Do zero carbon homes make sense?

Les Shorrock
BRE
United Kingdom
Shorrockl@bre.co.uk

John Henderson
BRE
United Kingdom
Hendersonj@bre.co.uk

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Abstract

The Code for Sustainable Homes (hereafter, "the Code") was launched in the UK in April 2007. The Code sets out six levels of sustainability which, in terms of carbon dioxide emissions, represent different levels of improvement relative to the requirements of the 2006 Building Regulations (Communities and Local Government, February 2008). Level 6 of the Code corresponds to a zero carbon home. The UK Government has an aim that, from 2016, all homes built should achieve this standard.

Many people question whether this ambitious timetable is actually feasible. It has been argued that it would be more sensible to focus on improving the energy efficiency of the existing housing stock rather than rushing to achieve zero carbon standards in new homes. This argument is examined by considering the cost-effectiveness of the different levels of the Code, the cost-effectiveness of energy efficiency measures that can be applied to the existing housing stock, and their respective carbon dioxide savings.

The results indicate that the energy efficiency measures that can be applied in existing homes are generally considerably more cost-effective than building new homes to different levels of the Code. On the other hand, if achieving carbon dioxide savings is of overriding importance, the results also suggest that constructing new homes to level 5 of the Code is actually more attractive, in terms of the cost per tonne of carbon dioxide saved, than constructing to levels 3 and 4. Equally, constructing to level 6 of the Code has a cost per tonne of carbon dioxide that is almost the same as that for levels 3 and 4, but it saves considerably more carbon. This argues for a rapid move towards a requirement for zero carbon homes, consistent with the Government aim.

Introduction/background

Carbon dioxide emissions from the UK housing stock amounted to 145.9 million tonnes in 2006 (this includes emissions at power stations that can be attributed to the electricity use of homes). Emissions across all sectors in 2006 were 554.5 million tonnes of carbon dioxide ($MtCO_2$), so the housing stock accounts for slightly over a quarter of the total. However, carbon dioxide emissions from the housing stock have been reducing. In 1990, the housing stock emission was 154.4 $MtCO_2$ so the 2006 emission represents an 8.5 $MtCO_2$ (5.5%) reduction in this figure.

The UK Government has an aim of reducing carbon dioxide emissions by 80% by 2050 (relative to 1990 levels) and improving the energy efficiency of buildings, and of homes in particular, is seen as a key means of achieving this target. Policies that are in place to reduce emissions from housing cover both existing homes and new homes.

For existing homes, the main policy is the Carbon Emissions Reduction Target, CERT (previously known as the Energy Efficiency Commitment). This operates by placing carbon dioxide savings targets on energy suppliers. The energy suppliers assist their customers to make savings through various energy efficiency offers, these being subsidised via a levy that all customers pay, and the suppliers claim the saving against their target. The current round of CERT runs from April 2008 to March 2011 and it aims to achieve annual savings of 4.2 $MtCO_2$ by 2010. Beyond March 2011 it is expected that there will be another supplier obligation and that this will be at least as demanding as the current CERT scheme.

For new homes, the main policy (in England and Wales) is Part L of the Building Regulations (Conservation of fuel and power), last revised in 2006 and next due for revision in 2010. Thereafter, it is intended that the Building Regulations requirements will be regularly revised (roughly every three years) and made more stringent with the aim of achieving a zero carbon standard for all new homes in 2016. The framework provided by the six levels of the Code for Sustainable Homes (see later) will form the basis for the different stages of the improvements. Social housing is already required to achieve level 3 of the Code, and there are already a number of homes that have been constructed to the higher levels (5 and 6). The experience gained from these is being shared in guidance material (Gaze et al 2008) which should help to pave the way for such dwellings becoming conventional. To further encourage such a transition, regulations have also been made under the 2003 Finance Act allowing relief from Stamp Duty Land Tax for zero carbon new homes.

Nonetheless, many people question whether this ambitious timetable for zero carbon homes is actually feasible. It has been argued that it would be more sensible to focus on improving the energy efficiency of the existing housing stock rather than rushing to achieve zero carbon standards in new homes. This argument is examined in this paper by considering the cost-effectiveness of the different levels of the Code, the cost-effectiveness of energy efficiency measures that can be applied to the existing housing stock, and their respective carbon dioxide savings. We start by considering the existing housing stock.

Improving existing housing

The Committee on Climate Change (CCC) was set up as an expert body that will independently assess how the UK can optimally achieve its emissions reductions goals to 2050. One of its tasks is to provide advice to Government on the three carbon budget periods defined in the Climate Change Bill – 2008 to 2012, 2013 to 2017 and 2018 to 2022. It produced its first report on this in December 2008 (The Committee on Climate Change, 2008). In 2007/08 BRE undertook work for the CCC (then, the Office of Climate Change) to assist them with this task. The following makes use of parts of that analysis as it relates to the existing housing stock. The CCC work was actually a development and extension of previous analyses undertaken for the former Department for Environment, Food and Rural Affairs (L D Shorrock, J Henderson and J I Utley, 2005).

