Policy Document

A cost review of the Code for Sustainable Homes

Report for English Partnerships and the Housing Corporation

February 2007

HOUSING CORPORATION

English Partnerships
The National Regeneration Agency

Foreword

The Housing Corporation and English Partnerships welcome the Code for Sustainable Homes. The Code provides a clear signpost of the road to low carbon homes. From 2008 our organisations will be delivering over 40,000 homes annually against Code Level 3.
The publication of the Code follows extensive consultation and marks the beginning of what will be a major and necessary transformation of the industry.

English Partnerships will have Code Level 3 as a standard from April 2007. The Housing Corporation will have Code Level 3 as a minimum standard for the 2008 National Affordable Housing Programme.

Both the Housing Corporation and English Partnerships are proud to be leading the way in sustainable design and build. However Government also recognises that the move to the Code Level 3 will be demanding, particularly in an environment of increased cost efficiency. In order to assist with this, the Department for Communities and Local Government asked the Housing Corporation and English Partnerships to investigate the costs of meeting the Code. In addition, English Partnerships has launched the Carbon Challenge for designs that meet higher Code standards. It will be particularly useful for the whole sector to learn from these designs.

This report outlines how the Code works, the key differences between EcoHomes 2006 and the Code for Sustainable Homes, provides a summary of the technical solutions that can be employed to meet different levels of the Code for a range of standard house types and attaches costs to each of these possible solutions.

Indicative costs are provided in the report but these are approximate. There are many factors that feed into each scheme such as orientation and aspect of the site, access to wind, supply chain and availability of materials and technologies. A definitive cost is hard to predict. Whilst cost is important, the key to achieving Code levels is early planning, integrating lower carbon solutions into design at the earliest stage of development, committed partnership working, and a robust supply chain.

It is particularly exciting to be jointly delivering this report. As we prepare for Communities England, it offers significant opportunities to learn from each other's strengths as we seek to provide more sustainable homes and communities.

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Executive Summary

Background

Cyril Sweett was commissioned by English Partnerships and the Housing Corporation in August 2006 to produce a report considering the implications of moving from EcoHomes Very Good to the Code for Sustainable Homes (the Code).

Limitations/caveats

Whilst every effort has been made to develop accurate and representative cost analyses, it is important to remember that these are cost estimates and are not definitive. The actual costs incurred will depend on numerous factors including the developer, their supply chain and circumstances of any specific site (e.g. location, housing mix, etc).

This project is the result of a request from the Department of Communities and Local Government for English Partnerships and the Housing Corporation to examine:

- How compliance with Ecohomes Very Good is typically achieved and the performance of these homes in terms of water and energy efficiency
- The extra-over costs and impact on environmental performance of housing complying with the Code rather than EcoHomes

The first section of this executive summary addresses these questions

What is achieved under EcoHomes?

EcoHomes 2006 was launched in April 2006[1]. EcoHomes is a 'fully flexible' assessment tool (i.e. there is no prescription as to which specific measures should be adopted), therefore it is not possible to say for certain how an EcoHomes Very Good rated home will perform in terms of energy and water efficiency. However, analysis of the costs of achieving each of the available EcoHomes credits suggests that the most cost effective solution for meeting Very Good does not involve reducing carbon dioxide emissions by more than the level necessary to meet the requirements of Building Regulations Part L 2006. It is more cost effective to raise standards in other areas of EcoHomes than to go beyond current Part L requirements for energy.

Costing research also shows that the most economic method for achieving a Very Good rating would result in average water usage of approximately 126 litres/person/day (using the EcoHomes 2006 water consumption calculator). The water calculator for the Code is undergoing further development, and will be slightly different to the EcoHomes calculator. For comparison, the UK average daily tap water consumption per person is approximately 150 litres.[2]

What will be achieved under the Code for Sustainable Homes?

The Code contains six performance levels, to achieve compliance with each level it is necessary to achieve the relevant minimum performance standards for energy and water efficiency together with a minimum number of 'flexible' Code credits which are determined in a similar manner to EcoHomes 2006. The minimum standards for energy and water efficiency at each Code level are shown in Table S.1.

[1] EcoHomes 2006 has been used as the relevant comparison. English Partnerships have been using EcoHomes 2006 since April 2006. The Housing Corporation would have used EcoHomes 2006 for the 2008/10 bid round.

[2] Waterwise www.waterwise.org.uk, Feb 2007

Table S.1 Energy and water performance standards in EcoHomes and the Code

		Proposed levels in the Code for Sustainable Homes					
	EcoHomes	1	2	3	4	5	6
Energy (% improvement over ADL1 2006)	0%	10%	18%	25%	44%	69%	100%
Water (litres per bedspace per day)	126	120	120	105	105	80	80

Code level 3 is more challenging than EcoHomes Very Good. The minimum performance standards for Code level 3 require a 25% reduction in carbon dioxide emissions (in comparison to the relevant Target Emissions Rate (TER) set out in Building Regulations 2006 Part L) together with potable water consumption levels of 105 litres per person per day[3].

The environmental savings expected from moving from Ecohomes 'Very Good' to Code level 3 equate to a 25% reduction in carbon emissions per house and 21 litres per person per day.

Impact on costs

There is a cost premium associated with achieving Code level 3 in comparison to EcoHomes Very Good. The major reductions in carbon dioxide emissions and water consumption account for the majority of this additional cost. These costs vary depending on the house type and the feasibility of using different carbon saving technologies (e.g. micro-wind turbines). The assessment[4] therefore looked at six generic house types and considered a wide variety of technological solutions for achieving improved performance.

The house types considered were:

- Four traditional housetypes (built using commonly applied construction methods)
  - Detached house (gross internal floor area of 116 m^2)
  - End terrace/semi-detached house (gross internal floor area of 101 m^2)
  - Low rise apartment (net unit area of 59 m^2)
  - Medium/high rise apartment (net unit area of 75 m^2)
- Two homes built using modern methods of construction and compliant with the requirements of English Partnerships' Design for Manufacture (DfM) competition[5]:
  - An end of terrace house (76.5 m^2); based upon the WeberHaus product
  - A mid terrace house incorporating a centralised CHP system (76.5 m^2); referred to in this report as the 'SixtyK House'

The central concern on getting to Code level 3 is reducing the carbon emissions associated with energy use. Four scenarios were considered for reaching the required energy levels. These scenarios represent only a selection of the multitude of different possible approaches. This report does not advocate any particular solution and the most suitable approach will need to be determined on a project specific basis.

Scenario 1. Initial energy efficiency measures followed by use of solar thermal technology and then photovoltaics and biomass systems.

Scenario 2. Initial energy efficiency measures initially followed by use of small scale wind turbines and then biomass systems

Scenario 3. Development with shared energy services, such as combined heat and power (CHP). For this scenario costs per unit are averaged for different infrastructure options for a theoretical 200 unit development.

Scenario 4. Achievement of Code level 3 without recourse to renewable energies through the use of a whole house mechanical ventilation system with heat recovery and by assuming the use of proprietary construction details[6].

Table S.2 shows the additional cost associated with achieving Code level 3 in comparison to EcoHomes Very Good for each house type. To show the significance of these costs relative to the base cost of each unit (thereby accounting for the size and construction method employed), these figures are also presented as a percentage uplift in cost.[7]

Analysis of the results shows that costs are lowest where it is possible to use wind energy or site wide CHP. However, not every location will be able to make use of these technologies. For example, some urban locations may not have sufficient consistent wind speed to generate appreciable quantities of wind energy.[8]

[3] There are 2.4 people living in each home meaning 19.2 litres are saved per home per day under the Code proposals.

[4] Energy performance was calculated using the BuildDesk 3.2 software (a BRE quality assured method for conducting SAP 2005 assessments). Water performance was assessed using the EcoHomes 2006 water consumption calculator.

[5] Costings and performance of MMC house types are provided in Appendix B. The remainder of the report deals with house types that make up the majority of annual build.

[6] Proprietary construction details are a proposed supplement to the SAP 2005 assessment process allowing for reduced heat loss from a building where the construction method reduces the extent of thermal bridging (explained further in Section 3). Proprietary construction details are not yet included within SAP 2005 however their use is currently being evaluated by DCLG.

[7] Calculation of the base cost is explained in Section 2 of the report.

[8] Following discussions with the Energy Saving Trust and other researchers, it has been assumed that on average 1100 kWh of electricity would be generated. This is less than many manufacturers claim for the technologies and assumes a relatively low average wind speed of around 5 metres per second.

This report is for the Housing Corporation and English Partnerships. As such it focuses on the move from EcoHomes 2006 Very Good to meeting the requirements of Code level 3. A comparison between the costs of building only to Building Regulations requirements and to Code level 3 reveals different results. These are detailed in Table 6.8.

Table S.2 Additional cost for Code level 3 over EcoHomes Very Good

	Traditional detached house	Traditional terraced house	Low rise apartment	High rise apartment	SixtyK House
Scenario 1	£4,525 (4.8%)	£4,373 (5.7%)	£2,579 (3.2%)	£4,900 (3.8%)	£0.00 (0.0%)
Scenario 2	£2,852 (2.9%)	£2,786 (3.5%)	£1,498 (1.9%)	£2,699 (2.0%)	
Scenario 3	£3,131 (3.2%)	£3,165 (4.1%)	£946 (1.2%)	£643 (0.4%)	
Scenario 4	£5,090 (5.4%)	£4,748 (6.2%)	Not achievable	£3,942 (3.0%)	

Factors expected to reduce costs

The above costs are those that would be incurred to meet Code standards if they were specified today. Solutions which are currently emerging and other factors that might lead to cost reductions are:

- Innovation in design and specification within the housing sector
- Emergence and development of new technologies/construction methods better suited to meeting the required performance standards
- The impact of the £80m set aside for grants and bulk purchase agreements of micro generation by the Department for Trade and Industry
- The involvement of an Energy Services Company (ESCO) in a development
- Reduction in cost of existing products arising from their widespread adoption
- Bulk purchasing of products

Carbon emissions reduction is a relatively recent focus for the sector. Once the collective intelligence of the construction industry is applied to the issue of meeting the required targets it is likely that more efficient/innovative solutions might be adopted that achieve the same performance at lower cost.

As the industry focuses on this issue other more effective solutions may come to light. This report is not an exhaustive report of all solutions. For example, air source or ground source heat pumps are not considered. Also, where it is possible to utilise large scale wind turbines costs are significantly reduced. The use of a 42m 200 kW turbine would enable a mixed use development to achieve the carbon savings required for Code level 4 at around £12 per m^2 (£1,200 for a 100 m^2 home). Although this model may be possible on numerous sites this report does not illustrate the large scale wind turbine option further because of the influence of local factors on their viability.

Some new technologies on the verge of becoming widely available may well enable Code standards to be achieved more cost effectively. For instance micro CHP units are currently being installed in small numbers in England however as they are not widely available in the UK, the summary costs in this report do not include micro CHP as an option. However, when they are available they should provide a low cost (only a relatively low increase over the cost of a high efficiency boiler) method for achieving at least Code level 3 that will be generally applicable to houses irrespective of their location. Also, micro CHP is better suited to larger homes of at least 100m^2. These are usually homes with four or more bedrooms. It should be remembered however, that micro CHP uses gas and therefore would not contribute towards meeting a renewable energy requirement.

Perhaps the most significant short term opportunity for cost reduction is the role of ESCOs in providing capital for site wide carbon saving measures (such as CHP). Evidence of the potential cost savings comes from the SixtyK house, which achieves the Code level 4 standard for energy/carbon without any increase in developer base cost by proposing to 'outsource' the energy services aspect of the development to an ESCO, i.e. any additional costs are off balance sheet. A number of ESCOs have recently entered the market and (depending on the site) offer to provide CHP and other low carbon energy systems at no extra cost to the developer, in return for a long term power purchase agreement.

The widespread adoption of Code standards will stimulate the markets for technologies favoured by the standards (e.g. micro CHP and renewables). Research suggests that depending on the type of technology being specified, cost reductions will be significant once demand is guaranteed and manufacturers are in a position to supply the market. Analysis of trends in the costs of new products suggests that for every doubling in the total demand for solar hot water and community heating, costs will reduce by around 8%, whilst a doubling in the market for photo voltaic technology and micro CHP is likely to result in an approximate 18% reduction in costs[9]. This analysis is supported by anecdotal information from suppliers of micro-wind turbines who believe that prices will fall by up to 60% over the next few years (the current installed capacity for micro-wind is low so several doublings in the market for these products can be expected).

Further work is required on the potential savings arising from the combined effects of an increase in demand, much higher levels of global investment in new technologies, growth in the ESCO market and bulk purchasing.

Summary of differences between the Code and EcoHomes 2006

As previously mentioned the most significant difference between the Code and EcoHomes 2006 is the inclusion of mandatory standards for energy/carbon. Other important differences are that the Code:

- Has a different weightings for each credit
- Uses a different method of measuring CO_2 emissions (% reduction on TER rather than the kg CO_2 per m^2 used in EcoHomes)
- Includes new credit areas for Lifetime Homes and composting facilities
- Uses the forthcoming revised (unpublished) version of the Green Guide to Specification (ratings in the current Green Guide have been used in this study).
- Does not include credits for public transport or local amenities

Each of the above differences impact upon the cost of achieving Code levels in comparison to the corresponding EcoHomes 2006 rating.

Approach to measuring energy/carbon performance

The house types considered in this study have TERs of less than 26 kg CO_2 per m^2 (with several having TERs of less than 21 kg). These 'just compliant' homes that make no substantial improvement on Building Regulations requirements would achieve a minimum of 6 energy credits under EcoHomes 2006. However under the Code this level of performance (i.e. Building Regulations compliance) would attract no credits and credits will only be awarded for further efficiency measures required to achieve the minimum performance standards.

The wide variation in the CO_2 emissions of the different house types (from 26 to 19 kg CO_2 per m^2) suggests that the approach of assessing performance using the percentage improvement over the TER is more suitable than setting definitive carbon emission levels (and is consistent with the approach taken in new Building Regulations).

[9] Taken from Hinnells, M The cost of 60% cut in CO_2 emissions from homes: what do experience curves tell us 2005.

New credit areas

The Code includes new credits for Lifetime Homes standards and composting facilities.

Lifetime Homes is not considered to have a significant impact on overall project costs because the requirements of the revised Part M of Building Regulations now require many of the same considerations to be addressed as a matter of course. It is estimated that compliance with the Lifetime Homes standard could result in additional costs of around £550 per home. However, because of the relatively low weighting of these voluntary credits it is unlikely that a developer would pursue this standard (unless required to do so) because there are less expensive ways of achieving the credits necessary for Code level 3. For instance a developer may prefer to provide energy efficient lighting or drying space, both of which cost less than £50, rather than attempting to achieve Lifetime homes requirements.

It should be noted that English Partnerships require that their developments meet Lifetime Homes standards so for their schemes, developers will not incur additional costs in meeting this element of the Code.

The new credits relating to composting facilities will have no significant impact on project costs (cost of around £70 per home).

Exclusion of credits for accessibility

The Code excludes the current EcoHomes credits relating to access to public transport and local amenities. As a result the Code is slightly more 'location independent', however, the inclusion of credits for ecological impact means that the assessment will still be influenced by building location.

Recommendations for further work

The research carried out in this study is only an initial analysis of the possible costs and implications of meeting the standards in the Code. Over the coming few years significant further work is required if the UK is to meet its longer term carbon reduction targets and other environmental standards. Specific areas where immediate work would be beneficial include:

- **Analysis of the potential savings arising from the combined effects of an increase in demand for and much higher levels of global investment in new technologies, growth in the ESCO market and bulk purchasing.**
- **Assessment of the whole life and operational costs associated with different approaches to meeting Code.**
- **Review of analysis in this study in light of the guidance in the final technical manual when this is published in April 2007 (although this is not expected to materially alter the results).**

1 Introduction

Cyril Sweett was commissioned by English Partnerships and the Housing Corporation to consider the implications of the proposals contained within the Code for Sustainable Homes (the Code). This final report considers the implications of the Code as published by the Department for Communities and Local Government (DCLG) on 13th December 2006[10].

The analysis presented in this report considers some of the possible ways in which the requirements of the Code could be achieved for different house types. However, the Code is new and therefore little practical experience exists of meeting all of the required standards together in new housing (although many of the Code criteria are developed from the existing EcoHomes standard). Therefore, the technical approaches and their commercial implications presented in this report should be taken as indicative of suitable responses to the Code and the likely range of cost, rather than as definitive benchmarks of cost implications.

Throughout the course of this study (Autumn 2006) substantial changes were noted in the markets for some of the technologies that could be used to respond to meet Code requirements, for example renewable energy systems as discussed in Section 1.3. These market changes, coupled with the growth in the market for energy and multi-utility service provision (e.g. ESCOs) suggest that the most effective solutions and associated costs of meeting different Code levels should be closely monitored during 2007-08 to assess how the market responds in practice.

1.1 Background to the Code

The Code has been introduced to ‘drive a step-change in sustainable home building practice’. It will become the national standard for sustainable homes and will provide the basis for future developments of Building Regulations in relation to carbon emissions.

The Code sets development standards for a range of areas of building performance, and in particular seeks to encourage energy/carbon and water efficient developments. Overall performance is graded in levels from 1 to 6.

The Code is a development of the existing EcoHomes standard. The key difference between them is that while EcoHomes is a flexible standard comprising a variety of performance criteria, from which the most cost effective are likely to be selected, the Code requires:

- Achievement of minimum performance standards for energy/carbon and water at each level
- Achievement of minimum ‘entry level’ standards for surface water runoff, material use and waste management
- A minimum percentage of ‘Code credits’ are awarded for meeting performance thresholds for energy/carbon, water and a range of other environmental considerations

Therefore, the Code is better suited to delivering targeted reductions in carbon dioxide emissions and water use than EcoHomes, but provides less flexibility.

The final technical manual to support the criteria within the Code will be published in April 2007 and homes will be assessed from this date. It is proposed that certification against the Code will be required for all new development from April 2008, whether or not a scheme achieves level 1 or above. Some publicly funded developments will be expected to achieve a minimum Code standard and planning authorities will be encouraged to adopt the Code as part of their drive to deliver sustainable development.

The Housing Corporation and English Partnerships intend to adopt level 3 of the Code on all their developments as a minimum standard from April 2007 onwards, moving to level 4 in 2010 and level 6 in 2013.

1.2 Objective

The principal objective of this report is to evaluate the technical and associated financial implications of:

- Achieving compliance with the different Code standards for energy and water
- Overall compliance with each level of the Code

The report also:

- Compares the cost and environmental performance of dwellings built to Code level 3 with that of a typical EcoHomes 2006 Very Good dwelling.
- Identifies the potential for medium to long term reductions in costs as a result of more widespread adoption of the technologies that are likely to be adopted to meet the required performance standards.

Particular emphasis is placed on assessing the implications of Code level 3 as this is the level that will be adopted for the majority of publicly funded projects. It was not possible to assess the implications of Code level 6 because the definition of zero carbon development under the Code is still being finalised.

1.3 Approach to cost analysis

The implications of meeting each Code level are presented in comparison to the costs of a baseline home (either a Building Regulations compliant home or in the case of two house types a specification developed for English Partnerships’ Design for Manufacture competition). Costs are presented on a per dwelling and per m^2 basis.

The analysis represents an estimate of the total costs to a contractor, including materials, plant and labour, preliminaries, overheads, contingencies, profit, and design fees.

[10] DCLG, Code for Sustainable Homes: A step change in sustainable home building practice, 2006.

The models relate to the construction of the dwellings only. They therefore make no specific allowance for items which would by their nature be site specific, such as:

- Substructure (other than ground floor slab)
- Below ground and site drainage
- Site works
- Site and common infrastructure

It should be noted that compliance with higher levels of the Code may require the introduction or re-specification of common infrastructure, such as use of Combined Heat and Power systems and/or sustainable drainage. In these instances, the assessment identifies the estimated net increase in cost on a cost per dwelling basis. The base dwelling costs themselves, however do not include allowance for infrastructure beyond the demise of the property.

The costings also exclude the following;

- Site acquisition costs
- Professional fees, other than design fees incurred by the contractor
- Party wall awards and any work in connection therewith
- Building Control and planning fees
- Any payments which may be required under Section 106 of the Town and Country Planning Act
- Remediation of site contamination
- Survey works
- Legal fees
- Finance costs
- Loose furniture and fittings, such as curtains, blinds, shelving, furniture and kitchen appliances
- Highways works
- Value Added Tax

The costings are current at Q3 2006 price levels for homes built by a housing developer with a trading turnover of around 5,000 to 10,000 dwellings per annum. It is appreciated that individual building contracts may vary in size from developments of small sites (around 12 units) to much larger sites accommodating 100 to 200 units. The estimated costs in this report are assumed to apply equally to these different scenarios on the basis that the type of contractor used would be similar[11], as would the design and specification of the individual dwellings.

Wherever possible, the costs in this report have been based upon quotations received from contractors and suppliers, with an adjustment made to reflect bulk purchase arrangements that might be applicable for projects of the sizes described.

To assess the likely discount available for bulk purchase on large procurement, a number of suppliers of energy and water efficient technologies were contacted. The technologies reviewed comprised; solar hot water, photovoltaics, biomass boilers, wind turbines, ground source heat pumps, greywater recycling, rainwater recycling and micro CHP.

The responses were highly variable, but suggested the following discounts may be available for large scale procurement (defined as orders of +5,000 units):

- Ground source heat pumps – 30% to 60%
- Solar thermal – 20% to 30%
- Micro CHP – around 20%
- Wind turbines – special conditions apply
- Biomass boilers – 10% to 20%
- Rainwater harvesting – 20% to 30%
- Greywater recycling (in house) – 10% to 20%
- Greywater recycling (outside house) – special conditions apply

No response was received from any of the photovoltaics companies contacted.

We recommend that further work be undertaken in this area, particularly now that the Code and associated consultation documents have been published.

The following points should be noted:

- With large orders a number of the companies said that they would need to implement special supply and distribution arrangements, which are assessed on a project by project basis. The wind turbine and greywater companies both said this.
- Large orders would necessitate increased investment in capacity to meet demand, which in turn would have an effect on the amount of discount available.
- Lead in periods appeared to increase significantly with orders over of 5,000 units. Reducing these lead in periods would require additional resources which would affect the discount available.

For consistency with the indicative development sizes upon which this report is based, the costs assume that the level of orders placed would be less than 1,000 units per individual order. This would attract a smaller discount, than those stated above. As a result, a discount of 10% for bulk purchase on a small to medium scale has been assumed for all technologies.

Irrespective of any bulk purchasing arrangement, it is important to remember that the actual costs incurred on a construction project will be highly variable as a result of numerous factors, such as:

- The size and type of contractor used
- The actual contractor selected
- Type and size of project
- Location and transport costs
- The project specific building specification or mix of technologies used

[11] They would therefore have the same corporate purchasing arrangements.

- General market conditions prevailing at the time, which may affect the price and availability of materials, products and labour

Furthermore, the nature of this type of research means that costs cannot be considered as definitive, as they are based upon generic and hypothetical building models, and technical solutions which in some cases are only just emerging and for which the markets have yet to mature.

The solutions presented in this study also present only a few of the multitude of available methods for meeting Code requirements and cover only a representative (but not comprehensive) selection of different dwelling types.

Given time, and the collective intelligence of the design and construction industry, it should be expected that more innovative/efficient solutions will be developed. The costs and technical solutions presented in this study should therefore be taken as indicative rather than definitive.

The potential effects of market expansion have not been specifically factored into the costings. Market expansion, and the forecasting of such, is a highly complex area that is outside the scope of this study. Indeed, it is likely that by 2010 (when it is proposed that the Code level 3 energy standard would be incorporated into Building Regulations), technologies and design solutions may have considerably evolved from those available on the market now.

In comparative terms, future systems may be considerably cheaper. Indeed the wind turbine manufacturer intimated that future generations of wind turbines could come down in price by as much as 60% from now. This issue is reviewed in more detail in section 9 of this report.

