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.

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.

NHBC Foundation
The NHBC Foundation was established in 2006 by NHBC in partnership with the BRE Trust. Its purpose is to deliver high-quality research and practical guidance to help the industry meet its considerable challenges.

Since its inception, the NHBC Foundation’s work has focused primarily on the sustainability agenda and the challenges of Government’s 2016 zero carbon homes target. Research has included a review of microgeneration and renewable energy techniques and the groundbreaking research on zero carbon and what it means to homeowners and housebuilders.

The NHBC Foundation is also involved in a programme of positive engagement with Government, development agencies, academics and other key stakeholders, focusing on current and pressing issues relevant to the industry.

Further details on the latest output from the NHBC Foundation can be found at www.nhbcfoundation.org.

This report is available as a PDF Download from www.zerocarbonhub.org

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August 2010

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The views and recommendations within this report are those of the Topic Work Group and do not necessarily reflect the views of the organisations represented.
The translation of a world-leading policy for all new homes to be zero carbon from 2016 into a practical reality for both government and industry is a hugely challenging task, but one made possible by the collaboration and support of all the stakeholders who contribute to the work of the Zero Carbon Hub. The first stage was to translate the aim for a stretching requirement for energy efficiency into a workable standard for regulation, and that work has been warmly welcomed by stakeholders from all sectors.

This strategic work on carbon compliance modelling addresses the next crucial stage. It is our insurance that tomorrow’s new homes are designed and built in a way that reliably delivers the government’s challenging 2016 carbon emissions reduction target. The findings and recommendations presented here are the result of six months’ hard work by a Zero Carbon Hub Task Group of recognised experts drawn from the wider house building sector including: developers, designers, consultants, professional bodies, product manufacturers and academics.

The carbon compliance tool is the means by which we will calculate the energy and carbon performance of new homes and is a fundamental part of zero carbon homes delivery. However as the review shows, the existing tool, SAP, is not adequate in its current form to meet the new challenges of delivering low energy/zero carbon homes. Work is urgently needed to ensure that we have a compliance tool that will be fit for purpose.

To provide an objective basis for such development, this review flags up the key issues for Government and industry consideration. Several of the recommendations indicate where research and further work is needed. Much of it is urgent. In the current economic climate, Government cannot be expected to meet all of the cost of this work so as the review emphasises, the regulatory framework, clarity of assumptions and a consistent direction to travel become even more important - to give assurance to the wider house building industry that money and time invested will be well spent.

We all recognise that this is an ambitious agenda. Development work is not only required for the compliance tool, but within the industry itself to ensure that new homes truly perform in line with the compliance assessment – translating performance on paper to achievement on the ground. This will mean a change of focus brought about by appropriate regulations starting immediately but taking many years to fully embed.

I am confident that this review will be well received and command considerable interest from across the wider industry. Early consideration and response by Government to its recommendations will give confidence to the industry and help assure that the 2016 target for zero carbon homes remains achievable and contributes to building the low carbon economy that we are all committed to.

Paul King
Chairman, Zero Carbon Hub
August 2010
This forward-looking review reports the findings of an expert Task Group, facilitated by the Zero Carbon Hub, to consider whether the existing carbon compliance tool, the assumptions on which it is based and the regulatory framework surrounding it are appropriate for low energy/zero carbon homes. It has been prepared primarily to inform government and the 2016 Task Force, the Senior Government/Industry steering group overseeing the implementation of the zero carbon new homes from 2016.

The work had three objectives:

1) To define an appropriate compliance (and design) tool for low carbon/energy homes from 2016

2) To recommend a way by which industry can have an indication of how the ‘likely’ future changes to the compliance model might impact the predicted dwelling performance

3) Propose a transition and implementation plan for the 2016 compliance tool

Five Topic Work Groups, reporting to the main Task Group, were established in Autumn 2009 to explore in detail the key issues and ensure wide input into recommendations. The Topic Work Groups reported in Spring 2010 and their work is presented as a series of separate Topic reports, listed below. The Task Group considered these reports and prepared an introductory Overview report summarising the main findings and recommendations.

**OVERVIEW**

**Overview of findings and recommendations**

The Task Group’s summary of the Topic Work Group reports

**TOPIC 1**

**Carbon compliance tools considerations**

Looking at modelling tools currently available both here and abroad and considering key characteristics, what they assess and the trade off between accuracy and ease of use.

**TOPIC 2**

**Carbon intensity of fuels**

Considering the implications of, and an appropriate response to, the changing carbon intensity of electricity and other fuels.

**TOPIC 3**

**Future climate change**

Setting out how projected national and local climate changes could affect energy demand. Exploring for example how the compliance tool should embrace overheating risk.

**TOPIC 4**

**Closing the gap between designed and built performance**

How the compliance tool should accommodate (and help reduce) any performance gap between design performance and what is achieved on site.

**TOPIC 5**

**How the performance standard should be expressed**

This looks at whether carbon compliance should be expressed as an improvement versus a notional building (as now) or in absolute terms (kg CO₂ emissions per unit area).

The work of the Topic Groups was informed by modelling commissioned on a range of house types, climate assumptions and compliance tools. The aim was not to provide accurate predictions, but rather to identify which, of a range of factors, have the greatest impact on the carbon performance of a new home.

**MODELLING**

**The modelling supporting this review**

Sets out the modelling undertaken to support this programme of work.
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ACKNOWLEDGEMENTS

The Zero Carbon Hub is extremely grateful to all participants who contributed to Topic 5 Work Group and gave generously of their time and expertise.

To enable it to carry out the necessary in-depth review work that underpinned the recommendations in this Report, Topic 5 Work Group is grateful for the funding support it received from Communities and Local Government (CLG), the Department of Energy and Climate Change (DECC) and the Zero Carbon Hub.

The Work Group also gratefully acknowledges the NHBC Foundation for generous sponsorship of the dissemination phase of this work, including this report series.

The members of this Topic Work Group were:

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EXECUTIVE SUMMARY

Background
In July 2009, the then Housing Minister announced that the carbon compliance target for zero carbon homes would be to achieve a 70% reduction in CO₂ emissions over Part L 2006 standards. The objective of this Topic Work Group (TWG) has been to recommend the best approach for setting this target, given the nature of low energy homes.

In particular, the TWG has considered the following:

- Firstly, whether the current approach where the percentage carbon emissions reduction target is set the same for each dwelling, regardless of type, is appropriate for zero carbon homes (‘individual approach’); or whether an aggregate approach to achieving the same overall saving is more appropriate

- Secondly, whether the target should be based on an historic notional dwelling (as now); a concurrent notional dwelling; or an absolute carbon limit (e.g. kgCO₂/m²/year)

To enable discussions to proceed, the two issues above were turned into a set of options, and variations were also discussed:

- ‘Individual’ percentage reduction approach based on historic notional dwelling (as now)
- Aggregate approach using concurrent notional dwelling
- Aggregate approach using absolute carbon limits

In order to make decisions, the TWG undertook a multi-criteria options analysis. Criteria were agreed to evaluate the different options. These considered the effort involved in developing the approach; the robustness of the approach; the resultant costs to industry of delivering the compliant solutions and how equitable this was between different dwelling types; ease of communication of the approach; and fit with wider Government policy. Each option was rated against the criteria to provide an overall evaluation and enable comparison.

The analysis was based on a mix of qualitative and quantitative data. This included information from two energy modelling exercises. The first investigated 70% compliant solutions for different dwelling types and fabric and services scenarios. The second investigated how carbon emissions vary for a given dwelling type and fuel, and variations by dwelling size.