The starting point for the CCC work was identifying the potential numbers of existing homes that could benefit from a range of energy efficiency measures, based on the most recent and comprehensive data that was available at the time (actually 2005). Given such numbers (some of which are better known than others), and an energy model, the potential energy and carbon dioxide savings for each measure could be estimated. The annual cost savings could also be determined from the energy savings and corresponding fuel prices so, given information on the capital costs of each measure, and an estimate of the lifetime, a net annual cost could be calculated. This is calculated as follows:

$$NAC = EAC - S$$

Where S is the annual saving (£/year) due to the measure and EAC is the equivalent annual cost given by:

$$EAC = \frac{Cr}{1-(1+r)^{-n}}$$

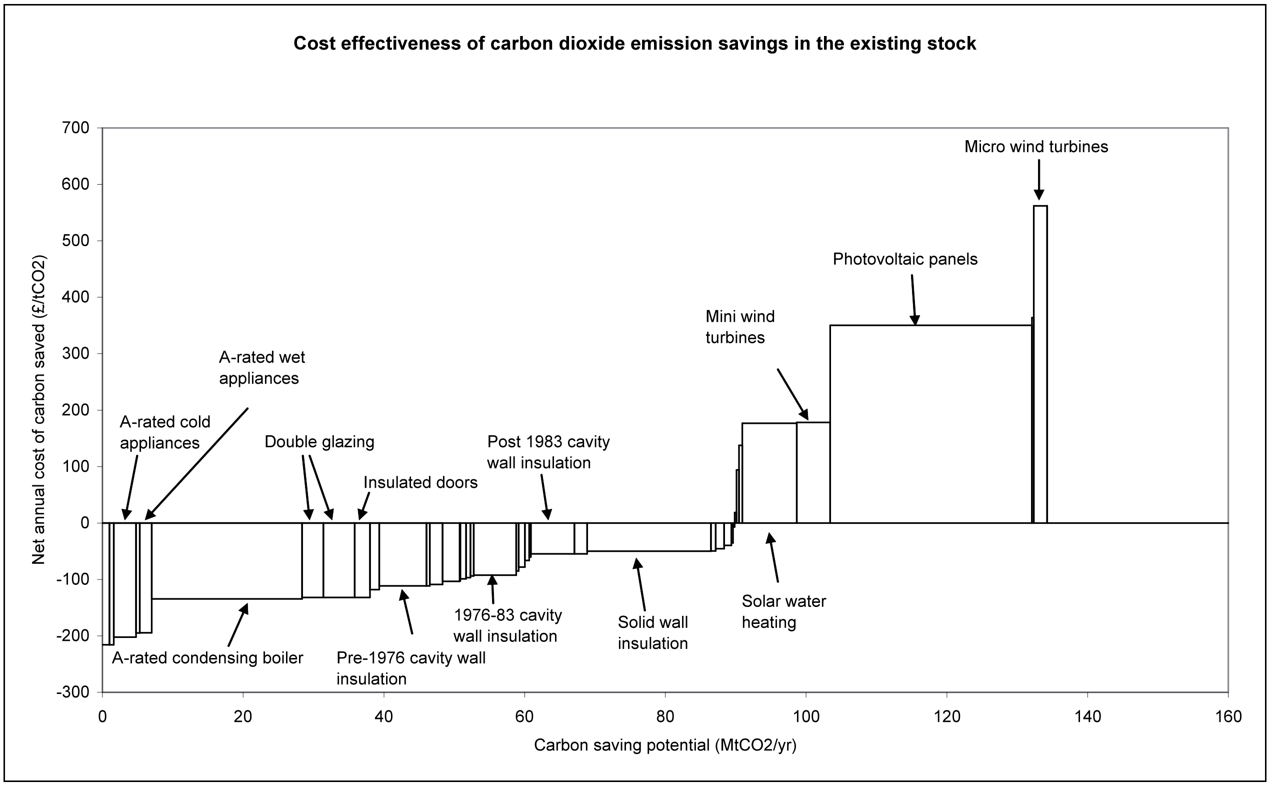
Where C is the capital cost of the measure (£), r is the discount rate (3.5% was used) and n is the lifetime of the measure over which the annual cost saving is made (years). Dividing NAC by the carbon dioxide saving gives the net annual cost per tonne of carbon dioxide saved, as plotted on Figure 1 and later figures. Note that all money values in this paper are quoted in pounds sterling (£). At the time of writing the pound and the Euro had approximately equal value.

If the net annual cost is negative this means that the energy efficiency measure in question is cost-effective. If it is positive, it is not cost-effective. The results when ranked according to cost-effectiveness produce a chart like that of Figure 1 which shows the carbon dioxide saving and the net annual cost of each measure. The largest of the carbon dioxide savings are labelled on Figure 1 so, for example, it shows that cavity wall insulation, solid wall insulation and condensing boilers are particularly important measures. The details for all of the 39 measures that were considered, some of which save relatively little, are given in the table under Figure 1.

There are some important points to note about the information contained in Figure 1. Firstly, there are interactions between measures. Such interactions have been taken into account in so far as it is possible to do so with this type of analysis. Thus, the savings from low energy appliances have been adjusted to allow for the fact that their use lowers the incidental gains which means that the heating system has to supply more heat to meet the same comfort conditions (often referred to as the "heat replacement effect"). And the boiler savings have been adjusted to allow for the fact that they would be reduced by the installation of the insulation measures that are considered. For such measures, therefore, it is meaningful to add the savings together to identify the potential cumulative savings.

However, there are certain measures shown that are effectively alternative technologies. For example, the installation of photovoltaic panels results in a de-carbonisation of the electricity supply, which means that the savings that have been ascribed to low energy appliances (and other electricity uses), which are based on the current electricity supply arrangements, would be changed. Photovoltaic panels and other alternative technologies make up most of the carbon dioxide savings that are identified as being not cost-effective in Figure 1. So the plot can be looked at cumulatively in the negative cost region, but in the positive cost region it must be recognised that this breaks down and the cumulative savings will inevitably differ from what is shown.

