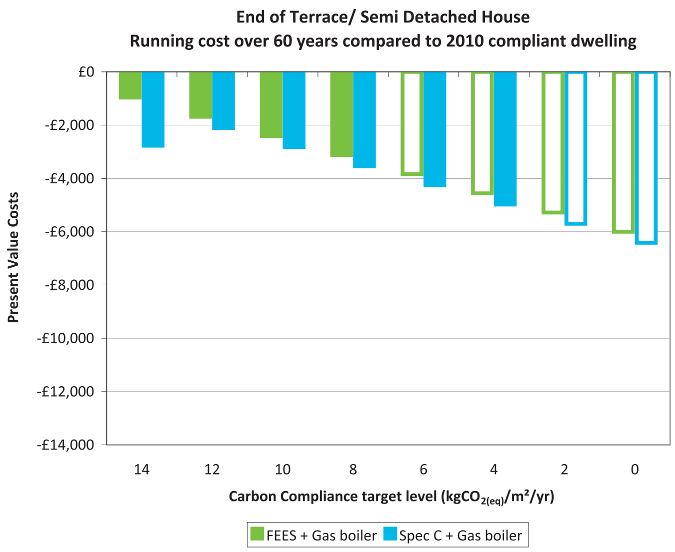


Figure 23 Running costs for an end terrace/semi-detached house: comparison with gas baseline

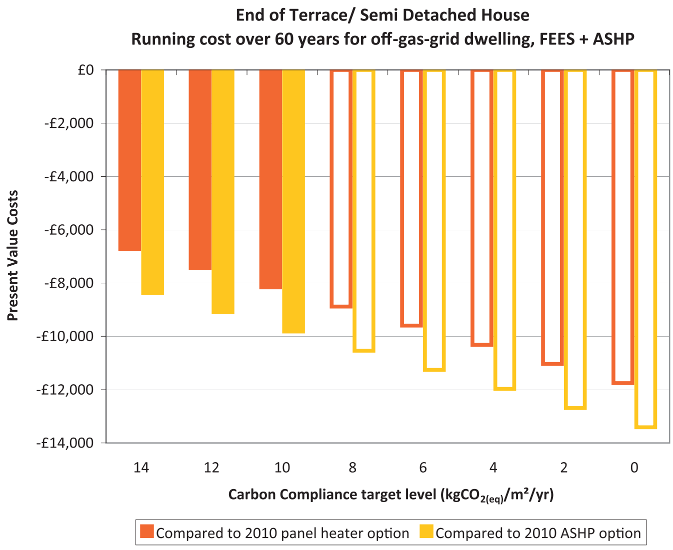


Figure 24 Running costs for an end terrace/semi-detached house: comparison with electric baseline

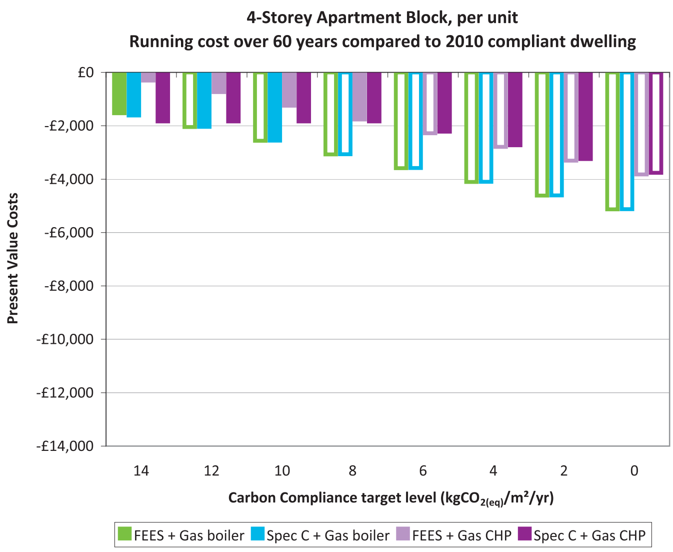


Figure 25 Running costs for a low rise apartment: comparison with gas baseline

Where the bars on the chart are not filled, the area of solar technologies used has exceeded 40% of the building's ground floor area. No allowance for income from the FiT or RHI is included.

This analysis uses DECC's published 'Central' energy price scenario which shows energy price rises to 2030 and then no further increases. The graphs show the difference in energy costs compared with a Part L 2010 home expressed in today's money (net present value). These costs are negative so householders would benefit from lower energy bills and would also be less exposed to energy price rises.

Householders may also obtain an additional income through the Feed-in Tariff (FiT) or, in the case of renewable heat sources, the Renewable Heat Incentive (RHI). As it is not known whether the FiT or the RHI will continue to be available in 2020, the date by which the majority of new homes being built will be covered by the 2016 Regulations, the Task Group has not assumed these in its considerations.

Different technology options may be implemented in different ways, affecting where the costs and benefits fall. For example, where shared systems are used in apartments, householders may not see the full benefits as a result of costs incurred by the management company.

As noted elsewhere, the definition and scope of Allowable Solutions have yet to be published but, from the original illustrations suggested by DCLG few offered any direct financial benefit to individual householders.

Overall CO_2 benefits

The overall carbon reduction associated with setting the Carbon Compliance limit at one level as opposed to another should be nil. Tightening the limit in itself will deliver gradual benefits to society, but under the overall zero carbon regime, a tighter standard will be offset by a reduction in the requirement for, and therefore the benefits from, Allowable Solutions. So long as Allowable Solutions deliver their intended benefits in off-site carbon savings, the overall effect should be neutral. There is a risk that it is hard to be sure that off-site measures are truly additional to what would have occurred anyway. Addressing this risk should be be an important feature of how Allowable Solutions are defined.

Cost effectiveness of Carbon Compliance options

Even though the specific Carbon Compliance limit should make no difference to total emissions savings for the reasons above, the cost effectiveness of different limits in terms of reducing emissions vary. The Task Group has therefore considered an analysis of cost effectiveness of on-site carbon savings achieved through different technology options in different house types at different levels of Carbon Compliance. The results are illustrated in figures 26 and 28.

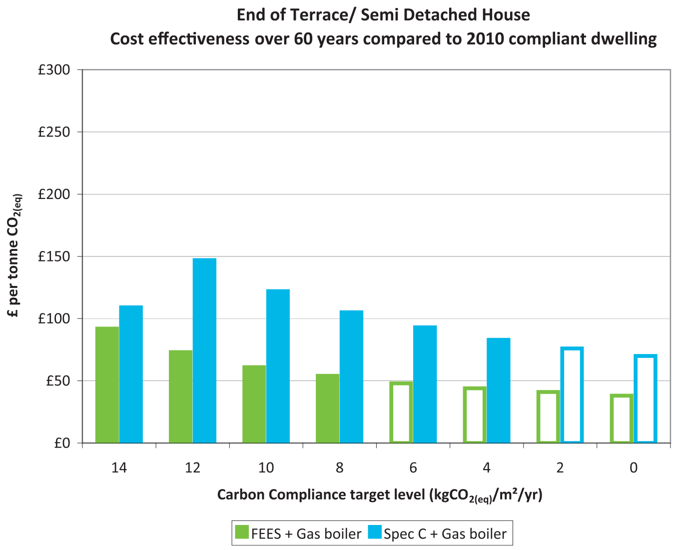


Figure 26 Cost effectiveness of achieving carbon savings solely through Carbon Compliance measures, end terrace house – gas baseline

A tighter Carbon Compliance limit improves the cost effectiveness of each technology option up to the point at which the option is no longer feasible. This is because the fixed costs of installation are spread across a greater PV output.

The cost effectiveness of Carbon Compliance options may be compared with the traded and non-traded costs of carbon used by government to value the benefits of carbon savings more widely. The current price of carbon is about

£14 per tonne in the traded sector and around £50 per tonne in the non-traded sector, but the Government expects that these will converge.

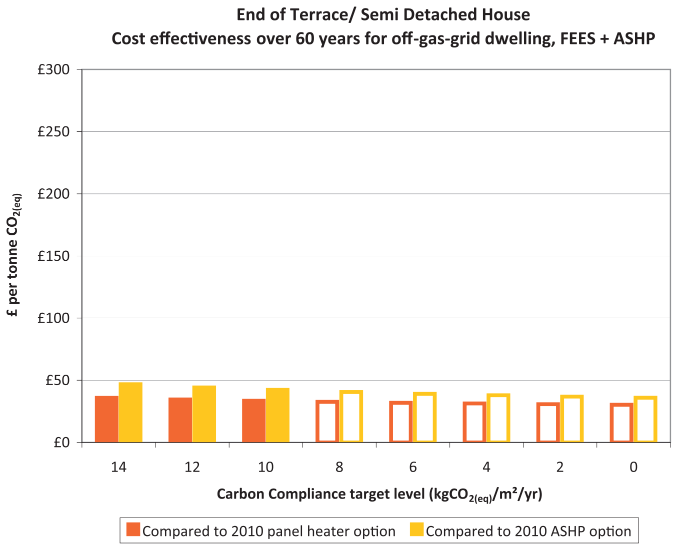


Figure 27 Cost effectiveness of achieving carbon savings solely through Carbon Compliance measures, end terrace house – electric baseline (off gas grid)

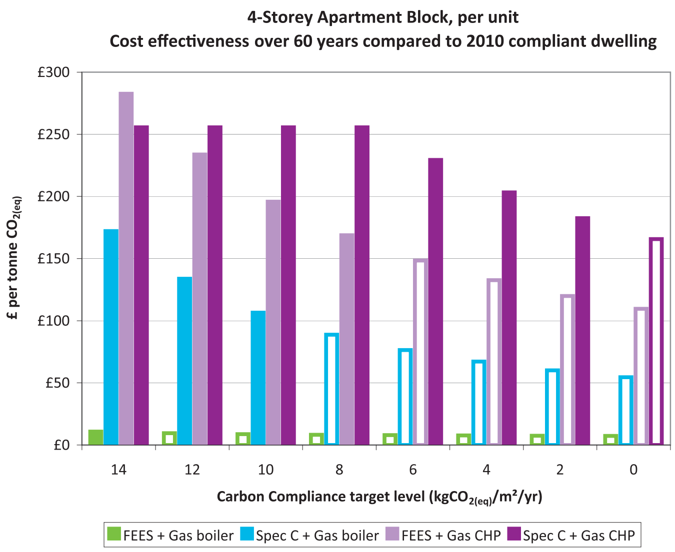


Figure 28 Cost effectiveness of achieving carbon savings solely through Carbon Compliance measures, low rise apartment - gas baseline

The cost of carbon is expected to increase over 60 years and future carbon costs should therefore be discounted in the same way as other costs. On this basis the discounted average price of carbon over 60 years from 2016 is around £50 per tonne. This suggests that installing FEES and a gas boiler into an end terrace/semi detached house, for example, is a socially cost-effective means of abating emissions of CO_2. This is also the case for an off-gas-grid dwelling. However, for other technology mixes, particularly at less ambitious Carbon Compliance levels, the £/tonne of carbon abated is estimated to be above the market price. Hence, if carbon price was the primary decision driver, there may be other, more socially optimal routes for abatement available to Government.