‘Individual’ percentage reduction approach based on historic notional dwelling

At an emissions reduction target of 70%, the modelling highlighted shortcomings with the current individual approach based on a reduction in emissions from a historic notional dwelling. It suggested that for many apartment buildings it would be very much harder to achieve this level of carbon reduction than for houses. This was due to apartments being a more energy-efficient built form (less exposed area per unit floor area) and thus having less opportunity to make carbon reductions from fabric improvements, and therefore greater reliance on other measures such as the use of PV. In addition, there is significantly less roof area per apartment on which to install PV to generate on-site electricity to off-set carbon emissions, compared to other dwelling types with fewer storeys.
However, the industry currently uses and understands this approach, and it is the only approach to guarantee delivery of a 70% improvement in designed performance.

On balance the TWG concluded that an individual % reduction was not an appropriate way to define carbon compliance and that account needed to be taken regarding dwelling type i.e. an aggregate approach.

An aggregate approach

The two aggregate approaches scored similarly in many areas. Both provide the flexibility for more equitable compliant solutions across dwelling types. In doing so, they equally suffer from a reliance on predictions of future build mix to achieve an overall 70% reduction.

Aggregate approach using concurrent notional dwelling

An aggregate approach using a concurrent notional dwelling has some advantages in that the notional dwelling itself is a compliant solution, and compliance model input errors would be minimised due to having similar impacts on both the actual and notional dwelling. This is also the approach adopted for Part L 2010 for non-domestic buildings and therefore there could be some presentational benefits to adopting it for the domestic sector as well.

However, there were some difficulties identified with this approach including that the derivation of the concurrent notional dwelling could be very complex: it needs to be Fabric Energy Efficiency Standard compliant (which is a performance standard and therefore different dwelling types need different fabric specifications to meet it, so coming up with a single notional dwelling fabric specification will be very difficult), and for its services to be EU Energy Related Products Directive compliant. There were also some potential perverse outcomes identified if the Carbon Compliance standard were to be specified using a notional dwelling whilst the Energy Efficiency and Zero Carbon standards are specified using absolute standards.

Aggregate approach using absolute carbon limits

The approach based on an absolute carbon limit was judged to be significantly easier to develop than the concurrent notional dwelling approach. The carbon limits to be chosen could be determined from an estimate of build emissions under 2006 regulations (based on future predicted build mix), reduced by 70%. Several different carbon limits could be chosen to better ensure equality over dwelling-type, still aiming to achieve 70% reduction overall.

There are also other advantages of the absolute approach. In particular, it fits well with the minimum energy efficiency standard and the zero carbon target, both of which are also absolute targets, which aids communication. It may also link better with wider Government policy e.g. provides carbon emissions to be counted in any lifecycle carbon assessment.

Conclusions, recommendations and implications

The conclusions and recommendations of this TWG were as follows:

1. Continuing the approach taken in the 2006 and 2010 amendments to Part L, of basing the carbon emissions target on a historic notional building plus a common improvement factor across all buildings, will not be suitable for 2016 (zero carbon). This approach does not recognise that it is easier and more cost effective to achieve carbon reduction in some dwelling types than in others and if continued will lead to significant inequalities between dwelling types. Furthermore, it is becoming increasingly complex to derive the current target
from a historic reference building with the need to include new adjustment factors over time.

2. The evaluation considered basing the carbon compliance target on a concurrent notional dwelling, rather than an historic one. This had some advantages but it was considered that this approach was more complex to derive and explain than an approach based on absolute carbon limits.

3. **The carbon compliance target should be set using an absolute carbon limit approach**, based on the amount of carbon emissions produced per year depending on the floor area of the dwelling (kgCO₂/m²/year). In a similar manner to the minimum Fabric Energy Efficiency Standard, greater equality can be achieved by setting appropriate limits for different dwelling types. The approach also benefits more energy conservative built forms, however, further investigation is recommended to understand the influence of built form on carbon emissions, to ensure that there are not any unintended consequences.

4. It is proposed that the work to derive the absolute carbon limits fits in with the Part L 2013 timetable. To provide industry with sufficient time to prepare for zero carbon dwellings, the 2013 and 2016 targets should be set with the 2013 regulations. Hence, proposals for the 2016 carbon limits and the associated design guidance should form part of the Part L 2013 consultation package. In order to achieve this, in particular, the carbon compliance tool methodology and emission rates would need to be finalised during 2011.

5. It is recommended that design guidance is produced to accompany the absolute carbon limit. This would indicate compliant solutions for different dwelling types, construction methods and service technologies and negate a key potential advantage of the notional dwelling approach.

6. The approach to carbon compliance target setting for non-domestic buildings is currently undecided and, if there is any difference in approach, it is likely a presentational issue and should not affect industry in application.

7. With the best intentions, the absolute (or any aggregated) approach will result in carbon reductions that will not be equal to a 70% reduction as currently proposed by CLG. The reductions may be more or they may be less, and will crucially depend on the difference between the predicted and actual build mix. The sensitivity to build mix, and possible means to reduce this sensitivity, can be investigated in deriving appropriate carbon limits. (It is noted that an aggregated approach has now been adopted for non-domestic buildings in Part L 2010, with the similar inherent risk that predicted carbon reductions may not be actually achieved).
Since 2006 the method for demonstrating carbon compliance with Part L of the Building Regulations has involved the use of a notional (reference) building. The CO₂ emission rate for the dwelling to be built has been calculated, i.e. the dwelling emission rate (DER), and compared to a target emission rate (TER) defined by a notional design of a dwelling of the same size and shape.

The target setting process is based on an historic, 2002 Part L compliant, notional building. Improvement factors have been introduced to achieve carbon emission reductions in successive amendments to Part L. Part L 2006 applied an improvement factor of 20%. Part L 2010 applied a further improvement factor of 25%.

The objective of this Topic Work Group (TWG) has been to recommend the best approach for setting the target emission rate to achieve carbon compliance for zero carbon dwellings. In particular, should the carbon emissions target continue to be based on an historic notional building with an appropriate improvement factor? Alternatively, is it better to move to an alternative notional building approach or should an absolute target level be set (e.g. kgCO₂/m²/year) in a similar manner to the minimum energy efficiency standard?

This Working Group has identified various approaches for setting the carbon compliance target for dwellings. The advantages and disadvantages of these different approaches have been explored and evaluated. The best approach has been recommended and implications and next steps presented.

It was outside the scope of this work to identify the performance value (e.g. details of the actual notional building or the absolute target levels). However, it did aid the evaluation to consider the likely difficulties in deriving the values in any approach and what the values might look like.