It is also important to note that savings from all fabric insulation measures have been downgraded to allow for comfort taking, using the best estimate that we have of the magnitude of this effect in practice (Sanders and Phillipson, 2006). Fur-



Measure	NAC/tCO2	MtCO2/yr	Cumulative
Reduced standby consumption	-215.93	1.00	1.00
Integrated digital TVs	-215.90	0.60	1.61
A++ rated cold appliances	-202.34	3.17	4.78
A rated ovens	-195.00	0.52	5.30
A+ rated wet appliances	-194.53	1.69	7.00
A-rated condensing boiler	-134.44	21.38	28.37
Glazing - old double to new double	-132.04	3.02	31.39
Glazing - single to new double	-131.97	4.46	35.85
Insulated doors	-131.89	2.19	38.04
Loft insulation 0 - 270mm	-117.89	1.31	39.34
Pre76 cavity wall insulation	-111.53	6.70	46.04
Induction hobs	-111.26	0.49	46.53
DIY floor insulation (susp. timber floors)	-108.69	1.82	48.35
Efficient lighting	-103.22	2.41	50.76
Loft insulation 25 - 270mm	-102.65	0.09	50.86
Uninsulated cylinder to high performance	-99.03	0.81	51.67
Insulate primary pipework	-96.76	0.62	52.29
76-83 cavity wall insulation	-93.95	0.48	52.77
Glazing - single to future double	-92.37	6.05	58.81
Loft insulation 50 - 270mm	-85.19	0.34	59.15
Room thermostat to control heating	-78.00	0.88	60.04
Loft insulation 75 - 270mm	-66.29	0.60	60.64
Post '83 cavity wall insulation	-60.14	0.24	60.89
Glazing - old double to future double	-54.71	6.19	67.08
Installed floor insulation (susp.TFs)	-54.61	1.82	68.90
Solid wall insulation	-49.78	17.59	86.49
Loft insulation 100 - 270mm	-49.52	0.67	87.16
Thermostatic radiator valves	-45.45	1.19	88.35
Improve airtightness	-39.69	1.04	89.39
Loft insulation 125 - 270mm	-35.22	0.22	89.62
Loft insulation 150 - 270mm	-7.00	0.24	89.86
Glazing - new double to future double	18.71	0.27	90.13
'Paper' type solid wall insulation	94.07	0.33	90.46
Modestly insulated cyl to high performance	137.69	0.48	90.94
Solar water heating	176.77	7.72	98.66
mini wind turbines	178.14	4.76	103.42
Photovoltaic generation	350.25	28.68	132.10
Hot water cylinder 'stat	363.84	0.25	132.35
micro wind turbines	561.81	1.90	134.25

Figure 1. Cost effectiveness of carbon dioxide emission savings in the existing stock

thermore, the savings that have been ascribed to cavity wall insulation and loft insulation have been adjusted to take account of the fact that, for reasons that are still not understood, the savings that are achieved in practice fall well short of what energy modelling would suggest (Sanders and Phillipson, 2006). If we could identify the reasons why cavity wall insulation in particular falls short of achieving the expected savings then it may be possible to recover some of these lost savings in future. For such reasons, the savings that are presented in Figure 1 are thought to be realistic rather than optimistic.

Figure 1 indicates that the cost-effective savings amount to about 90 $MtCO_2$/year. It would, of course, take time to install all of these measures but it should be feasible to do so by 2050 which is the year of interest – although some measures (such as solid wall insulation) would need significant support and promotion to increase their currently very slow uptake rates[1].

It will be noted that the 90 $MtCO_2$ saving from undertaking all of the cost-effective measures (plus the 8.5 $MtCO_2$ saving already achieved between 1990 and 2006) represents only a 64% reduction on the 1990 emissions from the housing stock so it is clear that to achieve an 80% saving will inevitably involve going beyond cost-effective measures. Therefore, it follows that measures to de-carbonise both the supply of electricity and heat will be essential if this target is to be achieved. In other words, technologies such as biomass boilers and heat pumps will by 2050 need to have largely replaced the conventional heating systems that are currently in use (i.e. predominantly gas boilers).

Furthermore, new homes will just add to the housing stock emissions unless they are built to zero carbon standards. Simply continuing to build new homes to the 2006 Building Regulations standards would result in an additional emission of around 23 $MtCO_2$/year by 2050, all other things remaining equal. So the 90 $MtCO_2$ saving would be eroded to just 67 $MtCO_2$, representing a reduction of only about 49% of the 1990 emissions (again, including the 8.5 $MtCO_2$ saving already made between 1990 and 2006).

It is evident from this that new homes will need to achieve much higher standards than those that presently apply if the 80% target is to be met. The Code for Sustainable Homes provides a framework for improving the standard of newly built dwellings and this is discussed next.

Improving new homes and the Code for Sustainable Homes

The Code for Sustainable Homes (hereafter, "the Code") was launched in the UK in April 2007. The Code sets out six levels of sustainability which, in terms of carbon dioxide emissions, represent different levels of improvement relative to the requirements of the 2006 Building Regulations (Communities and Local Government, February 2008). Level 1 represents a 10% improvement, level 2 an 18% improvement, level 3 a 25% improvement, level 4 a 44% improvement and level 5 a 100% improvement (all of these relate to just the elements of the energy use that are covered by Building Regulations – space heating, water heating, ventilation and lighting). Level 6 of the Code also encompasses the remaining elements of the energy use which are not presently subject to regulations (i.e. appliances and cooking), and achieving this level corresponds to a zero carbon home. As already noted, the UK Government has an aim that, from 2016, all homes built should achieve this standard.

The Department of Communities and Local Government (CLG) has undertaken work to assess the costs of achieving different levels of the Code (Communities and Local Government, July 2008). They examined costs for different dwelling types (detached, end terrace / semi-detached, mid terrace and flat), within four different "development scenarios" (Small, City infill, Market Town and Urban regeneration) using either the assumption that wind power can be used or that it can not be used (they assumed that it can be used in only two of the four development scenarios). The figures that CLG has produced have been used for the present study [2]. For this purpose, the costs for an end terrace/semi-detached house have been selected, and the high costs (corresponding to the case where wind power can not be used) have been used. Examination of the figures in the CLG report showed that the average of the cost figures across all four dwelling types were very close to those for this dwelling type, so it is an appropriate choice for this study. In general, the calculations relating to the existing housing stock have been undertaken using a standard semi-detached house (this is the most common house type in the UK, representing about a third of the stock), so this is a further reason for selecting this dwelling type for new homes as well.