1.4 Limitations/caveats

Whilst every effort has been made to develop accurate and representative cost analyses, it is important to remember the following limitations and caveats to this study when reviewing the report:

- The capacity of a house builder or contractor to secure products and services at a given cost will be dependent on their own supply chain expertise, buying power and product availability.
- The approach taken assumes that development sites are generally amenable to the solutions proposed. This may not be the case on all sites, for example:
  - Development in areas with high flood risk will incur additional cost to provide the required design solutions (e.g. raised roadways and ground floors).
  - On highly constrained sites it may be more difficult to achieve some of the performance standards because of restrictions on site layout. For example, on some sites it might be difficult to accommodate site wide infrastructure solutions (e.g. site wide Combined Heat and Power (CHP) systems or communal rainwater collection tanks) without losing developable area.
  - Where hydrological conditions (e.g. high groundwater) preclude the use of passive runoff attenuation techniques.
  - Additional costs will be incurred for sites with high levels of ecological value.
  - Where average wind speeds are low, the amount of electricity generated through these technologies could be less than the assumed 1100 kWh (for a 1.5 kW turbine).
- It has been assumed that contractors/housebuilders are already managing their construction activities to a relatively high standard.[12] Organisations that do not currently operate good practice in site management will incur additional costs for compliance with these aspects of the Code.
- Some of the technologies referred to in the report are not currently available at the scale that would be required for widespread use by the UK housing industry.
- No account has been taken of the cost in Code assessor fees or assessment time associated with any of the performance standards. Some of the standards (e.g. responsible sourcing of materials) require large quantities of information to be gathered and analysed resulting in increased effort (if not direct cost) associated with demonstrating compliance. In addition, every house type will need to be assessed twice, both at the design stage, and post construction stage.
- For the purposes of this report, the cost effectiveness of the technical solutions proposed has been considered on the basis of their estimated capital cost. Their respective benefits in terms of reduced running costs/charges or whole life cost was not considered.

We recommend that further work is commissioned to review the whole life and operational costs associated with the Code.

Within the limited overall timescale set for this study it has not been possible to investigate a large number of alternative scenarios for meeting each target; rather the study has drawn on previous experience of the EcoHomes 2005 and 2006 standards together with realistic scenarios for the new standards included within the Code.

At the time of completing this report the technical manual to support the Code had not been finalised and as a result some minor technical aspects remain unresolved, for example the detail of the water consumption calculator.

Whilst it is not expected that definition of these currently unresolved areas would substantially alter the findings of this study it is recommended that the findings are reviewed in light of the guidance in the technical manual when this is published in April 2007.

As previously mentioned this report does not consider how a zero carbon home would be achieved (although many of the carbon saving solutions proposed result in CO_2 reductions of over 100% in comparison to a home compliant with Building Regulations Part L 2006).

[12] There is some evidence for this in the growing number of housebuilders that now routinely register their sites under the Considerate Constructors Scheme, monitor site waste arisings and operate environmental management systems in line with ISO14001.

2 Method

2.1 Overview

The key steps in the study are shown in Figure 2.1, and described in more detail on the following pages.

Figure 2.1 Overview of project method

Stage	Activity
Select house types	House types were selected to reflect a variety of housing types and both modern and more traditional construction methods.
Establish cost and performance baseline	The base construction cost was developed using a 'standard' specification (or as proposed by contractors). Environmental performance was assessed using relevant assessment methods (e.g. SAP 2005).
Identify environmental enhancements (energy, water and other aspects included in the Code)	One or more technical solutions were developed to meet the proposed environmental targets. Priority was given to those options believed to be most cost effective in capital cost terms. Options were considered for energy, water and other environmental enhancements reflecting the content of the Code.
Cost analysis of enhanced specifications	The capital cost (Q3 2006) of each option was assessed relative to the baseline cost.
Analysis of meeting different Code levels	Using the information on cost and performance for each of the enhancement options, the costs of meeting each Code Level were assessed. The costs and environmental impact of achieving Code Level 3 were compared with those for an EcoHomes Very Good rating. Different scenarios were considered – i.e. development size and planning requirements (e.g. PPS22).
Review of measures to reduce costs	Analysis of the potential for cost savings arising from more widespread adoption of energy efficient technologies and from development of emerging technologies.
Summary, conclusions and proposals for further work	Summary of likely short term cost implications and how this might change in the medium to long term.

2.2 Selecting house types

Six house types were considered in this study. These reflect different dwelling types (houses and apartments), sizes and construction methods. The six homes considered were:

- A traditionally built detached house (116 m^2)
- A traditionally built end of terrace house (101 m^2)
- A traditionally built (i.e. non-framed) low rise apartment (59 m^2 net occupied area)
- A concrete framed medium/high rise apartment (75 m^2 net occupied area)
- Two homes built using modern methods of construction and compliant with the requirements of English Partnerships' Design for Manufacture (DfM) competition:
  - An end of terrace house (76.5 m^2); based upon the WeberHaus product
  - A mid terrace house incorporating a centralised CHP system (76.5 m^2); referred to in this report as the 'SixtyK House', derived from its estimated construction cost of £60,000

When considering the apartment types it is important to remember that the distinction between low rise and high rise apartments is a matter of the construction method and building services rather than the specific number of storeys. It has been assumed that the low rise apartment could be constructed using traditional masonry construction practices and that these homes would normally be heated by individual gas fired combi-boilers. For the high rise apartments it has been assumed that the building would be of a concrete framed design with a base specification of electric heating. Gas is rarely considered for apartments above five stories for safety reasons.

2.3 Establishing performance and cost baselines

The first stage of the review was to calculate a baseline against which performance and associated 'extra-over' costs could be measured. For each house type the performance and cost baseline was taken to be either the designed specification[13] (in the case of the DfM dwellings) or a 'standard specification ' compliant with 2006 Building Regulations in the case of the other house types. Base specifications are set out in Table 2.1.

[13] i.e. a level of finishings that would typically be included in homes built by volume house builders.

Table 2.1 Summary of benchmark specifications for different house types

Element	Traditional houses (detached and terraced)	Low rise apartment	High rise apartment
Storeys	2	up to 4	5-15
Foundations + ground floor	Strip footings and beam and block floor with screed finish	Deep strip with beam and block floor with screed finish	Piled foundations with ring beam and beam and block floor with screed finish
External walls/ structure	Dense blockwork with plasterboard on battens		Insitu RC concrete frame
Internal walls	Timber/metal studwork with plasterboard	Timber/metal studwork with plasterboard	Timber/metal studwork with plasterboard
Cladding	Brick		Aluminium panels/terracotta tiles
Upper Floors	Engineered I-beam joists with chipboard	Metal joists with concrete topping	Insitu RC concrete
U values	U-values to comply with Part L 2006 Walls – 0.28 W/m²K Roof – 0.14 W/m²K Ground floor – 0.22 W/m²K Windows – 1.8 W/m²K		U-values to comply with Part L 2006 Walls – 0.28 W/m²K Roof – 0.14 W/m²K Ground floor – 0.22 W/m²K Windows – 1.6 W/m²K
Roof	Timber with concrete tiles		Concrete with steel standing seam
Windows and doors	PVCu		
Water fittings	Non controlled taps 6 litres flush toilets Standard bath (70 litres per use) Uncontrolled shower (flow rate of >15 litres/minute) No dishwasher Typical washing machine		
Electrical fittings	Regular light fittings 2 double power points in each room (kitchen, living room, bedrooms) Phone line to living room and master bedroom		
Heating/hot water system	Condensing boiler (SEDBUK B, Seasonal efficiency 85%) with hot water cylinder		Electric heating
External space	Garden (timber fence), no shed	Communal gardens (fenced)	Balcony

For the non-DfM house types the baseline costs were developed from detailed design and specification information, using benchmark data with construction costs adjusted to reflect those commonly incurred by volume house builders. For the DfM house types, the baseline costs were based upon figures provided by the developer or contractor involved. In each case only high level costs were provided, comprising an elemental cost summary for one house type, with only the total construction cost (i.e. £60,000 per unit[14]) in respect of the other.

Table 2.2 shows that baseline costs for each house type. It is important to note that the 'SixtyK' house cost is based on the assumption that an Energy Services Company (ESCO) will provide a site wide heating and power service to each home. Under an ESCO arrangement (see Section 9) the costs of these services are not born by the house builder and so are not included in the overall £60k budget for these homes. For the purposes of like for like comparison, the cost of these site wide services has been shown as a separate cost item.

[14] Excluding external works, but including design fees, preliminaries, overheads and profit.

Table 2.2 Baseline costs for each house type (as specified or compliant with 2006 Building Regulations)

Unit Type	Base Cost (per unit)	Area (m^2)	Cost per m^2	Target emission rate (kg CO_2 m^2)
Detached House	£91,206	116	£786	24.1
End of Terrace House	£75,235	101	£745	21.1
Low Rise Flat (Non SDS)	£79,200	59	£1,342	20.6
High Rise Flat	£124,500	75	£1,660	24.9
WeberHaus; Terraced House	£59,958	77	£779	26.7
SixtyK House	£60,000	77	£779	19.3
Extra over for site wide heat and power services	£9,601	77	£125	

The environmental performance of each dwelling was based on established assessment methods. Energy performance i.e. the Dwelling Emission Rate (DER) was calculated using BuildDesk 3.2 software (a BRE quality assured method for conducting SAP 2005 assessments). Water performance was assessed using the Code 2006 water consumption calculator[15]. Analysis of the aspects of Code that do not relate to energy or water was based on criteria contained in EcoHomes 2006[16] or other specific assessment areas that are new to the Code. The full set of criteria considered is presented in the published Code summary.[17]

Baseline energy performance for each home was set where the house type's DER meets or is just below its Target Emission Rate[18] (TER). Both the DER and TER are expressed as kg of CO_2 per m^2 of internal area. Demonstration of compliance with the energy/carbon performance standards in the Code is based on an improvement in the DER relative to the TER. It is important to understand how both DER and TER are calculated and the link between different types of energy consumption and a home's carbon emissions. The full assessment process is described in detail in 'The Government's Standard Assessment Procedure for Energy Rating of Dwellings, 2005' (available at www.bre.co.uk), The process is summarised in Appendix C.

The baseline for other aspects of environmental performance that are not covered in detail by Building Regulations (e.g. water, materials, daylight, etc) was determined for each house type on the basis of either the designed specification (where this is detailed) or assuming the specifications commonly adopted by volume house builders.

2.4 Identifying environmental enhancements

Compliance with the Code requires that three specific criteria are met. These are:

1. Meeting mandatory performance standards for energy/carbon and water for each level of the Code
2. Meeting mandatory performance standards for surface water runoff, material use and waste management
3. Achieving a minimum number of 'Code points' with points being awarded for energy/carbon, water and other environmental aspects (but not for items listed at 2)

These criteria are described further below.

Energy/carbon and water

The energy/carbon and water targets that must be achieved at performance levels 1 to 6 are shown in Table 2.3. In this study it was not always possible to achieve an exact match with the energy and water targets prescribed by the Code. In some cases, a target has been exceeded while in other instances performance was just below the required standard. Where performance was very close to (i.e. within 1% for energy), but does not quite achieve the required standard this was considered acceptable. This is because in practice minor changes in other aspects of performance would enable the target to be achieved.

[15] The Code water calculator is being finalised by BRE. However, BRE provided an indication of the mix of technologies that would be suitable for achieving the required performance standards.

[16] The approach to assessing the environmental impact of materials proposed in the Code is based on an updated version of the Green Guide to Specification (due for release early 2007). In the absence of information on how materials will be weighted under this scheme, the analysis in this study is based on the current EcoHomes 2006 assessment method and Green Guide ratings.

[17] DCLG, *Code for Sustainable Homes: a step change in sustainable home building practice,* 2006 www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf

[18] i.e. the target level of carbon dioxide emissions for the dwelling (based on a measured improvement on a 2002 Building Regulations compliant home).

Table 2.3 Energy and water targets under each level of the Code

	Level					
	1	2	3	4	5	6
Energy (% improvement over ADL1 2006)	10%	18%	25%	44%	100%	Zero carbon
Water (litres per bedspace per year)	120 litres	120 litres	105 litres	105 litres	80 litres	80 litres

Other mandatory performance standards

Other mandatory requirements included in the Code are that:

- Peak run-off rates and annual volumes of run-off will be no greater than the previous conditions for the development site
- At least 3 of 5 key elements (roof, external and internal walls, upper floor, windows and doors) of construction are specified to achieve a BRE Green Guide 2006 rating of at least D[19]
- A site waste management plan is in place, which includes a commitment to monitor waste on site and set targets to promote resource efficiency
- That there should be adequate space for the containment of waste storage for each dwelling

Unlike the energy/carbon and water standards the above mandatory standards do not attract any Code points.

Code Points

A total of 96.3 Code points are included within the Code split between 9 categories. These include 44.6 points for energy/carbon and water related topics and 51.7 for other environmental aspects. The points available in each category are shown in Table 2.4.

Table 2.4 Code points available in different assessment categories

Category	Number of available points
Energy	35.6
Water	9
Materials	7.2
Surface Water Runoff	2
Waste	6.3
Pollution	2.5
Health and Wellbeing	13
Management	9.9
Ecology	10.8
Total	**96.3**

The Code points largely reflect a restructuring of the existing credits and standards in EcoHomes 2006 although some new standards have been added (e.g. home composting and Lifetime Homes), and some location specific credits present in EcoHomes have been removed (e.g. access to public transport and amenities). Further detail on the Code points and the performance standards to which they relate is available in the published Code document.[20]

2.5 Cost analysis of enhanced specifications

Once the appropriate technical solutions had been developed, the cost impact of these enhancements was assessed using standard cost planning techniques, including information sourced from suppliers and from previous built projects. Costs were based on the current (Q3 2006) additional cost of each enhancement item. The costs included appropriate discounts for bulk purchasing but do not consider future cost reductions that might arise following more wide spread adoption of these technologies (e.g. for >10,000 units a year).

[19] The new 2006 Green Guide ratings (A-E) have not yet been released therefore for the purposes of this study the current C (worst) rating is taken as being representative of a D rating. English Partnerships will require that no E rated specifications are used.

[20] www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf

2.6 Analysis of costs of meeting different Code levels

Using information on the costs of meeting each of the performance standards in the Code, the cost of achieving the performance required to comply with each Code level was calculated. Table 2.5 summarises the requirements at each Code level.

Table 2.5 Performance requirements at each Code level

Code level	Minimum standards: Energy – Standard (% improvement on Part L 2006)	Energy – Points awarded	Water – Standard (litres per person per day)	Water – Points awarded	Other points required
1	10	1.2	120	1.5	33.3
2	18	3.5	120	1.5	43.0
3	25	5.8	105	4.5	46.7
4	44	9.4	105	4.5	54.1
5	100	16.4	80	7.5	60.1
6	Zero carbon	17.6	80	7.5	64.9

While the Code points thresholds for levels 1 to 4 are similar to the EcoHomes 2006 thresholds for Pass, Good, Very Good and Excellent, EcoHomes 2006 does not include minimum performance standards for energy/carbon and water. As a result, the approach (and associated costs) of achieving each Code level will differ from those for the corresponding EcoHomes 2006 rating. Because of this the costs and performance of a home built to the key Code level 3 standard was compared to that achieving an EcoHomes 2006 Very Good rating.

2.7 Application to different development scales

To make the study more reflective of the developments typically undertaken by English Partnerships and the Housing Corporation the technical options and costs were applied to notional large (100-200 unit) and small (circa 12 unit) developments.

As noted in Section 1.4, the estimated costs of the individual dwellings should apply equally to these different scenarios on the basis that the developers used would be similar.[21]

On this basis, the major impact of development size is likely to be on the feasibility of using site wide services and infrastructure, with certain technologies being more economic or practical at different scales. For example, it may be more practical to install a site wide combined heat and power (CHP) system or a large scale wind turbine for larger developments (i.e. where there are more than 200 homes). Analysis of both site wide CHP systems and large scale wind turbines (Appendix B) show that large scale turbines can be significantly more cost effective in reducing carbon emissions than providing micro generation at the dwelling level.

The potential to adopt site wide solutions for water options on larger schemes was also considered.

2.8 Review of factors that are expected to reduce costs

If the Code targets are adopted widely by English Partnerships, Housing Corporation and others (e.g. Local Authorities) then the market for the technologies required for each level (particularly levels 1 to 3) is likely to increase substantially. This should produce a significant reduction in the capital costs of these items. This principle would apply to both existing and new/emerging technologies, but should be particularly evident with technologies where the current installed capacity is quite low, such as with micro CHP systems and micro wind turbines. The extent to which this widespread adoption might lead to reductions in cost was assessed based on current research of experience curves.

[21] Registered Social Landlords routinely use large contractors/house builders for their projects.

To investigate the likely potential for cost reductions in the short, medium and long term, the following aspects were considered:

- Discounts immediately available for large volume orders
- Medium term reductions in cost arising from growth in the market of key technologies
- Medium/long term reductions in cost arising from new technologies/approaches to achieving the necessary performance standards
- Mechanisms for transferring costs to third party organisations such as an ESCO who are prepared to provide a contribution to the capital cost of schemes in return for the right to provide energy (and other) services to tenants/residents.

3 Meeting energy/carbon standards

Analysis was carried out to establish the technical solutions, and associated costs, to meet the energy performance standards in the Code.[22]

3.1 Code Points for Energy/CO_2 saving

In addition to helping to achieve the mandatory reduction in CO_2 emissions (compared with Part L requirements); energy/carbon saving measures also result in Code points being achieved. These contribute towards achieving the minimum score required for each Code level.

Up to 22.4 Code points are awarded for three areas that directly relate to energy/carbon saving measures linked to Part L:

- Percentage improvement over the house type's TER (with up to 17.6 points available)
- Average heat loss parameter[23] (up to 2.4 points available)
- Percentage renewable energy (up to 2.4 points available)

Additional Code points are available for other energy/carbon efficient measures such as the use of low energy lighting and use of energy efficient appliances. These do not affect a building's performance against Part L (as they are not included within the TER and DER calculations) and so are not included as part of the package of measures employed to achieve the mandatory energy standards. These additional energy efficiency measures are considered in Section 5.

3.2 Carbon saving options considered

To meet the energy targets in the Code, a broad range of carbon saving measures were applied to the baseline house models. To test the effectiveness of different approaches several different combinations of technologies were investigated.

For each house type a selection of relatively low cost energy efficiency measures were considered as 'initial measures', these were then supplemented by the use of renewable/low carbon energy technologies and/or more advanced energy efficiency measures as required to achieve the necessary improvements in the DER relative to the TER.

Four broad categories of solution were considered:

Scenario 1. Initial energy efficiency measures followed by use of solar thermal technology and then photovoltaics and biomass systems.

Scenario 2. Initial energy efficiency measures followed by use of small scale wind turbines and then biomass systems.

Scenario 3. Development with shared energy services, such as combined heat and power (CHP). For this scenario costs per unit are averaged for each infrastructure option across a theoretical 200 unit development. The detailed analysis of the options and costs for this scenario are contained in Appendix B.

Scenario 4. Achievement of Code level 3 without recourse to renewable energies through the use of a whole house mechanical ventilation system with heat recovery and by assuming the use of proprietary construction details.

Although each of the above scenarios will be applicable to many development types, the most broadly applicable scenarios are 1 and 4, as they do not rely on the availability of wind energy or communal infrastructure. However, in practice it is likely that any given development will make use of a range of suitable technologies as appropriate for its context.

The types of energy/carbon saving measures applied to are described in more detail below.

Building Fabric

Improvements were made to the U values of the external walls and glazing in each case. It was not considered practical to improve the performance of the roofs and ground floors, as these elements were already heavily insulated to achieve Building Regulations Part L 2006 compliance.

Heating

The approach for improving the energy performance of the heating systems differed for each house type. For the low to medium density housing (detached and terraced models), independent heating systems were assumed for each dwelling. In the case of the apartments, a communal heating system was assumed. The impact of applying site wide solutions to large developments (e.g. community heating, CHP, etc) was considered separately.

The heating systems specified in the baseline house types included: secondary heating[24], thermostats, TRVs (thermostatic radiator valves) and boiler interlock controls (as required by Part L 2006). For each house type the carbon savings associated with improved controls (e.g. zoned time and temperature controls) were also evaluated.

Ventilation

Both natural ventilation and whole house mechanical ventilation (with heat recovery) options were considered. For naturally ventilated homes (Scenario's 1 to 3) the highest level of air tightness considered practicable was $5m^3/m^2/hr$. However, where a whole house mechanical ventilation system was included (Scenario 4), further improvements in air tightness (to $3m^3/m^2/hr$) were considered realistic without risk of condensation.[25]

[22] With the exception of Code Level 6 (i.e. zero carbon).

[23] A measure of building thermal insulation and air tightness.

[24] Flueless gas fires for the houses and electric heating for apartments.

[25] Passive houses in Germany and other countries are achieving air tightness of less than $1m^3/m^2/hr$ without developing condensation problems, however the design and control of thermal bridging must be analysed in detail to ensure this is achieved.

Where specified, heat recovery systems were assumed to be best practice – i.e. 85% efficient (i.e. 85% of the heat from the exhaust air is transferred to the incoming air) and to be driven by fans running at a specific fan power of 1 watt per second.

Low carbon technologies

Site wide combined heat and power (CHP) using natural gas as a fuel source was considered as an option for all house types (Scenario 3).

Micro CHP units were considered (detailed in Appendix B) to illustrate what could be achieved using these technologies. However, micro CHP was not considered as an immediate solution to achieving Code requirements because all options rely on technology that is currently not available to the mass market. While micro CHP has been successfully installed in some housing developments in the UK, it is currently not available for widespread adoption by the housing industry. Therefore, micro CHP is not included in the carbon reduction scenarios modelled in this report.

Nonetheless the two main suppliers of these systems (Baxi and Powergen[26]) have indicated that commercially available systems will be on the market by 2008 or before.

The environmental benefit of CHP was calculated on the assumption that two way metering would be used, i.e. that surplus electricity generated by the unit could be sent (ideally sold) back into the grid. Without two-way metering the environmental benefit would be substantially reduced. The level of electricity generated by the micro CHP was based on modelling the thermal energy demand of the houses using the assumption that 1.2 kWh of electrical energy would be generated for every 8 kWh of thermal energy demand.

Renewable energy

A number of currently available technologies were applied, in varying combinations to meet Code levels 3 – 6. These include:

- Solar water heating (SWH). Flat panel system with photovoltaic powered pump.
- Photovoltaics (PV). Various sizes of system were considered providing between 0.15 kW and 1 kW power.
- Wind turbines. Small scale (1.5 kW) and medium/large scale turbines
- Biomass. Biomass fired boilers (both domestic level and communal) and biomass fired CHP units.

For each renewable energy option a reasonable level of power generation was assumed. For example, it was assumed that solar based systems would be located on a south facing slope with reasonably uninterrupted exposure to the sun. Ensuring this level of solar exposure could be challenging on some developments but should be achievable if included within the design process at an early stage.

Similarly, it was assumed that 1.5 kW wind turbines would be able to generate around 1100 kWh per year (following discussions with the Energy Savings Trust, suppliers and researchers). Some wind turbines, particularly those in rural or coastal locations will generate more than double this amount, while other locations will generate substantially less. Current research indicates that turbines are generally not as effective in locations where buildings or other obstacles obstruct a clear flow of wind. This is more likely to be the case in urban locations. As a result care should be taken to evaluate the suitability of each site before considering installation of turbines. The carbon savings arising from the use of wind turbines are calculated using the emission factor for electricity displaced from the grid as defined in SAP 2005 (i.e. 0.568 kg per kWh). Generation of 1100 kWh per year therefore results in a carbon saving of 625 kg per 1.5 kW turbine.

The application of some renewable technologies (e.g. wind and solar) to the different housetypes was constrained by the practicalities of mounting sufficient quantities of turbines within a building (plot). For example, the maximum level of wind turbine provision has been capped at 1 in 2 dwellings for the low rise apartment and 1 in 4 dwellings for the high rise apartment.

Use of proprietary construction details

For Scenarios 1 to 3 it was assumed that homes will be built in line with accredited construction details (the standard used by the majority of UK housebuilders). The use of accredited construction details has the effect of increasing the overall U values in the home by a generic 0.08 kW/m^2 to allow for thermal bridging. Work is currently in progress to develop a series of proprietary construction details for which a more specific adjustment factor can be applied reflecting the specifics of the construction method used. It is likely that these proprietary details will result in the increase in U values being reduced to around 0.04 kW/m^2 (thereby having a similar affect to reducing the building U values by this amount). For Scenario 4 (no renewables) it was assumed that proprietary construction details could be used and that this would have the effect of increasing U values by only 0.04 kW/m^2 (rather than the 0.08 kW m^2 assumed by accredited construction details)

3.3 Summary of results

The options for each of the house types are summarised on the following pages. The approaches modelled for each house type (Appendix A) utilise energy efficiency measures, together with different combinations of low carbon and renewable energy technologies.

3.4 Traditional detached house

Table 3.1 summarises the costs of achieving each Code level using different combinations of technologies and efficiency measures. Particular emphasis is placed on the costs of achieving Code level 3.

These costs are shown graphically in Figure 3.1.

[26] Powergen are UK distributors of the Whispergen micro CHP unit.