Context

The form of the carbon compliance target (CCT) must be viewed in the context of the other performance requirements that underpin the zero carbon agenda:

1. The energy efficiency standard, defined as a kWh/m² for space heating and cooling demand. Two levels have been defined, which relate to different built forms:
   a. 39 kWh/m²/year for apartments and mid terrace homes
   b. 46 kWh/m²/year for end terrace, semi detached and detached homes.
2. The zero carbon goal, i.e. net zero carbon emissions over the course of a year

There is a parallel policy strand that is pursuing the same zero carbon agenda in respect of non-domestic buildings. In defining the approach to setting the carbon compliance target, consideration should be given as to the merits of having a consistent approach between dwellings and non-dwellings. Consistency of approach aids understanding, particularly given the large number of mixed-use developments and the fact that future energy planning is likely to be community rather than building based. However, consistency for consistency’s sake may not be appropriate if a given approach does not work particularly well in a given sector. Indeed, for many members of the industry, it is the target that is the main interest and less the approach that derived it (i.e. hidden away in a computer model).
How the performance standard should be expressed

PROCESS

The group followed a six step process as follows:

1. Firstly, the group identified the different approaches for setting the carbon compliance target that should be considered. These were developed by the group members, taking account of experience gained through revisions of Part L, the Code for Sustainable Homes (CSH) and the development of the Fabric Energy Efficiency Standard. Three basic approaches were considered, although variants on these were also reviewed (see later discussions). The basic approaches were:
   
a. ‘Individual’ % reduction approach based on historic notional dwelling (as used by Part L 2006 and 2010)
   
b. Aggregate approach using concurrent notional dwelling i.e. a reference specification that is deemed reasonable in 2016, and which sets a level of carbon emissions that defines the target.
   
c. Aggregate approach using absolute carbon limits (e.g. kgCO₂/m²/year)

   A key distinction between these approaches is that the first approach would achieve a 70% carbon reduction for each dwelling compared to 2006. The other two approaches achieve an ‘aggregated’ 70% carbon reduction over the build mix, allowing for variations for different dwellings due to relative difficulties of achieving the 70% target.

2. Secondly, the group developed the evaluation criteria against which the various options should be tested. Seven main assessment criteria were identified as follows:

   a. Cost effectiveness: a key issue, especially in the current economic climate, is to achieve the CO₂ reduction target in the most cost effective way. This could, for example, result in increasing the target for dwellings for which it is easier to comply and easing the target for those dwellings where it is harder – with an overall target of 70% achieved.

   b. Ease of developing the carbon compliance target (CCT): Each of the approaches needs a means of deriving the CCT. For example, for a percentage improvement over a historic building it is straightforward. It is more complex to select an appropriate concurrent notional building or absolute target value.

   c. Equitable and proportionate: The approach chosen could impact disproportionately on the costs for different dwelling types to meet the carbon compliance standard (see cost effectiveness above). Setting a carbon compliance standard will inevitably impact on technology and fuel choices, since it must drive improvements in energy efficiency and low carbon fuel choices. However, it should be done so in a manner that is not unduly impacted by the choice of approach. Furthermore, certain of the approaches have the potential to impact on build form – which could be seen as advantageous if it leads to more energy conservative built forms, but disadvantageous, to at least some stakeholders, if it over-limits built form.

   d. Stability to achieve 70% reduction: the Government has set out that the carbon compliance target should achieve a 70% carbon reduction compared to 2006 regulations. This cannot be guaranteed using all approaches (i.e. the aggregated approaches rely on the projected build mix to achieve a 70%
reduction, which will differ to some degree from actual build mix).

e. Stability to achieve a compliant solution: to achieve the demanding zero carbon target, it is important that house builders and their supply chain have stability such that at the end of the product development cycle, they do not find the goal posts have significantly shifted. Various factors outside the construction sector itself can impact on the predicted levels of CO₂ emissions from a given dwelling specification. Examples are changes to the carbon compliance tool methodology and assumptions and fuel emission factors.

f. Easy to understand: communicating the carbon compliance setting approach in an easily understood way is an important part of the process. This will aid designers, builders and the building control community. As part of this issue, it is important that the carbon compliance setting approach be viewed in the context of the wider zero carbon standard, i.e. how does it relate to the energy efficiency and allowable solutions definitions?

g. Links to other Government policy: zero carbon new homes is part of a wider policy to mitigate climate change. It would be advantageous to link with wider Government initiatives, noting that Government policy and its implementation can vary over time.

3. Thirdly, data gathering was undertaken to aid the main evaluation. This included a modelling exercise to assess issues associated with practically achieving a 70% reduction in CO₂ emissions relative to a 2006 Part L standard.

4. Fourthly, the group carried out the assessment via a structured workshop that reviewed the various approaches for setting the carbon compliance target against the full range of assessment criteria. The approach teased out the strengths and weaknesses of the different approaches (and their variants) and in particular sought to identify any ‘show stoppers’ that meant a particular approach was not fit for purpose. The assessment also sought to identify any gaps in the evidence base.

5. Fifthly, the group undertook a second round of evidence gathering to help close the gap in the evidence base and to help refine the initial conclusions.

6. The final stage was to finalise the recommendations based on the available evidence base, and to identify issues that warrant further consideration.
IDENTIFYING THE OPTIONS

Three primary options for the approach to setting the carbon compliance target were identified, and the following paragraphs outline the thinking that led to these forms of parameter.

‘Individual’ percentage reduction approach based on historic notional dwelling

The use of a CO₂ target as the means of setting the Part L standard was introduced with the 2006 amendment, and was driven principally by the requirements of the Energy Performance of Buildings Directive (EPBD). Because the principal policy driver was CO₂ reduction rather than (e.g.) security of energy supply, CO₂ emissions was chosen as the primary metric, though energy limits were also imposed through limits on design flexibility.

Initially, the Part L team proposed an equation based CO₂ target (i.e. an ‘absolute’ target) for dwellings that attempted to capture the impact of floor area, built form and heating fuel. Feedback from the consultation indicated that such an approach unduly penalised certain valid forms of dwelling (e.g. those with integral garages). There was a concern that however much testing was done, there might always be a special case that was a valid design but was unduly penalised by any implicit form of target. Out of that concern, the concept of the notional building was born.

The notional building approach works on the premise that:

1. the appropriate approach to setting standards is one based on defined elemental energy efficiency standards coupled with constraints on fuel selection; and
2. the regulations should not dictate size or form (and in the context of non-domestic, whether air conditioning is necessary or not). Designers should be free to develop solutions that meet perceived market needs, the only constraint being that whatever they do, it must be done in an energy efficient way. This approach emphasises the difference between energy efficiency and energy conservation.

When developing the Part L 2006 standard, there were two options:

1. To base the notional building on the previous 2002 elemental standard and set an improvement factor.
2. To develop an improved set of elemental standards to form a concurrent notional building.

The former approach was adopted, principally because there was strong move away from elemental standards. This was largely driven by the EPBD, which required the standard setting process to be based on a calculation methodology.

As part of the development of the 2010 Part L, the target setting process was reviewed. The main reason for this was concern that as the target tightens, different building types might find it harder to achieve the same percentage improvement. This problem is particularly pronounced in non-domestic buildings, where there is a much greater diversity in intensity of use. Initially, it was thought that the problem could also be significant in dwellings, but the differences between SAP 2005 and SAP 2009 meant...
that for the same dwelling, the calculated space heating demand increased and the hot water demand reduced, thereby reducing the scale of the problem. Consequently, as far the 2010 amendment was concerned, the government preferred to stick with the flat 25% approach for dwellings, mainly because it is simple to understand. However as the target is tightened further, the original problem will inevitably re-emerge/intensify; this has already been highlighted by the fact that the energy efficiency standard is set at two levels depending (essentially) on the ratio of exposed area to floor area.

Another problem that has emerged with the percentage improvement approach is that the baseline may not be fixed as was originally anticipated. In Part L 2010, to accommodate changes in CO₂ emission factors and better align with the Code for Sustainable Homes, meant that the target ceased to become a simple 0.75 multiplying factor on 2006 standards. This was manageable for 2010, but it should be realised that the moving baseline is unlikely to be a one-off. It may be necessary to allow in future, for example, for changes in assumptions in the carbon compliance tool and the impact of EUP on system efficiency calculations. This means that the percentage improvement target is likely to get more convoluted and more open to challenge and debate as we move forward.