Biomass

The use of biomass is one possible means of achieving Carbon Compliance. Indeed, beyond a certain point, tighter Carbon Compliance limits would increasingly drive solutions using biomass. However, biomass is a finite resource for which there are competing demands, so its availability and price are uncertain.

Carbon Compliance limits which are set so tightly that they are effectively dependent on the use of biomass may also reduce overall carbon effectiveness nationally. The biomass would be used less efficiently than in larger scale installations, and transporting the fuel stock to a large number of different sites would itself have a significant carbon footprint.

Widespread use of biomass at dwelling and communal scale may also be constrained by clean air legislation, particularly in areas of high population density.

The Task Group concludes that the supply and carbon footprint issues described above are a neutral influence for Carbon Compliance levels above circa 6 kg $CO_{2(eq)}$ /m^2/year, but weigh against setting Carbon Compliance limits which are tighter than that.

Neutral impacts

Householder health and wellbeing

The choice of materials and technologies in order to achieve a specified Carbon Compliance limit may have implications for the health and safety of householders, and for fuel poverty.

Health and safety concerns arise from the use of new design elements, materials and technologies. There will be new challenges in terms of safe construction practices. There is also a risk that householders may be unable or unwilling to use the new technologies effectively.

The risk and consequences of fuel poverty will be significantly reduced in a zero carbon home, where basic energy costs should be low and exposure to changes in energy prices much reduced. On the other hand, whilst on average the costs are low, at particular points in time the maintenance and replacement of costly on-site technology may be expensive for some future occupants.

In each case, however, there is no direct fixed relationship between the level of risk and a particular Carbon Compliance limit. Whilst the Task Group recognises health and well being of households and the risk of fuel poverty are critical issues, it considers that their impact on setting a Carbon Compliance limit is neutral.

The need for desirable homes on a mass scale

Consumers put a premium on place and the quality of design. It is unclear whether house purchasers will welcome the new features introduced in order to achieve Carbon Compliance, or will find them unattractive.

The parameters set by the Task Group for modelling technical feasibility specify that reliance on any particular single technology should be avoided so far as possible; different design solutions should be able to be adopted, reflecting the constraints of the site and the need for effective place-making. Carbon Compliance limits set on this basis should allow sufficient flexibility for developers to apply a range of solutions to respond to market preferences.

The Task Group also notes that, as with other issues involving the possible future behaviour or choices of individuals, there is a lack of evidence to assess the impact of particular Carbon Compliance levels on marketability.

For both these reasons, the Task Group considers the impact of this issue to be neutral.

Deliverability of new homes

There is a wide range of potential impacts from Carbon Compliance on the demand for professional and trade skills and the supply and availability of materials.

The availability of skills and materials will be influenced by the extent to which other markets (such as non-domestic buildings and retrofit of existing homes) create parallel or competing demand. For homes this demand will be stimulated by the Feed-in Tariff, the Renewable Heat Incentive and the Green Deal. While over time the market may be expected to respond to shortages, there may be a risk in the short term, especially if total demand increases quickly.

Concerns have also been expressed about the future availability and price of materials currently required for some low and zero carbon technologies. These include rare earth magnets, silicon wafers, gallium and tellurium. However, considerable effort is being made globally to address this risk. It is impossible to predict how this will develop between now and 2016.

The Task Group considers that while these risks are real, they arise equally wherever the Carbon Compliance limit is set within the range being considered. Their effect on the specific question of where the limit should be set is therefore neutral. If circumstances change, this could be considered during consultation on the 2016 Building Regulations.

Energy infrastructure and security

The demands on the electricity grid will change in a number of ways. In order to achieve Carbon Compliance, new homes will increasingly need to incorporate PV and other means of generating electricity on-site, as well as technologies such as heat pumps. There are also likely to be more developments with community-wide electricity generation. Yet, homes will continue to need to be connected to the grid: to provide power when the LZC energy technologies are not generating; to cope with peak demands; and also to allow export of surplus electricity generated.

These changes will create new challenges for the management of national energy infrastructure. However, electricity networks will in any event need to be reinforced in the context of all mainstream 2050 scenarios[24], and to become "smarter." In this context the additional requirements arising from tighter Carbon Compliance levels for new homes are insignificant and the choice of a specific Carbon Compliance limit, within the range being considered, is not material.

[24] DECC 2050 Pathways Analysis: www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/2050/2050.aspx

The same considerations arise in relation to shared and community schemes. Where feasible, these can be an effective means of achieving Carbon Compliance. It is likely that take-up of such systems will increase, and the grid will need to be able to cope with changing patterns of demand and supply. However, they are not an appropriate solution in every case, and cannot form the basis for a national minimum standard.

The UK has a broad base of energy generation plant. The renewable energy targets will broaden this further. At an individual dwelling level, homes will still be connected to the grid to ensure energy demand can be met when it is needed. At a national level the differential contribution to energy security represented by different levels of Carbon Compliance will be slight, as the number of new homes built per year is small compared with the rest of the stock, and the energy implications of a more or less stringent level are also relatively small.

Monitoring and enforcement

It has been suggested that tightening the Carbon Compliance limit may result in additional complexity which may need to be built into monitoring and enforcement regimes.

Monitoring and enforcement are unquestionably important for the success of any Carbon Compliance regime. It may well also be the case that the introduction of new designs, materials and technologies will increase the challenge, particularly where they are used in combination.

However, the issues of monitoring and enforcement will need to be addressed with equal effect at any level of Carbon Compliance within the range being considered. The Task Group considers, therefore, that their effect on the specific question of where the Carbon Compliance limit should be set is neutral. It should be noted that monitoring and enforcement is a completely different issue to 'designed and built performance' (see page 36) where homes comply with all regulatory requirements yet may not, in practice, deliver the performance intended.

Consumer behaviour and perceptions

Consumer behaviour and perceptions may be relevant for Carbon Compliance in a number of ways. As noted above, there is a lack of evidence to assess the impact of particular Carbon Compliance levels on consumer preferences and hence on marketability.

There is a risk that householders may choose to consume any cost savings achieved through Carbon Compliance measures by increasing the amount of energy they consume for other purposes. This "rebound effect" would in turn offset the carbon savings which the Carbon Compliance limit is intended to achieve.

The "rebound effect" may be greater or less, depending upon the technologies used, and also on individual consumers' choices. However, the effect is impossible to predict or quantify. Moreover, some "rebound effects" involve consumer choices (such as to use more electricity for other purposes) which are themselves subject to measures to reduce their carbon impact though other initiatives and legislation.

Other householder behaviours may also prevent the full benefits from being secured: for instance some may choose to keep their homes warmer than previously, or fail to operate LZC systems efficiently (whether due to design fault or user error), or may simply leave windows and doors open.

In the absence of evidence either way, the Task Group concludes that the "rebound effect" should be assumed to have no effect on where the Carbon Compliance limit is set.

The impact of UK targets for renewable energy and CO_2 emissions

The policy objective of zero carbon homes will contribute to achieving the UK's greenhouse gas and 2020 renewable targets. Carbon Compliance and Allowable Solutions will each share in this contribution. A tighter Carbon Compliance limit will be offset by a reduction in the requirement for, and therefore the benefits from, Allowable Solutions, and vice versa. So long as Allowable Solutions deliver the intended benefits in additional off-site carbon savings, the overall effect should be neutral.

WIDER CONSIDERATIONS

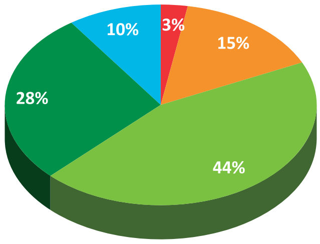


Figure 29 Prior to this event how aware were you of the potential gap between designed and built performance?

Views from the industry Have Your Say events

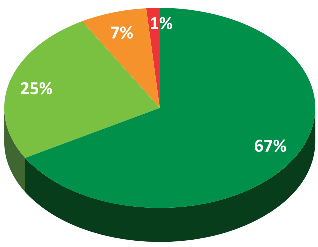


Figure 30 Do you agree with the Task Group's conclusion that we need to ensure that built performance meets designed performance?

Views from the industry Have Your Say events

'Designed' performance and 'Built' performance

A previous Zero Carbon Hub Task Group report[25] drew attention to the potential gap between the calculated (designed) performance of new homes and how they perform when built. The evidence to date that built performance falls short is drawn from a very small base. But the scale of the shortfalls identified is significant, relative to the Carbon Compliance levels being considered, and important: none of the homes tested met their designed performance, although a few were quite close. This was **not** a compliance problem. The homes whose built performance was tested will have complied with the regulations of the day.