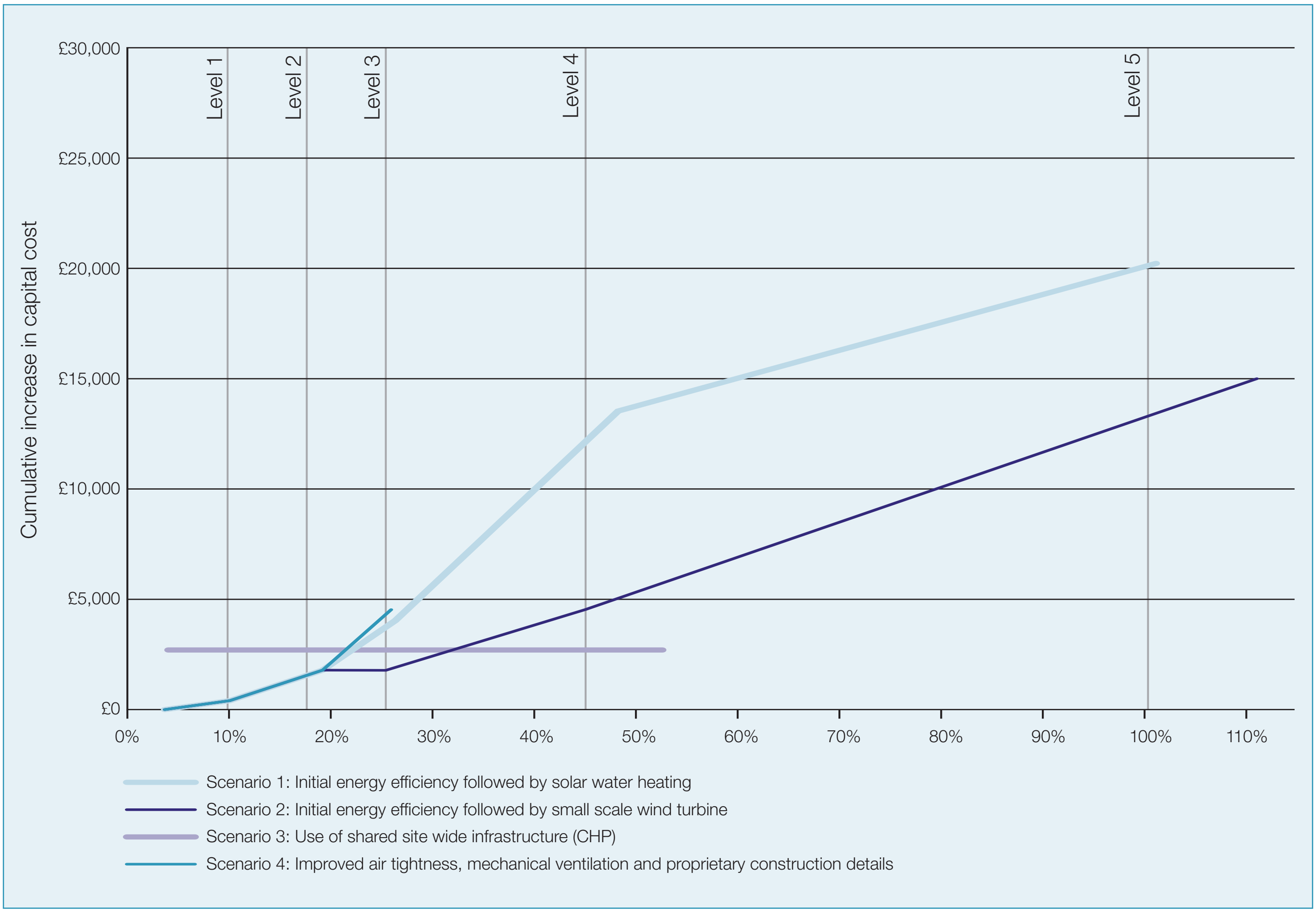
Table 3.1 Costs of achieving carbon targets for a traditional detached house (over a Building Regulations 2006 compliant home)

Code level	Measure	DER Kg CO_2 m[2]	% improvement on TER	Cumulative cost (£)	Code Points for each level	Cumulative Code Points
Scenario 1: Initial energy efficiency followed by solar water heating, PV and biomass						
Baseline		23.0	4%	£0		
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system	21.5	10%	£275	1.18%	1.18%
2	Reduce air permeability to 5 $m^3/m^2/hr$ Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 and of windows to 1.5 kW/m^2	19.3	19%	£1,648	4.72%	5.90%
3	Add 4 m^2 flat panel solar water heater with PV powered pump	17.5	26%	£3,916	3.54%	9.44%
4	Reduce U value of external walls to 0.21 and of windows to 1.3 kW/m^2 Add 1 kW photovoltaic array	12.34	48%	£13,525	4.72%	14.16%
5	Add 15 kW biomass heating system (wood chip/pellet), omit solar water heater	-0.31	101%	£20,270	7.08%	21.24%
Scenario 2: Initial energy efficiency followed by small scale wind turbine and biomass						
Baseline		23.0	4%	£0		
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system Reduce air permeability to 5 $m^3/m^2/hr$	20.9	12%	£275	1.18%	1.18%
2	Install one 1.5 kW wind turbine (1100 kWh per year) for every 4 homes	19.3	18%	£984	2.36%	3.54%
3	Install additional 1.5 kW wind turbines (1100 kWh per year) to level of one for every 2 homes	17.9	25%	£1,693	3.54%	7.08%
4	Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 kW/m^2 Add additional 1.5 kW wind turbines (1100 kWh per year) so that every home has one turbine	13.2	45%	£4,484	7.08%	14.16%
5	Reduce U value of windows to 1.3 kW/m^2 and external wall to 0.21 kW/m^2 Add 15 kW biomass heating system	-2.5	111%	£14,943	7.08%	21.24%

Table 3.1 Costs of achieving carbon targets for a traditional detached house (over a Building Regulations 2006 compliant home) continued

Code level	Measure	DER Kg CO_2 m^2	% improvement on TER	Cumulative cost (£)	Code Points for each level	Cumulative Code Points
Scenario 3: Use of shared site wide infrastructure (CHP)						
Baseline		23.0	4%	£0	0%	0%
4	Combined heat and power across a mixed site of at least 200 units	11.4	52.42%	£2,622	10.62%	10.62%
Scenario 4: Improved air tightness, mechanical ventilation and proprietary construction details						
Baseline		23.0	4%	£0	0%	0%
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system	21.5	10%	£275	1.18%	1.18%
2	Reduce air permeability to 5 $m^3/m^2/hr$ Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 and of windows to 1.5 kW/m^2	19.3	19%	£1,648	4.72%	5.90%
3	Proprietary construction details (0.04 x total exposed surface area) Reduce air permeability to 3 $m^3/m^2/hr$ and add balanced whole house ventilation system with heat recovery (specific fan power of 1 W/s)	17.50	26%	£4,481	2.36%	8.26%

Figure 3.1 Costs of achieving carbon targets for a traditional detached house (over a Building Regulations 2006 compliant home)



This analysis indicates that:

- The cost of achieving Code level 1 is relatively low and involves only enhanced controls to heating and hot water systems.
- For Code level 2 it is necessary to reduce building U values to 0.25 for external walls and to 1.5 for windows together with an efficient heating system. This results in additional costs of approximately £1,650.
- For Code level 3 the most cost effective approach is to share the carbon savings associated with small scale wind turbines. If this approach is adopted the additional cost is £1,700 per home. However, small scale wind may not be appropriate in all locations and if each home must achieve the required carbon savings by itself, the most effective approach is to use a solar hot water system. In this case the total additional costs are around £3,900 per home. If a non renewables option is pursued (i.e. using mechanical ventilation and proprietary construction details) then the cost of achieving Code level 3[27] is approximately £4,500.
- For Code level 4 the most cost effective means of achieving the energy target lies in the use of a site wide CHP system.
- For Code level 5 it is necessary to use a biomass (wood chip/pellet) boiler system for all scenarios. This results in significant additional cost and requires homes to have sufficient fuel storage facilities. However biomass systems enable substantial reductions in CO_2 emissions because heating and hot water demand can be met be a virtually carbon neutral energy source.

3.5 Traditional end terrace house

The measures and strategies for the traditional end terrace house are very similar to those for the detached house. The key difference is the absolute levels of cost and CO_2 emissions rather than the benefits of different approaches.

[27] Some researchers (EST and Passiv Haus) believe that it is possible to achieve Code level 4 using the approach described for Scenario 4.

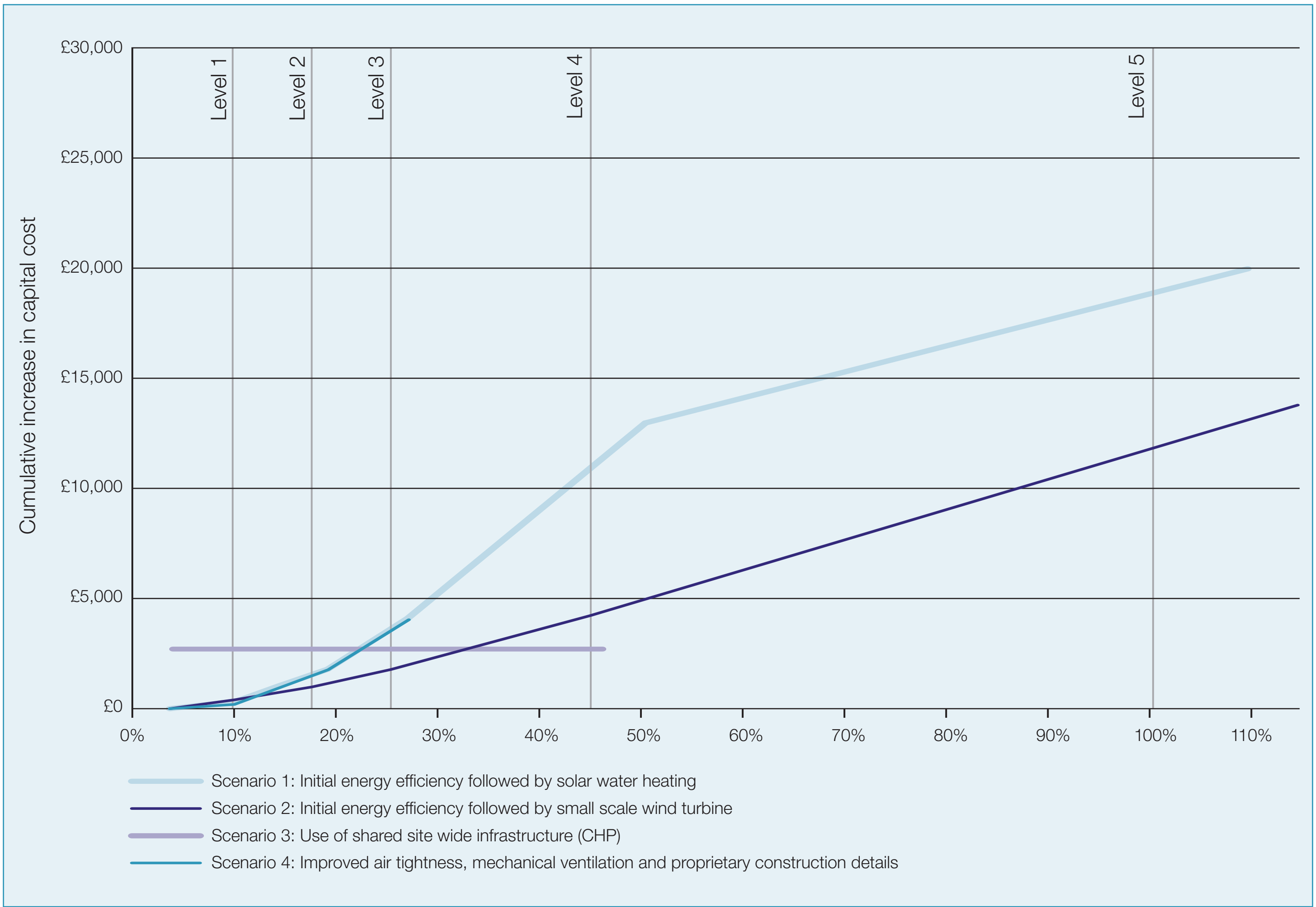
Table 3.2 Costs of achieving carbon targets for a traditional end terraced house (over a Building Regulations 2006 compliant home)

Code level	Measure	DER Kg CO_2 m²	% improvement on TER	Cumulative cost (£)	Code Points for each level	Cumulative Code Points
Scenario 1: Initial energy efficiency followed by solar water heating, PV and biomass						
Baseline		20.56	4%	£0		
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system	18.91	10%	£275	1.18%	1.18%
2	Reduce air permeability to 5 m³/m²/hr Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 and of windows to 1.5 kW/m²	17.04	19%	£1,778	4.72%	5.90%
3	Add 4 m² flat panel solar water heater with PV powered pump	15.87	26%	£3,692	3.54%	9.44%
4	Reduce U value of external walls to 0.21 and of windows to 1.3 kW/m² Add 1 kW photovoltaic array	10.64	50%	£12,947	4.72%	14.16%
5	Add 15 kW biomass heating system (wood chip/pellet), omit solar water heater	-2.01	110%	£19,962	7.08%	21.24%
Scenario 2: Initial energy efficiency followed by small scale wind turbine and biomass						
Baseline		20.56	4%	£0		
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system Reduce air permeability to 5 m³/m²/hr	18.91	10%	£275	1.18%	1.18%
2	Install one 1.5 kW wind turbine (1100 kWh per year) for every 4 homes	17.38	18%	£984	2.36%	3.54%
3	Install additional 1.5 kW wind turbines (1100 kWh per year) to level of one for every 2 homes	15.84	25%	£1,693	3.54%	7.08%
4	Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 kW/m² Add additional 1.5 kW wind turbines (1100 kWh per year) so that every home has one turbine	11.5	46%	£4,260	7.08%	14.16%
5	Reduce U value of windows to 1.3 kW/m² and external wall to 0.21 kW/m² Add 15 kW biomass heating system	-3.9	118%	£14,365	7.08%	21.24%

Table 3.2 Costs of achieving carbon targets for a traditional end terraced house (over a Building Regulations 2006 compliant home) continued

Code level	Measure	DER Kg CO_2 m²	% improvement on TER	Cumulative cost (£)	Code Points for each level	Cumulative Code Points
Scenario 3: Use of shared site wide infrastructure (CHP)						
Baseline		20.56	4%	£0	0%	0%
4	Combined heat and power across a mixed site of at least 200 units	11.5	46%	£2,296	10.62%	10.62%
Scenario 4: Improved air tightness, mechanical ventilation and proprietary construction details						
Baseline		20.56	4%	£0	0%	0%
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system	18.91	10%	£275	1.18%	1.18%
2	Reduce air permeability to 5 m³/m²/hr Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 and of windows to 1.5 kW/m²	17.04	19%	£1,778	4.72%	5.90%
3	Proprietary construction details (0.04 x total exposed surface area) Reduce air permeability to 3 m³/m²/hr and add balanced whole house ventilation system with heat recovery (specific fan power of 1 W/s)	15.39	27%	£3,917	2.36%	8.26%

Figure 3.2 Costs of achieving carbon targets for a traditional end terrace house (over a Building Regulations 2006 compliant home)



As mentioned previously the results for the terraced house are similar to those for the detached house.

3.6 Traditional low rise apartment

Table 3.3 summarises the costs of achieving each Code level using different combinations of technologies and efficiency measures. Particular emphasis is placed on the costs of achieving Code level 3.

These results are shown graphically in Figure 3.3.

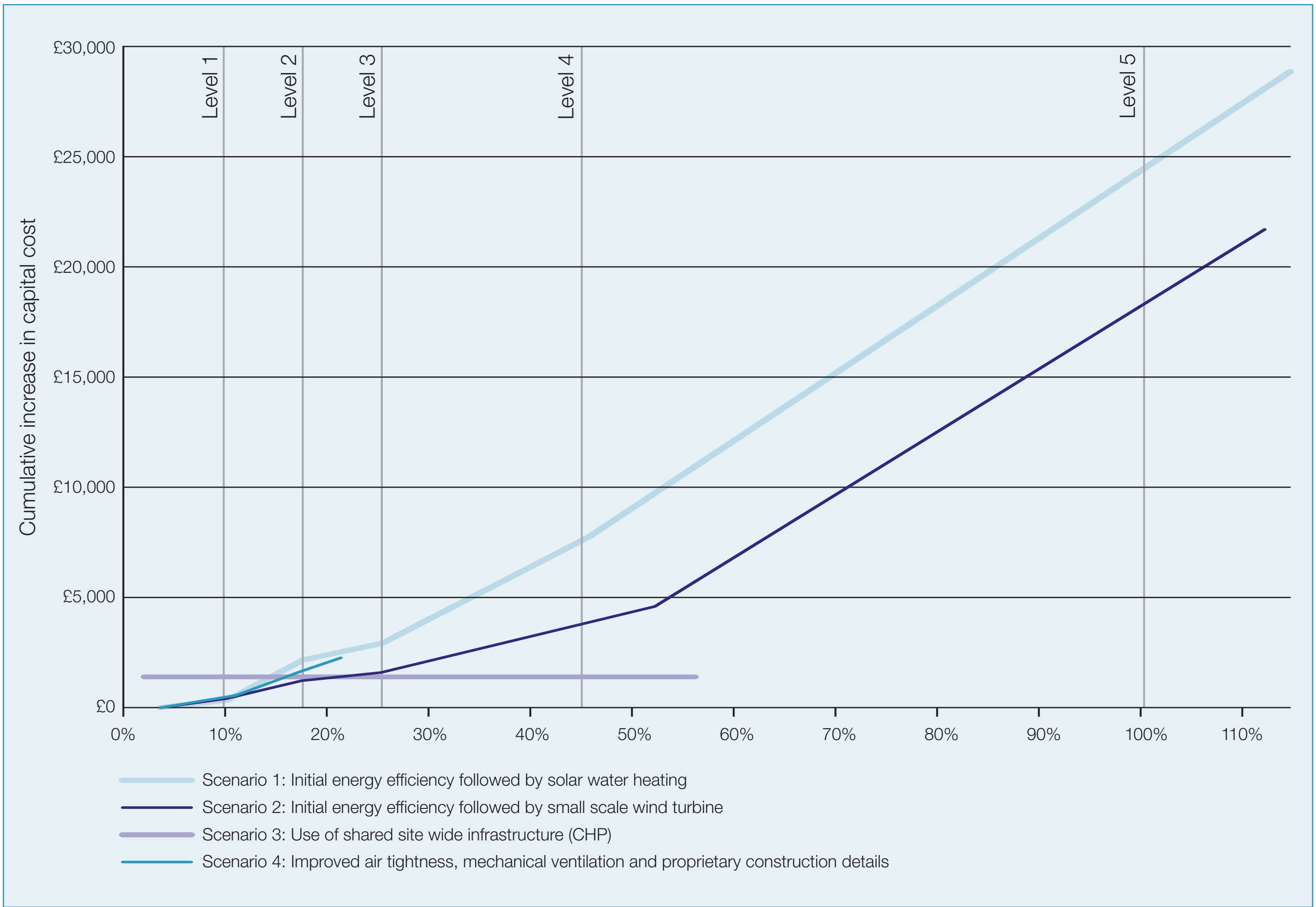
Table 3.3 Costs of achieving carbon targets for a traditional low rise apartment (over a Building Regulations 2006 compliant home)

Code level	Measure	DER Kg CO_2 m^2	% improvement on TER	Cumulative cost (£)	Code Points for each level	Cumulative Code Points
Scenario 1: Initial energy efficiency followed by solar water heating, PV and biomass						
Baseline		20.32	4%	£0		
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system	18.31	11%	£460	1.18%	1.18%
2	Reduce air permeability to 5 $m^3/m^2/hr$ Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 and of windows to 1.5 kW/m^2	17.03	18%	£2,244	4.72%	5.90%
3	Add 4 m^2 flat panel solar water heater with PV powered pump	15.37	26%	£2,907	3.54%	9.44%
4	Reduce U value of external walls to 0.21 and of windows to 1.3 kW/m^2 Add 1 kW photovoltaic array	11.45	45%	£7,590	4.72%	14.16%
5	Add 15 kW biomass heating system (wood chip/pellet), omit solar water heater	-3.72	118%	£29,951	7.08%	21.24%
Scenario 2: Initial energy efficiency followed by small scale wind turbine and biomass						
Baseline		20.32	4%	£0		
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system Reduce air permeability to 5 $m^3/m^2/hr$	18.31	11%	£460	1.18%	1.18%
2	Install one 1.5 kW wind turbine (1100 kWh per year) for every 4 homes	16.67	19%	£1,216	2.36%	3.54%
3	Install additional 1.5 kW wind turbines (1100 kWh per year) to level of one for every 2 homes	15.27	26%	£1,600	3.54%	7.08%

Table 3.3 Costs of achieving carbon targets for a traditional low rise apartment (over a Building Regulations 2006 compliant home) continued

Code level	Measure	DER Kg CO_2 m²	% improvement on TER	Cumulative cost (£)	Code Points for each level	Cumulative Code Points
4	Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 kW/m² Add additional 1.5 kW wind turbines (1100 kWh per year) so that every home has one turbine	9.9	52%	£4,511	7.08%	14.16%
5	Reduce U value of windows to 1.3 kW/m² and external wall to 0.21 kW/m² Add 15 kW biomass heating system	-2.5	112%	£21,742	7.08%	21.24%
Scenario 3: Use of shared site wide infrastructure (CHP)						
Baseline		20.3	2%	£0	0%	0%
4	Combined heat and power across a mixed site of at least 200 units	9.1	56%	£1,349	10.62%	10.62%
Scenario 4: Improved air tightness, mechanical ventilation and proprietary construction details						
Baseline						
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system	18.31	11%	£460	1.18%	1.18%
2	Reduce air permeability to 5 m³/m²/hr Upgrade boiler to high efficiency (91.3%) condensing boiler Reduce U value of external walls to 0.25 and of windows to 1.5 kW/m²	16.33	21%	£2,194	4.72%	5.90%

Figure 3.3 Costs of achieving carbon targets for a traditional low rise apartment (over a Building Regulations 2006 compliant home)



This analysis indicates that:

- Costs of achieving Code level 3 are approximately £2,900 per home where a solar water heater is used. If small scale wind turbines are feasible then the cost reduces to £1,600. It is not possible to achieve Code level 3 for Scenario 4[28], this is possibly because of the relative significance of hot water systems and lighting in small apartments (which cannot be offset by improved thermal performance).
- To achieve Code level 5 it is necessary to install a communal biomass boiler system resulting in a substantial increase in costs to between £22-29k per apartment (depending on whether wind or solar energy is used for electrical generation).

3.7 High rise apartment

Table 3.4 summarises the costs of achieving each Code level using different combinations of technologies and efficiency measures. Particular emphasis is placed on the costs of achieving Code level 3.

These results are shown graphically in Figure 3.4.

This analysis indicates that:

- Costs of achieving Code level 3 are approximately £3,466 per unit, but the majority (£2,800) of this cost arises from the installation of a gas fired community heating system (rather than an electric heating system). On the same basis, the cost of achieving level 4 compliance is £8,070 per unit.

- Where high rise apartments are part of a broader mix of developments (including houses) then the costs of achieving Code levels reduce substantially because the cost of the system is shared between the different housing types. For the illustrative scenario of 200 units the costs per home are around £1,700. However, these will vary depending on the number and mix of homes in the development.

[28] Some researchers (EST and Passiv Haus) believe that it is possible to achieve Code level 4 using the approach described for Scenario 4.