For these reasons, there have been suggestions as to alternative approaches to setting the CO₂ target. The two principal alternatives are:

1. A concurrent notional dwelling approach.
2. An absolute CO₂ emissions limit, based on defined value(s) of kgCO₂/m²/year

Concurrent (2016) notional building approach

The notional building calculates a bespoke CO₂ target for each building, based on a current specification (i.e. no improvement factor required). It therefore delivers an infinite number of levels of kgCO₂/m²/year, but each one is based on equal levels of difficulty in terms of elemental specification.

A version of this was presented as part of the consultation package for the 2010 amendments to Part L. Two forms of notional dwelling were selected – one for electrically heated dwellings and another for other fuels. Different heating system efficiencies were included in the latter notional building depending on what was reasonable for different fuel types, with the elemental standards for the other design specifications being the same.

A problem shared with the absolute approach is how to derive the target level(s) in a way that delivers a projected overall level of improvement. For the 2010 amendment of Part L, a method was developed for the consultation that delivered the 25% target based on equalising marginal abatement costs. The calculation is quite complex, and its robustness depends critically on the marginal costs of different energy efficiency measures and on assumptions about the build mix.

It should be realised that a lot of calculation could be done now to derive a concurrent specification that delivers a 70% CO₂ reduction compared to 2006. However, by the time we arrive at 2016, it is extremely unlikely that such a specification will deliver a 70% improvement – the carbon compliance model will have changed, the build mix will have changed, and CO₂ emission factors will have changed. Whatever approach is adopted, a key decision will therefore have to be whether

1. the stated 70% reduction target is taken as a general guideline, and work starts as soon as possible to derive the actual targets that will deliver somewhere in the region of (say) 65-75%; or
2. the work is done at the last minute, when all the variables can sensibly be
How the performance standard should be expressed

Frozen and we can be more confident of hitting close to 70%. Even then, it should be realised that the stock of buildings constructed to that standard will only deliver 70% for the duration that the assumptions upon which it was based remain valid. [Note that the underlying methodology and how we will derive the input data necessary, can be agreed in advance].

It should be noted that a concurrent specification does not mean a prescriptive standard. It is a means of calculating a robust and equitable performance standard, with the TER becoming the emissions from the notional building constructed to the concurrent specification. Provided the actual building matches or better that TER, designers have total flexibility to achieve the TER in whatever way they choose (subject to any other constraints such as the FEES). However, it is worth debating the value of the concurrent specification as a ‘deemed to satisfy’ solution, as this may be of considerable value to the smaller builder, and it may also assist with compliance checking.

**Absolute carbon limit approach (kgCO₂/m²/year)**

There are two obvious advantages of defining the target in such a form:

1. It would be broadly analogous to the energy efficiency standard; and
2. The overall zero carbon target is effectively expressed in the same terms.

Thus adopting this approach would mean all the elements of the zero carbon standard are expressed in a similar way. However, three issues were noted at the time.

1. A methodology needs to be developed in order to determine an equitable basis for setting the acceptable level of emissions. This could be based on a method similar to the concurrent notional building.
2. It may be inequitable to set the same CO₂ target across all dwelling types. If two energy efficiency levels are needed, then at least two CO₂ levels were considered likely to be necessary, one corresponding to each energy efficiency level. Indeed, as the number of factors accounted for in the approach expand (the CO₂ standard must additionally include hot water, lighting, ventilation, system efficiencies, on-building renewables etc) it may be necessary to expand the number of levels of the standard.
3. It has to address fuel selection. A house with the same energy efficiency standard can have hugely variant CO₂ emissions depending on whether the heating fuel is (e.g.) wood chip or grid electricity. At every Part L review, the most emotive issue is always how the target should be adjusted to account for different fuels. Many argue that the target should be based on equal energy demand irrespective of fuel; others argue that there should be equal CO₂ emissions.
DATA GATHERING AND ANALYSIS

A series of activities were undertaken to gather necessary data for the analysis. These are detailed below.

Achieving 70% compliance

A series of energy modelling was undertaken to assess the relative feasibility of achieving 70% improvement on Part L 2006 carbon emissions. The issue was examined by considering five typical dwellings with two levels of energy efficiency as defined in the earlier work on the Fabric Energy Efficiency Standard (FEES). These levels were compliance with the Fabric Energy Efficiency Standard (FEES) and an improved specification, Spec C (see Annex 1).

The dwelling types were:

- Detached house
- End of terrace/semi detached house
- Mid-terrace house
- 4 storey apartment block consisting of 32, 1 and 2 bed flats
- 8 storey apartment block consisting of 64, 1 and 2 bed flats

A range of technologies were modelled. In meeting the 70% carbon compliance target a designer will be expected to design future dwellings to meet the FEES. The designer would then consider options to deliver space and hot water heating to the home and potentially to generate low or zero carbon electricity. Having chosen the heat delivery technology, any heat recovery technologies, and reconsidered whether further energy efficiency measures would be cost effective, the designer will need to make up any shortfall in carbon savings through the generation of onsite electricity. Currently the preferred option to generate electricity onsite is roof mounted photovoltaic (PV) panels. Fuel cell micro-CHP could be a future option.

There is a physical limit to the use of photovoltaic panels, due to the maximum area that can be installed on a roof. The analysis of technology impact was therefore based on viability:

1. an assessment of the kWp required for different technology solutions to make up any shortfall in carbon savings through the generation of onsite electricity, and
2. whether there was enough roof area to install sufficient PV to deliver the kWp to meet the 70% target.

An indication is given of the limitation of PV capacity based on 40% of the footprint of the dwelling. This proportion was chosen to take account of factors such as: overshading; sub-optimum orientation or the inclusion of dormer windows. It was also considered an appropriate proportion for flat roofs.

The technologies principally considered were:

- Gas condensing boiler
- Gas condensing boiler with solar hot water (SHW)
- Direct electric
How the performance standard should be expressed

- Direct electric with SHW
- Biomass boiler using wood pellets
- Biomass boiler using wood chip
- Air Source Heat Pump (ASHP)
- Ground Source Heat Pump (GSHP)
- Large district gas CHP
- Large district biomass CHP (wood chip boiler peak)

A wider range of technologies was considered in Topic Work Group 2.

Results

A summary of the results are shown in Figures 1 to 5. These use a carbon emission factor of 0.517 for electricity (import and export) and a fuel factor of 1 (i.e. no allowances made for more carboniferous fuel types).

Figure 1 Detached house – ability of different technologies to achieve 70% improvement

Figure 2 End-terraced house – ability of different technologies to achieve 70% improvement
Figure 3 Mid-terraced house – ability of different technologies to achieve 70% improvement

Figure 4 Four storey apartment block – ability of different technologies to achieve 70% improvement
How the performance standard should be expressed

Analysis

The results indicate that it is not practical to achieve the target in an eight storey block of flats for all but biofuels or a large district gas CHP. This is due to the relatively small roof area per dwelling in multi-storey apartment buildings.