Ensuring what is designed is actually delivered will represent a significant challenge for the whole industry, including designers, the supply chain, and housebuilders. The effort required should not be underestimated. However, the arguments for embracing the need to close the potential performance gap are also strong. The risks otherwise are that new home owners will not get the warm, low-energy homes they expect, housebuilders will incur additional costs without delivering the intended outcome, and the Government's target for carbon emissions will not be met. In the context of new low energy / carbon homes, aiming to meet a specific Carbon Compliance limit will mean little if this is not matched by actual performance. The Task Group concludes that built performance should meet designed performance. This view was strongly endorsed by participants at the Have Your Say events.

The Task Group recommends that the Carbon Compliance limit apply to 'built' performance.

The approach taken to close the potential performance gap should be developed urgently. **The Task Group recommends that an industry / government group should be established to oversee the process of measuring and addressing the potential gap between designed and built performance, supported by appropriate regulation.** The first stage must be to collect data in order to establish the scope and scale of the issue.

Schemes should be developed, building upon the work done by the Carbon Compliance for Tomorrow's New Homes Task Group, to address any gap identified by the research, and should be applied to dwellings built from 2016. These schemes should address the potential difficulties at all stages of the house building process. The previous report accordingly recommended that different schemes should be developed for designers, materials / products / systems, and builders of new dwellings. Industry would arrange for the independent testing of actual energy / carbon performance of a statistically representative random sample of homes. This would be verified by third party measurement covering fabric, services and LZC technologies. The findings should be widely published, and should inform the broader industry and government.

The Task Group recommends that from 2020 the test results distribution should demonstrate that at least 90% of all dwellings would meet or perform better than the designed energy / carbon performance.

[25] *Carbon Compliance for Tomorrow's New Homes*, Zero Carbon Hub, July 2010, pages 40-44

Development averaging

Areas within a development may have particular constraints which restrict the efficient use of solar technologies. They may, for instance, be poorly oriented or overshadowed by trees or other buildings. It may be unnecessarily restrictive, and problematic, to require each individual dwelling to achieve the prescribed standard.

The Task Group recommends that there should be an option to achieve compliance on a development by reference to the aggregate of the limits which would otherwise apply to the individual dwellings on that development. Developers would be free to choose how far to take advantage of this flexibility. There are practical constraints which will prevent too great a divergence in the performance of different homes on the same development site.

This is not a new concept. Within current Building Regulations, the use of block averaging is already allowed to demonstrate compliance in buildings which contain multiple dwellings.

The Task Group recommends that rules are developed to ensure that this option provides appropriate flexibility yet delivers overall compliance. Any "averaging" scheme would need to be carefully designed to address issues such as phasing of a development site and compliance checking, but would need also to avoid undue bureaucracy which would negate the intended benefits.

The concept of development averaging was approved by 75% of participants at the Have Your Say events, though there were some practical concerns. The aim of the further work recommended by the Task Group would be to ensure that these practical issues can be resolved.

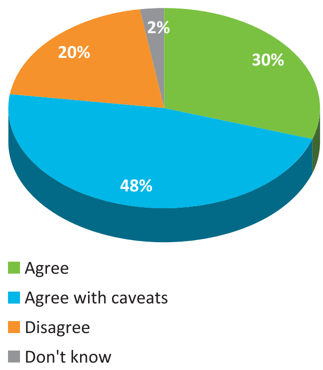


Figure 31 What is your view on the option of Carbon Compliance being 'averaged' over a development?
Views from the industry Have Your Say events

National or Regional weather

Since the demand for heating is affected by the weather, Building Regulations use weather data in calculating the carbon performance of a new home. At present, this calculation uses data from the East Pennines region for all new dwellings, wherever located[26]. Technical analysis carried out for the Task Group indicates that the use of a national or regional weather assumption has a considerable impact.

Under the current regime, a semi-detached dwelling designed to meet the minimum Fabric Energy Efficiency Standard (FEES) would have a FEE of 46 kWh/m^2/year if it were located in the East Pennines region. If that exact same dwelling were located in the South West or the Borders, its FEE would be 38 or 51 respectively (although in both cases the compliance calculation would show 46).

The same effect applies to Carbon Compliance. Figure 32 shows the example of a semi-detached house achieving 11 kg $CO_{2(eq)}$ /m^2/year in East Pennines. If located in the South West the carbon performance would be 8.5 and in the Borders 13.1. This range of emissions is significant.

It would be possible to specify a dwelling such that the national FEES standard is achieved in each region taking account of regional weather. On that basis, the fabric specification could be less demanding for locations south of East Pennines, but would need to be more demanding for locations north of East Pennines compared to that anticipated by the FEES Task Group[27].

[26] Except for cooling and summertime overheating calculations, which are based on regional weather.
[27] The FEES Task Group were only able to consider FEES on a national weather basis.

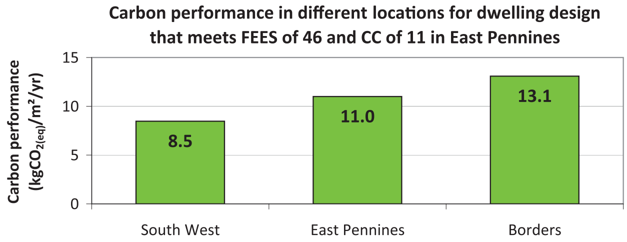


Figure 32 Regional carbon performance of semi-detached house where the design is based on a National FEES and Carbon Compliance limit using National weather

Likewise, in order to achieve a Carbon Compliance level of 11 kg $CO_{2(eq)}$ /m^2/year in each location based on regional weather, then in addition to having a different fabric specification per region there would be a slight reduction in the amount of PV required south of East Pennines, and a slight increase north of East Pennines: a difference of about ± 1m^2[28].

The cost of using regional weather for Carbon Compliance, including the difference in cost for achieving the minimum FEES, represents savings of about £930 per dwelling in the South West and an additional cost of £1240 per dwelling in the Borders (2016 costs).

The difference in fuel cost to the occupant if a national weather regime is used is in the order of +£30 per year in the Borders and -£35 in the South West. Using regional weather would typically equalise these costs across the country (recognising there would be local variations).

In England, in 2009/10, 10% of house completions occurred north of East Pennines region, and 75% to the south. Using the current national weather assumption to calculate the residual CO_2 emissions this differential in build across the country would result in an overestimate nationally of residual emissions and therefore an over payment nationally of Allowable Solutions. This would equate to approximately £25 million per year[29].

The tables below (Figures 33 and 34) show the pros and cons discussed by the Task Group for the two main approaches.

Both approaches have disadvantages. To reduce these, possible policy responses include:

- Varying FEES by region
- Setting different Carbon Compliance limits, by region
- Pricing Allowable Solutions to take account of the national "overpayment"

Figure 35 shows the effects of combining these and other responses in different ways. This table is best read by choosing the desired outcomes and then reading across to the appropriate policy option.

A more detailed description of how to read Figure 35, and an explanation of some of the terms used, is contained in the National or Regional Weather report available at www.zerocarbonhub.org.

[28] Due to regional differences in temperature, solar radiation, solar irradiation and wind speed.
[29] Based on an Allowable Solutions price of £75 per tonne over 30 years and 150K new homes built per year.

Pros and cons of moving to a Regional weather approach (with National Standards)	
Pros	**Cons**
Flexibility on fabric is increased S of East Pennines (EP) (75% of build)	Flexibility on fabric is reduced N of East Pennines (EP) (10% of build)
Cost of compliance is reduced S of EP	Cost of compliance is increased N of EP where viability is generally worse
AS don't 'overshoot' zero carbon nationally (for AS, properties S of EP are not "overpaying" and those N of EP are not "underpaying")	Necessitates dealing with 'boundary' issues
Reflects 'reality' more accurately & reflects regional differences	Less on-site reduction of CO_2 nationally
Makes sense to require better fabric in N where colder	Closer to the technical limits N of EP
Recognises improved solar tech performance S of EP	If use solar technologies, end up needing more in N than S
Fuel cost to a std occupant approx same across the country (same property type) compared to ± £30pa	Potential increased complexity?
Achieves consistency with cooling & overheating calculations (currently based on regional weather)	Potential increased supply chain costs (greater spec variability)
There are already other areas of building design treated in this manner (e.g. flood risk, exposure)	Potential negative impact on land owners if values are reduced in more challenging regions (market distortion)
Implications for EPCs	
Localism	

Figure 33 Pros and cons of moving to compliance based on a Regional weather approach with National Standards

Pros and cons of staying with a National weather approach (with National Standards)	
Pros	**Cons**
Same fabric standard nationally with potential supply chain cost advantages	'Over-specified' fabric in S and 'under-specified' in N
Same capital cost burden nationally (not increasing costs in N of East Pennines)	Not reducing costs S of East Pennines
Avoids 'boundary' issues	'Overshoots' zero carbon nationally ie increased house builder costs (for AS, more properties S of EP "overpaying" than those N of EP "underpaying")
More on-site reduction of CO_2 nationally	Doesn't reflect 'reality' – doesn't reflect regional differences
Avoids potential increased complexity?	Fuel cost to a std occupant different across the country (for same property type) ± £30pa
Fabric and solar solutions equally challenging in all regions	Does not recognise improved solar tech performance S of EP
Is 'known'	Doesn't encourage better fabric in N where colder
Less potential for the Carbon Compliance methodology to negatively affect value of land for owners due to location	Inconsistency with cooling & overheating calculations (currently based on regional weather)
Implications for EPCs	
Localism	

Figure 34 Pros and cons of staying with a National weather approach to compliance with National Standards