Given the costs and carbon dioxide emission savings from the CLG report, and assuming that about 8 million homes will be built up to 2050 (the number is uncertain but it should be of this order), it is possible to calculate the net annual cost per tonne of carbon saved in 2050 in exactly the same way as for existing homes. For this we use exactly the same assumptions about fuel prices and carbon dioxide emission factors, and we use the same discount rate. For the lifetime a figure of 100 years has been used. It would be expected that a dwelling should have a lifetime of at least 100 years since many existing homes in the UK have already lasted longer than this (almost 20% of homes in the UK were built before 1918). Clearly, however, at least some of the technology incorporated within the dwellings would not last this long so there is an inevitable uncertainty about the most appropriate figure to use (as, indeed, there is for the lifetimes of the individual measures considered in Figure 1). Fortunately, it is a characteristic of this type of cost-benefit analysis that the results are not very sensitive to the assumed lifetime once it is reasonably large so this uncertainty should not significantly affect the general conclusions.

Figure 2 is the same as Figure 1 except that it now includes within the ranking the savings that would be achieved in 2050 by building dwellings to level 1 of the Code rather than to the requirements of the 2006 Building Regulations. It may be observed that the level 1 savings are cost-effective but, in comparison with the existing home savings, they are very small, which emphasises the importance of improving the existing stock. But it also needs to be borne in mind that although the

1. The work for CCC actually considered the uptake rates of measures explicitly, leading to charts like Figure 1 relating to the remaining potential at the end of each of the carbon budget periods.

2. Only costs relating to the energy efficiency aspects of the Code have been used here. There are some other costs associated with achieving different levels of the Code but they are small in comparison.

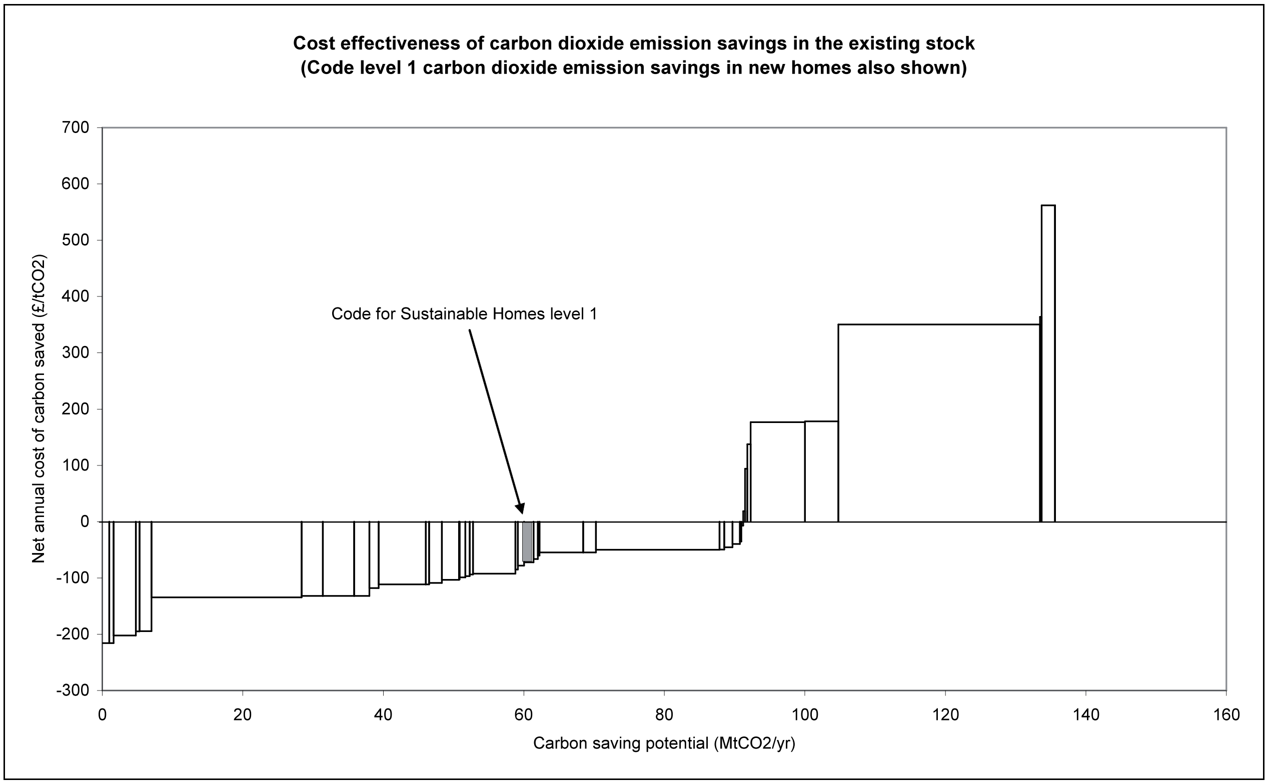


Figure 2. Cost effectiveness of carbon dioxide emission savings in the existing stock (Code level 1 for new homes also shown)