Some further analysis and thinking was undertaken into whether the limitation in fuel types for an apartment building posed a significant challenge. This included an analysis of capital and discounted lifetime costs (over 25 years) that considered different dwelling types and Low and Zero Carbon (LZC) technology solutions, including allowances for feed-in tariffs and the renewable heat incentive. The cost comparisons are based on per m² of floor area. Observations included the following:

- Large gas CHP is limited by the possibility of a developer being able to access an available network. However, an alternative is for the developer to install a smaller CHP with PV for the apartment building. This would have a lower efficiency than for a larger system, but would be under the control of the developer. Based on results from Topic Work Group 2 (which looked at a smaller-scale CHP), it is likely that a small CHP with PV on the roof would be sufficient with the fabric energy efficiency standard (FEES) for a four-storey apartment but would need the higher Spec C fabric efficiency for the eight-storey apartment. As the number of stories increased further, this strategy would become more challenging e.g. the need to clad suitably facing vertical facades with PV. The cost analysis suggests that it is much more affordable to achieve carbon compliance for a semi-detached dwelling with a gas boiler and PV than for an apartment building with CHP and PV, due chiefly to an increased capital cost for CHP and less feed-in tariffs for apartments as there is less PV used per unit floor area of dwelling.

- Broadly the lifetime costs are the same for an apartment building with biomass and PV, and for a semi-detached dwelling with a gas boiler and PV. The capital costs are actually cheaper for biomass option, and the lifetime costs benefit from the renewable heat incentive.

Hence, this suggests that biomass may be a viable solution to deliver carbon compliance in apartment buildings. However, there are other issues that would need to be considered such as any planning issues related to concerns regarding external air
quality from using biomass in city centres (a typical location for many apartment blocks). Furthermore, more strategically, biomass is seen as a potential source for the decarbonisation of other sectors (e.g. conversion to biofuels for transport) where there may be fewer alternatives and a higher cost premium paid. The UK could import from overseas but other countries will also be looking to decarbonise and we need to achieve security of our energy supply.

Reducing the carbon compliance target for apartments would allow other options to become feasible such as gas boilers with PV, which has comparable costs as for a semi-detached dwelling. It is noted that whatever allowance might be made for apartments, there are likely to be additional challenges as the storey height increases.

The view of the Topic Work Group is that it would be disproportionately challenging to achieve a 70% compliance target for multi-storey apartment blocks. This is particularly the case due to part of the reason for this increased challenge is that apartment buildings are energy efficient dwelling types. Due to the limited amount of exposed surface area, less improvement can be achieved from improving fabric and there will always be a greater reliance on other measures (such as LZC technologies) to achieve a percentage carbon reduction. It was considered unfair and perverse to penalise apartments due to their more energy efficient built form.

The results suggest that for an eight storey apartment building built to Spec C with a gas boiler, solar water heating and PV, it would be possible to achieve a 63% carbon reduction from 2006 levels.

It is worth pointing out why the tougher Spec C is less favourable for bio-fuels. It is because the MVHR unit included in Spec C (to ensure adequate ventilation with the very low air permeability level) tends to produce more carbon emissions through the use of electricity to run the unit than the carbon emissions saved from using less bio-fuels as less space heating required. On the other hand, an efficient MVHR unit should reduce overall carbon emissions for homes heated by electricity or gas.

**Impact of change in emission rates**

The modelling exercise also investigated the impact of a changing CO₂ emission rate for grid electricity on the feasibility of technology/fuel choices (see also the results of Topic Work Group 2). Figure 6 provides an example – the key features being the same for all five dwelling types.

![Figure 6 Detached house – ability of different technologies to achieve 70% improvement for different emission rates](image-url)
For fossil fuels, a reduction in emission rates in the shorter-term simply tends to increase the amount of PV required and the choice of technology would depend on factors such as cost. As the grid decarbonises, the amount of PV will increase until it is not a practical option. The timetable for this is indicated in the Topic Work Group 2 report which suggests the transition point starts mid/late 2020s with the FEES specification, although it can be delayed by the use of the Spec C fabric standard.

The choice of emission rates influences the feasibility of direct electric as an option in the shorter-term. A reduction in emission rate for electricity tends to reduce the emissions from the dwelling but increase the amount of PV required (because for the same PV area, less emissions will be off-set). Overall, a lower emissions factor tends to improve the viability of electrically heated dwellings.

**Impact of change in fuel factor**

The modelling exercise also investigated the impact of the electric fuel factor on the feasibility of technology/fuel choices. Figure 7 provides an example – the key features being the same for all five dwelling types. Overall, the inclusion of the current fuel factor does not appear to significantly influence the feasibility of direct electric as an option. For heat pump technologies, it affects the amount of PV required and thus the relative cost of adopting different technology approaches.

**Breakdown of energy uses**

Based on the results from the model, Figures 8 and 9 highlight how the energy end-uses vary for the different dwelling types and different fabric specifications. Hot water is becoming more significant, particularly if constructing to Spec C. This means that much greater design and assessment focus needs to be given to such issues, whereas historically, the main attention has been given to space heating. This is important, because as we improve fabric to the point of diminishing returns, it would be easy to shift into ‘LZC mode’, whereas the same level of improvement might be achievable by (say) radical re-thinking of hot water provision.
Impact of regional climate data

Topic Work Group 3 propose to include regional climate data the calculation of overheating, energy demand and carbon emissions in the compliance model. These are some initial thoughts as to the consequence for the approach to setting the carbon compliance target.

One decision to be made is whether to vary the 2006 baseline with climate (the baseline on which the 70% reduction is measured). It would be expected that there would be significant differences, for example, in space heating demand in Part L 2006 compliant dwellings built in different regions and thus different carbon emissions.

In setting the 2016 carbon compliance target, it may be necessary to specify different notional dwellings or absolute standards in different regions. Even if the absolute standard itself was the same across the regions, the compliant solution that achieved
the absolute standard would be likely to change. This work has not assessed the
degree of difference in compliant solutions between different regions and this would
need to be addressed in the next stages of work. It may simply affect the amount of
on-site electricity generation required (e.g. amount of PV) or could more fundamentally
affect the choice of fabric and services solutions.

Overall, regional climate data better determines carbon emissions and the effects of
mitigation strategies to address them. If it is introduced into the compliance regime, it
needs to be presented in such a way that its impacts are easy to understand and
comply with.

**What might a concurrent notional dwelling look like, if this
route was chosen?**

Table 1 and 2 broadly show what a concurrent notional dwelling may look like. These
are solutions that were derived from the energy modelling to achieve 70% carbon
reduction from Part L 2006 with Spec C. Table 1 shows the fabric specification that
would be applied to the notional dwelling, and then Table 2 shows the further
percentage reduction required to be achieved from on-site LZC electricity generation
(in this case, illustrated as % over 2006 regulatory baseline).