OPTION	Weather used for FEES & CC compliance calc	Fabric Energy Efficiency Standard (FEES)	Carbon Compliance (CC)	Allowable Solutions (AS)	OUTCOME: Minimum fabric spec across country	Difference in regulatory burden of ZC policy across country (semi detached house, 2016 Costs, compared to Option: Current)			Zero Carbon	Average household fuel costs across country (semi detached, compared to East Pennines)		Comparison to 70% CC level (red'n from BR 2006, detached/ attached/ low-rise apt)	Accuracy of performance claim (std. occupant, assuming designed = built performance)	Geographic optimisation of solar technologies	Technical 'headroom' (Fabric / PV)	Complexity for Industry	Policy Complexity
						eg South West	eg East Pennines	eg Borders		eg South West	eg Borders						
Current	National Weather	National Standard	National Standard	AS calc using National weather	Same	£0	£0	£0	Negative carbon	- £35/yr	+ £30/yr	eq. %, ave 60/56/44	'Worse than' in N, 'Better than' in S	Same m² in North & South	Reference	Reference	Reference
1a	National Weather	National Standard	National Standard	National weather. AS scheme adjusted to avoid National overpayment	Same	-£170	-£170	-£170	Zero Carbon on ave. nationally	- £35/yr	+ £30/yr	eq. %, ave 60/56/44	'Worse than' in N, 'Better than' in S	Same m² in North & South	Equal / Equal	Equal	Slightly more
1b	National Weather	National Standard	National Standard	AS calc using Regional weather	Same	-£435	£0	£360	Zero Carbon on all dwellings	- £35/yr	+ £30/yr	eq. %, ave 60/56/44	'Worse than' in N, 'Better than' in S	Same m² in North & South	Equal / Equal	Equal	Equal
2a	Regional Weather	National Standard	National Standard	AS calc using Regional weather	Higher in N, Lower in S	-£930	£0	£1,240	Zero Carbon on all dwellings	Equal	Equal	eq. %, ave 56/52/40	Correct	More m² in North	Less in N, more in S / Less in N, more in S	More	Equal
2b	Regional Weather	Regional Standard	Regional Standard	AS calc using Regional weather	Same	-£435	£0	£360	Zero Carbon on all dwellings	- £35/yr	+ £30/yr	eq. %, ave 60/56/44	Correct	Same m² in North & South	Equal / Equal	Equal	Equal
2c	Regional Weather	Regional Standard	Regional Standard	AS calc using National weather	Same	£0	£0	£0	Negative carbon	- £35/yr	+ £30/yr	eq. %, ave 60/56/44	Correct	Same m² in North & South	Equal / Equal	Equal	Equal
2d	Regional Weather	Regional Standard	Regional Standard	National weather. AS scheme adjusted to avoid National overpayment	Same	-£170	-£170	-£170	Zero Carbon on ave. nationally	- £35/yr	+ £30/yr	eq. %, ave 60/56/44	Correct	Same m² in North & South	Equal / Equal	Equal	Slightly more
2e	Regional Weather	National Standard	Regional Standard	AS calc using Regional weather	Higher in N, Lower in S	-£710	£0	£957	Zero Carbon on all dwellings	- £30/yr	+ £25/yr	eq. %, ave 60/56/44	Correct	More m² in South	Less in N, more in S / More in N, less in S	More	Equal
2f	Regional Weather	National Standard	Regional Standard	National weather. AS scheme adjusted to avoid National overpayment	Higher in N, Lower in S	-£445	-£170	£430	Zero Carbon on ave. nationally	- £30/yr	+ £25/yr	eq. %, ave 60/56/44	Correct	More m² in South	Less in N, more in S / More in N, less in S	More	Slightly more

Figure 35 Various options for compliance regime, showing the outcomes in a number of different areas. The pros and cons in Figures 33 and 34 above relate to options '2a' and 'current' respectively.

There are significant consequences associated with some of the options presented. Different members of the Task Group gave different weights to the various possible outcomes, and therefore to the different options; no clear consensus emerged. **The Task Group therefore recommends that:**

- **the weather assumption for compliance calculations should be further considered by Government. A provisional view should be expressed when the Carbon Compliance levels for 2016 are announced, and full consultation undertaken with the 2013 regulations.**
- **regardless of which option is chosen, a mechanism should be implemented to ensure that Allowable Solutions does not over-compensate for residual emissions nationally.**
- **should a regional approach to weather be implemented, a review of the number of, and appropriate drawing of boundaries between, 'regions' should be undertaken.**

Further information can be found in a separate report, available on the Zero Carbon Hub website.

Localism

The Carbon Compliance limit is set in Building Regulations, which apply nationally[30]. However, some local authorities already attach conditions to planning consents so as to require new homes (and other new buildings) to achieve specific other performance standards in relation to energy efficiency or Carbon Compliance. Their freedom to do so is guided and constrained by national Planning Policy Statements on Delivering Sustainable Development (PPS 1) and Renewable Energy (PPS 22).

The Government has made clear that it regards localism as a priority, and has published a Localism Bill which "will herald a ground-breaking shift in power to councils and communities overturning decades of central government control[31]. "The Task Group has considered whether and how localism and Carbon Compliance may work together.

The Task Group's own analysis and recommendations are robustly underpinned by a complex technical analysis. Against this background, **the Task Group recommends there should be no local power to set a different limit for Carbon Compliance, or to make other related stipulations**[32]. The Task Group is concerned that capacity limitations may mean that local decisions lack the same robust underpinning. This risks poor decisions being made, especially in light of the key recommendation for an 'as built' Carbon Compliance limit.

However, the Task Group also acknowledges the weight attached by the Government to localism, and recognises from its own work that a national limit designed to be achievable everywhere may leave some "headroom" in specific cases: for example where particular low / zero carbon energy sources exist, or where there is more freedom on house design and appearance.

[30] The Task Group assumes that local authorities will have to respect national Building Regulations.

[31] Statement by the Secretary of State for Communities and Local Government on 13 December 2010: see http://www.communities.gov.uk/news/newsroom/1794971

[32] The LGA do not support this recommendation but do recognise the need for robust evidence based decision making so do support recommendations 9a-d.

Should the Government, in pursuit of localism, wish local authorities to be able to set a more stringent requirement for Carbon Compliance or make additional stipulations for new dwellings, the Task Group recommends:

- Local authorities should be required to set out this intention in local plans whose soundness will be independently tested at examination as per current procedures, and should not be able to introduce planning conditions in relation to Carbon Compliance if not covered by the local plan;
- local plans and specific planning conditions should be underpinned by a rigorous technical analysis (utilising the extensive analysis undertaken for this Task Group), and should use the same metric as in Building Regulations;
- house builders should be given flexibility in how they deliver the locally imposed Carbon Compliance requirement, subject to any conditions in the local plan (see bullet above);
- both local plans and specific consents should be subject to whatever new arrangements the Government introduces to constrain the total regulatory burden such as a commercial viability test.

In making these recommendations the Task Group has assumed that there will be a ceiling price for Allowable Solutions set nationally. There may be an option for local reduction in the price set for Allowable Solutions, in which case the implications will need to be fully assessed to avoid unintended outcomes. But this lies beyond the scope of the Group's own work.

Looking beyond 2016

The Task Group's focus has been on the picture as it will be in 2016, when it is intended that the regulations to implement zero carbon will be made. Accordingly, the analysis in this report uses 2016 values and a projection of emissions factors for 2016, following the methodology set out in a previous report by the Zero Carbon Hub[33].

However, as shown in that report, during the 15 years from 2016 the national electricity grid will start to decarbonise, while at the same time the carbon performance of gas will also change as a result of changes in where it is sourced. As a result, carbon emission factors for both grid electricity and gas will substantially change. The practical effect will be that to achieve the same levels of Carbon Compliance with a gas boiler will require increasing amounts of PV, but with a heat pump will require reducing amounts of PV. This effect is likely to be compounded by progressive improvements in the efficiency of heat pumps.

Figure 36 illustrates this effect. This suggests that, depending on future technology costs, the relative attractiveness of gas boilers and heat pumps may reverse. The timing of this depends on a host of factors but using the assumptions contained within this report such a switch could occur around the 2019 / 2022 period.

The Task Group takes the view that these effects are too speculative to steer its recommendations for 2016. But they are worth noting now as they may feature strongly in the following review of regulations, due in 2019.

[33] *Carbon Compliance for Tomorrow's New Homes*, Zero Carbon Hub, July 2010

East Pennines Location			Carbon Compliance Level									
$kgCO_{2(eq)}/m^2/yr$			14		12		10		8		6	
Approx % reduction from 2006 Part L			44%								70%	
End Terrace House	Gas boiler	@ 2016	7.6	1.0	10.1	3.5	12.6	6.0	15.1	8.5	17.6	11.0
		@ 2019 (ish)	8.6		11.9	2.7	15.2	5.9	18.5	9.2	21.8	12.5
		@ 2022 (ish)	10.0		14.4	1.5	18.8	5.9	23.2	10.3	27.6	14.7
	ASHP	@ 2016	9.4	3.3	11.9	5.8	14.4	8.3	16.9	10.8	19.4	13.3
		@ 2019 (ish)	3.8		7.1	1.0	10.4	4.3	13.7	7.6	17.0	10.9
		@ 2022 (ish)			0.5		4.9		9.3	3.2	13.7	7.6
Fabric specification *			FEES	Spec C	FEES	Spec C	FEES	Spec C	FEES	Spec C	FEES	Spec C

Number in cell = m^2 PV required

Key	Area of solar technology required, as % of ground floor area †	No PV	Up to 25%	25% to 40%	40% to 60%	60% to 80%	over 80%

* FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

Figure 36 The effect of decarbonisation in the electricity grid

Rebasing

It is recognised that the assumptions underpinning the analysis, discussion and recommendations for the Carbon Compliance limit will change to a greater or lesser extent by 2016. Whilst such changes may have a material affect on dwelling design, delaying a decision on the limit until greater certainty is known is not an option as industry needs clarity on the zero carbon definition to make necessary investments in both time and money to meet this challenging programme.

To reconcile these two apparently conflicting demands an approach is adopted which 'rebases' the Carbon Compliance limit recommendations based on updated assumptions before the formal consultation on Part L 2016.

The types of assumptions include:

- Developments within SAP
- Carbon emission factors
- Findings from the work on closing the potential gap between designed and built performance (which may identify areas which substantially alter the technical and commercial feasibility)
- More extensive modelling which identifies robust technical concerns for specific house types

The rebasing process involves taking a series of typical properties whose technical specification complies with the original Carbon Compliance limits recommended within the Zero Carbon Hub's modified SAP 2009. These properties are then re-modelled with the new assumptions. The Carbon Compliance limits with the new assumptions are determined. If these limits are materially different to those of the original Task Group recommendations then a proposal is made to update the limits.