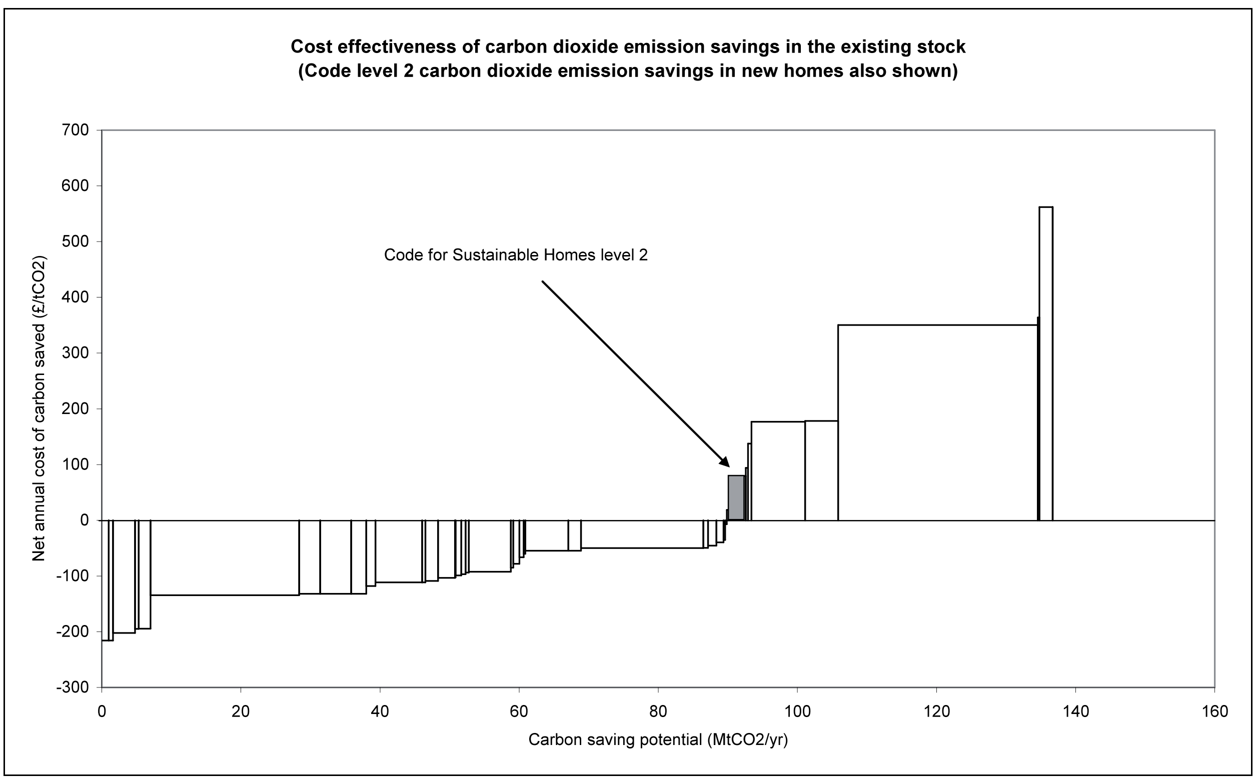


Figure 3. Cost effectiveness of carbon dioxide emission savings in the existing stock (Code level 2 for new homes also shown)

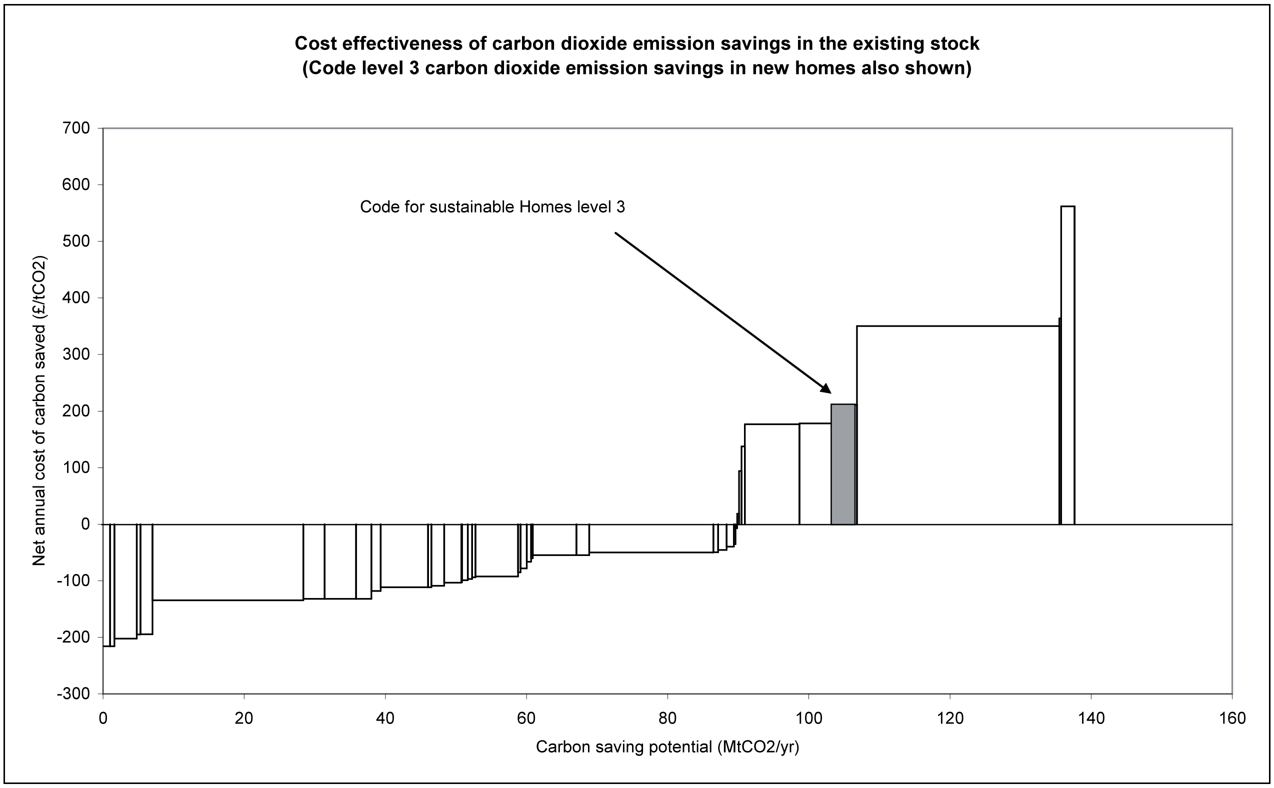


Figure 4. Cost effectiveness of carbon dioxide emission savings in the existing stock (Code level 3 for new homes also shown)