<table>
<thead>
<tr>
<th>Ext. Walls (W/m²K)</th>
<th>0.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Party Walls (W/m²K)</td>
<td>0</td>
</tr>
<tr>
<td>Floor (W/m²K)</td>
<td>0.15</td>
</tr>
<tr>
<td>Roof (W/m²K)</td>
<td>0.11</td>
</tr>
<tr>
<td>Windows (W/m²K) whole window</td>
<td>0.8 (triple glazed)</td>
</tr>
<tr>
<td>Doors (W/m²K)</td>
<td>1</td>
</tr>
<tr>
<td>Window g-value</td>
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</tr>
<tr>
<td>Airtightness (m³/hr/m²)</td>
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</tr>
<tr>
<td>Thermal bridging y-value (W/m²K)</td>
<td>0.04</td>
</tr>
<tr>
<td>Ventilation type</td>
<td>MVHR</td>
</tr>
<tr>
<td>Mech vent spec</td>
<td>SFP = 1 W/l/s HR eff = 88%</td>
</tr>
<tr>
<td>Low energy lighting</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heating type</th>
<th>Percentage additional CO₂ reduction over 2006 regs through on-site generated LZC electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct electric</td>
<td>72%</td>
</tr>
<tr>
<td>Direct electric + solar hot water</td>
<td>43%</td>
</tr>
<tr>
<td>Gas boiler</td>
<td>29%</td>
</tr>
<tr>
<td>Gas boiler + solar hot water</td>
<td>16%</td>
</tr>
<tr>
<td>Air source heat pump (COP 2.5)</td>
<td>25%</td>
</tr>
<tr>
<td>Ground source heat pump (COP 3.2)</td>
<td>19%</td>
</tr>
<tr>
<td>Large district gas CHP</td>
<td>13%</td>
</tr>
<tr>
<td>Biomass boiler (pellet)</td>
<td>0%</td>
</tr>
<tr>
<td>Biomass boiler (chip)</td>
<td>0%</td>
</tr>
<tr>
<td>District biomass CHP</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 1 Example of notional dwelling fabric specification

Table 2 Example on-site electricity generation required in addition to notional dwelling based on different heating types, to achieve 70% carbon compliance
Assuming no fuel factor, it should only be necessary to select one of these solutions for a notional dwelling. Other solutions are viable as long as they achieved the same carbon performance as the notional dwelling. For instance, we could select the option of gas boiler as the notional dwelling.

Spec C was selected in this example as it should meet the minimum energy efficiency standard for all dwellings. Care is needed in setting the fabric elemental standards in the notional dwelling, as different fabric levels (u-values, airtightness etc) are required for different dwellings to meet the minimum FEES (see Annex 1). If the standard in the notional dwelling is set too low, it could mean that in some cases the minimum energy efficiency standard will not be achieved.

The table does not specify an on-site electricity generating technology to avoid any unintended LZC technology bias. Rather, it proposes a percentage carbon reduction over 2006 through on-site electricity generation. The value chosen is simply the average of the percentage required for the five dwelling types analysed.

There was not a significant variation of the percentage of on-site electricity generation required between dwelling types – the range being at most an absolute +/- 5% variation around the mean. This suggests that it could be possible to have the same notional building for different dwelling types, which should deliver similar percentage carbon reductions for each type (noting the need for some modification for apartments as discussed earlier).

It is noted that this solution does include mechanical ventilation with heat recovery (MVHR). It may be preferable if the final notional dwelling did not suggest a preference towards mechanical ventilation and leave it to the user to make this choice. Spec C was defined with an airtightness of 1 and it was chosen with a MVHR system. It may be better to go for a notional specification with a natural ventilation solution.

It may be necessary to change the notional dwelling as emission factors change. In particular, as the grid decarbonises, an electrically heated notional dwelling would likely be most affected as the amount of on-site electricity generation required would fall. If a gas boiler is selected, the notional building should need to vary much less until such a point as sufficient on-site electricity generation is not possible. In the latter case, until the point at which a gas boiler option is not viable, it would need to be decided whether the benefit of changing the notional dwelling to accurately ensure 70% reduction outweighed the need for stability in compliant solutions for industry.

How many absolute standard levels might be necessary, if this route was chosen?

In order to develop an equitable carbon compliance target, it may be necessary to have more than one absolute carbon limit.

- The carbon emission rates for different dwelling types built to the same elemental standards will vary. In particular, it will depend on the ratio of exposed surface area to floor area. For example, heat loss (and thus space heating demand) will typically be higher for a detached building than for a mid-floor flat.

- The carbon emission rates for different dwellings of the same type, built to the same elemental standards, will vary. Again, a key issue will be the ratio of exposed surface area to floor area. This will depend on both the size and the shape of the building. For example, a larger building will tend to produce less carbon emissions per unit floor area than a smaller building. A cube-shaped building will tend to produce less carbon emissions per unit floor area than a building with a more complex floor plan.
To investigate this further, analysis was undertaken of a database of 180,000 Part L 2006 compliant dwellings that have actually been built. The target emission rates (TER) of these buildings were investigated. The target is effectively based on a building of the same size and shape as the actual building, but with a standard elemental specification (and a 20% CO₂ emissions reduction applied). Hence, this would provide a good indication of the degree of the variation of carbon emissions by dwelling type and its distribution. It is noted that the actual variation identified would be different for zero carbon dwellings due to the different proportions of energy end uses from a Part L 2006 compliant dwelling (e.g. space heating being less dominant). The data is shown in Figure 10 and 11.

**Figure 10** TER variation by dwelling type, showing distribution of occurrences (number in brackets = number of total occurrence for that dwelling type)

**Figure 11** TER variation by dwelling type, showing distribution by floor area (number in brackets = number of total occurrence for that dwelling type)
Table 3 shows the mean TER levels for the largest six dwelling types in the sample, focusing on gas fuelled dwellings to avoid the need to make allowances for fuel factor. Overall, the mean carbon emission rates are similar (less than 20% between highest and lowest value). Thus it suggests that differences in dwelling type should not, by themselves, result in a significant number of different absolute carbon limits.

<table>
<thead>
<tr>
<th>Building</th>
<th>Mean TER (kgCO²/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat - Ground floor</td>
<td>24.8</td>
</tr>
<tr>
<td>Flat - Mid floor</td>
<td>21.2</td>
</tr>
<tr>
<td>Flat - Top floor</td>
<td>24.3</td>
</tr>
<tr>
<td>House - Detached</td>
<td>22.2</td>
</tr>
<tr>
<td>House - Mid-terrace</td>
<td>20.6</td>
</tr>
<tr>
<td>House - Semi-detached</td>
<td>22.7</td>
</tr>
</tbody>
</table>

Table 3 Mean TER levels for different building types

From Figure 10, it can be seen that for a particular property type, there is significant variation in TER. This suggests that if an absolute carbon limit was set, there are potentially significant opportunities to reduce carbon emissions from carefully designing build size and form. This opportunity does not currently exist when using a notional building approach as it has the same size and shape as the actual building. However, the large variation in results does also highlight a risk of making it significantly harder for some built forms to comply, and perhaps effectively eliminating them. It is possible that from an energy-saving viewpoint, we should not be building at least some of these designs. However, there may be good reasons for making allowances for such designs and it is important to understand the implications before setting any absolute carbon limit.

Figure 11 shows how the TER values from Figure 10 relate to floor area. The sizes of the bubbles represent the number of occurrences at a particular TER and floor area, with remarkable consistency in TER across a wide range of floor area and dwelling type.

Figure 12 Variation in average carbon emission rates by total floor area for semi-detached dwellings
for the bulk of the data analysed. Figure 12 shows the information for semi-detached/ end terrace houses in more detail. As the floor area increases, the TER values tend to fall. This is to be expected, as the perimeter area per unit floor area tends to decrease with an increase in floor area – reducing the heat loss through walls, floor and roof per unit floor area. Hence, setting an absolute carbon limit would tend to promote larger buildings, although their overall carbon emissions would be higher (taking account their increased floor area). If we wished to reduce the influence of floor area, we could modify the absolute limit such that rather than simply being a constant, it would be of the following form which reduces as floor area increases:

\[
\text{Absolute carbon limit} = \text{constant} - (\text{multiplier} \times \text{floor area})
\]

Before setting any absolute carbon limit(s), further work would need to be undertaken to better understand the influence of built size and shape. Factors, other than floor area, may also be significant and their implications need to be understood and suitably addressed.