The Task Group recommends that the Carbon Compliance limits should be rebased whenever there is a substantive change to the assumptions on which the levels were based.

DETERMINING THE CARBON COMPLIANCE LIMIT FOR 2016

The Task Group has considered all the evidence and analysis set out above, but has not found any single consideration so weighty that it leads immediately to a clear conclusion on what should be the Carbon Compliance limit. Finding the appropriate limit has to be a matter of striking the right balance among the many different considerations which have emerged.

The Task Group considers that it is undesirable to require the majority of homes to be designed for optimum solar performance. This would have an impact on good place-making and the ability to integrate with the local vernacular, and could put at risk other desirable goals such as the effective use of in-fill sites and the redevelopment of brown field land. The Group also considers that to rely on biomass would be undesirable, its availability is not unlimited and there are health concerns if it is deployed at a mass scale. Irrespective of other arguments, these two reasons alone preclude a Carbon Compliance limit tighter than 6 kg $CO_{2(eq)}$ /m^2/year. This reduces the range for consideration to between 14 and 6 kg $CO_{2(eq)}$ /m^2/year.

Within this range, the Group has considered a variety of arguments. Many of the policy concerns identified are very significant in themselves but do not drive the decision for one Carbon Compliance level or another. There are, however, other considerations with a material impact on where the Carbon Compliance limit should be set.

Figures 37 and 38 summarise the arguments. Different members of the Task Group attach different weights to these various considerations.

Summary of arguments for a less stringent standard:

- When Allowable Solutions are also taken into account, all Carbon Compliance levels result in a zero carbon home, so maximum flexibility on-site should be allowed.
- Sites come in all shapes and sizes. Each has its own challenges. Even with development averaging, 'headroom' is required above the theoretical minimum at which solar design is not required, to ensure that developments and in particular smaller starter homes are not compromised.
- Expressing Carbon Compliance in terms of 'as built' performance has the potential to result in significant additional CO_2 savings compared with today's approach to regulation. The compliance regime is likely to require the use of confidence factors to drive good practice. Headroom is required to put such a system into place.
- More stringent Carbon Compliance levels increase upfront capital costs with associated impact on development viability and therefore housing supply.
- New homes are significantly more energy efficient than the existing stock, yet there is little evidence that house buyers / renters 'value', ie will pay a premium for, this benefit. The increased costs would therefore need to be absorbed by land price reduction or reductions in other burdens such as affordable housing else housing supply would be impacted.
- For apartments where widespread use of shared energy systems might be assumed, there are concerns this would affect their desirability for purchasers.

Figure 37 Summary of arguments for a less stringent standard

Summary of arguments for a more stringent standard:

- Householders directly benefit from a lower Carbon Compliance level through lower running costs and reduced exposure to energy price rises. The benefit from Allowable Solutions in mitigating CO_2 emissions is unlikely to accrue directly to the householder.
- In addition to the householder benefit, the carbon cost-effectiveness of Carbon Compliance improves as the standards are made more stringent.
- In the context of an 80% reduction in carbon emissions by 2050, the UK will need to make best use of all low and zero carbon energy opportunities. A lower Carbon Compliance level, maximising the on-site delivery, will help to realise this.
- There is more confidence that real CO_2 reductions will be delivered on-site than through off-site mitigation: it is hard to be sure that off-site measures are truly additional to what would have occurred anyway. The fact that Allowable Solutions have not yet been defined compounds this concern.
- To be credible and reduce the likelihood of future retrofit, zero carbon homes policy requires a reasonable level of on-site LZC energy generation.
- With on-site energy generation, the householder is better able to see the connection between energy demand and supply, encouraging behavioural change.

Figure 38 Summary of arguments for a more stringent standard

Two other key observations have emerged from the Group's analysis:

Within the narrowed range, for a particular dwelling, the marginal cost for moving the carbon compliance limit by 1kg is as shown in Figure 39:

	2010 prices	2016 prices
Detached houses	£610	£175
Attached houses	£395	£110
Low rise apartments	£280	£80

Figure 39 Marginal capital cost per dwelling of moving the carbon compliance limit by 1kg $CO_{2(eq)}$ /m^2/year

The zero carbon homes policy thus increases the regulatory burden. The aggregate cost is impossible to determine, as the challenges and opportunities of different development sites can vary so widely. However, for the illustrative developments used by the Task Group the proportion of the overall regulatory burden represented by Carbon Compliance ranged from 17%, where other regulatory demands are low, to 2% where other regulatory demands are high.

Weighing up the technical, commercial and wider policy considerations, a universally compelling reason for choosing one level over another did not emerge. However, members of the Task Group recognised that there was considerable value in reaching an agreed set of recommendations to present to Government, as opposed to just presenting various views. Following much debate the following recommendations were agreed for 2016 Building Regulations[34]

Detached houses

From the Group's analysis, the technical minimum is 6 kg $CO_{2(eq)}$ /m^2/year. However, as described above, good place-making precludes the assumption that all properties will be able to achieve ideal solar orientation and roof pitch, with no overshading. The recommendation for 'as built' performance increases the challenge further. Development averaging mitigates, but does not remove, these concerns. This said, the arguments for a stringent limit also have weight. On balance, and taking account also of the marginal cost drivers, a level of headroom is considered important and pragmatic.

Recommendation: 10 kg $CO_{2(eq)}$ /m^2/year for detached houses[35]

Terraced and other attached houses

The technical minimum is 8 kg $CO_{2(eq)}$ /m^2/year. On average these tend to be smaller than detached houses, with correspondingly less roof space; but their energy demand per m^2 is generally higher so overall they face a slightly greater challenge. Modelling suggests smaller homes might be particularly sensitive. In the wider respects, similar considerations apply as for detached houses. Again, on balance a level of headroom is considered important and pragmatic.

Recommendation: 11 kg $CO_{2(eq)}$ /m^2/year for attached houses[36]

Low rise apartments

From the Group's analysis the technical minimum is 8 kg $CO_{2(eq)}$ /m^2/year if shared building services are installed, but rises to 14 kg $CO_{2(eq)}$ /m^2/year if individual building services alone are used. The difference is primarily driven by the reduced effective roof area per dwelling. On balance it was considered overly restrictive to base the national minimum limit on the presumption that all apartments from 2016 must use some form of shared building services. However, the option of shared services gives a degree of flexibility not available in the case of houses, so the argument for further headroom is diminished.

Recommendation: 14 kg $CO_{2(eq)}$ /m^2/year for low rise apartment blocks (four storeys and below)[37]

Comparison with today's language

These recommendations apply to built performance, whereas the 2010 Regulations relate to designed performance. For this reason the recommendations *cannot* be directly compared with current standards. However, in addition to any carbon savings achieved by moving from designed to built performance, the percentage improvements on the 2006 standard would be:

- 60% for detached houses
- 56% for attached houses
- 44% for low rise apartment blocks

[34] Although agreed by all at the time the HBA subsequently withdrew their support for the recommended levels for houses
[35] Based on a modified version of SAP 2009
[36] As above
[37] As above

Implications

These recommendations represent a very challenging, but we believe a deliverable, national minimum standard. The level of this challenge should not be underestimated especially for some very small or infill sites where options may be more limited.

Whilst extensive modelling has been undertaken around relatively standard house types, there may be implications for some sub-categories of dwellings. **The Task Group recommends further modelling work is undertaken on a wider set of dwellings including very small houses and those on particularly difficult small sites, prior to formal consultation** to determine if there are particular difficulties which need to be addressed.

Modelling suggests the following for a typical semi-detached house at the Carbon Compliance level recommended of 11 kg $CO_{2(eq)}$ /m^2/year and a detached house at 10 kg $CO_{2(eq)}$ /m^2/year, in this example both using a gas boiler and PV[38]:

	Cost of Carbon Compliance				Total cost of zero carbon			
	Semi Detached		Detached		Semi Detached		Detached	
	2010 prices	2016 prices	2010 prices	2016 prices	2010 prices	2016 prices	2010 prices	2016 prices
Cost over 2006 Regulations	£8,500	£4,800	£12,900	£7,600	£13,700	£10,000	£19,800	£14,500
Cost over 2010 Regulations	£6,700	£3,500	£9,700	£5,400	£11,900	£8,700	£16,600	£12,300

Where Allowable Solutions represent £5,200[39] for the semi detached and £6,900 for the detached

For a semi detached dwelling without access to a gas supply for heating, using an air source heat pump and PV the net additional cost of zero carbon, beyond what is required by 2010 Regulations (assuming an electric panel heater), would be £10,300 at 2010 prices (£4,900 at 2016 prices).

To absorb this additional cost will require either a reduction in land prices, moderation of negotiated demands (such as section 106 agreements), the willingness (and ability) of house purchasers to pay more or a combination of these responses. Failing this, there will be an impact on the viability of house building schemes and the delivery of new homes.

House builders need to be fully aware of these costs when purchasing land. Likewise planners will need to recognise the implications of the Carbon Compliance levels for housing design.

Rebasing of the Carbon Compliance levels will be required prior to final implementation, to accommodate changes in assumptions. This may mean that the particular recommended Carbon Compliance limits also need to be adjusted to ensure that the standard dwellings which 'complied' under the old assumptions do so when the new assumptions are applied. It will also provide an opportunity to accommodate any findings from more extensive modelling of specific house types and work on closing the potential performance gap.

This report highlights the need for the wider house building industry to change in order to achieve the standards, not least to ensure that built performance is in line with designed performance. This will have an impact on every aspect of the house building process including: master planning, detail planning, design, modelling tools, construction/energy products, construction methods / skills and quality assurance. The challenge may be greatest for smaller house builders. For this reason, Government needs to make its decisions promptly to drive innovation and give industry the time to respond.