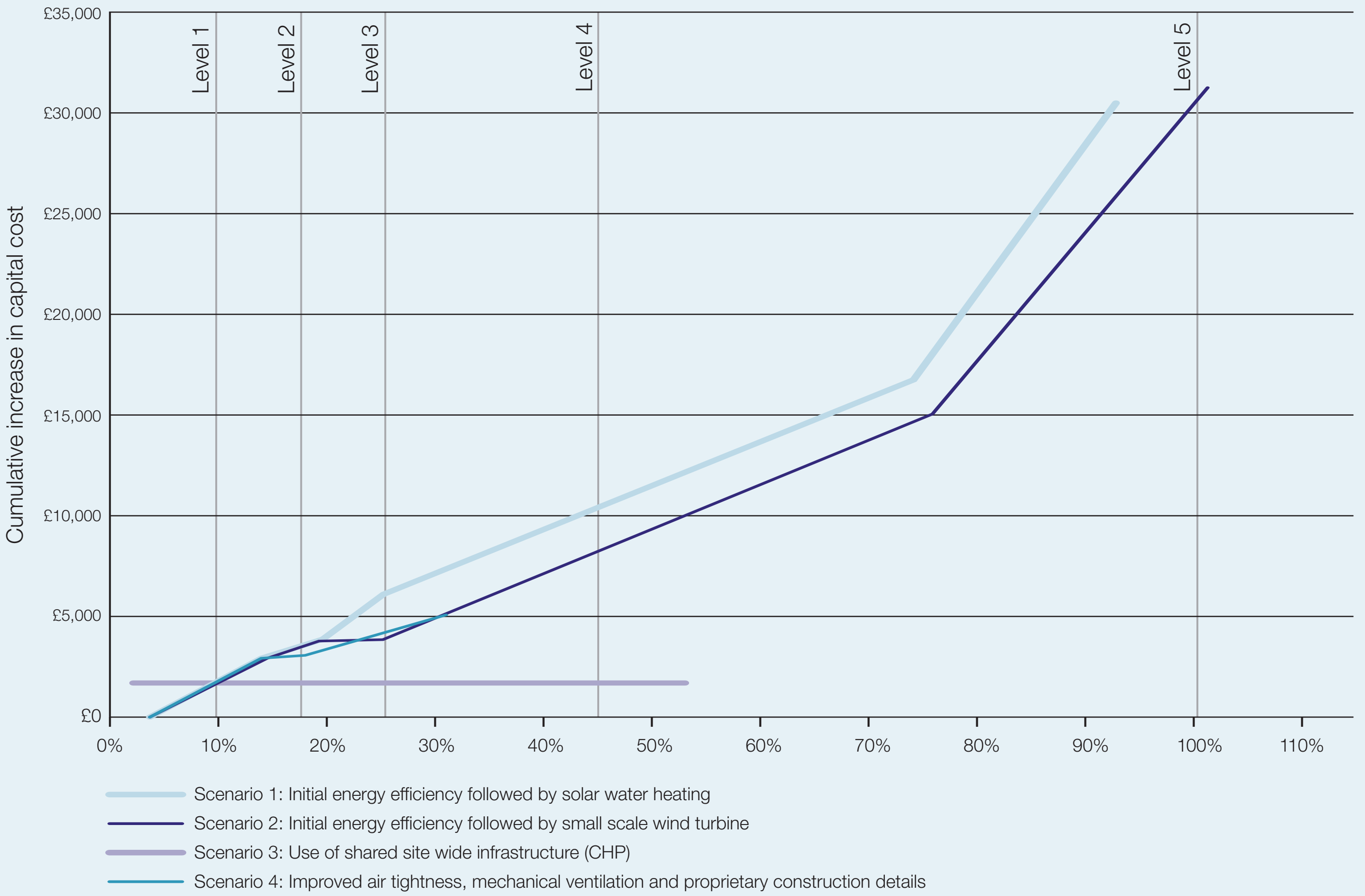
Table 3.4 Costs of achieving carbon targets for a traditional high rise apartment (over a Building Regulations 2006 compliant home)

Code level	Measure	DER Kg CO_2 m²	% improvement on TER	Cumulative cost (£)	Code Points for each level	Cumulative Code Points
Scenario 1: Initial energy efficiency followed by solar water heating						
Baseline		20.56	4%	£0		
1	Gas fired community heating Charging linked to use, programmer and TRV's	21.5	14%	£2,858	2.36%	2.36%
2	Reduce window U value from 2.0 W/m²K to 1.8 W/m²K Reduce external wall U value to 0.21 W/m²K	20.3	19%	£3,684	4.72%	7.08%
3	Add 4 m² flat panel solar water heater with PV powered pump	18.8	25%	£5,952	3.54%	10.62%
4	Gas CHP with gas boilers (omit SWH) Gas CHP with biomass boilers	6.5	74%	£16,647	7.08%	17.70%
5	0.3 kW photovoltaic array Biomass CHP with biomass boilers	0.3	99%	£32,776	3.54%	22.42%
Scenario 2: Initial energy efficiency followed by small scale wind turbine						
Baseline		24.9	4%	£0	0%	0%
1	Gas fired community heating Charging linked to use, programmer and TRV's	21.5	14%	£2,858	2.36%	2.36%
2	Reduce window U value from 2.0 W/m²K to 1.8 W/m²K Reduce external wall U value to 0.21 W/m²K	120.3	19%	£3,684	4.72%	7.08%
3	Return U value of external wall to 0.27 W/m²K Add 1.5 kW wind turbine (1100 kWh per year) to level of one for every 4 homes	18.7	25%	£3,751	3.54%	10.62%
4	Gas CHP with gas boilers Gas CHP with biomass boilers Reduce external wall U value to 0.21 W/m2K	5.9	76%	£15,100	8.26%	18.88%
5	0.3 kW photovoltaic array Biomass CHP with biomass boilers	-0.25	101%	£28,151	3.54%	22.42%
Scenario 3: Use of shared site wide infrastructure (CHP)						
Baseline		24.9	4%	£0	0%	0%
4	Combined heat and power across a mixed site of at least 200 units	13.3	53%	£1,695	10.62%	10.62%

Table 3.4 Costs of achieving carbon targets for a traditional high rise apartment (over a Building Regulations 2006 compliant home) continued

Code level	Measure	DER Kg CO_2 m^2	% improvement on TER	Cumulative cost (£)	Code Points for each level	Cumulative Code Points
Scenario 4: Improved air tightness, mechanical ventilation and proprietary construction details						
Baseline		24.9	4%	£0	0%	0%
1	Add delayed start thermostat Add zoned time and temp control to heating system and timed and thermostatic control to hot water system Reduce air permeability to 5 $m^3/m^2/$ hr	21.5	14%	£2,858	2.36%	2.36%
2	Proprietary construction details (0.04 x total exposed surface area)	20.5	18%	£3,030	2.36%	4.72%
3	Reduce air permeability to 3 $m^3/m^2/hr$ and add balanced whole house ventilation system with heat recovery (specific fan power of 1 W/s)	17.21	31%	£4,933	3.54%	8.26%

Figure 3.4 Costs of achieving carbon targets for a traditional high rise apartment (over a Building Regulations 2006 compliant home)



3.8 End terrace house built with MMC (WeberHaus) and mid terrace SixtyK house

Tables provided in Appendix A illustrate the costs of achieving each Code level for the WeberHaus and the SixtyK house. In both cases the base specification achieves high Code levels in the base case. The SixtyK House for instance is already very energy efficient incorporating a highly insulated building envelope, a site wide CHP system and extensive use of photovoltaics. As a result the baseline house already achieved a 47% improvement on the TER (sufficient for compliance with Code level 4).

The DfM homes achieve the lower standards of energy/carbon efficiency more cost effectively than the traditional houses. This reflects the higher base specification of these homes. However, in the case of the WeberHaus the cost of achieving very high levels of efficiency (i.e. 100% improvement on TER) is comparable to the traditional homes at around £150 per m^2 (compared to £186 per m^2 for a traditional end terrace house).

The SixtyK House achieves very high levels of carbon efficiency at relatively low additional cost to the developer because the analysis is based on 1.5 kW of photovoltaics and a site wide CHP system being provided 'off balance sheet' through the use of an ESCO. This indicates the potential for savings in capital costs by involving an ESCO in suitable developments. With out the involvement of an ESCO it is expected that the energy performance of the SixtyK house would be broadly similar to the WeberHaus.

3.9 Summary of costs of achieving Code energy/carbon efficiency standards

Table 3.7 Costs of Code level 3 (over a Building Regulations 2006 compliant home)

Via the most cost effective method (Scenario 2 for the detached/terrace houses and low rise apartment, and Scenario 3 for the high rise apartment) it is possible to achieve compliance with the energy standards for Code level 3 for under £2,000 for all house types. However, this relies on the use of wind energy which may not be available in all locations. Therefore, it would be more prudent to allow between £3,000 and £4,000 for the houses and low rise apartments and up to £6,000 for the high rise apartment. The higher additional costs associated with achieving Code level 3 for the high rise apartment are a result of the need to install a communal heating system (the base case for this building was electric heating), without this additional cost (around £2,800) the costs of achieving energy targets for the traditional house types are relatively similar.

The solutions proposed under Scenario 1 would also satisfy a local authority requirement to include renewable energy as part of the development (see section 8 on the impact of planning requirements on approaches to meeting the Code).

Impact of using micro CHP

The use of micro CHP systems provide a potential means of achieving reductions in CO_2 emissions without incurring major additional cost, however these systems are not currently available on a large scale in the UK and so have not been considered in detail in this study.

Also, the potential of current micro CHP units to achieve very low levels (i.e. 85%+ improvements on ADL1A) is limited because they rely on gas as an energy source.

Table 3.7 Costs of Code level 3 over a Building Regulations 2006 compliant house

House type	Scenario 1 – solar water heating	Scenario 2 – small scale wind	Scenario 3 – site wide energy services	Scenario 4 – No renewables
Detached house	£3,916	£1,693	£2,622	£4,481
End terrace house	£3,692	£1,693	£2,622	£3,917
Low rise apartment	£2,907	£1,600	£1,349	–
High rise apartment	£5,952	£3,751	£1,695	£3,917
WeberHaus	£120			
SixtyK House	£0*			

Note: *Costs of SixtyK House do not include for costs associated with provision of CHP and PV as these are to be provided by an ESCO.

3.10 Other carbon saving measures

The analysis of the energy options covered a wide range of energy efficiency measures, including improvements to U values, efficient heating systems and controls, and the use of renewable and low carbon technologies. The following is a short summary of other carbon saving measures available:

- **Water efficiency measures** – as housing becomes more thermally efficient the energy required to provide hot water represents an increasing proportion of energy use. The use of low flow taps and regulated showers reduces the consumption of hot water (as well as total water consumption) thereby further reducing energy demand.
- **Waste water heat recovery** – the recovery of heat from waste water from showers, dishwashers and washing machines. The reclaimed heat is used to pre-heat water for other applications.
- **Ground or air source heat pumps** – the basic principle of operation of a ground source heat pump is similar to a domestic refrigerator. Heat from the ground or air is absorbed at a low temperature and emitted at a higher temperature, which can be used for space heating. In general, for every unit of electricity used to power the heat pump, 3 – 5 units of thermal energy are generated.
- **Passive environmental strategies** – although the SAP software used in the energy analysis can take into account passive solar heating and natural ventilation, it is difficult to accurately model less conventional strategies. This could include night purge cooling to limit summer overheating, or the use of a sun space to pre-heat incoming air, possibly in combination with a 'Whole House' ventilation strategy.

These opportunities for further energy savings have not been considered in this study but may present important opportunities to improve the energy efficiency of housing. They require a whole house/design (and where appropriate site based) approach to carbon reductions, which must be increasingly adopted.

4 Meeting water standards

Table 4.1 Code internal potable water consumption standards

Water consumption	Mandatory at level	Available points
120 litres/person/day (45 m^3)	1 and 2	1.5
110 litres/person/day (43 m^3)		+1.5
105 litres/person/day (40 m^3)	3 and 4	+1.5
90 litres/person/day (38 m^3)		+1.5
80 litres/person/day (30 m^3)	5 and 6	+1.5

The mandatory water consumption standards for the Code include only three benchmarks spread across the six levels. In addition non-mandatory Code points are available and a total of five points are achievable for different water consumption levels. Table 4.1 shows the Code water consumption standards, mandatory thresholds and available points.

4.1 Water saving options considered

The following water conservation measures have been applied to the baseline specification to meet Code requirements.

WCs

For the purposes of this report, a standard specification is deemed to be a 6 litre cistern, although experience suggests that for the majority of people a 6/4 litre dual flush arrangement is equally acceptable. Lower flush toilets (e.g. 4/2.5 litres) are becoming more widely available and are believed to work more efficiently than previous very low flush systems.

Taps

Standard taps have been specified for the baseline, with flow restrictors included for levels 1 to 6. Alternative arrangements, such as aerating or auto-shut off, would achieve the same reduction in consumption.

Showers

A "power shower" has been specified as the baseline for each home, with lower flow rate options used to reduce water consumption rates. A flow rate of 9 litres per minute is generally considered acceptable[29], although many new electric shower systems have lower flow rates (as low as 4 litres per minute). While the use of low flow electric showers would reduce overall water consumption, their use increases overall carbon emissions associated with water heating and therefore electric showers have not been included in this study.

Baths

The baseline home specifications were for standard baths (approx 80 litres per use), however for some specifications smaller 'shaped' baths were considered (approx 60 litres per use). The smaller bath specifications are still large enough for an adult to lie down comfortably, but use less water.

Appliances

It is not standard practice to include white goods in new houses (other than as part of a buyer incentive package). When included, housebuilders do not believe they secure any additional sale value for the homes so as a result 100% of the cost of these appliances is additional to the base cost of the homes.

Where only standard practice white goods are required to achieve the necessary performance standard, no cost is attributed to these items because such appliances could be provided by either the developer or occupier.

Grey water

Two approaches to greywater recycling have been considered, an in home system which is positioned behind the toilet cistern and larger scale systems involving buried tanks. For both technologies water from wash hand basins, baths and showers is collected and used for toilet flushing.

Rainwater

Rainwater harvesting systems involve the collection of rainwater from housing/apartment roofs, this is then filtered and stored and used for toilet flushing and/or laundry.

[29] Based on discussions with housebuilders regarding their current practices and market expectations.

Table 4.2 Specifications to meet Code water consumption targets for housing

Code level	Estimated water consumption (litres/person/day)*	Specification	Cost Additional Cost (£)	 Cumulative cost (£)	Code Points
1 and 2	120	2 x 6/4 litre flush toilets 4 x taps with flow regulators 1 x shower 6 to 9 litres/ min 1 x standard bath (80 litres per use) 1 x standard washing machine** 1 x standard dishwasher**	£0	£0	1.5
3 and 4	105	As above, except: 1x smaller shaped bath 2x4/2.5 litre flush toilets	£125	£125	4.5
5 and 6	80	**Houses** As above, except: add grey water recycling or rainwater harvesting system (30% reuse)	£2,520	£2,645	7.5
		Apartments As above, except: add communal grey water recycling or rainwater harvesting system (30% reuse)	£680	£805	7.5

Notes: *To be verified on release of finalised water calculator. **Additional cost of washing machine and dishwasher is assumed to be zero as these fittings are 'standard' industry performance. Therefore, if they are typically installed by house builder there would be no additional cost over their current specifications.

4.2 Options for achieving Code requirements

There is no control over water efficiency in current Building Regulations and the Water Supply (Water Fittings) Regulations only provide minimum performance standards for toilets (setting the maximum flush at 6 litres). The Government is currently consulting on setting new minimum performance standards either within a new Building Regulation or by amendment to Water Supply Regulations.

Performance against the water consumption standards in the Code will ultimately be assessed using a bespoke water consumption calculator. This will be a modified version of the calculator used in EcoHomes 2006. At present the Code water calculator has yet to be finalised, therefore the assessment of the technologies required to achieve each performance standard is based on the model solutions presented in the published Code[30]. As a result, it is only possible to assess the specifications needed to achieve the 3 mandatory performance standards (120, 105 and 80 litre per person per day) and not the intermediary levels for which additional Code points are available (see Table 4.1).

The specifications and costs required for Code levels 1 to 4 (i.e. down to 105 litres per person per day) are the same for both houses and apartments and do not require greywater recycling or rainwater harvesting systems. For greater levels of water efficiency (i.e. to achieve consumption levels below 80 litres per person per day) it is necessary to use greywater or rainwater systems to provide approximately 30% of internal water use.

Table 4.2 summarises the specifications that are believed to achieve the three mandatory performance thresholds in the Code for both houses and apartments.

The costs of rain and greywater recycling systems are significant for housing when assessed on the basis of a single dwelling. Greywater systems are cheaper than rainwater systems where an in bathroom unit such as the Ecoplay system is used. In apartments both greywater and rainwater systems are significantly less expensive than in housing, this reflects the economies of scale achievable when using single tanks to serve multiple dwellings.

[30] DCLG, *Code for Sustainable Homes: A step-change in sustainable home building practice, 2006*

4.3 Site wide approaches to water efficiency

It is possible to share water harvesting and recycling systems between several dwellings[31] and the efficiencies of this approach are evident from the reduced costs of water savings for apartments in comparison to housing.

For housing developments the impact of sharing a grey or rainwater system between multiple adjoining dwellings is such that for a row of five terraced houses the costs for each home are 50-60% lower than for standalone systems; with installed costs per grey water unit reducing from £2,520 to £1,000 and for rainwater units from £4,662 to <£2,000. However, the applicability of communal systems depends on the availability of shared space for location of tanks and the ability to set up suitable management arrangements.

At present very few housing schemes have implemented communal rainwater or greywater systems. As a result, it should be expected that the costs presented here will reduce following more widespread adoption. However, it may also be the case that a rapid increase in the use of rainwater or greywater systems before there is sufficient UK experience and/or expertise could be problematic.

[31] Although this would require joint rather than individual maintenance which is more problematic for freehold houses.

5 Other environmental standards in the Code

In addition to the mandatory performance standards for energy and water, the Code also adopts four further mandatory performance standards and further 'flexible' Code points from which a minimum number are required to achieve a specific Code level (Table 2.4).

5.1 Other mandatory standards

The costs of meeting the four mandatory standards are shown in Table 5.1. No Code points are awarded for compliance with these standards.

5.2 Code Points

Table 5.2 summarises the points included in the proposed Code (excluding those for energy/carbon and water which have already been considered) together with the cost of meeting the standards for different house types[32]. The DfM house types already meet many of these standards as they were designed to achieve an EcoHomes Excellent rating. The detailed requirement for each Code point are provided, pending the release of the Code technical manual. The estimates used here are based on the published Code summary and the current equivalent standards in EcoHomes 2006.

Table 5.1 Achieving Code mandatory performance standards

Requirements	Approach	Cost house	Cost apartment
Peak run-off rates and annual volumes of run-off will be no greater than the previous conditions for the development site	Assumed to be no additional cost because required measures are routinely required as part of the planning process.	£0	£0
At least 3 of 5 key elements (roof, external and internal walls, upper floor, windows and doors) of construction are specified to achieve a BRE Green Guide 2006 rating of at least D	No additional cost as standard housing materials are A rated, it can assumed that these would not be D rated, e.g. • External walls – brick and blockwork or timber/steel frame • Internal walls – timber or steel stud with plasterboard • Roof – timber with concrete or clay tiles	£0	£0
Site waste management plan, which includes a commitment to monitor waste on site and set targets to promote resource efficiency	Survey of major housebuilders indicates that most are already operating waste management plans on their sites.	£0	£0
Adequate space for the containment of waste storage for each dwelling	Each home will need a fixed waste containment area, costs based on a 1 x 1.5 x 1.5m brick structure with wooden doors. No cost for apartments as a facility would normally be provided as standard practice.	£490	£0
Total		**£490**	**£0**

[32] For clarity the costs for the different house types are summarised in Table 5.2 using the examples of the traditional detached house and high rise apartment. The cost analysis in Section 6 uses the costs calculated for each specific house type.

Table 5.2 Flexible Code standards, points and costs

Category	Name	Performance	Points	Cost house	Cost apartment	Comments
Energy (other)	Internal lighting	>40% of fixed light fittings are dedicated low energy fittings	1.2	£10	£10	Allowance for additional cost of low energy light fittings.
		>75% of fixed light fittings are dedicated low energy fittings	1.2	£40	£30	Allowance for additional cost of low energy light fittings.
	Drying Space	Provide as required under EcoHomes 2006	1.2	£20	£20	Cost allowance for internal clothes drying fittings in bathroom
	Ecolabelled White Goods	Information on or provision of A+ rated fridges/freezers	1.2	£0	£0	No cost for provision of information on these goods.
		Provide washing machines and dishwashers	1.2	£540	£540	Cost of providing energy and water efficient washing machine and dishwasher (providing these appliances also results in a benefit for overall water consumption calculations, see Section 4).
	External Lighting	Energy efficient space lighting	1.2	£15	£15	Costs for provision of space lighting included in base construction (additional cost is for energy efficient fittings).
		Energy efficient security lighting	1.2	£0	£0	If no security lighting is fitted then points are awarded by default (and if lighting is provided the additional cost of Code compliant specifications is negligible).
	Cycle storage	For 50% of dwellings	1.2	£500	£150	Provision of shed with concrete footings and secure lock (communal storage for apartments). Total cost for housing around £1000, but this is averaged for 50% of homes. Costs for apartments based on communal storage areas.
		For 95% of dwellings	1.2	£500	£150	As above, cost for further 45%.
	Home office	Provide as required under EcoHomes 2006	1.2	£210	£210	Cost allowance for provision of telephone / data points in second bedroom (cost includes points and wiring work).
Water	External potable water consumption	Provide system to collect rainwater for use in external irrigation (e.g. water butts)	1.5	£200	£30	Costs based on provision of 1 water butt for housing and communal butts for apartments. Costs include, butt, footings, downpipes and overflow. Actual costs for apartments will depend on storey number and layout.

Table 5.2 Flexible Code standards, points and costs continued

Category	Name	Performance	Points	Cost house	Cost apartment	Comments
Materials	Environmental impact of materials	3 points (roof)	0.9	£0	£0	No additional cost for timber and tiled / slated roof (standing seam roofs could be used for apartments).
		3 points (external walls)	0.9	£0	£0	No additional cost for brick and block walls.
		3 points (internal walls)	0.9	£0	£0	No additional cost for steel or timber studwork
		3 points (floors)	0.9	£280	–	Additional cost for use of plywood upper floor. Base cost includes for use of Jetfloor style floor (provided ground conditions are relatively stable). In apartments it is difficult to achieve these points as concrete upper floors are not A rated.
		3 points (windows)	0.9	£140	£140	Additional cost for timber windows over uPVC
	Responsible sourcing of basic materials	2 points	0.6	£0	£0	No additional cost, should be readily achievable with some analysis of supply chain, could require significant internal / consultant time in product analysis.
		3 points	0.3	£0	£0	As above.
		4 points	0.3	–	–	No additional cost, but could be difficult to secure in practice without significant constraints on materials selection (easier for timber framed housing).
		6 points	0.6	–	–	As above.
	Responsible sourcing of finishing elements	1 point	0.3	£0	£0	No additional cost, should be readily achievable with some analysis of supply chain; could require significant internal / consultant time in product analysis.
		2 points	0.3	–	–	No additional cost, but could be difficult to secure in practice without significant constraints on materials selection.
		3 points	0.3	–	–	No additional cost, but could be difficult to secure in practice without significant constraints on materials selection (easier for timber framed housing).
Surface water runoff	Reduction in surface water runoff	From hard surfaces	0.5	£0	£0	Use of permeable surfacing.
		From roofs	0.5	£450	£450	Cost of one swale for every 2 dwellings.
	Flood risk	Low flood risk area	1	£0	£0	No cost (provided development is in low flood risk area).

Table 5.2 Flexible Code standards, points and costs continued

Category	Name	Performance	Points	Cost house	Cost apartment	Comments
Waste	Household Recycling Facilities	2 Points	1.8	£160	£160	Cost allowance for provision of internal bins
		6 points	1.8	£0	£0	Assumed that local authority will provide kerbside collection service.
	Construction Waste	Monitor, sort and recycle construction waste	1.8	£0	£0	No cost, routinely implemented by several large housebuilders.
	Composting facilities	Home composting facilities	0.9	£70	£70	Cost based on 220l composter
Pollution	Insulant GWP	Use insulant with GWP of less than 5	0.5	£0	£0	No cost, mineral wool, air blown and several types of rigid insulation comply.
	NOx emissions	NOx emissions from space heating system (thresholds still to be determined).	0.5 to 2	£0	£0	No cost; high efficiency boilers meet highest performance standards in EcoHomes 2006 (assumption that should be verified on release of Code technical manual).
Health and wellbeing	Daylighting	Kitchen	1.3*	£140	£140	Cost allowance for additional glazing (based on needs of typical house); costs for specific houses will vary according to design and size of glazed area.
		Living room	1.3*	£150	£150	Cost allowance for additional glazing (based on needs of typical house); costs for specific houses will vary according to design and size of glazed area.
		View of sky	1.3*	£0	£0	No additional cost, although achieving a view of the sky from all homes requires careful layout.
	Sound insulation	Part E + testing (lower level of testing)	1.3*	£100	£100	No cost for detached units, but on an average site (including flats and terraced homes) costs are approx £100 per unit.
		Part E + testing (higher level of testing)	1.3*	£20	£20	No cost for detached units, but on an average site (including flats and terraced homes) costs are approx a further £20 per unit.
		3dB better than Part E	1.3*	–	–	Not considered.
		5dB better than Part E	1.3*	–	–	Not considered.
	Private space	Provide	1.3*	£0	£0	Housing has private space, can easily be designed into apartment blocks (also balconies considered broadly cost neutral as they increase sales value).
	Lifetime Homes	Compliance with all requirements	4	£550	£75	Allowance for additional supports / fixing points within partitions and drainage point in first floor toilets.