**What might a non-domestic carbon compliance target look like?**

Part L 2010 has moved from an individual improvement to a concurrent notional building approach for non-domestic buildings. This is to avoid disproportionately requiring much tougher fabric and services specifications for particular build types. In principal, this approach could be taken forward to zero carbon albeit with the notional building being modified to meet the stricter carbon targets.

An initial evaluation was undertaken of whether the absolute approach would be appropriate for non-domestic buildings. The non-domestic building types and designs considered in the Part L 2010 impact assessment were utilised. Carbon emissions were determined that complied with the Part L 2006 standard and then they were reduced by 70%. The results are shown in Table 4.

<table>
<thead>
<tr>
<th>Building type</th>
<th>2016 target (70% of 2006) kgCO₂/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotel</td>
<td>31</td>
</tr>
<tr>
<td>Office (Deep planned, Air Conditioned)</td>
<td>18</td>
</tr>
<tr>
<td>Office (Shallow planned, Air Conditioned)</td>
<td>20</td>
</tr>
<tr>
<td>Office (Shallow planned, Natural Ventilation)</td>
<td>10</td>
</tr>
<tr>
<td>Retail</td>
<td>39</td>
</tr>
<tr>
<td>School</td>
<td>8</td>
</tr>
<tr>
<td>Supermarket</td>
<td>59</td>
</tr>
<tr>
<td>Warehouse (With roof-lights)</td>
<td>9</td>
</tr>
<tr>
<td>Warehouse (Without roof-lights)</td>
<td>9</td>
</tr>
</tbody>
</table>

*Table 4: Carbon emission levels in 2016 for non-domestic buildings*

The results show a significant variation in emission levels – much more than identified in dwellings. Based on this limited evaluation, it suggests that there may need to be more absolute limits then for dwellings and a concurrent notional building approach may be more preferable in this case. It is noted that this calculation assumes a similar 70% carbon reduction for all non-domestic building types and this is unlikely to be the case with any aggregated approach. However, it is anticipated that the same conclusions will still apply as any aggregate approach would not be expected to smooth out the significant differences observed in the table.
ASSESSING THE OPTIONS

The three options outlined in section ‘Identifying the Options’ were then tested against the evaluation criteria via a structured workshop of TWG members.

‘Individual’ percentage reduction approach based on historic notional dwelling

With this approach, every dwelling would have to achieve a 70% reduction in emissions relative to the 2006 Part L standard.

The perceived advantages are:

1. It is easy to understand and is consistent with the current Part L approach
2. It is relatively easy to derive the 2016 TER. However, there may need to be some modifications e.g. due to changes in carbon compliance tool methodology.
3. It guarantees a 70% reduction at the building site level. However, this is thought to be of lesser importance because the CCT is a secondary target; the overall target being set by the zero carbon standard. Thus if the CCT varies either way from 70%, the difference could be absorbed by allowable solutions.
4. The notional building basis provides some protection from changes to the compliance tool or other factors, because to a degree they will affect the notional and actual dwelling, although this will be less robust than using a 2016 concurrent notional building.

The disadvantages are:

1. As demonstrated, it is disproportionately difficult for apartment buildings to meet the 70% target. For the cases modelled, it is not practical to achieve the target in the eight storey apartment block for all but biofuels or a large district gas CHP. Whilst it is easier for a four storey apartment block to comply, it is much harder than for the other dwellings considered. The view of the TWG is that it would be disproportionately difficult to achieve a 70% compliance target for apartment buildings. It was deemed as a ‘show-stopper’, and eliminated the individual 70% improvement reduction as a valid approach for 2016.
2. A weakness of all notional building approaches is that they provide no incentive for improved built form – indeed it can encourage profligacy. Because hot water is a much more significant demand in flats, there have been suggestions that designers have introduced additional and unnecessary areas of exposed fabric into designs in order to increase exposed area and make the percentage reduction easier to achieve.

As part of making the assessment, variants on the basic approach were identified that might help reduce the disadvantages. The main variant discussed is to combine the percentage improvement with an absolute CO₂ threshold, i.e. if the emissions were less than the threshold value, then compliance would be achieved, even if the 70% reduction value were not reached. It would be necessary to modify the percentage improvement to ensure that 70% was met over the build mix. This would solve the first of the disadvantages listed above, however; the benefit of simplicity would be lost.
Aggregate approach using concurrent notional dwelling

With this approach, a design specification would be provided, which if all dwellings were constructed to it, an overall 70% improvement would be achieved across the mix of dwelling types in the assumed build mix. Although there would be a 2016 notional specification, this would represent a performance standard, in that designers could adopt any alternative specification, provided the same level of emissions were achieved.

The perceived advantages are:

1. As it is an aggregated approach, the overall objective of zero carbon homes should be achieved in the most cost effective way.
2. The specification provides a robust model design that may assist smaller builders
3. Having a notional building minimises the impact of any input errors in the compliance model, because for many variables the error would similarly affect both the actual and notional dwelling (i.e. impacting the TER/DER by a similar amount)
4. It is consistent with the non-domestic approach adopted for Part L in 2010, which may provide the basis for the non-domestic zero carbon standard (although any difference in approach may not overly affect industry as the focus is the target to be achieved and less the approach for its derivation assuming the target is deemed reasonable).

The disadvantages are:

1. As it is an aggregated approach, achieving 70% reduction cannot be guaranteed; it depends on the actual build mix.
2. Arriving at the notional dwelling specification depends on robust cost data. This may be problematic when technologies and costs are changing quickly.
3. Deriving the concurrent notional building may be very complex. In particular, it would be necessary to ensure that the fabric elements in the notional building always meet the minimum FEES (which effectively requires different standards of fabric performance for different dwelling designs and thus the most demanding fabric performance would need to be determined and included in the notional building). Furthermore, it is necessary for the service elements to meet standards from the European Energy Related Products Directive which are as yet to be finalised and it may be more complicated to apply if they are system rather than product based. It is also necessary to ensure that any notional dwelling adopted over the different dwelling types provides a fair means of achieving compliance.
4. The complexity of deriving the concurrent notional may be compounded by the need to change the specification of the notional dwelling to take into account updates to other regulations.
5. It may be necessary to develop different notional dwellings for different part of the country if regional weather data is used in the compliance model, as proposed by Topic Work Group 3.
6. It may also be necessary for the notional dwelling to consider issues of overheating, daylighting and indoor air quality
7. There is also a potential perverse outcome of adopting the absolute kWh/m²/year metric space heating and cooling energy demand for the minimum Energy Efficiency standard and a concurrent notional dwelling for Carbon Compliance. This can be seen in the example of taking a mid-terrace
house and modifying it such that the floor area remained the same but the exposed area increased. The energy efficiency standard would require better fabric construction specifications in the latter case to address the increased heat loss through the greater exposed surface area. However, with the notional dwelling approach, the TER would increase with a greater exposed area. Thus this combination would require a higher fabric specification but allow greater carbon emissions – hence potentially perverse outcomes.

8. There is no incentive to adopt a more energy efficient built-form. One way around this considered in assessing this approach, could be to specify the shape of the notional building (e.g. a rectangular shape with a fixed front-to-back depth and width adjusted to provide the same floor area as the actual design). However, this does add complexity.

**Aggregate approach using absolute carbon limits**

With this approach, the target would be set as a defined amount of CO₂ emissions per unit floor area. Different levels could be set, for example for different dwelling types.

The perceived advantages are:

1. As it is an aggregated approach, the overall objective of zero carbon homes should be achieved in the most cost effective way.