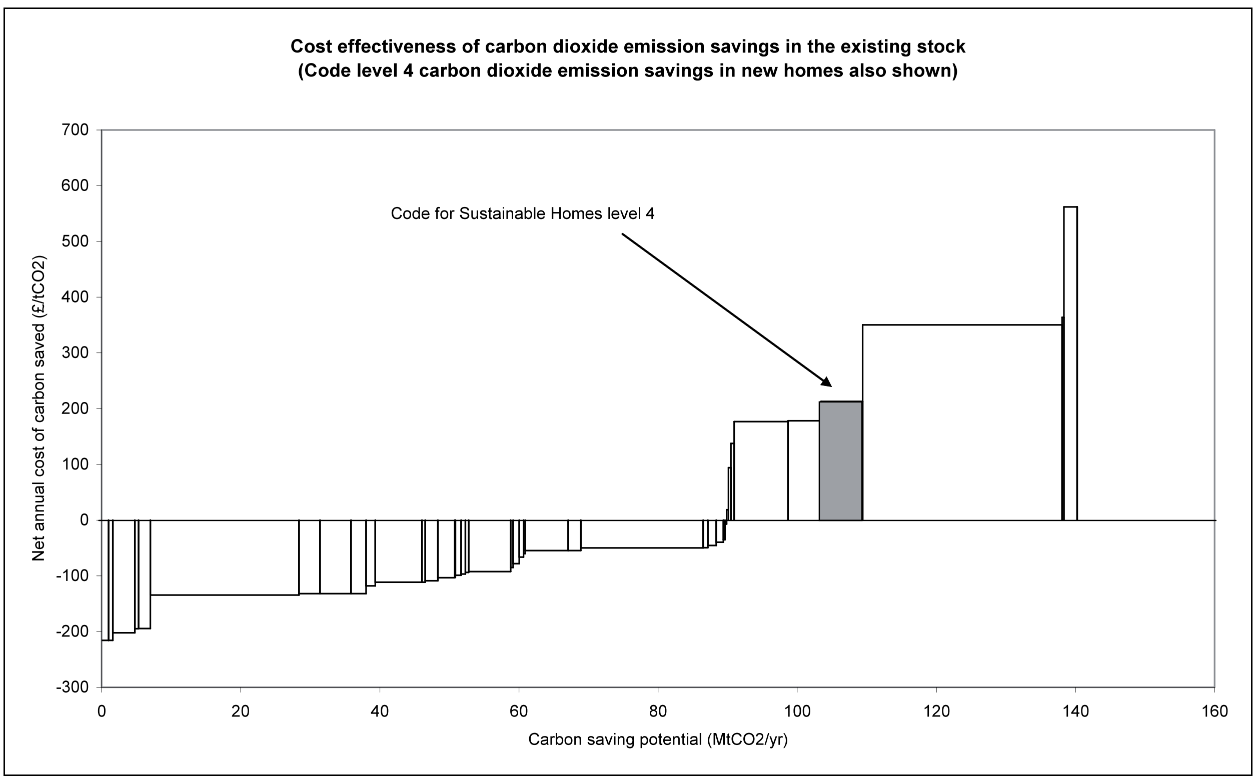


Figure 5. Cost effectiveness of carbon dioxide emission savings in the existing stock (Code level 4 for new homes also shown)

Code figure is shown as a saving (so that it can be compared with the existing housing stock savings) this is actually just a small reduction to the additional emissions that new homes constructed up to 2050 will produce if they are built to the current Building Regulations.

Figures 3 to 7 are the same as Figure 2 but they show the savings for levels 2 to 6 of the Code in turn. It may be observed that none of these are shown as being cost-effective but it is interesting that levels 5 and 6 appear more attractive than levels 3 and 4. Level 5 has a lower cost per tonne of carbon dioxide than levels 3 and 4 and considerably larger savings, whilst level 6 has