Table 5.2 Flexible Code standards, points and costs continued

Category	Name	Performance	Points	Cost house	Cost apartment	Comments
Management	Home user guide	Provide for home	2.2	£0	£0	Assuming that housing is relatively standard.
		Provide for surroundings	1.1	£100	£100	Cost estimate for commissioning consultant to provide necessary location information (costs lower for larger sites).
	Considerate constructors	1 point (commitment to comply with best practice site management principles and regular audit)	1.1	£0	£0	No cost for compliance (other than nominal site registration fee).
		2 points (commitment to go beyond best practice)	1.1	£0	£0	No cost for compliance (other than nominal site registration fee).
	Construction site impacts	Prevention of pollution to air or water	1.1	£0	£0	No cost for compliance, already implemented by several large house builders.
		Monitoring of CO_2 emissions and water consumption	1.1	£100	£100	Estimated cost for monitoring.
	Security	Compliance with Secured by Design – New Homes (Section 2: Physical Security)	2.2	£0	£0	No cost (although there may be an impact on site layout).
Ecology	Ecological value of site	Development of a site of low ecological value	1.2	Variable	Variable	Cost will vary with location.
	Ecological enhancement	Ecological enhancements designed in based on recommendations of qualified ecologist	1.2	Variable	Variable	Cost will vary with location.
	Protection of ecological features	Features of ecological value maintained and protected during construction	1.2	Variable	Variable	Cost will vary with location.
	Change in ecological value of the site	Minor negative change to major enhancement	1.2 - 4.8	Variable	Variable	Cost will vary with location.
	Building footprint	Floor area to footprint ratio	1.2 - 2.4	Variable	Variable	Cost will vary with location.

Notes: *Value of points for the Health and Wellbeing category are amended from the published Code summary following discussion with BRE.

6 Overall costs of Code compliance

Using the information in Sections 3 to 5 of this report it is possible to estimate the likely scale of cost of achieving the different Code levels for each house type. The approach to building up these costs is shown in Figure 6.1.

Figure 6.1 Approach to cost estimates for Code levels

For clarity the minimum performance required for each Code level is repeated in Table 6.1.

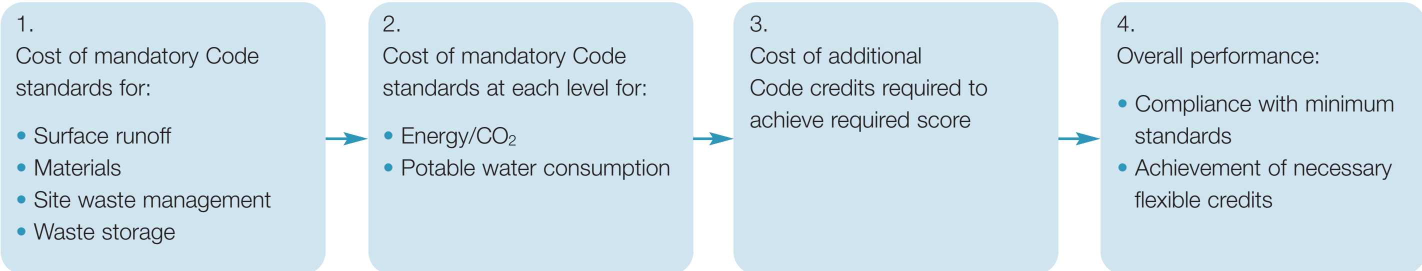


Table 6.1 Minimum performance required for Code levels 1 to 6

Code level	General	Energy - % improvement on ADL1A	Water - litres per person per day (m^3 per year)	Overall points
1	Compliance with minimum requirements for: • Surface runoff • Materials • Site waste management • Waste storage	10%	<120 litres (<45 m^3)	36
2		18%	<120 litres (<45 m^3)	48
3		25%	<105 litres (<37 m^3)	57
4		44%	<105 litres (<37 m^3)	64
5		100%	<80 litres (<30 m^3)	84
6		Zero carbon	<80 litres (<30 m^3)	90

Tables 6.2 to 6.5 summarise the estimated costs for each Code level for the four 'traditional' house type considered, these results are also shown graphically in Figures 6.2 to 6.5. In each instance the lowest cost options have been selected first.

Because of the impact of the costs of achieving mandatory energy standards on the costs of Code compliance the overall costs are considered for the energy scenarios described in Section 3. Scenarios 1, 2 and 4 would be applicable to all locations while Scenario 3 (site wide CHP) is only likely to be applicable to larger sites.

The majority of the points available in the Code are applicable irrespective of location; however those for the Ecology category are linked to the inherent ecological value of the site and the opportunities to protect/enhance its value through development. To provide consistent analysis this cost assessment is based on an assumed 'average site' where 3.6 of the available 10.8 points are available.

6.1 Traditional detached house

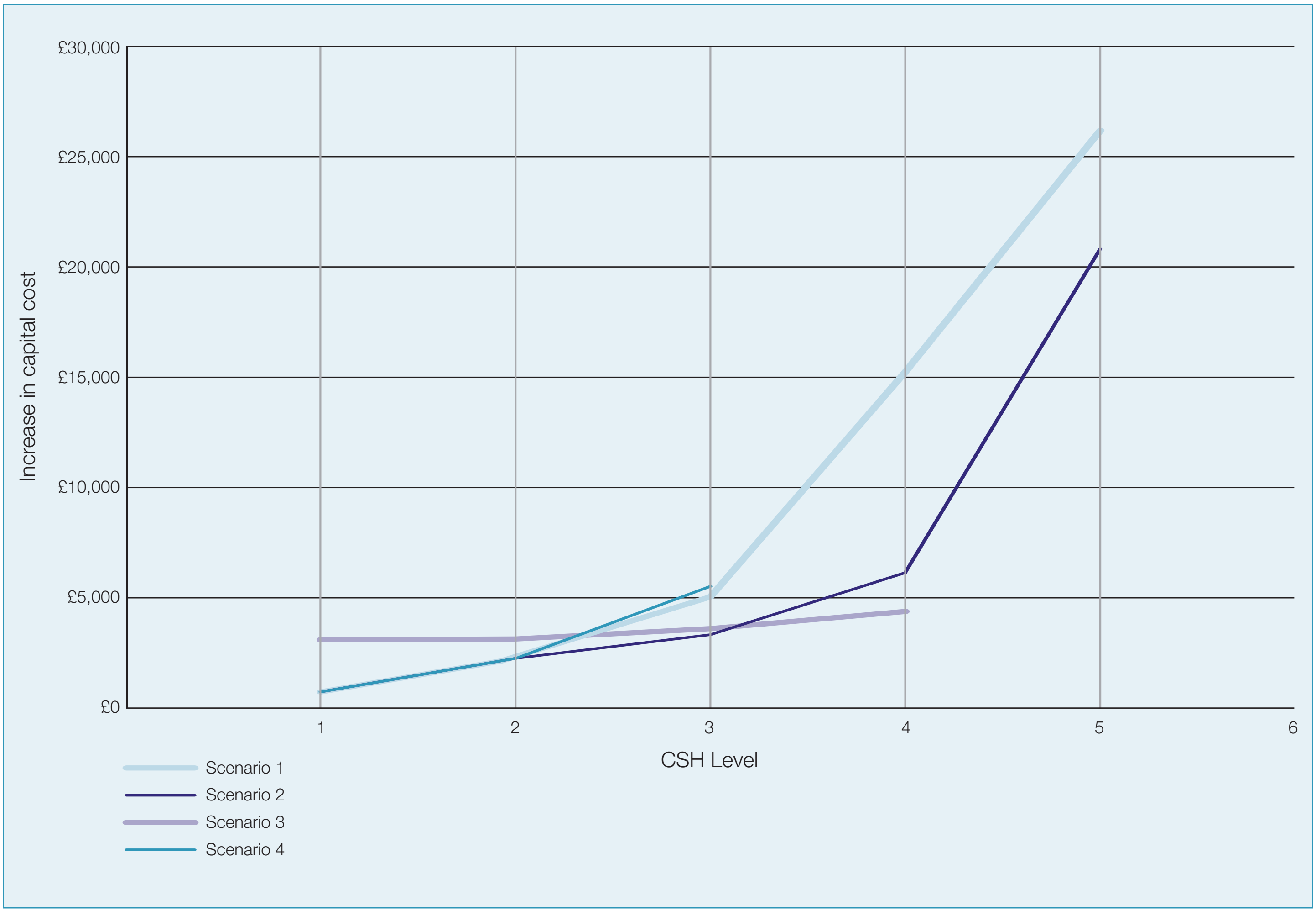
The cumulative costs of achieving progressively higher Code levels are shown in Table 6.2. The cumulative increase in capital cost is shown graphically in Figure 6.2.

Table 6.2 Cost per home of achieving different Code levels – Traditional detached house (compared to 2006 Building Regulations compliant home)

Code level	Mandatory standards General (£)	Energy/ carbon (£)	Water (£)	Other Code points Cost (£)	Overall Total cost (£)	Cost £ per m²	% increase on base cost
Scenario 1							
1	£490	£275	£0	£0	£765	£7	0.8%
2	£490	£1,648	£0	£188	£2,326	£20	2.6%
3	**£490**	**£3,916**	**£125**	**£494**	£5,025	**£43**	**5.5%**
4	£490	£13,525	£125	£1,044	£15,184	£131	16.6%
5	£490	£20,270	£2,645	£2,668	£26,073	£225	28.6%
6*	Not achievable with the approaches considered in this study						
Scenario 2							
1	£490	£275	£0	£0	£765	£7	0.8%
2	£490	£1,648	£0	£133	£2,271	£20	2.5%
3	**£490**	**£1,693**	**£125**	**£1,044**	£3,352	**£29**	**3.7%**
4	£490	£4,484	£125	£1,044	£6,143	£53	6.7%
5	£490	£14,943	£2,645	£2,668	£20,746	£179	22.7%
6*	Not achievable with the approaches considered in this study						
Scenario 3							
1	£490	£2,622	£0	£0	£3,112	£27	3.4%
2	£490	£2,622	£0	£30	£3,142	£27	3.4%
3	**£490**	**£2,622**	**£125**	**£394**	£3,631	**£31**	**4.0%**
4	£490	£2,622	£125	£1,182	£4,419	£38	4.8%
5	Not achievable with the approaches considered in this study						
6*	Not achievable with the approaches considered in this study						
Scenario 4							
1	£490	£275	£0	£0	£765	£7	0.8%
2	£490	£1,648	£0	£188	£2,326	£20	2.6%
3	**£490**	**£4,481**	**£125**	**£494**	£5,590	**£48**	**6.1%**
4	Not achievable with the approaches considered in this study**						
5	Not achievable with the approaches considered in this study						
6*	Not achievable with the approaches considered in this study						

Note – *It is not possible to estimate the costs of Code level 6 because a carbon neutral home was not modelled as part of this study. **Some researchers believe that with appropriate designs it is possible to achieve Code level 4 through using the approach described for Scenario 4.

Figure 6.2 Cost per home of achieving different Code levels – Traditional detached house (compared to 2006 Building Regulations compliant home)



It is noticeable that for Code levels 3 and 4 there is a substantial variation in costs between the different scenarios. Where a site wide approach can be used or where wind turbines are suitable then significant reductions in the cost of compliance can be achieved.

6.2 Traditional end terrace house

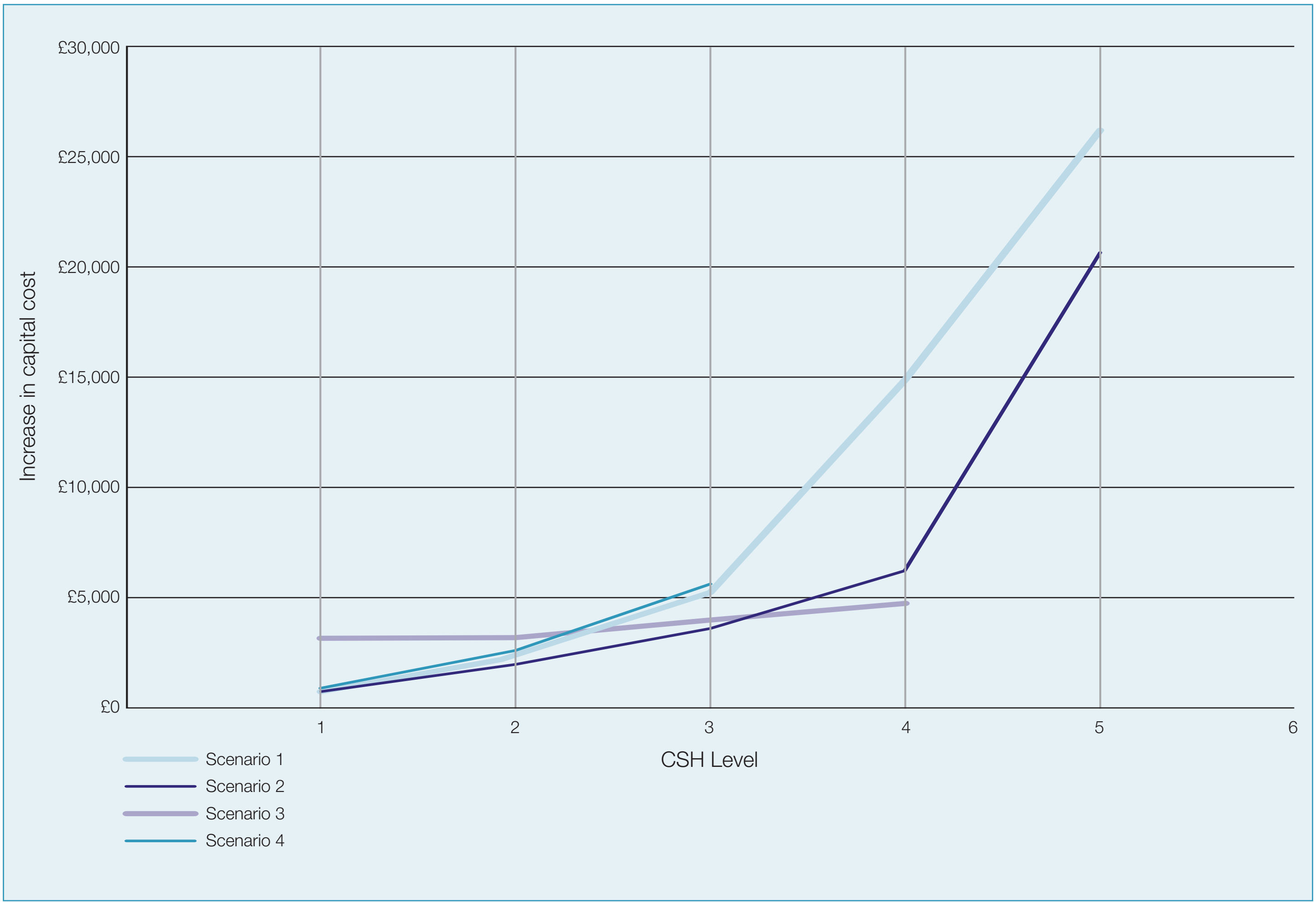
The cumulative costs of achieving progressively higher Code levels are shown in Table 6.3. The cumulative increase in capital cost is shown graphically in Figure 6.3.

Table 6.3 Cost per home of achieving different Code levels – Traditional end terrace house (compared to 2006 Building Regulations compliant home)

Code level	Mandatory standards General (£)	Energy/ carbon (£)	Water (£)	Other Code points Cost (£)	Overall Total cost (£)	Cost £ per m²	% increase on base cost
Scenario 1							
1	£490	£275	£0	£30	£795	£8	1.1%
2	£490	£1,778	£0	£238	£2,506	£25	3.3%
3	**£490**	**£3,692**	**£125**	**£752**	£5,059	**£50**	**6.7%**
4	£490	£12,947	£125	£1,164	£14,726	£146	19.6%
5	£490	£19,962	£2,645	£2,915	£26,012	£258	34.6%
6*	Not achievable with the approaches considered in this study						
Scenario 2							
1	£490	£275	£0	£30	£795	£8	1.1%
2	£490	£984	£0	£394	£1,868	£18	2.5%
3	**£490**	**£1,693**	**£125**	**£1,164**	£3,472	**£34**	**4.6%**
4	£490	£4,260	£125	£1,164	£6,039	£60	8.0%
5	£490	£14,365	£2,645	£2,915	£20,415	£202	27.1%
6*	Not achievable with the approaches considered in this study						
Scenario 3							
1	£490	£2,622	£0	£0	£3,112	£31	4.1%
2	£490	£2,622	£0	£48	£3,160	£31	4.2%
3	**£490**	**£2,622**	**£125**	**£614**	£3,851	**£38**	**5.1%**
4	£490	£2,622	£125	£1,452	£4,689	£46	6.2%
5	Not achievable with the approaches considered in this study						
6*	Not achievable with the approaches considered in this study						
Scenario 4							
1	£490	£275	£0	£30	£795	£8	1.1%
2	£490	£1,778	£0	£168	£2,436	£24	3.2%
3	**£490**	**£3,917**	**£125**	**£902**	£5,434	**£54**	**7.2%**
4	Not achievable with the approaches considered in this study						
5	Not achievable with the approaches considered in this study						
6*	Not achievable with the approaches considered in this study						

Note – *It is not possible to estimate the costs of Code level 6 because a carbon neutral home was not modelled as part of this study.

Figure 6.3 Cost per home of achieving different Code levels – Traditional end terrace house (compared to 2006 Building Regulations compliant home)



Again costs are substantially reduced where a site wide solution can be adopted or where wind energy is feasible. Many of the absolute costs for the terraced house example are the same as for the detached house because they are based on a per item cost rather than being relative to the size of the home. The percentage increase in costs is therefore higher for a terraced (or other smaller house) than for a detached house.

6.3 Traditional low rise apartment

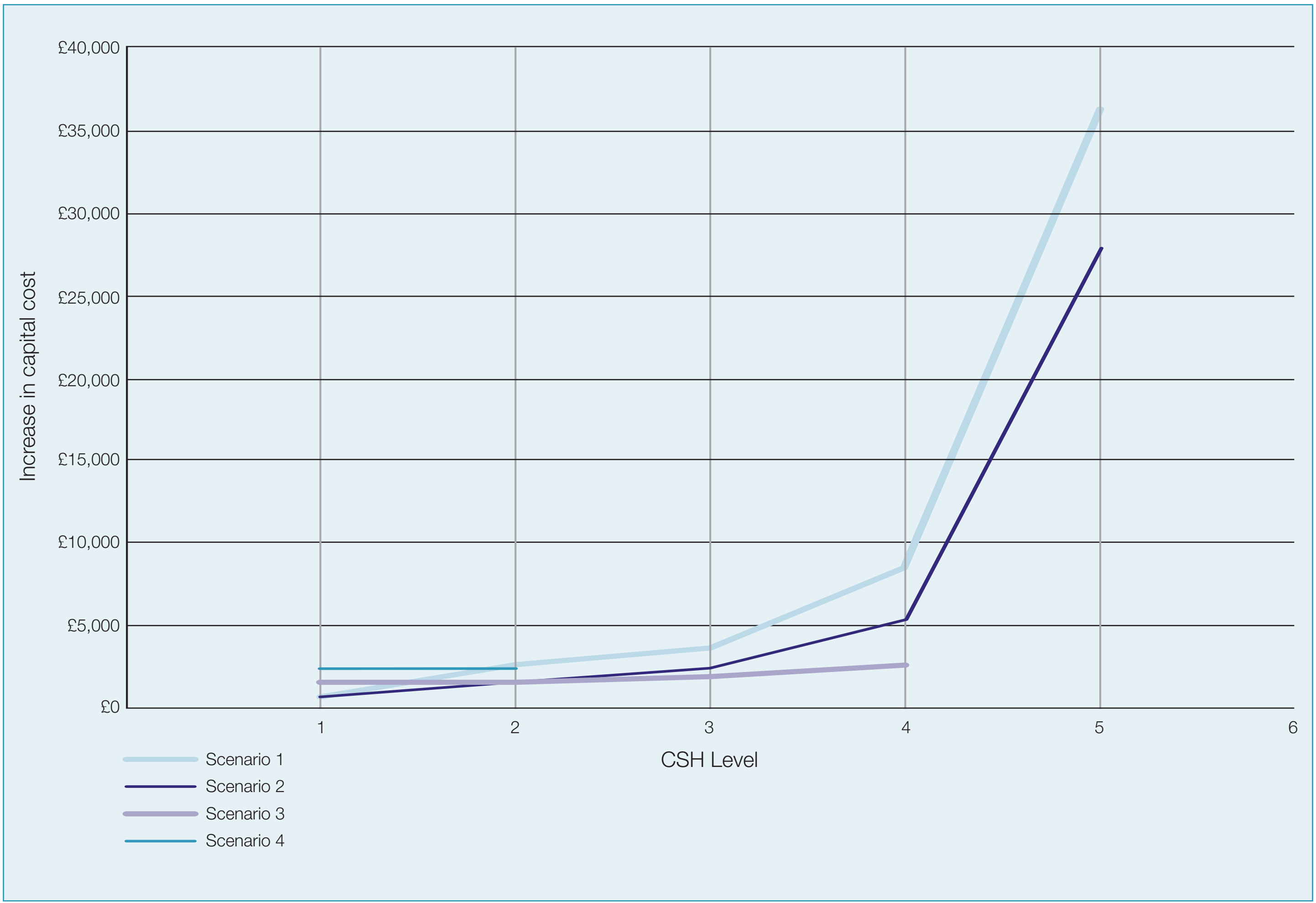
The cumulative costs of achieving progressively higher Code levels are shown in Table 6.4. The cumulative increase in capital cost is shown graphically in Figure 6.4. For the low rise apartment option there is no cost saving associated with implementing site wide solutions to energy or water, therefore only one option for meeting Code requirements is considered.

Table 6.4 Cost per home of achieving different Code levels – low rise apartment (compared to 2006 Building Regulations compliant home)

	Mandatory standards			Other Code points	Overall		
Code level	General (£)	Energy/ carbon (£)	Water (£)	Cost (£)	Total cost (£)	Cost £ per m²	% increase on base cost
Scenario 1							
1	£0	£460	£0	£95	£555	£9	0.7%
2	£0	£2,244	£0	£141	£2,385	£40	3.0%
3	**£0**	**£2,907**	**£125**	**£356**	£3,388	**£57**	**4.3%**
4	£0	£7,590	£125	£582	£8,297	£141	10.5%
5	£0	£29,951	£805	£3,318	£34,074	£578	43.0%
6*	Not achievable with the approaches considered in this study						
Scenario 2							
1	£0	£460	£0	£95	£555	£9	0.7%
2	£0	£1,216	£0	£171	£1,387	£24	1.8%
3	**£0**	**£1,600**	**£125**	**£582**	£2,307	**£39**	**2.9%**
4	£0	£4,511	£125	£582	£5,218	£88	6.6%
5	£0	£21,742	£805	£3,318	£25,865	£438	32.7%
6*	Not achievable with the approaches considered in this study						
Scenario 3							
1	£0	£1,349	£0	£95	£1,444	£24	1.8%
2	£0	£1,349	£0	£95	£1,444	£24	1.8%
3	**£0**	**£1,349**	**£125**	**£281**	£1,755	**£30**	**2.2%**
4	£0	£1,349	£125	£1,010	£2,484	£42	3.1%
5	Not achievable with the approaches considered in this study						
6*	Not achievable with the approaches considered in this study						
Scenario 4							
1	£0	£2,194	£0	£10	£2,204	£37	2.8%
2	£0	£2,194	£0	£141	£2,335	£40	2.9%
3	Not achievable with the approaches considered in this study						
4	Not achievable with the approaches considered in this study						
5	Not achievable with the approaches considered in this study						
6*	Not achievable with the approaches considered in this study						

Note – *It is not possible to estimate the costs of Code level 6 because a carbon neutral home was not modelled as part of this study.

Figure 6.4 Cost per home of achieving different Code levels – Low rise apartment (compared to 2006 Building Regulations compliant home)



6.4 Traditional high rise apartment

The cumulative costs of achieving progressively higher Code levels are shown in Table 6.5. The cumulative increase in capital cost is shown graphically in Figure 6.5.

6.4 Traditional high rise apartment

The cumulative costs of achieving progressively higher Code levels are shown in Table 6.5. The cumulative increase in capital cost is shown graphically in Figure 6.5.