[38] See also Appendix D for other dwelling types
[39] Assuming allowable solutions cost of £75 per tonne over 30 years

APPENDICES

Appendix A

'2016' carbon emission factors

Fuel	2016 carbon emissions factor ($kgCO_{2(eq)}/kWh$)
Grid electricity	0.527
Electricity generated on-site	0.527
Mains gas	0.227
Wood pellets	0.037
Wood chips	0.015
Biomass community heating	0.019

Fabric specification 'FEES' (minimum Fabric Energy Efficiency Standard for 2016)

	[East Pennines Location]	Small apartment	Large apartment	Mid terrace house	End terrace house	Detached house
U-values	Ext. Walls (W/m^2K)	0.18	0.18	0.18	0.18	0.15
U-values	Party Walls (W/m^2K)	0	0	0	0	n/a
U-values	Semi exposed walls, inc adjustment (W/m^2K)	0.17	0.17	n/a	n/a	n/a
U-values	Floor (W/m^2K)	0.15	0.15	0.17	0.18	0.15
U-values	Roof (W/m^2K)	0.13	0.13	0.13	0.13	0.13
U-values	Windows (W/m^2K) whole window u-value	1.4 (double glazed)	1.4 (double glazed)	1.4 (double glazed)	1.4 (double glazed)	1.4 (double glazed)
U-values	Doors (W/m^2K)	1.0	1.0	1.0	1.0	1.0
	Window g-value	0.63	0.63	0.63	0.63	0.63
	Airtightness ($m^3/hr/m^2$)	5	5	5	5	3.1
	Thermal bridging y-value (W/m^2K)	0.04	0.04	0.04	0.04	0.04
	Ventilation type	Natural	Natural	Natural	Natural	Natural
	Number of extract fans	2	3	4	4	4
	Low energy lighting	100%	100%	100%	100%	100%

Fabric specification 'Spec C'

		Small apartment	Large apartment	Mid terrace house	End terrace house	Detached house
U-values	Ext. Walls (W/m²K)	0.15	0.15	0.15	0.15	0.15
	Party Walls (W/m²K)	0	0	0	0	n/a
	Semi exposed walls, inc adjustment (W/m²K)	0.14	0.14	n/a	n/a	n/a
	Floor (W/m²K)	0.15	0.15	0.15	0.15	0.15
	Roof (W/m²K)	0.11	0.11	0.11	0.11	0.11
	Windows (W/m²K) whole window u-value	0.8 (triple glazed)	0.8 (triple glazed)	0.8 (triple glazed)	0.8 (triple glazed)	0.8 (triple glazed)
	Doors (W/m²K)	1.0	1.0	1.0	1.0	1.0
	Window g-value	0.57	0.57	0.57	0.57	0.57
	Airtightness (m³/hr/m²)	1	1	1	1	1
	Thermal bridging y-value (W/m²K)	0.04	0.04	0.04	0.04	0.04
	Ventilation type	MVHR	MVHR	MVHR	MVHR	MVHR
	Low energy lighting	100%	100%	100%	100%	100%

Additional technologies modelled for sensitivity analysis

Individual

Gas boiler + SHW (+PV)

ASHP + SHW (+ PV)

GSHP (+PV)

GSHP + SHW (+ PV)

GSHP + biomass back boiler (+ PV)

Biomass boiler (+ PV)

Communal

Gas boiler + SHW (+PV) [Apartment block]

Biomass CHP + gas boiler (+ PV)

Gas CHP + biomass boiler (+ PV)

Gas CHP + gas boiler (+PV), CHP fraction 0.7 or less

Gas CHP + gas boiler (+PV), no tank in dwelling

Technology	Specification	Notes
Gas condensing boiler (individual)	95% efficient	Assuming an integrated flue gas heat recovery system - i.e. 91% for condensing boiler + 4% for FGHR. Note that SAP already has an in-use factor for boilers contained in it.
Gas condensing combi boiler (individual)	95% efficient	Assuming an integrated flue gas heat recovery system - i.e. 91% for condensing boiler + 4% for FGHR. Note that SAP already has an in-use factor for boilers contained in it.
ASHP (individual)	250% efficient	Use current SAP default. HP trials said 80% performed worse than expected, however much of this was put down to poor installation. Assumption that by 2016 improvements in installation will bring performance up. So considered reasonable to assume current SAP default - no justification to assume anything different.
GSHP (individual)	320% efficient	Use current SAP default. HP trials said 80% performed worse than expected, however much of this was put down to poor installation. Assumption that by 2016 improvements in installation will bring performance up. So considered reasonable to assume current SAP default - no justification to assume anything different.
GSHP (communal)	300% efficient	Use current SAP default. HP trials said 80% performed worse than expected, however much of this was put down to poor installation. Assumption that by 2016 improvements in installation will bring performance up. So considered reasonable to assume current SAP default - no justification to assume anything different.
Gas boiler (communal)	86% efficient	Limit for non-condensing boilers.
Biomass boiler (communal)	86% efficient	Limit for non-condensing boilers.
Gas CHP (communal)	37% elec efficiency 47% heat efficiency	Confirmed by CHPA, based on 250kWe
Biomass CHP (communal)	17% elec efficiency 60% heat efficiency	Adjusted data from CHPA
Solar hot water	Zero loss collector efficiency = 0.81; heat loss coefficient = 3.9	Confirmed by REA
Photovoltaics	$7m^2$/kWp assumed	Confirmed by REA
Biomass boiler (individual)	85% efficient	
Biomass back boiler (individual)	75% efficient	

Other modelling assumptions

Item	Specification	Notes
DHW cylinder size	Apartments: 120 litre Mid & End terrace: 150 litre Detached: 200 litre	Declared loss factors of 0.96, 1.14 and 1.44 respectively. Water use less than or equal to 125 litres/person/day.
Space heating controls (individual system)	Time & temperature zone control	As proxy for well controlled heating system. To be used in all dwelling types.
Space heating controls (communal system)	Programmer + TRV, charging linked to use	Gives best performance in SAP
Compensator (where applicable)	Weather compensator	Weather and Enhanced Load compensators give same performance boost in SAP.
Communal heating type (where applicable)	100degC or below full control variable system	
Hot water storage for communal heating options	Cylinder in dwelling	It was considered more likely that developers will want to include cylinder in dwelling to help ameliorate occupant concerns over connection to a communal system which is not under their direct control.
Fraction of heat from CHP (where applicable)	To be equivalent to hot water demand	Ratio of hot water demand to total heat demand calculated for each dwelling modelled.
Heat pump (individual)	Use immersion	Use deemed to be likely
Solar hot water	Orientation = South Collector tilt = 30deg Overshading = none/ very little	Optimum performance assumed
Photovoltaics	Orientation = SE/SW Collector tilt = 45deg Overshading = none/ very little	Not quite optimum orientation & tilt. Sensitivity analysis also carried out for all orientation, tilt and overshading combinations.

Appendix B

Designed vs Built performance file note – as agreed at Task Group meeting 9/12/10

File note - Designed v Built performance

As agreed – Task Group Meeting 09 Dec 2010

The Carbon Compliance level recommended by the Task Group is predicated on house builders and the wider industry working over time to close the potential gap between the designed and built energy / carbon performance.

This is a significant challenge to the industry as a whole and represents a 10 year programme. The recommendations from the Carbon Compliance for Tomorrows New Homes (CC4TNH) Task Group were:

- (P1) Government and industry should develop Carbon Compliance accreditation schemes for designers, systems suppliers/manufacturers, and builders of new dwellings that assure in-use performance of dwelling fabric and services.

  [CCTG note: this means the verification of carbon performance, not of compliance]

- (P2) Whole house post-construction fabric and services audit tests should be developed and implemented on a sample basis as part of accreditation.

  [CCTG note: this does not preclude the testing being on individual elements or at different stages of the process, nor should it be taken as meaning only co-heating tests]

- (P3) The Carbon Compliance regime for zero carbon should incorporate confidence factors* (for design, systems, build and post construction testing), scaled so as to provide an incentive for industry to improve its processes and to participate in an accredited compliance scheme**.

  [CCTG note: This needs to be based on robust evidence and science]

- (P4) The use of confidence factors should be taken into account when reviewing the proposed Carbon Compliance level of a 70% reduction from 2006 levels.

The CC4TNH report recommendation P4 has been taken into account when the CCTG determined the recommended Carbon Compliance level.

To provide clarity to all CC Task Group members; as part of working to close the potential performance gap, the industry would arrange for the testing of actual energy / carbon performance of a statistically representative random sample of homes. This would be verified by third party measurement covering fabric, services and LZC technologies.

The approach taken to close the potential performance gap should be urgently developed by industry with regulatory support provided by government as appropriate. The first stage must be to collect data in order to establish the scope and scale of the issue.

A scheme should be developed to address any gaps identified by the research and applied to dwellings built from 2016. The results should inform industry and government with the aim that from 2020 the test results distribution would demonstrate that at least 90% of all dwellings would meet or perform better than the designed energy / carbon performance.

Therefore the industry invites partners and government to join in devising and committing to a process that investigates best ways to measure and address this and to make the new compliance procedures widely known in the industry and amongst regulators by no later than 2016. This should build upon the work done by the Carbon Compliance for Tomorrow's New Homes Task Group.