2. It is analogous to the approach taken for setting the Fabric Energy Efficiency Standard, and this may help overall understanding, especially as the overall zero carbon target is also expressed in the same form (zero CO₂ emissions).

3. It may fit in better with the wider policy landscape (e.g. cradle to grave carbon budgets).

4. If a single value is adopted (overall or for a particular dwelling type), it will encourage efficient built forms.

The disadvantages are:

1. As it is an aggregated approach, achieving 70% reduction cannot be guaranteed; it depends on the actual build mix.

2. Arriving at the specification may depend on robust cost data. This may be problematic when technologies and costs are changing quickly.
How the performance standard should be expressed

Outcome of assessment

Table 5 summarises the pluses and minuses for each option, with the symbols having the following meanings against each particular criterion:

1. ‘+’ means the approach has advantages
2. ‘0’ means the approach has no overall strength or weakness
3. ‘-’ means the approach has a significant weakness
4. ‘x’ means that the approach is unacceptable

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<tr>
<th>Evaluation Criteria</th>
<th>Individual 70%: Historic notional dwelling</th>
<th>Individual 70%: Historic notional dwelling + carbon threshold</th>
<th>Aggregate: Concurrent notional dwelling</th>
<th>Aggregate: Absolute carbon limit</th>
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<td>Integration with wider government policy</td>
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Table 5 Summary of the evaluation

It can be seen that the individual 70% option should be eliminated because it fails to satisfy an important criterion of being equitable.

It was proposed to also eliminate the 70% improvement with carbon threshold approach. This option has no significant advantage over the other two remaining approaches. Furthermore, as it is essentially a combination of the notional building and absolute approaches, it is likely to be more complex to derive the carbon compliant target (i.e. the overall percentage reduction and the threshold necessary to achieve 70% in a cost-effective and equitable manner), and harder to explain to industry.

The aggregate approaches of concurrent notional dwelling or absolute carbon limit have similar ratings for many of the criteria:

- Both are aggregated approaches and thus the carbon compliance target (concurrent notional dwelling(s) or absolute carbon limits) can be derived to be most cost-effective and equitable across the build mix. Note that the absolute approach allows the added flexibility of variation of built form, which analysis suggests could be a cost-effective means to help meet the compliance target, but this could also be introduced as a modification of the concurrent notional building approach as described earlier.
- A further issue common to the aggregate approach is that it cannot guarantee a 70% reduction. It is based on projections of the build mix. It can be developed in such a way to reduce the sensitivity to actual build mix but cannot eliminate it. However, any difference could be absorbed by allowable solutions.
• Both approaches are quite susceptible to changes outside the control of the house-building industry. For example, changes in the carbon compliance methodology or fuel emission rates may result in the need to modify the notional dwelling to ensure that overall policy aim of achieving 70% carbon compliance is met. Whilst these factors are less likely to require a change in an absolute limit (if based on 70% reduction on a fixed 2006 baseline), it will require a change in the compliant solutions to meet the absolute limit.

• The similarity of the ratings in terms of ease of understanding is based on the fact that the key information that users require is a target value (TER) and an actual value (DER) which would be provided by both options. The apparent advantage of the concurrent notional dwelling, in that it is itself a compliant dwelling, can mainly be negated by producing model designs for an absolute approach which can indicate compliant solution for a range of dwelling types and constructions. Furthermore, many people will elect not to construct to the notional dwelling in such an approach.

Overall, there is probably a greater advantage to the absolute approach in terms of ease of understanding, because:

1. The absolute limit is in the same format as for the FEES and the overall zero carbon target itself. Hence, as a package it is easier to explain and understand.

2. For the notional dwelling to meet the minimum energy efficiency standard in all cases, the fabric performance levels will need to be quite high. This may be very off-putting and misleading as users may expect these levels of fabric performance to be required.

3. Having an absolute amount of carbon which is still being emitted may aid clarity in assessing how much carbon needs to be offset through allowable solutions.

It should be easier to develop the carbon compliance target for the absolute approach than for the concurrent notional dwelling. There may also be an advantage of the absolute approach in terms of linking to wider policy. It provides a ‘count’ of actual carbon emissions. This may be useful for the future and when accounting for all lifecycle emissions. However, it is unclear whether carbon compliance levels would be used in such calculations or simply ‘zero carbon’.

Overall, there was a clear preference for the absolute carbon limit approach. However, there are two important complementary actions:

1. A need to better understand the impact of setting an absolute carbon limit on build size and form, and ensure that it does not result in unintended consequences.

2. The development of model designs to aid understanding of compliant designs.
The Topic Work Group agreed on the following recommendations:

1. Absolute carbon limits should be derived for zero carbon dwellings, as the metric of Carbon Compliance.

2. Design guidance should be developed to accompany the carbon limits. The guidance should indicate cost-effective compliant solutions for a range of dwelling types. This will aid the house-building industry, particularly those who have limited technical resources to develop such designs themselves.

3. Further analysis is necessary to assess the impact of built form on carbon emissions. It is important to ensure that the absolute carbon limits benefit the more energy conservative built form and that there are no unintended consequences of this new target-setting approach.

4. In developing the carbon compliance tool for 2016, the number of input variables are the minimum necessary and the tool provides good self checking to ensure that the inputs are sensible to reduce errors.

5. An overall energy performance standard should also be considered. This is to complement the carbon limit and restrict the energy consumption for low and zero carbon fuels. The minimum energy efficiency standard is still required to ensure the focus on putting fabric first in achieving both the carbon and energy performance standards.
TRANSITION PLAN

The next step is to determine the absolute carbon limit(s). Some key questions need to be addressed.

- What do we mean by 70% carbon reduction for an aggregate approach? For example, one approach would be to simply take the total 2006 new-build dwelling carbon emissions and divide by the total floor area. Then the average emissions per m² for 2016 should be a 70% reduction from this.
- Should different emissions per m² apply to different dwelling types (e.g. accept higher emissions per m² from apartment blocks due to practical considerations) and, if so, what should the allowed variation be? In a similar manner, should there be variations for different build form to avoid, for example, potential bias towards larger buildings.

In undertaking this work, it will be necessary to have the following.

- Prediction of the build mix in 2016
- A compliance modelling tool
- Carbon emission rates
- An understanding of practical and cost-effective low-carbon solutions for different dwelling types

Any such work would need a sensitivity analysis. This would assess the robustness of the solution in light of data uncertainties (e.g. build mix). It would also assess the robustness of the solution in light of changes in the future (e.g. changes in emission rates).

To allow time for industry to prepare it is proposed that in Part L 2013 the following is included.

- The carbon standards for both 2013 and 2016 are provided
- Both carbon standards are in terms of absolute limits (i.e. replace the current notional building approach)

A better solution could be derived the closer we get to 2016 (e.g. a better prediction of build mix). This would more accurately ensure that 70% was achieved and in the most cost-effective way. However, this needs to be balanced by the advantages to industry of providing early knowledge of the target to be achieved. The inclusion in Part L 2013 appears to provide a reasonable compromise.
### Transition plan

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**Figure 12:** Proposed transition plan for expression of the carbon compliance standard
### ANNEX 1

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*Annex I. Construction that meets FEES and Spec C energy efficiency standards.*

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### Table: Energy Efficiency Standards

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*Annex I. Construction that meets FEES and Spec C energy efficiency standards.*
How the performance standard should be expressed
This publication was produced to ISO14001 Environmental 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 CO₂ emissions created during the manufacturing process were neutralised through investment in climate friendly projects around the world.