Table 6.5 Cost per home of achieving different Code levels – high rise apartment (compared to 2006 Building Regulations compliant home)

Code level	General (£)	Mandatory standards Energy/ carbon (£)	Water (£)	Other Code points Cost (£)	Overall Total cost (£)	Cost £ per m²	% increase on base cost
Scenario 1							
1	£0	£2,858	£0	£20	£2,878	£38	2.3%
2	£0	£3,684	£0	£113	£3,797	£51	3.0%
3	**£0**	**£5,952**	**£125**	**£281**	£6,358	**£85**	**5.1%**
4	£0	£16,647	£125	£181	£16,953	£226	13.6%
5	£0	£32,776	£805	£2,205	£35,786	£477	28.7%
6*	Not achievable with the approaches considered in this study						
Scenario 2							
1	£0	£2,858	£0	£20	£2,878	£38	2.3%
2	£0	£3,684	£0	£113	£3,797	£51	3.0%
3	**£0**	**£3,751**	**£125**	**£281**	£4,157	**££55**	**3.3%**
4	£0	£15,100	£125	£181	£15,406	£205	12.4%
5	£0	£28,151	£805	£2,205	£31,161	£415	25.0%
6*	Not achievable with the approaches considered in this study						
Scenario 3							
1	£0	£1,695	£0	£0	£1,695	£23	1.4%
2	£0	£1,695	£0	£95	£1,790	£24	1.4%
3	**£0**	**£1,695**	**£125**	**£281**	£2,101	**£28**	**1.7%**
4	£0	£1,695	£125	£1,014	£2,834	£38	2.3%
5	Not achievable with the approaches considered in this study						
6*	Not achievable with the approaches considered in this study						
Scenario 4							
1	£0	£2,858	£0	£10	£2,868	£38	2.3%
2	£0	£3,030	£0	£141	£3,171	£42	2.5%
3	**£0**	**£4,933**	**£125**	**£342**	£5,400	**£72**	**4.3%**
4	Not achievable with the approaches considered in this study						
5	Not achievable with the approaches considered in this study						
6*	Not achievable with the approaches considered in this study						

Note – *It is not possible to estimate the costs of Code level 6 because a carbon neutral home was not modelled as part of this study.

Figure 6.5 Cost per home of achieving different Code levels – high rise apartment (compared to 2006 Building Regulations compliant home)

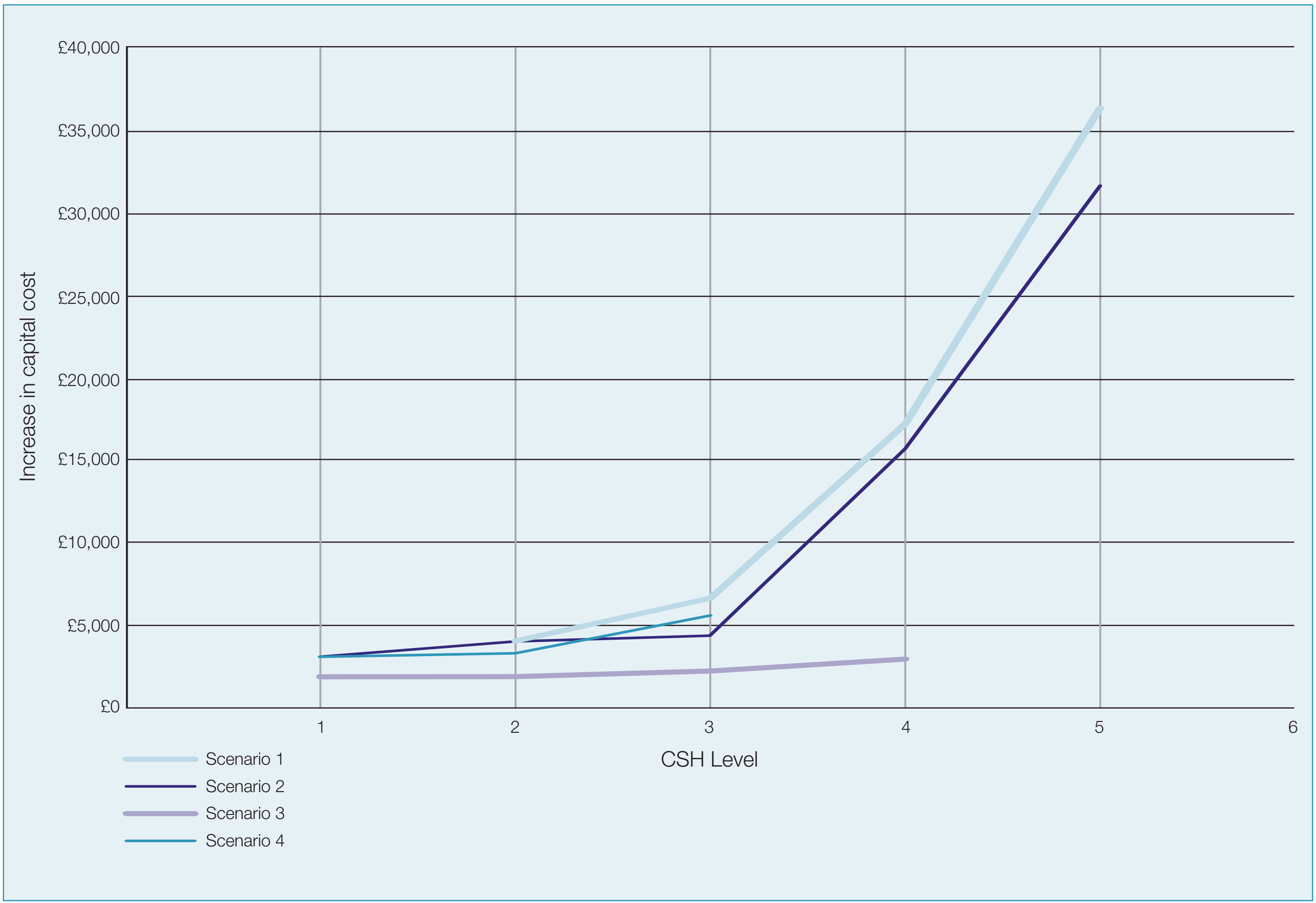


Figure 6.5 illustrates the substantial reductions in cost per dwelling that can be achieved where a 'site wide' approach to energy services is adopted. This is because the cost of the energy services infrastructure is distributed across a larger number of units in the development.

6.5 Summary of costs for each Code level and house type

Analysis of the cost information on each house type indicates that the energy standards dominate the overall costs of achieving each Code level (other than for Code level 1).

Figure 6.6 shows the additional cost associated with achieving each Code level for each of the six house types considered, based on Scenario 1 (the most widely applicable). This information is also presented in Table 6.6. To show the significance of these costs relative to the base cost of each unit (thereby accounting for the size and construction method employed), these figures are also presented as a percentage uplift.

Figure 6.6 Additional cost of achieving each Code level for each house type (Scenario 1)

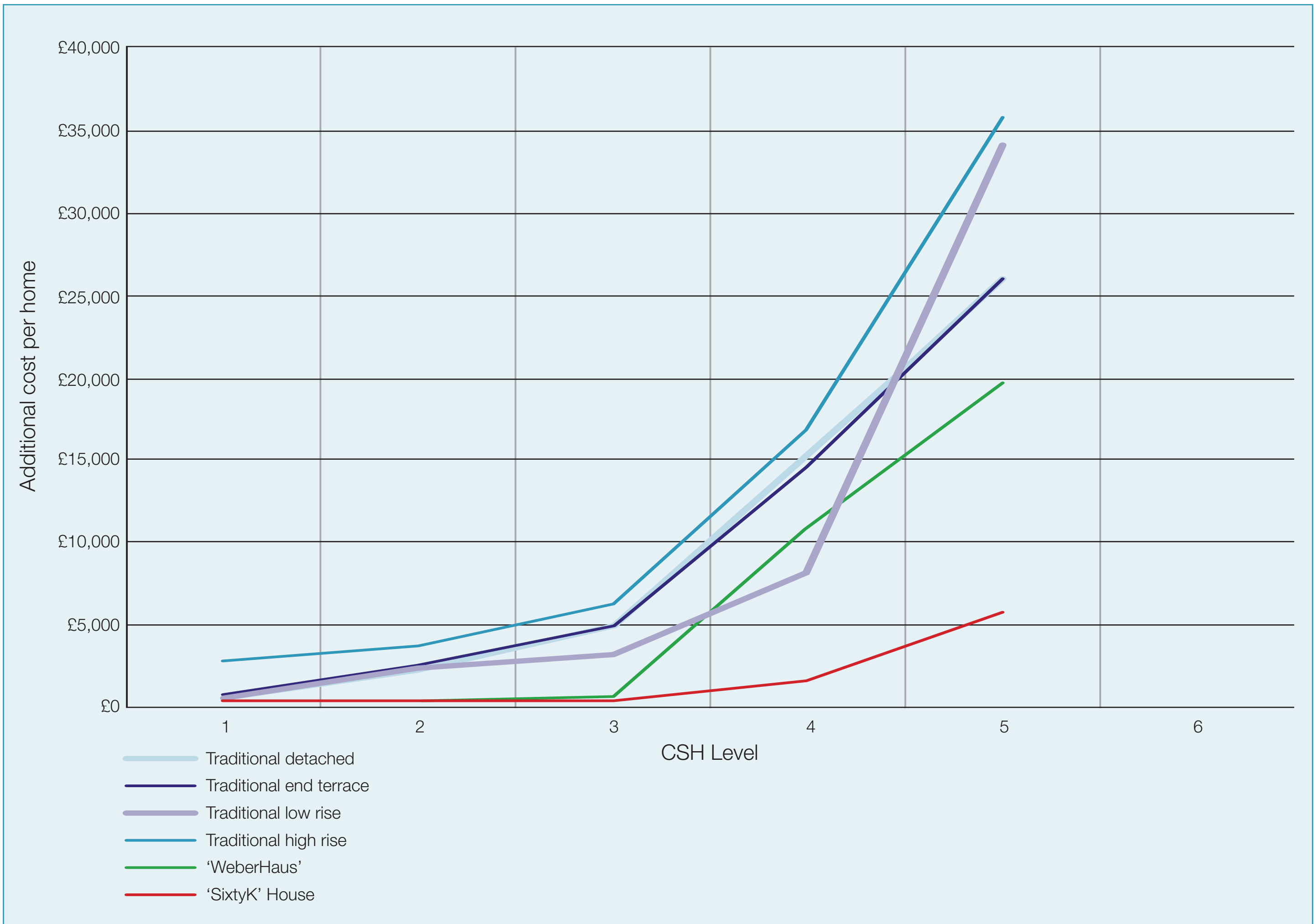


Table 6.6 Additional cost above building regulations of achieving each Code level (Scenario 1)

Code	Traditional detached	Traditional and terraced	Traditional low rise	Traditional high rise	'WeberHaus'	'SixtyK House'
1	£765 (0.8%)	£795 (1.1%)	£555 (0.7%)	£2,878 (2.3%)	£490 (0.8%)	£490 (0.8%)
2	£2,326 (2.6%)	£2,506 (3.3%)	£2,385 (3.0%)	£3,797 (3.0%)	£490 (0.8%)	£490 (0.8%)
3	**£5,025 (5.5%)**	**£5,059 (6.7%)**	**£3388 (4.3%)**	**£6,358 (5.1%)**	**£793 (1.3%)**	**£615 (1.0%)**
4	£15,184 (16.6%)	£14,726 (19.6%)	£8,297 (10.5%)	£16,953 (13.6%)	£10,653 (17.8%)	£1,001 (1.7%)
5	£26,073 (28.6%)	£26,012 (34.6%)	£34,074 (43.0%)	£35,786 (28.7%)	£21,829 (36.4%)	£5,975 (10.0%)
6	–	–	–	–	–	–

Percentage increase is shown in brackets.

Where it is possible to use wind energy or site wide solutions for energy and water (i.e. Scenarios 2 and 3) compliance costs are lower. Where it is viable to use large scale wind turbines this also presents an opportunity to achieve the necessary energy targets at lower cost (see Appendix B). However, these options are not widely applicable (either for reasons of planning or wind speed) and the appropriateness of each technology needs to be evaluated as each scheme is designed. If no renewable energies are used (i.e. Scenario 4) it is still possible to achieve Code level 3 in all of the homes (except the low rise apartment) through the use of proprietary construction details and efficient mechanical ventilation systems with heat recovery. To achieve improvement beyond Code level 3 it is necessary to use renewable energies or site wide CHP.

These results show that:

- **Code level 1 –** costs are likely to add around 1% of construction cost or less with the exception of the high rise flat (where a substantial cost is incurred for a communal gas fired heating system)
- **Code level 2 –** costs are more significant for the traditional homes but are unchanged for the two DfM homes (because these were designed to achieve an EcoHomes Excellent rating)
- **Code level 3 –** an increase in cost occurs for all house types except the SixtyK house. For the 'traditional' house types the cost is quite substantial adding a further 4% to 7% to construction cost. The majority of this additional cost is associated with carbon saving measures (detailed in Section 3) and where lower cost approaches are viable (i.e. wind turbines or site wide CHP) costs are reduced).
- **Code level 4 –** additional costs are between 12% and more than 20% of the base cost for all house types (with the exception of the SixtyK House). The growth in these costs is a result of the use of significant quantities of photovoltaics. Where wind turbines can be used then the level of additional cost is reduced to between 7% and 9%. The low level of additional cost for the SixtyK House can be ascribed to the inclusion of substantial energy efficiency measures in the base product (i.e. PV and CHP). Although the environmental benefit of PV and CHP is included in analysis of the SixtyK houses the cost of these elements is not. This is because the cost of these items is assumed to be covered by an ESCO.[33]
- **Code levels 5 and 6 –** costs become substantial for all homes, reflecting the high performance standards involved. However, the costs for the SixtyK house are substantially lower than for any other house type with Code level 5 compliance achieved for only 14% over the cost of the base home.

[33] These figures should be treated with a little caution as we cannot currently confirm that an ESCo has formally agreed to provide the specified energy services to the site, and no detailed cost breakdown was available for use in this study.

7 Comparison of the Code and EcoHomes 2006

The key differences between the Code and EcoHomes are that the Code:

- Includes mandatory standards for energy/carbon, water and other issues
- Has different weightings for each point/credit
- Uses a different method of measuring CO_2 emissions (% reduction on TER rather than the kg CO_2/m^2 used in EcoHomes)
- Includes new point areas for Lifetime Homes and composting facilities
- Uses the forthcoming revised (unpublished) version of the Green Guide to Specification (ratings in the current Green Guide have been used in this study).
- Does not include points for public transport, local amenities

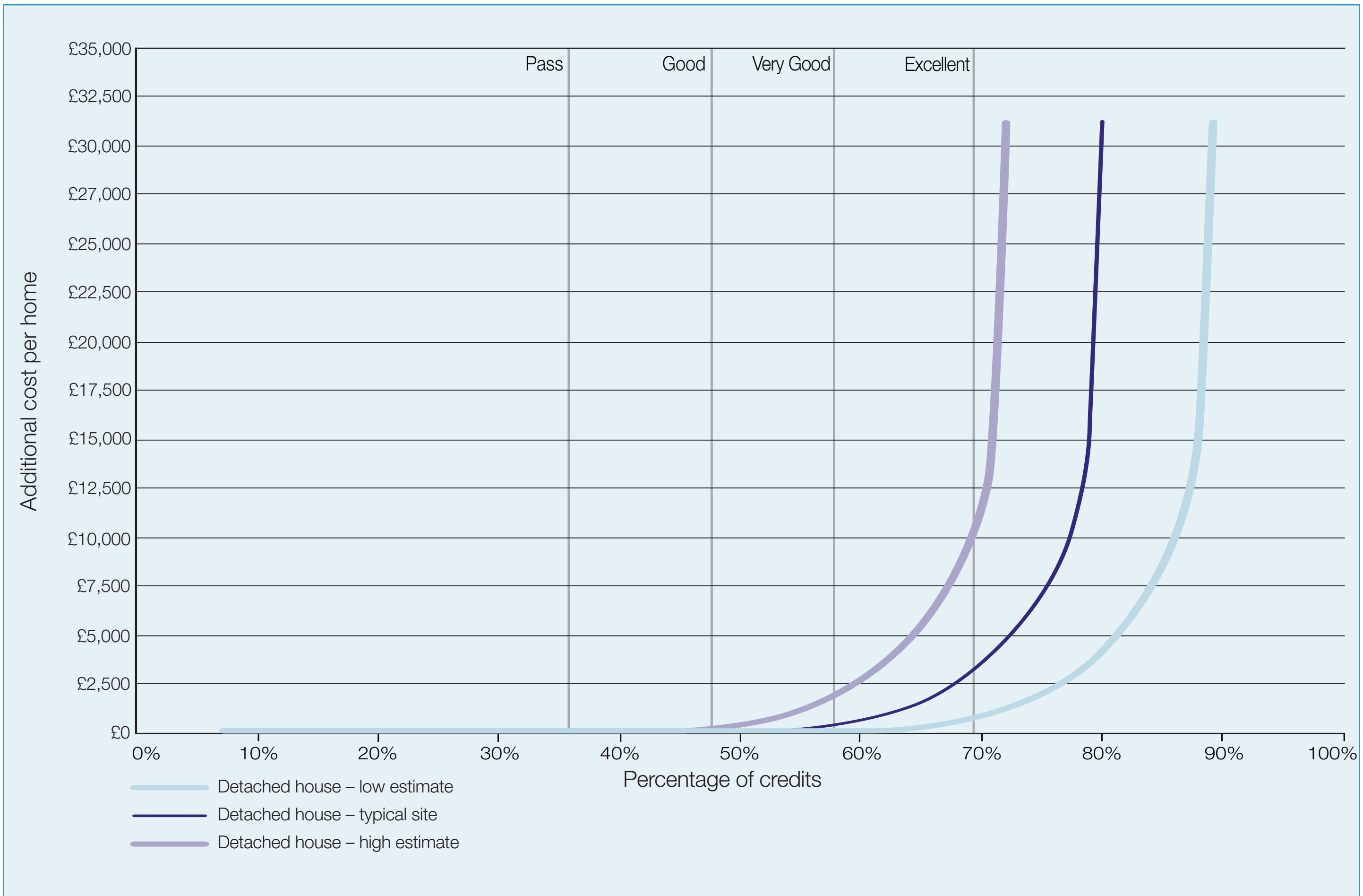
Each of the above differences influence the cost of achieving Code levels 1 to 4 in comparison to the corresponding EcoHomes 2006 rating. However, the most significant changes are the mandatory performance standards for energy/carbon and water.

7.1 Cost comparison

The range of costs of achieving Pass, Good, Very Good and Excellent ratings have been estimated for each traditional house type.[34]

Figure 7.1 shows the costs of achieving different EcoHomes 2006 ratings for the traditional detached house only assuming that either all or none of the EcoHomes credits for accessibility to public transport and amenities or impact on ecology are awarded together with an estimate for a typical site (i.e. reasonable accessibility and some ecological value).

Figure 7.1 Cost of achieving EcoHomes 2006 ratings for a detached house



[34] Costs are nil for the WeberHaus and SixtyK House which already achieve EcoHomes Excellent

Table 7.1 Costs of EcoHomes Very Good compliance

	Traditional detached house	Traditional terraced house	Low rise apartment	High rise apartment
EcoHomes Very Good	£500	£686	£809	£1458

Table 7.2 Additional cost for Code level 3 over EcoHomes Very Good

	Traditional detached house	Traditional terraced house	Low rise apartment	High rise apartment
Scenario 1	£4,525 (4.8%)	£4,373 (5.7%)	£2,579 (3.2%)	£4,900 (3.8%)
Scenario 2	£2,852 (2.9%)	£2,786 (3.5%)	£1,498 (1.9%)	£2,699 (2.0%)
Scenario 3	£3,131 (3.2%)	£3,165 (4.1%)	£946 (1.2%)	£643 (0.4%)
Scenario 4	£5,090 (5.4%)	£4,748 (6.2%)	Not achievable	£3,942 (3.0%)

The critical comparison for English Partnerships and the Housing Corporation is that between the costs of an EcoHomes Very Good rating and Code level 3.

Table 7.1 shows the costs of EcoHomes Very Good compliance for each of the housetypes. Table 7.2 shows the comparative (extra over) costs for Code level 3 and EcoHomes Very Good for all traditional house types together with information on relative performance for energy/carbon and water.

Table 7.2 demonstrates that the cost premium for Code level 3 over an EcoHomes 2006 Very Good rating is highly variable (between <1% and 6.2%) depending on the house types considered and the approach taken. Where it is not possible to use wind energy or site wide CHP, then additional costs fall in the range of 3% to 6.2%. However, Code level 3 delivers major reductions in carbon dioxide emissions and reduced water consumption.

7.2 Other general comments on the Code vs EcoHomes 2006

As mentioned previously the Code differs from EcoHomes 2006 in several key respects. The most obvious are the minimum performance standards, however others are worth mentioning.

Approach to measuring energy/carbon performance

The house types considered in this study all have TERs of less than 26 kg CO_2 per m^2 (with several having TERs of less than 21 kg. As a result these homes, which make no substantial improvement on current building regulations requirements, would achieve a minimum of 6 energy credits under EcoHomes 2006. Under the draft Code this level of performance would attract no points.

The wide variation in actual CO_2 emissions of the different house types (from 26 to 19 kg CO_2 per m^2) suggests that the approach of assessing performance using percentage improvement over the TER is more suitable than setting definitive carbon emission levels (and is consistent with the approach taken in new Building Regulations).

New point areas

The Code includes new points for Lifetime Homes standards and compositing facilities.

Lifetime Homes is not considered to have a significant impact on overall project costs because the requirements of the revised Part M of Building Regulations now require many of the same considerations to be addressed as a matter of course. It is estimated that compliance with the Lifetime Homes standard could result in additional costs of around £550 per home. However, because of the relatively low weighting of these points it is unlikely that a developer would pursue this standard (unless required to do so) because there are less expensive ways of achieving the credits necessary for Code level 3.

It should be noted that English Partnerships require that their developments meet Lifetime Homes standards so for their schemes, developers will not incur additional costs in meeting this element of the Code.

The new points awarded for providing composting facilities will have no significant impact on project costs (cost of around £70 per home).

Exclusion of credits for accessibility

The Code excludes the current EcoHomes credits relating to access to public transport and local amenities. As a result the Code is slightly more ‘location independent’, however, the inclusion of points for ecological impact means that the assessment will be influenced by site location.

8 Implications of other policy/planning requirements

In addition to the development requirements imposed by English Partnerships and the Housing Corporation, developments also need to address the requirements of planning authorities.

Planning Policy Statements relating to renewable energy (PPS22) and Planning Policy Guidance on flood risk (PPG25) encourage planning authorities to require developers to address these issues irrespective of the requirements in the Code or EcoHomes. A recent survey by the Town and Country Planning Association showed that 30% of local authorities have a planning policy relating to renewable energy either in draft form or fully adopted. In the majority of instances this requires the use of renewable energy for a minimum of 10% of site energy requirements (measured as CO_2 emissions).

It is likely that within 18 months the vast majority of planning authorities will expect some form of renewable or low carbon energy supply in new homes. Scenarios 1 and 2 make use of renewable energies (solar thermal or wind energy) at a level that is likely to meet these requirements. Where developers use an approach that does not include renewables, (e.g. the site wide CHP scenario), and a local authority micro generation requirement is in place[35], developers will need to assess the best mechanism for achieving this.

[35] Such as the London Borough of Merton's requirement that 10% of site energy is provided from renewable sources, see http://themertonrule.org.

9 Potential for cost reductions

The analysis presented in this report identifies cost increases associated with meeting improved standards of environmental performance in new housing. While it is likely that these additional costs would be incurred in the short term it does not necessarily follow that cost increases will be incurred in the long (> 5 years) or even medium (2-5 years) term.

Potential opportunities for cost savings relative to the initial costs presented in this report include:

- Identification of more innovative solutions
- Discounts arising from bulk purchases
- Reduction in cost of existing materials and products arising from their widespread adoption
- Emergence and development of new technologies/construction methods better suited to meeting the required performance standards
- The involvement of an ESCO in a development

Once the collective intelligence of the construction industry is applied to the issue of meeting the required targets then it is likely that more efficient/innovative solutions might be adopted that achieve the same performance at lower cost. Clearly it is not possible at this stage to predict what these solutions might be or the level of cost saving achieved. The potential for this is therefore noted but not considered further

The other opportunities are, however, considered in more detail below.

9.1 Bulk purchase discounts

As discussed in Section 1.4 several suppliers of technologies that could potentially deliver the standards in the Code provided estimates of the level of discount that might be available for bulk (5,000 units or more) purchases. The results of the survey showed savings of between 20% and 30% were commonly available, while savings of up to 60% were estimated for ground source heat pumps.

Nonetheless for very large orders there would be a need to implement special arrangements to ensure delivery and these might have the impact of an increased product lead time or a reduction on the level of discount.

9.2 Cost savings arising from more widespread adoption of targets

The current costs of technologies are not generally a good indication of their future cost (or at least the level of delivered value per unit of cost). Perhaps the most well known example of rapid improvements in the performance to cost ratio is in microprocessors[36]. While performance increases in other sectors may not be as significant as in computing, the principle of technological innovation and efficiency coming from increasing experience of its design and production holds true.