* *as opposed to 'safety factors' which have no regard for the actual quality of the design / product / construction processes.*

** *The factor applied would reflect the level of confidence in the design / product / construction in delivering the stated performance.*

Appendix C

Technical feasibility: Core technologies, Houses – Narrowed zone, at 1kg increments

East Pennines Location			Carbon Compliance Level									
$kgCO_{2(eq)}/m^2/yr$			12		11		10		9		8	
Fabric specification *			FEES	Spec C	FEES	Spec C	FEES	Spec C	FEES	Spec C	FEES	Spec C
Detached House	Communal options	Biomass boiler										
		Biomass CHP					1.5		3.4		5.3	
		Gas CHP	4.9		6.8		8.7		10.6	0.6	12.6	2.5
		GSHP	2.1		4.0		5.9		7.9	1.8	9.8	3.8
	Individual options	ASHP + SHW	5.1		7.1		9.0	1.6	10.9	3.6	12.9	5.5
		ASHP	11.6	4.3	13.6	6.3	15.5	8.2	17.4	10.1	19.4	12.1
		Gas + SHW	5.5		7.4		9.3	1.1	11.3	3.0	13.2	5.0
		Gas	10.1	2.0	12.0	3.9	14.0	5.9	15.9	7.8	17.8	9.7
End Terrace House	Communal options	Biomass boiler										
		Biomass CHP					0.6		1.8		3.1	
		Gas CHP	4.5		5.8		7.0		8.3		9.5	1.1
		GSHP	3.7		4.9		6.2	1.1	7.4	2.3	8.7	3.6
	Individual options	ASHP + SHW	6.0		7.2	1.1	8.5	2.3	9.7	3.6	11.0	4.8
		ASHP	11.9	5.8	13.1	7.0	14.4	8.3	15.6	9.5	16.9	10.8
		Gas + SHW	5.9		7.2	0.4	8.4	1.6	9.7	2.9	10.9	4.1
		Gas	10.1	3.5	11.4	4.7	12.6	6.0	13.9	7.2	15.1	8.5
Mid Terrace House	Communal options	Biomass boiler										
		Biomass CHP									0.9	
		Gas CHP	2.3		3.6		4.8		6.1		7.3	
		GSHP	2.1		3.4		4.6	0.1	5.9	1.3	7.1	2.6
	Individual options	ASHP + SHW	4.2		5.4		6.7	1.2	7.9	2.4	9.2	3.7
		ASHP	10.1	4.7	11.3	5.9	12.6	7.2	13.8	8.4	15.1	9.7
		Gas + SHW	4.0		5.2		6.5	0.4	7.7	1.6	9.0	2.9
		Gas	8.2	2.3	9.4	3.5	10.7	4.8	11.9	6.0	13.2	7.3

Number in cell = m² PV required

Key	Area of solar technology required, as % of ground floor area †	No PV	Up to 25%	25% to 40%	40% to 60%	60% to 80%	over 80%

* FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

Technical feasibility: Core technologies, Low-rise Apartment Blocks – Narrowed zone, at 1kg increments

East Pennines Location

$kgCO_{2(eq)}/m^2/yr$		Carbon Compliance Level	14		13		12		11		10	
Fabric specification *			FEES	Spec C	FEES	Spec C	FEES	Spec C	FEES	Spec C	FEES	Spec C
3-Storey Apartment Block	Shared/ Communal options	Biomass boiler										
		Biomass CHP										
		Gas CHP			2		23		44		66	
		GSHP	3		24		46		67		89	18
	Individual options	ASHP + SHW	59		80		102	17	123	39	144	60
		ASHP	170	83	191	105	213	126	234	148	256	169
		Gas + SHW	47		68		90		111	18	133	40
		Gas	126	30	148	52	169	73	191	94	212	116
4-Storey Apartment Block	Shared/ Communal options	Biomass boiler										
		Biomass CHP										
		Gas CHP					17		46		74	
		GSHP			24		52		81		109	18
	Individual options	ASHP + SHW	68		96		125	17	154	45	182	74
		ASHP	219	105	247	134	276	162	304	191	333	219
		Gas + SHW	51		80		109		137	18	166	47
		Gas	157	33	186	61	215	90	243	119	272	147

Number in cell = m² PV required

Key	Area of solar technology required, as % of ground floor area †	No PV	Up to 25%	25% to 40%	40% to 60%	60% to 80%	over 80%

* FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

Technical feasibility: Core technologies, High-rise Apartment Blocks – Narrowed zone, at 1kg increments

East Pennines Location

$kgCO_{2(eq)}/m^2/yr$			14 FEES	14 Spec C	13 FEES	13 Spec C	12 FEES	12 Spec C	11 FEES	11 Spec C	10 FEES	10 Spec C
			Carbon Compliance Level									
8-Storey Apartment Block	Shared/ Communal options	Biomass boiler										
		Biomass CHP										
		Gas CHP							51 (Up to 25%)		109 (Up to 25%)	
		GSHP			20 (Up to 25%)		78 (Up to 25%)		135 (25% to 40%)		192 (40% to 60%)	20 (Up to 25%)
	Individual options	ASHP	414 (over 80%)	192 (40% to 60%)	471 (over 80%)	249 (40% to 60%)	528 (over 80%)	306 (60% to 80%)	586 (over 80%)	364 (over 80%)	643 (over 80%)	421 (over 80%)
		Gas	281 (60% to 80%)	44 (Up to 25%)	338 (60% to 80%)	101 (Up to 25%)	395 (over 80%)	158 (25% to 40%)	453 (over 80%)	215 (40% to 60%)	510 (over 80%)	273 (60% to 80%)
20-Storey Apartment Block	Shared/ Communal options	Biomass boiler										
		Biomass CHP										
		Gas CHP							68 (Up to 25%)		211 (40% to 60%)	
		GSHP			11 (Up to 25%)		154 (25% to 40%)		297 (60% to 80%)		440 (over 80%)	25 (Up to 25%)
	Individual options	ASHP	999 (over 80%)	453 (over 80%)	1143 (over 80%)	596 (over 80%)	1286 (over 80%)	739 (over 80%)	1429 (over 80%)	882 (over 80%)	1572 (over 80%)	1026 (over 80%)
		Gas	652 (over 80%)	76 (Up to 25%)	795 (over 80%)	220 (40% to 60%)	938 (over 80%)	363 (over 80%)	1081 (over 80%)	506 (over 80%)	1224 (over 80%)	649 (over 80%)
Fabric specification *			FEES	Spec C	FEES	Spec C	FEES	Spec C	FEES	Spec C	FEES	Spec C

Number in cell = m^2 PV required

Key						
Area of solar technology required, as % of ground floor area †	No PV	Up to 25%	25% to 40%	40% to 60%	60% to 80%	over 80%

* FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

Appendix D

Cost summary table for Zero Carbon homes

Dwelling Type	Carbon Compliance Level $kgCO_{2(eq)}/m^2/yr$	@ 2010 prices: Fabric ('06 to '10)	@ 2010 prices: Fabric (over 2010)	@ 2010 prices: Carbon Compliance (excl fabric)	@ 2010 prices: Allowable Solutions @ £75/tCO_2 over 30 yrs	@ 2010 prices: TOTAL over 2010	@ 2010 prices: TOTAL over 2006	@ 2010 prices: Marginal cost of CC limit moved by 1$kgCO_2$ (within 14-10kg range)	@ 2016 prices: Fabric ('06 to '10)	@ 2016 prices: Fabric (over 2010)	@ 2016 prices: Carbon Compliance (excl fabric)	@ 2016 prices: Allowable Solutions @ £75/tCO_2 over 30 yrs	@ 2016 prices: TOTAL over 2010	@ 2016 prices: TOTAL over 2006	@ 2016 prices: Marginal cost of CC limit moved by 1$kgCO_2$ (within 14-10kg range)
Low-rise Apartment Block, ave per unit	**14**	£1,071	£51	£2,600	£4,259	**£6,910**	£7,981	£283	£760	£36	£1,332	£4,259	**£5,627**	£6,387	£80
		Base build cost: £60,000													
Mid Terrace House	**11**	£1,194	£0	£5,752	£5,179	**£10,931**	£12,125	£396	£848	£0	£3,004	£5,179	**£8,183**	£9,031	£112
		Base build cost: £67,820													
End Terrace House	**11**	£1,804	£80	£6,632	£5,179	**£11,891**	£13,695	£396	£1,281	£57	£3,444	£5,179	**£8,680**	£9,961	£112
		Base build cost: £71,820													
Detached House	**10**	£3,153	£1,913	£7,809	£6,930	**£16,652**	£19,805	£611	£2,239	£1,358	£4,033	£6,930	**£12,321**	£14,560	£173
		Base build cost: £107,380													

Appendix E

Example ways to achieve the recommended Carbon Compliance standards

Please note the following when reading the table overleaf:

- Main heating technologies shown are those on the core list agreed by the Technical Work Group
- Where zero carbon electricity is required to achieve the required Carbon Compliance limit, this could be attained in a number of ways. One example – the use of photovoltaic panels – has been shown as an example
- Where the amount of zero carbon electricity required is low, it is likely that the fabric specification could be adjusted such that no such electricity is required
- All individual heat pump options include for the use of an immersion heater to top-up hot water production
- All CHP options are sized on the base heat demand – hot water – with a gas boiler producing any top-up required
- The residual emissions for the dwellings modelled have been included for information – this is the element that Allowable Solutions would apply to.

Mid Terrace House – Carbon Compliance Level = 11kg $CO_{2(eq)}/m^2/yr$

	Fabric Spec	Main heat tech	Other heat tech	kWh zero carbon elec required	If zero carbon elec via PV kWp	If zero carbon elec via PV m²	Solar tech as % of total roof area#	Carbon Compliance level achieved $kgCO_{2(eq)}/m^2/yr$	Residual emissions to Zero Carbon* $kgCO_{2(eq)}/yr$
Individual options	FEES	Gas boiler	none	1,090	1.3	9.4	15%	11.0	2,302
	FEES	Gas boiler	SHW	605	0.7	5.2	15%	11.0	2,302
	FEES	ASHP	none	1,309	1.6	11.3	18%	11.0	2,302
	FEES	ASHP	SHW	626	0.8	5.4	15%	11.0	2,302
	FEES	GSHP	none	576	0.7	5.0	8%	11.0	2,302
	FEES	GSHP	SHW	171	0.2	1.5	9%	11.0	2,302
	Spec C	Gas boiler	none	407	0.5	3.5	6%	11.0	2,302
	Spec C	Gas boiler	SHW	0			6%	10.3	2,248
	Spec C	ASHP	none	684	0.8	5.9	10%	11.0	2,302
	Spec C	ASHP	SHW	0			6%	10.9	2,297
	Spec C	GSHP	none	550	0.7	4.8	8%	11.0	2,302
	Spec C	GSHP	SHW	0			6%	10.3	2,251
Communal options	FEES	Biomass boiler	none	0				4.1	1,777
	FEES	Gas CHP	Gas boiler	411	0.5	3.6	6%	11.0	2,302
	FEES	Biomass CHP	Gas boiler	0				8.7	2,129
	Spec C	Biomass boiler	none	0				4.6	1,814
	Spec C	Gas CHP	Gas boiler	0				7.7	2,046
	Spec C	Biomass CHP	Gas boiler	0				3.7	1,741