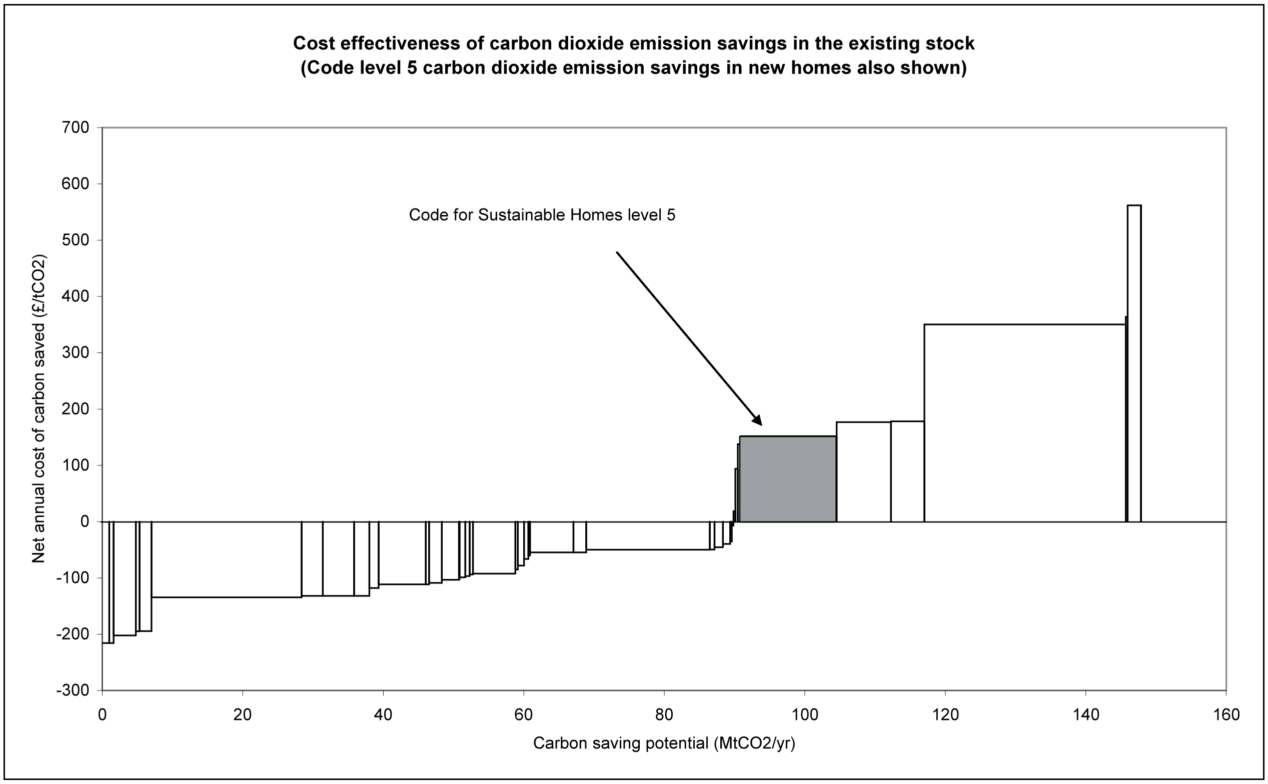


Figure 6. Cost effectiveness of carbon dioxide emission savings in the existing stock (Code level 5 for new homes also shown)

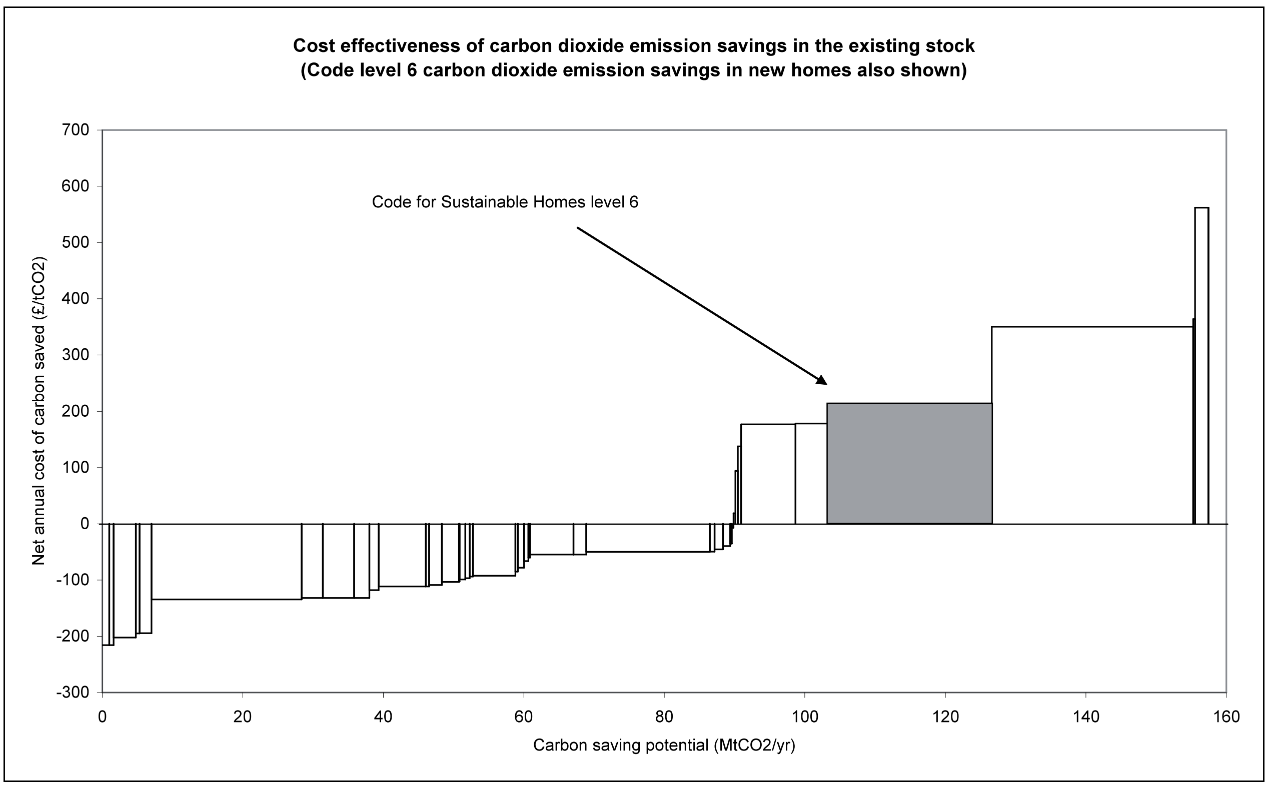


Figure 7. Cost effectiveness of carbon dioxide emission savings in the existing stock (Code level 6 for new homes also shown)

a cost per tonne which is almost the same as levels 3 and 4 and a much larger saving (bearing in mind again that these are not savings as such – they are reductions to the additional emissions that would otherwise occur by building new dwellings to the 2006 Building Regulations, and only level 6 reduces these emissions to zero).

Table 1 summarises the carbon dioxide emission reductions that the different levels of the Code might achieve in 2050 together with their net annual costs, presenting these in order of cost-effectiveness.