Experience curves

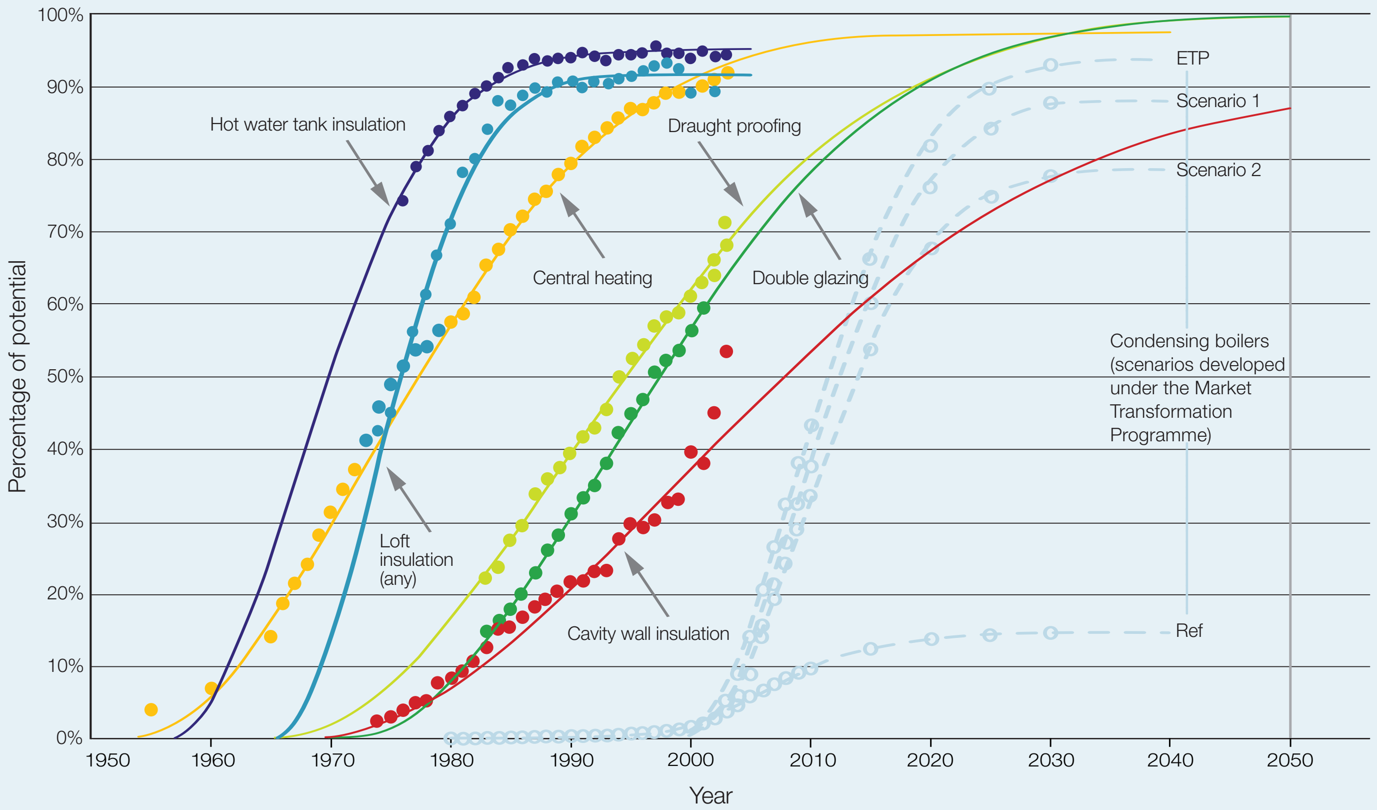
The reductions in cost associated with scale of production are known as 'experience curves' (or learning curves). Research has shown that the critical factor influencing 'experience' and therefore cost reduction is usually volume of production rather than time. Therefore, larger and more rapid cost reductions can be expected where there is a strong incentive (e.g. a policy requirement) to use a particular technology. In the absence of a firm push to the market such cost reductions will arise at a much slower rate and it may be that the new technology never reaches competitiveness with existing technologies.

It is likely that those technologies best suited to addressing the requirements of the Code will see a growth in demand and installed capacity. This process has been noted for a number of energy saving technologies (see Figure 9.1[37]).

[36] Where Moore's Law postulates that the complexity of microchips should double every 18 months.

[37] The scenarios shown in figure 9.1 do not relate to the Code scenarios used in this study.

Figure 9.1 Impact of policy measures on the uptake of energy efficient technologies



(Taken from: Reducing Carbon Emissions from the UK Housing Stock, BRE, 2005)

Experience curves for low and zero carbon technologies (i.e. CHP and renewable energies) suggests[38] that the level of costs could be reduced to between 95% and 60% of their previous level for each doubling in installed capacity with a reduction to around 82% of previous cost being considered a reasonable average figure.

While cost reductions for technologies associated with the proposed Code can be estimated using an experience curve approach there are some important caveats to remember before assuming that cost reductions will result at a consistent rate. Factors that influence the level of cost reduction achieved from experience/learning include[39]:

- Timing – Costs will reduce more rapidly where the timescale for introduction of new requirements is complementary to existing cycles of innovation.
- Differential learning rates – Learning may be applied to different elements of a technology at different rates (e.g. for PV systems, cost reduction could be different for installation, interface systems and the arrays themselves).
- Scale of learning – effects within a single country could be less significant than where the same process applies at a global scale. For example, where the UK only comprises one of several markets for a given product, then a doubling of capacity in the UK does not equate to a doubling of overall capacity for the product and therefore the corresponding level of cost savings will not arise.
- Step changes in progress – while evidence suggests that cost reductions continue in a relatively linear fashion there may be periodic step changes, e.g. with changes in materials or manufacturing process
- Difference between cost and price – while costs may reduce this does not necessarily mean that purchase price will be affected immediately (although it should in the longer term providing the market is competitive).

Notwithstanding the above factors, experience curves do provide a useful method for assessing the longer term implications of regulations that would necessitate a change in technology performance or type.

Examples of experience curves for different technologies

Experience curves have been assessed for a broad range of energy efficient technologies including PV, micro CHP, boilers, insulation systems, lighting, appliances, etc. Analysis of the potential progress ratios for each technology is shown in Table 9.1 (after Hinnells, M 2005). This information together with data on the current market capacity of these technologies and the potential scale of their adoption under the Code could give an indication of the scale of cost reduction that might arise. The example of micro CHP is considered in more detail below.

[38] Based on research conducted by M. Hinnells, the International Energy Agency and the Government Performance and Innovation Unit

[39] Taken from Hinnells, M, The cost of 60% cut in CO_2 emissions from homes: what do experience curves tell us 2005

Table 9.1 Reduction in cost differential for energy efficient technologies following widespread adoption

	Heat pump	Community Heating	Solar hot water	Energy efficient fridge	External Wall Insulation	LED lighting	PV	Micro CHP	Fuel cell CHP
Estimated progress ratio (i.e. cost is reduced to this level each time capacity doubles)	92%					82%			

Looking at the example of heating systems in more detail, the technical and material differences between a micro CHP system and a gas boiler are not in themselves sufficient to justify the current cost differential (if we assume that a micro CHP system costs around £3,000 and gas boiler £800-£1,000). The principal causes of this cost differential are:

- Experience and understanding of the technologies – conventional boilers are well understood, while micro CHP technologies are newer and are still being refined
- Risk – micro CHP systems are subject to potential uncertainty regarding their grid connections
- Scale – micro CHP is manufactured in comparatively small numbers and all opportunities for value engineering are unlikely to have been pursued
- Funding – micro CHP is likely to be funded via higher risk capital (or venture capital) and will have higher and more immediate research costs to repay
- Awareness and training of installers – micro CHP will require more specialist installers increasing this cost element
- Competition – only one or two commercial suppliers exist therefore the need for innovation and price reductions is not present to the same extent (provided the manufacturer can sell all of their current capacity).

Therefore, if the impact of above factors were reduced by a strong market demand for micro CHP then it is likely that, subject to the industry increasing capacity to meet demand, the cost differential would diminish significantly. Industry analysts have predicted that if there were 12m installed units (internationally) then the additional cost might be £400 or less. Evidence of recent prices for bulk purchase of micro CHP (where the installed cost was £1,350 per unit) also suggests that the cost differential with conventional boilers might reduce to below £400 if adopted widely.

The survey of renewable energy suppliers indicated that the same principles should hold for small scale wind turbines with an approximate 60% reduction in cost estimated by one supplier.

Impact on cost of achieving Code

At this stage it is only possible to talk qualitatively about the impact of increased market demand for energy efficient technologies on their additional cost (proposals for more detailed analysis are described in Section 6). The technologies/products likely to be required to meet the Code can be grouped into two broad categories:

1. Technology items where cost differential and change required is low (e.g. low flow taps, low flush toilets, fridges, etc)
2. Technology items where cost differential and change required is high (e.g. micro CHP, PV, etc)

It is likely that the items in category one will rapidly become mainstream and will ultimately replace 'standard' products.

Those items in category two will also reduce in cost. This could be significant for those technologies, such as micro CHP and small scale wind turbines and solar water heating systems, which are favoured by the Code requirements. However, it is likely that some residual cost premium will still be present for some time.

9.3 Emerging technologies/construction methods

In addition to reductions in the cost of existing technologies arising from their greater adoption there is also potential for new technologies to deliver the required performance improvements more efficiently. Some of these emerging technologies are already gaining market acceptance (such as modern methods of construction) while others (e.g. phase changing materials, which increase thermal mass by storing energy as latent heat) are still highly experimental. The potential benefits of new approaches to construction and of developments in housing technology are considered below.

Construction Methods

Modern methods of construction (MMC)[40] have two principal benefits over traditional construction methods when it comes to environmental performance. These lie in their ability to achieve better thermal performance than traditional masonry construction (without the need for enlarged cavities or external insulation) and in the relative ease by which improved standards of airtightness can be achieved. Both these factors mean that for achieving higher standards of energy efficiency a MMC based option can be more cost effective than masonry housing because there is no need to enlarge cavities or use external/internal insulation to achieve the required performance.

Other benefits claimed for MMC approaches include:

- Reduced construction time onsite
- Reduced number of skilled workers required onsite
- Reduced waste arisings and better management of wastes

At present there is still believed to be a cost premium associated with MMC (although it is argued that much if not all of this premium is offset by increased speed onsite). However, if increased energy efficiency standards provide an additional stimulus to the MMC market then it may be that this cost premium will reduce as more experience is gained through increased application.

It must be remembered that there is also a debate about overheating and the benefits or otherwise of thermal mass vs lightweight construction.

Other technological developments

A wide range of technologies are currently in development that could result in more efficient delivery of improved environmental performance in housing. Some interesting measures are described below (some still at a highly experimental stage).

- Vertical axis wind turbines – these systems are designed for use in urban areas where wind speed and direction is more variable and where there is greater need for renewable energies to be located on or very near to buildings. As well as working well in turbulent wind conditions, vertical axis systems generate less noise and vibration and are also low maintenance. At present, costs for a 6 kW turbine are around £25,000 (this is more expensive than a comparable horizontal system) however these costs should fall with wider adoption of the technology.
- Phase changing materials – these can be incorporated into the walls or roof of a building to simulate thermal mass in lightweight buildings. They store energy as latent heat. Examples of systems in development include a glass system that blocks the entry of infrared light once it reaches 29°C and a plasterboard that is impregnated with a substance that has a melting temperature 1-3°C above room temperature.
- Use of solar energy to power cooling systems – systems are being developed that utilise solar thermal energy to deliver cooling using absorption, desiccant and vapour compression systems
- Dual purpose solar systems – systems such as the Solar Veil (developed by Atkins) comprise a louvred arrangement of evacuated solar tubes over the façade of a building providing a combined solar thermal and solar shading system.
- Fuel cell boilers – British Gas intends to make a fuel cell powered boiler commercially available in the next 3 – 4 years. The wall mounted unit will provide heating, hot water and electricity for a standard home and can run on natural gas, lpg or propane

[40] Such as closed timber frame, Structural Insulated Panel (SIP) systems or light steel frame

- Use of groundwater as a thermal store – this technology uses aquifers to store heat and coolth to provide space heating and cooling. Such systems would probably only work effectively on larger scale applications (e.g. apartments or large housing projects).
- Use of LEDs as low energy light systems – new forms of LEDs are being developed that are highly efficient and offer a diffuse and adaptable light source.
- Vacuum waste collection – these have been pioneered by Swedish firm Envac and pioneered in a housing complex next to the new Wembley stadium. Householders separate rubbish into appropriate components (e.g. biodegradable, non-biodegradable and various recyclable fractions) drop in appropriate street collection point. A vacuum suction system then takes waste from each fraction to the relevant central collection point. The system provides a quick and low visibility system for dealing with waste and simplifying the collection process (as collections only need take place from one source).
- Thin film PV – developments in PV technology mean that production processes become continuous (and therefore much cheaper) due to the use of thin film technologies. Thin film PV can be used on glass and other substrates and recent versions are delivering energy conversion efficiencies comparable with traditional crystalline systems.
- More intelligent control of appliances – dynamic demand devices may start to emerge over the next few years helping to reduce domestic CO_2 emissions. Examples include:
  - The use of micro-controllers in domestic fridges or freezers, to measure the internal temperature/current frequency of the national grid and turn the electricity supplied on and off as appropriate.
  - Highly water efficient washing machines that use ultra-sonic agitation and reuse rinse water

Although several of these technologies are still experimental they indicate that, provided a sufficiently strong market incentive is in place, it should be possible to achieve further savings in energy and water consumption either by use of new approaches (such as fuel cells or thermal storage systems) or by making existing technologies more cost effective/efficient as in the case of thin film PV and vertical axis turbines.

9.4 Energy Services Companies

The involvement of an ESCO can make a substantial impact on the costs and practicalities of implementing site wide energy efficiency measures such as CHP.

Generally, ESCO's take responsibility for the on-going operation and maintenance of on-site energy centres producing power, heat and cooling. In certain instances they also provide state of the art data services, including digital television, telephony and high speed broadband. The level of ESCO involvement can range from provision of project funding (covering the additional capital cost of constructing an on-site energy centre) to the design and construction itself.

The involvement of an ESCO's in a development can help provide;

- **Power –** energy efficient electricity is produced in an energy centre and is distributed around the site by means of a private power distribution network.
- **Heat –** heat is distributed around a site by means of a district or community heating infrastructure from a central generation source. This can be in the form of medium or low-pressure hot water or, in certain circumstances, steam.
- **Cooling –** cooling can be provided by using excess heat bi-product from generation turbines and an absorption chiller(s) in a central energy centre. Again this is distributed via a cooling network around the site.
- **Digital Services –** these are delivered by way of a fibre optic cable to each property. This fibre can also be utilised in some cases to relay live billing information to computer servers in an energy centre from the energy and water meters.

Finance towards the construction of the Energy Centre is provided by the ESCO, providing significant reduction in developer capital costs for the central plant for power, heat and cooling generation, and reducing the cost disparity with conventional heating and power systems.

The ESCO owns the plant and equipment and is responsible for its maintenance and efficient operation.

Utilities costs should be lower than with conventional provision. Despite the involvement of an ESCO within a development, occupiers remain free to use alternative suppliers. However, whilst gas pricing is essentially unregulated, the ESCO does have an obligation to benchmark its pricing against a basket of other energy providers and ensure that it offers lower charges, typically by around 10%.

Typically, the threshold at which an ESCO managed energy centre becomes viable equates to a development size of around 350 residential units. This benchmark is improved, however, with mixed use developments (for instance, schemes including retail and leisure units) which would have a higher and more continuous demand for heat and power than a residential only development. ESCO's will consider developments of varying density. However, as a rule of thumb, densities of around 50 dwellings per hectare are considered acceptable for site wide CHP provision.

10 Summary and conclusions

Following this study of a selection of house types and construction methods it is possible to draw several conclusions about the implications of the Code for the performance and cost of housing. These include:

- The cost and relative environmental performance of Code level 3 in comparison to EcoHomes 2006
- The cost of achieving the specified standards for Code levels 1 to 5 for energy and water together with the position of step changes in cost occurring between levels
- The potential benefit of site wide approaches to meeting Code requirements
- The potential for future cost reductions arising from widespread adoption of technologies

These conclusions are described below.

10.1 Mandatory energy standards

For the traditional house types, the costs for achieving the mandatory performance standards for energy can be summarised as:

- Code level 1 – relatively little additional cost is incurred as this level of performance improvement can be achieved through simple measures such as enhanced building controls. The only exception is for the high rise apartment where a cost of around £2,800 per dwelling is incurred to install a communal heating system
- Code level 2 – at this level the costs begin to be influenced by the approach taken to achieve energy efficiency improvements (i.e. improved insulation, wind turbines or CHP). Costs range from around £1,000 to £1,800 per home.
- Code level 3 – again costs are variable depending on the carbon reduction route chosen. Costs range from around £1,600 (where wind turbines are used) to over £4,400 (where mechanical ventilation is used). For the high rise apartment the costs vary substantially from nearly £6,000 (where solar water heating is used) to as low as £1,700 where the apartments are included within a site wide CHP system.
- Code level 4 – costs increase to between £5,000 and £16,000 per home depending on whether a wind turbines or photovoltaics are used to achieve carbon savings. Achieving Code level 4 compliance if no wind energy can be used requires substantial use of photovoltaics (1 kW). The use of a site wide CHP system should also enable the level of performance to be achieved more cost effectively.
- Code level 5 – costs vary between £14,000 and £30,000 depending on house type. However, for the houses and low rise apartment the enhancements required to achieve Code level 5 (i.e. biomass heating systems) result in an over 100% improvement on TER (sufficient for Code level 6).

Code level 3 compliance could be achieved more cost effectively for housing through the use of micro CHP systems. However, these are not currently widely available in the UK and it is not expected that they will be available in significant numbers until 2008.

For the DfM house types the situation is quite different. It is estimated that both house types could achieve the energy standards for Code level 3 at no additional cost, while the SixtyK House could achieve the level 4 standard at no additional cost to the developer (assuming that costs of site infrastructure solutions are borne by an ESCO). The DfM homes have substantially lower costs of compliance because their base specifications are already highly thermally efficient, and in the case of SixtyK House include the use of renewable and low carbon technologies.

10.2 Mandatory water standards

It is possible to achieve reductions in water consumption to 105 litres per bedspace per day (38m^3 per year) at very little or no additional cost.[41] This requires the use of:

- Dual flush toilets (6/4 litres)
- Aerated taps
- Smaller 'shaped' baths
- Flow controlled showers (to between 6-9 litres per minute)

This level of water efficiency is sufficient for compliance with Code levels 1 to 4.

To achieve further reductions beyond 105 litres per bedspace per day (38m^3 per year) there is a need for at least one of the following:

- Use of ultra low flow showers and very low flush toilets. These options are not significantly more expensive but might impact the marketability of homes
- Installation of water efficient white goods (washing machine and dishwasher)
- nstallation of greywater recycling or rainwater harvesting systems, or both.

For levels below 105 litres per day (Code levels 5 and 6) costs are approximately £2,520 for houses and £640 for apartments. In houses it should still be possible to reduce the costs of greywater and rainwater systems by around 50% by the use of shared infrastructure.

[41] Subject to the release of a finalised Code water calculator.

10.3 Cost and performance of Code relative to EcoHomes 2006

The mandatory performance standards in Code mean that the costs of compliance are higher at every level although this becomes most noticeable at Code levels 3 and 4 (equivalent to Ecohomes Very Good and Excellent ratings).

The energy requirements associated with Code level 3 are such that the costs of achieving this standard are between 1% and 6.2% of the base cost of a home higher than for EcoHomes Very Good. Costs are critically dependant on the approach taken to achieving the energy component of the Code. Where it is not possible to use site wide CHP or wind turbines then the additional cost of Code level 3 over EcoHomes Very Good is 3% to 6.2%. A Code level 3 compliant home will have a far lower level of CO_2 emissions (approximately 25% better) and reduced water consumption than an EcoHomes 2006 Very Good rated home.

10.4 Potential of site wide approaches to reduce the costs of compliance

Analysis of the costs of site wide technologies for a 200 unit development scenario suggest that higher energy and water performance standards can be achieved more cost effectively using site wide approaches. In particular, the use of an ESCO can help to substantially offset the costs associated with meeting carbon reduction targets. In the case of the SixtyK house the Code level 4 standard for energy/carbon should be achieved by 'outsourcing' the energy services aspect of the development to an ESCO. In this instance the developer expects the involvement of an ESCO to enable the capital cost of the installation to be fully offset.

10.5 Potential for future cost reductions

Evidence suggests that all of the technologies likely to be needed to deliver Code level 3 are likely to reduce in cost over the next 2 to 5 years. This would result from the increased demand associated with the adoption of the Code and also from other initiatives such as the proposed PPS on climate change and PPS22 that are encouraging the use of renewable energies. However, further work would be required to assess more quantitatively the likely scale of price reductions.

Where the scale of development is appropriate the involvement of an ESCOs could offset all or a large proportion of the additional capital expenditure associated with the use of low carbon technologies. However ESCO's are only likely to be viable in relatively large schemes (+350 units) and would need appropriate development phasing and densities

Further cost reductions may also arise in the medium term from the use of technologies still at a relatively early stage of development, such as thin film PV and vertical axis wind turbines.

Appendix A: Detailed information on energy efficiency measures for each house type

Table A.1 Detailed breakdown of costs of achieving carbon targets for a detached house

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m²)	DER (kg m²)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m² per measure	£ per kg CO_2 reduction
Option A Solar Water Heater								
Baseline			22.60	5%		£0	£0	
Delayed start thermostat	27	0.27	22.33	6%	£110	£110	£1	£4
Thermostat in hot water cylinder + separate time control for hot water	37	0.36	21.97	8%	£64	£174	£2	£2
Add zoned time and temperature control to heating system	49	0.48	21.49	10%	£101	£275	£3	£2
Reduce air permeability to 5 m³ hr m²	57	0.56	20.93	12%	£0	£275	£3	£0
Upgrade boiler to high efficiency (91.5%) condensing boiler	53	0.52	20.41	14%	£418	£693	£7	£8
Reduce external wall u value to 0.25	51	0.50	19.91	16%	£511	£1,204	£12	£10
Reduce window U value to 1.5 kW m²	59	0.58	19.33	19%	£444	£1,648	£16	£8
4m² flat panel solar water heater with PV powered pump	179	1.76	17.57	26%	£2,268	£3,916	£39	£13
Reduce window U value to 1.3 kW m²	60	0.59	16.98	29%	£444	£4,360	£43	£7
Reduce external wall u value to 0.21	37	0.36	16.62	30%	£1,002	£5,362	£53	£27
0.2 kW of Photovoltaic array	87	0.86	15.76	34%	£2,050	£7,412	£73	£23
0.15 kW of Photovoltaic array	64	0.63	15.13	36%	£983	£8,395	£83	£15
0.65 kW of Photovoltaic array	283	2.79	12.34	48%	£5,130	£13,525	£133	£18
15 kW Biomass system (omit solar water heater)	1285	12.65	-0.31	101%	£6,745	£20,270	£200	£5
Option B Small scale wind								
Baseline			22.60	5%	£91,056	£0	£0	
Delayed start thermostat	27	0.27	22.33	6%	£110	£110	£1	£4
Thermostat in hot water cylinder + separate time control for hot water	37	0.36	21.97	8%	£64	£174	£2	£2
Add zoned time and temperature control to heating system	49	0.48	21.49	10%	£101	£275	£3	£2
Reduce air permeability to 5 m³ hr m²	57	0.56	20.93	12%	£0	£275	£3	£0
1.5 kW small wind turbine (1100 kWh per year) 1 in 2 homes	312.5	3.08	17.85	25%	£1,418	£1,693	£12	£5

Table A.1 Detailed breakdown of costs of achieving carbon targets for a detached house continued

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m^2)	DER (kg m^2)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m^2 per measure	£ per kg CO_2 reduction
Additional 1.5 kW small wind turbines (1100 kWh per year) so that every home has one turbine.	312.5	3.08	14.8	38%	£1,418	£3,111	£33	£5
Upgrade boiler to high efficiency (91.5%) condensing boiler	53	0.52	14.3	40%	£418	£3,529	£35	£8
Reduce external wall u value to 0.25	51	0.50	13.8	42%	£511	£4,040	£40	£10
Reduce window U value to 1.5 kW m^2	59	0.58	13.2	45%	£444	£4,484	£44	£8
Reduce window U value to 1.3 kW m^2	95	0.94	12.2	49%	£444	£4,928	£45	£5
Reduce external wall u value to 0.21	37	0.36	11.9	50%	£1,002	£5,930	£60	£27
4 m^2 flat panel solar water heater with PV powered pump	179	1.76	10.1	57%	£2,268	£8,198	£96	£13
15 kW Biomass system (omit solar water heater)	1285	12.65	-2.5	111%	£6,745	£14,943	£149	£5
Option C Micro CHP								
Baseline			22.60	5%	£91,056	£0	£0	
Delayed start thermostat	27	0.27	22.33	6%	£110	£110	£1	£4
Thermostat in hot water cylinder + separate time control for hot water	37	0.36	21.97	8%	£64	£174	£2	£2
Add zoned time and temperature control to heating system	49	0.48	21.49	10%	£101	£275	£3	£2
Reduce air permeability to 5 m^3 hr m^2	57	0.56	20.93	12%	£0	£275	£3	£0
Micro CHP unit (with 2 way metering)	632	6.22	14.71	38%	£496	£771	£8	£1
1.5 kW small wind turbine (1100 kWh per year)	625	6.15	8.6	64%	£2,836	£3,607	£36	£5
Option D Site wide CHP								
Baseline			23.07	3%	£91,056	£0	£0	
Site wide CHP	1179	11.60	11.5	52%	£2,296	£2,296	£23	£2
Option E Proprietary construction details and WHMV								
Baseline		22.60	5%	£91,056	£0	£0		
Delayed start thermostat	27	0.27	22.33	6%	£110	£110	£1	£4
Thermostat in hot water cylinder + separate time control for hot water	37	0.36	21.97	8%	£64	£174	£2	£2
Add zoned time and temperature control to heating system	49	0.48	21.49	10%	£101	£275	£3	£2