* Including non-regulated emissions

End Terrace/ Semi-detached House – Carbon Compliance Level = 11kg $CO_{2(eq)}$/m²/yr

	Fabric Spec	Main heat tech	Other heat tech	kWh zero carbon elec required	If zero carbon elec via PV		Solar tech as % of total roof area*	Carbon Compliance level achieved	Residual emissions to Zero Carbon*
					kWp	m²		$kgCO_{2(eq)}/m^2/yr$	$kgCO_{2(eq)}/yr$
Individual options	FEES	Gas boiler	none	1,315	1.6	11.4	18%	11.0	2,302
	FEES	Gas boiler	SHW	833	1.0	7.2	18%	11.0	2,302
	FEES	ASHP	none	1,518	1.9	13.1	21%	11.0	2,302
	FEES	ASHP	SHW	834	1.0	7.2	18%	11.0	2,302
	FEES	GSHP	none	737	0.9	6.4	10%	11.0	2,302
	FEES	GSHP	SHW	374	0.5	3.2	12%	11.0	2,302
	Spec C	Gas boiler	none	545	0.7	4.7	8%	11.0	2,302
	Spec C	Gas boiler	SHW	41	0.1	0.4	7%	11.0	2,302
	Spec C	ASHP	none	812	1.0	7.0	11%	11.0	2,302
	Spec C	ASHP	SHW	122	0.2	1.1	8%	11.0	2,302
	Spec C	GSHP	none	649	0.8	5.6	9%	11.0	2,302
	Spec C	GSHP	SHW	65	0.1	0.6	7%	11.0	2,302
Communal options	FEES	Biomass boiler	none	0				4.3	1,787
	FEES	Gas CHP	Gas boiler	669	0.8	5.8	9%	11.0	2,302
	FEES	Biomass CHP	Gas boiler	0				10.5	2,260
	Spec C	Biomass boiler	none	0				4.7	1,818
	Spec C	Gas CHP	Gas boiler	0				8.9	2,140
	Spec C	Biomass CHP	Gas boiler	0				3.7	1,741

* Including non-regulated emissions

Detached House – Carbon Compliance Level = 10kg $CO_{2(eq)}$/m²/yr

	Fabric Spec	Main heat tech	Other heat tech	kWh zero carbon elec required	If zero carbon elec via PV		Solar tech as % of total roof area*	Carbon Compliance level achieved	Residual emissions to Zero Carbon*
					kWp	m²		$kgCO_{2(eq)}/m^2/yr$	$kgCO_{2(eq)}/yr$
Individual options	FEES	Gas boiler	none	1,616	2.0	14.0	16%	10.0	3,080
	FEES	Gas boiler	SHW	1,081	1.3	9.3	15%	10.0	3,080
	FEES	ASHP	none	1,795	2.2	15.5	18%	10.0	3,080
	FEES	ASHP	SHW	1,040	1.3	9.0	15%	10.0	3,080
	FEES	GSHP	none	1,287	1.6	11.1	13%	10.0	3,080
	FEES	GSHP	SHW	580	0.7	5.0	10%	10.0	3,080
	Spec C	Gas boiler	none	678	0.8	5.9	7%	10.0	3,080
	Spec C	Gas boiler	SHW	128	0.2	1.1	6%	10.0	3,080
	Spec C	ASHP	none	949	1.2	8.2	9%	10.0	3,080
	Spec C	ASHP	SHW	190	0.2	1.6	6%	10.0	3,080
	Spec C	GSHP	none	682	0.8	5.9	7%	10.0	3,080
	Spec C	GSHP	SHW	0			5%	9.9	3,066
Communal options	FEES	Biomass boiler	none	0				3.7	2,334
	FEES	Gas CHP	Gas boiler	1,009	1.2	8.7	10%	10.0	3,080
	FEES	Biomass CHP	Gas boiler	170	0.2	1.5	2%	10.0	3,080
	Spec C	Biomass boiler	none	0				4.2	2,396
	Spec C	Gas CHP	Gas boiler	0				9.3	2,996
	Spec C	Biomass CHP	Gas boiler	0				5.5	2,554

* Including non-regulated emissions

4-Storey Apartment Block, 32 units – Carbon Compliance Level = 14kg $CO_{2(eq)}/m^2/yr$

	Fabric Spec	Main heat tech	Other heat tech	kWh zero carbon elec required (for block)	If zero carbon elec via PV (for block)		Solar tech as % of total roof area*	Carbon Compliance level achieved	Residual emissions to Zero Carbon (ave per unit)*
					kWp	m²		$kgCO_{2(eq)}/m^2/yr$	$kgCO_{2(eq)}/yr$
Individual options	FEES	Gas boiler	none	18,215	22.5	157	36%	14.0	1,893
	FEES	Gas boiler	SHW	5,932	7.3	51	26%	14.0	1,893
	FEES	ASHP	none	25,296	31.2	219	50%	14.0	1,893
	FEES	ASHP	SHW	7,848	9.7	68	30%	14.0	1,893
	Spec C	Gas boiler	none	3,795	4.7	33	8%	14.0	1,893
	Spec C	Gas boiler	SHW	0			15%	11.6	1,764
	Spec C	ASHP	none	12,142	15.0	105	24%	14.0	1,893
	Spec C	ASHP	SHW	0			15%	12.6	1,815
Communal/ Shared options	FEES	Biomass boiler	none	0				4.2	1,356
	FEES	GSHP	none	0				13.8	1,883
	FEES	Gas CHP	Gas boiler	0				12.6	1,817
	FEES	Biomass CHP	Gas boiler	0				6.2	1,466
	Spec C	Biomass boiler	none	0				4.6	1,381
	Spec C	GSHP	none	0				10.6	1,709
	Spec C	Gas CHP	Gas boiler	0				7.3	1,529
	Spec C	Biomass CHP	Gas boiler	0				3.6	1,323

* Including non-regulated emissions

[#] note most of the Task Groups analysis used floor rather than roof area to simplify calculations and allow 'headroom' but this is less common so these tables have been converted to reflect the more common metric.

GLOSSARY

Allowable solutions	Forms of carbon abatement delivered off-site which mitigate any residual carbon emissions from a building once onsite requirements have been met. Specific details have not yet been announced.
ASHP	Air source heat pump
BIS	Department for Business Innovation and Skills
CC	Carbon Compliance
CHP	Combined heat and power. A system under which the heat generated in the process of electricity generation is used to heat dwellings and other buildings through the circulation of hot water or steam
CIBSE	Chartered Institution of Building Services Engineers
CIL	Community Infrastructure Levy. A levy which local authorities in England and Wales may choose to charge on new developments in their area
CO_2	Carbon dioxide. A greenhouse gas.
$CO_{2(eq)}$ /m²/year	Carbon dioxide (and other greenhouse gases expressed as equivalents) per square metre per year. A measure of emissions
Community energy	Distribution of locally generated energy within a development
DCLG	Department for Communities and Local Government
DECC	Department of Energy and Climate Change
District energy	Large scale distribution of locally generated energy to new and / or existing buildings across multiple developments ie town scale
FEES	Fabric Energy Efficiency Standard. Defined in a report by the Zero Carbon Hub, *Defining a Fabric Energy Efficiency Standard for Zero Carbon Homes*, published in November 2009
Fuel Factors	In current (2010) compliance methodology, Fuel Factors are applied to the calculation of Target CO_2 Emission Rate (TER) depending on the fuel used to provide heat to the dwelling. The effect is that, for example, electrically heated dwellings are allowed to emit more CO_2 than an equivalent gas heated dwelling
Green Deal	The Energy Bill introduced to Parliament on 8 December 2010 includes provision for a new "Green Deal," under which a framework would be established to enable private firms to offer consumers energy efficiency improvements to their homes and recover the costs through a charge on the energy bill levied over an extended period of time

GSHP	Ground source heat pump
Notional dwelling	An imagined dwelling used in the assessment of carbon intensity; it uses data about the size and shape of the real dwelling, and standardised data for the carbon performance of its components
LZC	Low or zero carbon
Part L	Part L (Conservation of Fuel and Power) of the Building Regulations
PassivHaus	A specific construction standard for low energy buildings which are designed to have excellent comfort conditions in both winter and summer. Originally developed by the PassivHaus Institut in Germany
PV	Photovoltaics. PV panels convert sunlight to electricity
SAP	Standard Assessment Procedure. An energy assessment tool currently used to determine whether new dwellings comply with Part L (Conservation of Heat and Power) of the Building Regulations. The tool consists of a core computer algorithm which is applied to data about the new dwelling
Section 106	Section 106 of the Town and Country Planning Act 1990. This allows a local planning authority (LPA) to enter into a legally-binding agreement or planning obligation with a landowner in association with the granting of planning permission. The obligation is termed a Section 106 Agreement
Shared energy	Distribution of energy generated within a central plant room to separate dwellings / units within the same building envelope
Spec C	A demanding standard for the energy efficiency of building fabric, similar to the PassivHaus specification. The full Spec C specification is set out in Appendix A
SHW	Solar hot water
TFA	Total floor area

Notes:

Notes:

Housing research in partnership with BRE Trust

This publication was produced to ISO14001 Enviromental Management System standards, and 95% of the waste created during the process was recycled. The materials used included vegetable oil inks, elemental chlorine free pulp and fibre from managed forests. The publication was made CarbonNeutral.® The unavoidable CO_2 emissions created during the manufacturing process were neutralised through investment in climate friendly projects around the world.

ZERO CARBON HUB

LONDON OFFICE
62-68 Rosebery Avenue
London EC1R 4RR

MILTON KEYNES OFFICE
NHBC House, Davy Avenue
Milton Keynes MK5 8FP

T 0845 888 7620
F 0871 813 0569
info@zerocarbonhub.org
www.zerocarbonhub.org

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