Table 1. Savings from different levels of the Code for Sustainable Homes ranked by cost-effectiveness

Code for Sustainable Homes level	NAC/tCO2	MtCO2/yr
Level 1	-72.40	1.36
Level 2	79.21	2.45
Level 5	151.83	13.60
Level 3	211.13	3.40
Level 4	213.06	5.98
Level 6	213.67	23.19

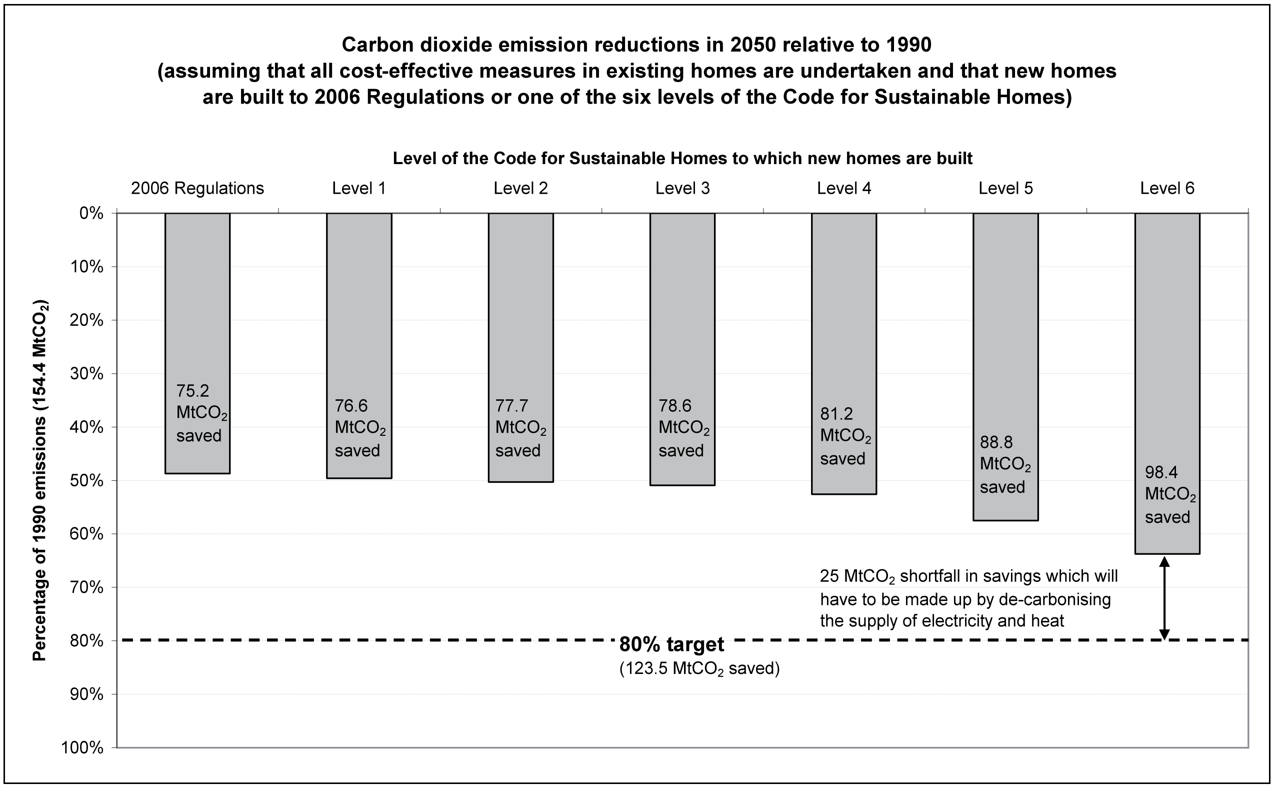


Figure 8. Carbon dioxide emission reductions in 2050 relative to 1990 compared with the 80% target.

Conclusions

The question posed by the title of this paper was "Do zero carbon homes make sense?".

The answer is that it depends on the context of the question.

If the question relates to a conventional economic assessment of cost-effectiveness then zero carbon homes do not make sense. This is illustrated by Figure 7 which shows that zero carbon homes are not cost-effective and there are much larger, and cost-effective, savings to be obtained by improving the existing housing stock.

However, if the question relates to the aim of achieving an 80% reduction to carbon dioxide emissions by 2050 then this paper has shown that zero carbon homes are in fact essential. By undertaking all cost-effective improvements to existing dwellings, and by building all new homes to the 2006 Building Regulations, the reduction to housing stock carbon dioxide emissions in 2050 will only be in the region of 49%. By building new homes to zero carbon standards this would be improved to about 64%, which still falls short of the Government's 80% target. To achieve the 80% target it will be necessary to go further and de-carbonise both the supply of electricity and heat. This is illustrated in Figure 8.

Thus, the 80% target is extremely challenging and it will not be met unless the standards for new homes are increased to zero carbon at the earliest opportunity (indeed, it will not be met unless essentially all practical energy efficiency options are pursued with urgency).

This paper has also shown that constructing new homes to levels 5 and 6 of the Code is actually more attractive, in terms of the cost per tonne of carbon dioxide saved, and the amount of carbon dioxide saved, than constructing to levels 3 and 4 (see Table 1). Level 5 has a lower cost per tonne of carbon dioxide than levels 3 and 4 and considerably larger savings, whilst level 6 has a cost per tonne which is almost the same as levels 3 and 4 and a much larger saving. So this is a further argument for rapidly moving towards a requirement for zero carbon homes.

Of course, there are practical reasons why it may be necessary to build to the intermediate levels of the Code for a short period of time. The higher levels of the Code represent a difficult challenge for house builders and designers and some time will be needed for them to adapt to such requirements. Thus, it is currently anticipated that the Building Regulations requirement introduced in 2010 will be to build to level 3, rising to level 4 in 2013, and finally to level 6 in 2016 (Communities and Local Government, July 2007).

Finally, it is worth noting that the 80% reduction target for 2050 relates to the entire carbon dioxide emissions of the UK and some sectors (i.e. transport) will present even greater challenges. This means that the housing sector (and buildings generally) will probably need to exceed the 80% reduction target to make up for shortfalls in other sectors.

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