Table A.1 Detailed breakdown of costs of achieving carbon targets for a detached house continued

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m^2)	DER (kg m^2)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m^2 per measure	£ per kg CO_2 reduction
Reduce air permeability to 5 m^3 hr m^2	57	0.56	20.93	12%	£0	£275	£3	£0
Upgrade boiler to high efficiency (91.5%) condensing boiler	53	0.52	20.41	14%	£418	£693	£7	£8
Reduce external wall u value to 0.25	51	0.50	19.91	16%	£511	£1,204	£12	£10
Reduce window U value to 1.5 kW m^2	59	0.58	19.33	19%	£444	£1,648	£16	£8
Proprietary construction details (0.04 x TESA)	86	0.85	18.48	22%	£0	£1,648	£16	£0
Reduce air permeability to 3 m^3 hr m^2 and Add balanced whole house ventilation system with heat recovery (specific fan power of 1 W/s)	100	0.98	17.50	26%	£2,833	£4,481	£44	£28

Table A.2 Detailed breakdown of costs of achieving carbon targets for a traditional end terrace house

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m²)	DER (kg m²)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m² per measure	£ per kg CO_2 reduction
Option A Solar Water Heater								
Baseline			20.56	3%	£91,056	£0	£0	
Delayed start thermostat	24	0.24	20.32	4%	£110	£110	£1	£5
Thermostat in hot water cylinder + separate time control for hot water	39	0.38	19.94	5%	£64	£174	£2	£2
Add zoned time and temperature control to heating system	39	0.38	19.56	7%	£101	£275	£3	£3
Reduce air permeability to 5 m³ hr m²	66	0.65	18.91	10%	£0	£275	£3	£0
Upgrade boiler to high efficiency (91.5%) condensing boiler	48	0.47	18.44	13%	£418	£693	£7	£9
Reduce external wall u value to 0.25	28	0.28	18.16	14%	£377	£1,070	£11	£13
Reduce window U value to 1.5 kW m²	54	0.53	17.63	16%	£354	£1,424	£14	£7
4m² flat panel solar water heater with PV powered pump	179	1.76	15.87	25%	£2,268	£3,692	£36	£13
Reduce window U value to 1.3 kW m²	60	0.59	15.28	28%	£354	£4,046	£40	£6
Reduce external wall u value to 0.21	37	0.36	14.92	29%	£738	£4,784	£47	£20
0.2 kW of Photovoltaic array	87	0.86	14.06	33%	£2,050	£6,834	£67	£23
0.15 kW of Photovoltaic array	64	0.63	13.43	36%	£983	£7,817	£77	£15
0.65 kW of Photovoltaic array	283	2.79	10.64	50%	£5,130	£12,947	£127	£18
15 kW Biomass system (omit solar water heater)	1285	12.65	-2.01	110%	£6,745	£19,692	£194	£5
Option B Small scale wind								
Baseline			20.56	3%	£91,056	£0	£0	
Delayed start thermostat	24	0.24	20.32	4%	£110	£110	£1	£5
Thermostat in hot water cylinder + separate time control for hot water	39	0.38	19.94	5%	£64	£174	£2	£2
Add zoned time and temperature control to heating system	39	0.38	19.56	7%	£101	£275	£3	£3
Reduce air permeability to 5 m³ hr m²	66	0.65	18.91	10%	£0	£275	£3	£0
1.5 kW small wind turbine (1100 kWh per year) 1 in 2 homes	312.5	3.08	15.84	25%	£1,418	£1,693	£12	£5

Table A.2 Detailed breakdown of costs of achieving carbon targets for a traditional end terrace house continued

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m²)	DER (kg m²)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m² per measure	£ per kg CO_2 reduction
Additional 1.5 kW small wind turbines (1100 kWh per year) so that every home has one turbine.	312.5	3.08	12.8	40%	£1,418	£3,111	£33	£5
Upgrade boiler to high efficiency (91.5%) condensing boiler	48	0.47	12.3	42%	£418	£3,529	£35	£9
Reduce external wall u value to 0.25	28	0.28	12.0	43%	£377	£3,906	£38	£13
Reduce window U value to 1.5 kW m²	54	0.53	11.5	46%	£354	£4,260	£42	£7
Reduce window U value to 1.3 kW m²	60	0.59	10.9	48%	£354	£4,614	£45	£6
Reduce external wall u value to 0.21	37	0.36	10.5	50%	£738	£5,352	£60	£20
4 m² flat panel solar water heater with PV powered pump	179	1.76	8.8	58%	£2,268	£7,620	£96	£13
15 kW Biomass system (omit solar water heater)	1285	12.65	-3.9	118%	£6,745	£14,365	£149	£5
Option C Micro CHP								
Baseline			20.56	3%	£91,056	£0	£0	
Delayed start thermostat	24	0.24	20.32	4%	£110	£110	£1	£5
Thermostat in hot water cylinder + separate time control for hot water	39	0.38	19.94	5%	£64	£174	£2	£2
Add zoned time and temperature control to heating system	39	0.38	19.56	7%	£101	£275	£3	£3
Reduce air permeability to 5 m³ hr m²	66	0.65	18.91	10%	£0	£275	£3	£0
Micro CHP unit (with 2 way metering)	632	6.22	12.69	40%	£496	£771	£8	£1
1.5 kW small wind turbine (1100 kWh per year)	625	6.15	6.54	69%	£2,836	£3,607	£36	£5
Option D Site wide CHP								
Baseline			23.07	-9%	£91,056	£0	£0	
Site wide CHP	1179	11.60	11.5	46%	£2,296	£2,296	£23	£2
Option E Proprietary construction details and WHMV								
Baseline			20.56	3%	£91,056	£0	£0	
Delayed start thermostat	24	0.24	20.32	4%	£110	£110	£1	£5
Thermostat in hot water cylinder + separate time control for hot water	39	0.38	19.94	5%	£64	£174	£2	£2
Add zoned time and temperature control to heating system	39	0.38	19.56	7%	£101	£275	£3	£3

Table A.2 Detailed breakdown of costs of achieving carbon targets for a traditional end terrace house continued

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m²)	DER (kg m²)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m² per measure	£ per kg CO_2 reduction
Reduce air permeability to 5 m³ hr m²	66	0.65	18.91	10%	£0	£275	£3	£0
Upgrade boiler to high efficiency (91.5%) condensing boiler	48	0.47	18.44	13%	£418	£693	£7	£9
Reduce external wall u value to 0.25	28	0.28	18.16	14%	£377	£1,070	£11	£13
Reduce window U value to 1.5 kW m²	53	0.52	17.64	16%	£354	£1,424	£14	£7
Proprietary construction details (0.04 x TESA)	71	0.70	16.94	20%	£0	£1,424	£14	£0
Reduce air permeability to 3 m³ hr m² and Add balanced whole house ventilation system with heat recovery (specific fan power of 1 W/s)	157	1.55	15.39	27%	£2,493	£3,917	£39	£16

Table A.3 Detailed breakdown of costs of achieving carbon targets for a traditional low rise apartment

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m^2)	DER (kg m^2)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m^2 per measure	£ per kg CO_2 reduction
Option A Solar Water Heater								
Baseline			20.32	2%	£0	£0		
Reduce air permeability to 5 m^3 hr m^2	34	0.62	19.70	5%	£100	£100	£2	£2.94
Add time and temperature control to heating system	25	0.16	19.54	5%	£101	£201	£3	£4.04
Delayed start thermostat	9	0.29	19.25	7%	£120	£321	£5	£13.33
Reduce external wall u value to 0.27	28	0.49	18.76	9%	£318	£639	£11	£11.36
4 m^2 flat panel solar water heater with PV powered pump	198	3.39	15.37	26%	£2,268	£2,907	£49	£11.45
Reduce window U value to 1.3 kW m^2	27	0.45	14.92	28%	£460	£3,367	£56	£17.04
Reduce external wall u value to 0.21	20	0.34	14.58	29%	£162	£3,529	£59	£8.10
0.15 kV of Photovoltaic array	56	0.94	13.64	34%	£983	£4,512	£76	£17.55
0.3 kV of Photovoltaic array	131	2.19	11.45	45%	£3,078	£7,590	£127	£23.59
0.65 kV of Photovoltaic array	293	4.91	6.54	68%	£5,130	£12,720	£213	£17.51
15 kW Biomass system	612	10.26	-3.72	118%	£17,231	£29,951	£502	£28.16
Option B Small scale wind								
Baseline		20.32	2%	£0	£0			
Reduce air permeability to 5 m^3 hr m^2	34	0.62	19.70	5%	£100	£100	£2	£2.94
Add time and temperature control to heating system	25	0.16	19.54	5%	£101	£201	£3	£4.04
Delayed start thermostat	9	0.29	19.25	7%	£120	£321	£5	£13.33
Reduce external wall u value to 0.27	28	0.49	18.76	9%	£318	£639	£11	£11.36
Small scale wind 1.5 kW one per 5 homes	125	2.09	16.67	19%	£577	£1,216	£20.38	£4.61
Small scale wind 1.5 kW one per 3 homes	83	1.40	15.27	26%	£385	£1,600	£26.82	£4.61
Small scale wind 1.5 kW one per 2 homes	104	1.75	13.5	35%	£481	£2,081	£34.88	£4.61
Reduce external wall u value to 0.21	20	0.34	13.2	36%	£162	£2,243	£37.59	£8.10
4 m^2 flat panel solar water heater with PV powered pump	198	3.32	9.9	52%	£2,268	£4,511	£75.60	£11.45
15 kW Biomass system	612	10.26	-0.4	102%	£17,231	£21,742	£364.37	£28.16

Table A.3 Detailed breakdown of costs of achieving carbon targets for a traditional low rise apartment continued

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m^2)	DER (kg m^2)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m^2 per measure	£ per kg CO_2 reduction
Option C Communal heating and then CHP								
Baseline	0	20.3	2%	£0	£0			
Community heating system, charging linked to use, programmer and TRVs	39	0.65	19.7	5%	£4,829	£4,829	£80.93	£123.82
Reduce external wall u value to 0.27	28	0.47	19.2	7%	£318	£5,147	£86.26	£11.36
Reduce external wall u value to 0.21	23	0.39	18.8	9%	£162	£5,309	£88.97	£7.04
145 litre cylinder insulated pipework and vessel	67	1.12	17.7	14%	£553	£5,862	£98.24	£8.25
Small scale wind (1 for 5 flats)	125	2.09	15.6	25%	£577	£6,439	£107.91	£4.61
Gas CHP with gas boilers	304	5.09	10.5	49%	£9,504	£15,943	£267.18	£31.26
Gas CHP with biomass boilers	414	6.94	3.6	83%	£1,931	£17,874	£299.54	£4.66
Biomass CHP with biomass boilers	145	2.43	1.1	95%	£11,897	£29,771	£498.92	£82.05
Option D Site wide CHP								
Baseline			20.32	2%	£0	£0		
Site wide CHP	668	11.19	9.1	56%	£1,349	£1,349	£22.60	£2.02
Option E Proprietary construction details and WHMV								
Baseline		20.32	2%		£0	£0		
Reduce air permeability to 5 m^3 hr m^2	34	0.62	19.70	5%	£100	£100	£2	£2.94
Add time and temperature control to heating system	25	0.16	19.54	5%	£101	£201	£3	£4.04
Delayed start thermostat	9	0.29	19.25	7%	£120	£321	£5	£13.33
Reduce external wall u value to 0.25	28	0.22	19.03	8%	£318	£639	£11	£11.36
Proprietary construction details (0.04 x TESA)	35	0.58	18.45	11%	£0	£639	£11	£0.00
Reduce window U value to 1.3 kW m^2	27	0.29	18.16	12%	£460	£1,099	£18	£17.04
Reduce external wall u value to 0.21	23	0.27	17.89	13%	£162	£1,261	£21.13	£7.04
Reduce air permeability to 3 m^3 hr m^2 and Add balanced whole house ventilation system with heat recovery (specific fan power of 1 W/s + 85% efficient)	93	1.56	16.33	21%	£1,555	£2,194	£37	£17

Table A.4 Detailed breakdown of costs of achieving carbon targets for a traditional high rise apartment continued

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m²)	DER (kg m²)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m² per measure	£ per kg CO_2 reduction
Option A Solar Water Heater								
Baseline			24.9	0%	£0	£0	£0	
Gas fired community heating 869	11.59	23.8	4%	£2,700	£2,700	£36	£3	
Charging linked to use, programmer and TRV's	175	2.33	21.5	14%	£158	£2,858	£38	£1
Reduce window U value from 2.0 m² to 1.8	51	0.68	20.8	16%	£172	£3,030	£40	£3
Reduce external wall U value to 0.21	39	0.52	20.3	19%	£654	£3,684	£49	£17
4 m² flat panel solar water heater with PV powered pump	114	1.52	18.8	25%	£2,268	£5,952	£79	£20
Gas CHP with Gas boilers (omit SWH)	187	2.49	16.3	35%	£3,590	£9,542	£127	£19
Gas CHP with Biomass boilers	732	9.76	6.5	74%	£7,105	£16,647	£222	£10
0.3 kV of Photovoltaic array	131	2.19	4.3	83%	£3,078	£19,725	£263	£24
Biomass CHP with Biomass boilers	300	4.00	0.3	99%	£13,051	£32,776	£437	£44
Option B Small Scale Wind								
Baseline			24.9	0%	£0	£0	£0	
Gas fired community heating	869	11.59	23.8	4%	£2,700	£2,700	£36	£3
Charging linked to use, programmer and TRV's	175	2.33	21.5	14%	£158	£2,858	£38	£1
Reduce window U value from 2.0 m² to 1.8	51	0.68	20.8	16%	£172	£3,030	£40	£3
1.5 kw Wind turbine (1 in 4 units)	156	2.08	18.7	25%	£721	£3,751	£50	£5
Gas CHP with Gas boilers	187	2.49	16.2	35%	£3,590	£7,341	£98	£19
Reduce external wall U value to 0.21	39	0.52	15.7	37%	£654	£7,995	£107	£17
Gas CHP with Biomass boilers	732	9.76	5.9	76%	£7,105	£15,100	£201	£10
0.3 kV of Photovoltaic array	131	2.19	3.75	85%	£3,078	£18,178	£242	£24
Biomass CHP with Biomass boilers	300	4.00	-0.25	101%	£13,051	£28,151	£375	£44
Option C Site wide CHP								
Baseline			24.9	0%	£0	£0	£0	
Site wide CHP	871	11.61	13.3	53%	£1,695	£1,695	£23	£2

Table A.4 Detailed breakdown of costs of achieving carbon targets for a traditional high rise apartment continued

Efficiency measure	CO_2 saving by measure (per year)	CO_2 saving by (kg m^2)	DER (kg m^2)	% improvement on TER	Additional cost per measure	Cumulative cost	Total additional £/m^2 per measure	£ per kg CO_2 reduction
Option E Proprietary construction details and WHMV								
Baseline			24.9	0%	£0	£0	£0	
Gas fired community heating	869	11.59	23.8	4%	£2,700	£2,700	£36	£3
Charging linked to use, programmer and TRV's	175	2.33	21.5	14%	£158	£2,858	£38	£1
Reduce window U value from 2.0 m^2 to 1.8	51	0.20	21.3	15%	£172	£3,030	£40	£3
Proprietary construction details (0.04 x TESA)	0	0.76	20.5	18%	£0	£3,030	£40	£0
Reduce air permeability to 3 m^3 hr m^2 and Add balanced whole house ventilation system with heat recovery (specific fan power of 1 W/s + 85% efficient)	27	3.31	17.21	31%	£1,903	£4,933	£66	£70

Table A.5 Detailed breakdown of costs of achieving carbon targets for the WeberHaus

Efficiency measure	CO_2 saving by measure (per year)	CO_2 emissions	CO_2 emissions (kg m²)	% improvement on TER	Additional cost per measure	Total additional cost	£/m² per measure
Option A Solar Water Heater							
Baseline		0	21.6	19%	£0	£0	£0
Reduce air permeability to 5 m³ hr m²	38	0.5	21.1	21%	£0	£0	£0
Delayed start thermostat, time and temperature control	76	1.0	20.1	25%	£120	£120	£2
4 m² solar water heating	158	2.1	18.1	33%	£3,670	£3,790	£50
0.75 kV of Photovoltaic array	303	4.0	14.1	47%	£6,120	£9,910	£130
15 kW Biomass system	801	10.5	3.6	86%	£5,340	£15,250	£199
0.25 kV of Photovoltaic array	101	1.3	2.3	91%	£2,040	£17,290	£226
Option B Small Scale Wind							
Baseline		0	21.6	19%	£0	£0	£0
Reduce air permeability to 5 m³ hr m²	38	0.5	21.1	21%	£0	£0	£0
Delayed start thermostat, time and temperature control	76	1.0	20.1	25%	£120	£120	£2
1.5 kW wind turbine (1100 kWh) (five in eight homes)	391	5.1	15.0	44%	£1,773	£1,893	£25
Delayed start thermostat, time and temperature control	76	1.0	14.0	48%	£120	£2,013	£26
4 m² solar water heating	158	2.1	12.0	55%	£3,670	£5,683	£74
1.5 kW wind turbine (1100 kWh) to achieve level of one for each home	234	3.1	8.9	67%	£1,064	£6,746	£88
15 kW Biomass system	662	8.6	0.3	99%	£5,340	£12,086	£158

Table A.6 Detailed breakdown of costs of achieving carbon targets for the SixtyK House

Efficiency measure	CO_2 saving by measure (per year)	CO_2 emissions	CO_2 emissions (kg m[2])	% improvement on TER	Additional cost per measure	Total additional cost	£/m[2] per measure
Baseline			10.3	46%	£0	£0	£0
Specific fan power of 1 W/l/s	94	1.2	9.0	53%	£64	£64	£1
Change boiler fuel to Biomass	910	47.7	0.6	97%	£1,390	£1,454	£19

Appendix B: Site wide energy solutions

The use of a site wide approach to carbon saving could offer benefits in terms of cost, practicalities and spatial requirements in comparison to measures applied for an individual building. The use of a single, centralised, piece of equipment in place of several independent units can reduce inefficiencies, while also facilitating easier maintenance of the system. The financial and other considerations associated with site wide solutions for energy supply are considered in Section 9.

A number of technologies were assessed on a site-wide basis for comparison with the use of the individual systems applied to each of the house types. The following assumptions were made with regards to the site, for the prediction of the energy demand, only:

- Mixed use site
- 200 residential units
- Proportion of residential units assumed at 40% detached, 40% terraced and 20% apartments
- Where present, a CHP system (site wide) would run for 4,500 hours per year
- Site has an appropriate wind resource

The following energy strategies are applied to the theoretical 200 unit site. It should be remembered that these are theoretical models and the feasibility of each of the systems would require thorough investigation for any proposed installation. The costs of these site wide options have been averaged across each of the units in the development based on their floor area.

Combined Heat and Power (Whole Site)

The simultaneous generation of both electricity and thermal energy is an efficient use of a single fuel source. CHP systems use a turbine to generate electricity, and the heat produced is reclaimed and used to provide hot water for either space heating or domestic hot water use.

If a community CHP system were to be introduced across the site, then the following specifications would apply:

- CHP units totalling 115 kWe/145 kWth
- Gas fired boilers totalling 2,855 kW
- Removal of boilers from individual dwellings

The CHP unit would supply 100% of the electricity load, and 50% of the thermal load to each of the residential units. The resulting annual CO_2 savings per unit would be as follows:

- Detached house 1,179 kg CO_2
- Terraced house 1,179 kg CO_2
- Apartment 871 kg CO_2

Average cost per dwelling (£/m²)	£22.6
Level of Code compliance	Level 4

Community Heating – Biomass

The use of energy crops as a fuel source is considered to be a 'carbon neutral' process, as the amount of CO_2 released during combustion is equal to that absorbed during the growth of the plants. Crops such as Willow or Hazel can be grown and harvested for use in a biomass system. Alternatively, fuel can be bought and imported to site, usually in the form of wood chips, pellets, or certain types of grain.

To meet the heating load of the residential portion of the site, a biomass system with a peak capacity of 1,500 kW would be required. In both of the options listed below, a storage facility of up to 150 m^3 would also be required.

Three biomass boilers would be installed, to provide enough total capacity to meet the full load. This arrangement has a higher initial cost, but will increase reliability and will also allow the system to operate more efficiently at part loads.

In both options, the annual CO_2 savings would be as follows:

- detached house 1,344 kg CO_2
- terraced house 1,117 kg CO_2
- apartment 925 kg CO_2

Average cost per dwelling (£/m²)	£67.85
Level of Code compliance	Level 4

Wind Turbine

Rather than fitting a small scale wind turbine to each of the houses in the development, it could be more efficient, economic and practical to install a single large scale turbine for the site as a whole.

The options are as follows:

- 2 turbines at 100 kW (hub height 35m, rotor diameter 21m)
- 1 turbine at 200 kW (hub height 42m, rotor diameter 29.5m)

Assuming an appropriate available wind resource on site, the following annual CO_2 savings will apply, per dwelling:

- detached house 1134 kg CO_2
- terraced house 1134 kg CO_2
- apartment 837 kg CO_2

Average cost per dwelling (£/m²)	£67.85
Level of Code compliance	Level 4

Summary of site wide approaches

Each of the site wide measures investigated would deliver carbon savings that are sufficient to meet at least level 3 of the Code (independent of other energy efficiency measures) with cost implications of between £12 m² (wind) and £67 m² (biomass). It is likely that medium/large wind turbines are unlikely to be appropriate for many development sites meaning that a more likely site wide solution would be gas fired CHP (£22 m²).

The cost of £22 m² for a CHP system is compares well with the cost of achieving Code level 4 using dwelling level measures (where the cost is around £22-£25 per m² for houses), particularly if this capital cost can be covered by an ESCO. However, the feasibility and environmental benefit will be dependent on site specific considerations such as layout, density and tenure (see Section 9) and it is unlikely that such systems will be suitable for small developments.

Appendix C: Summary of energy/carbon assessment process

The energy/carbon performance of each dwelling was calculated using the Government's Standard Assessment Procedure (SAP). The SAP method was used in line with the specific requirements of Approved Document Part L of Building Regulations (Part L). This method predicts energy consumption for heating, hot water, lighting and building services (i.e. pumps and fans), but does not consider energy used by appliance.

Energy consumption is modelled by assessing:

- materials used for construction of the dwelling
- thermal insulation of the building fabric
- ventilation characteristics of the dwelling and ventilation equipment
- efficiency and control of the heating system(s)
- solar gains through openings of the dwelling
- the fuel used to provide space and water heating, ventilation and
- lighting
- renewable energy technologies

The assessment is not affected by geographic location or the likely number of occupants of the dwelling.

In predicting the energy consumption and carbon emissions from a home (i.e. the DER) the certain fixed parameters were adopted in line with the requirements of Part L. For example, all homes were modelled on the basis that only 30% of the lighting would be energy efficient as this is the factor required for a Part L compliant assessment. Increasing the percentage of low energy lighting would reduce the energy/carbon emissions from the home but this benefit is not recognised in the DER calculation. Similarly, all homes were modelled on the basis that a secondary heating system would provide 10% of the home's heating needs (except those using a communal heating system).

Carbon emissions were calculated from the predicted energy consumption in kWh from different fossil fuel or renewable sources, using the emission factors set out in SAP 2005 and shown in Table C.1.

Table C.1 Emission factors for different fuel sources

Fuel	Kg CO_2 per kWh
Mains Gas	0.194
Electricity	0.422
Electricity generated from CHP	0.568
Biomass (wood pellets / chips)	0.025

Where electricity was generated onsite the carbon emissions avoided (i.e. the reduction in the total home carbon emissions) was calculated using the SAP 2005 emission factor for electricity displaced from the grid (0.568 kg per kWh)