



The **Concrete Centre**™

# Energy and CO<sub>2</sub>

## Achieving targets with concrete and masonry



Guidance on meeting the requirements of the Code for Sustainable Homes

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## About this Publication

Of the nine design categories in the Code for Sustainable Homes, 'Energy and CO<sub>2</sub>' accounts for up to 36 of the 100 available points. This reflects the importance placed on minimising operational CO<sub>2</sub> emissions relative to the other impacts included in the Code. Realising these points can require significant use of renewable energy along with enhanced insulation and air leakage performance. This guide focuses on these issues in the context of masonry and concrete construction, and presents a range of fabric and services solutions for meeting code requirements. A supporting commentary is also provided on the practicalities of achieving the enhanced levels of fabric performance that are necessary.

Much of the work underlying the guide was carried out by a working group comprising members of the Home Builders Federation (HBF) and the Modern Masonry Alliance (MMA).

The guidance offered is made in good faith and is based on SAP 2005. A major update of SAP 2005 is expected in 2008 and may affect some of the conclusions reached in this guide.

### Notes:

- For clarity, degrees Celsius (°C) is used (where appropriate) for references to temperature in this publication.
- Calculations relating to partial fill cavity walls assume a 50mm air gap. However, it should be noted that in some parts of the country a 75mm air gap may be required.
- 'Passiv Haus' refers to a specific construction standard for residential buildings. For more information visit [www.passivhaus.org.uk](http://www.passivhaus.org.uk).

The Code for Sustainable Homes presents considerable challenges for all types of construction, and with regard to energy, requires what is effectively a step change in thermal performance. Central to this is the need for enhanced insulation and reduced air leakage. The research underlying this guide examined these issues in the context of masonry and concrete construction and reached a number of specific conclusions which are detailed below.

If these were to be summarised, it could be said that the overarching outcome of the study has been to show that the standard of fabric performance required at each level of the Code can be achieved with the systems and materials available today. However, ongoing improvements in the performance and cost of renewable technologies and products such as triple glazing will assist future code compliance, particularly at the higher levels.



## Key Conclusions

### The Code Challenge

At each level of the Code the challenges for different house types are the same for all materials. See Figure 4 on pages 6-7.

### No single approach

No single design approach to minimising CO<sub>2</sub> emissions will suit all house types. For example, houses with a large exposed area benefit most from improved U-values, whilst smaller attached units benefit more from the introduction of renewable energy.

### Wall U-values – code levels 3 and 4

A U-value of between 0.2 and 0.28 W/m<sup>2</sup>K for external walls was found to be appropriate for code levels 3 and 4.

### Wall U-values – code levels 5 and 6

At code levels 5 and 6, the optimal U-value for all types of wall construction may currently be around 0.15-0.17 W/m<sup>2</sup>K, reflecting the best balance between overall CO<sub>2</sub> reduction and insulation costs.

### Orientation

Orientation and passive solar design have an important role to play in optimising heating energy requirements and the performance of active solar systems. The thermal mass in concrete and masonry construction allows full benefit to be made of passive solar design.

### Air leakage

Concrete and masonry can provide robust, long term solutions to airtight construction and can achieve air leakage rates below 2m<sup>3</sup>/(h.m<sup>2</sup>) with good site practice and detailing.

### Airtightness at code levels 5 and 6

At code levels 5 and 6, insulation and airtightness requirements are essentially the same for all construction systems, and the emphasis shifts to the provision of renewable energy.

### Cavity width

A cavity width of 150mm can provide a U-value of 0.15 W/m<sup>2</sup>K, which equates with Passiv Haus performance and is suitable for the highest level of the Code.

# Introduction

The Code for Sustainable Homes provides an overall sustainability rating for new dwellings, assessed against nine key design categories of which Energy and CO<sub>2</sub> is the most significant.

In December 2006, the Code for Sustainable Homes - a new national standard for the sustainable design and construction of homes - was launched. The Code assesses sustainability against nine key design categories (see Figure 1), resulting in an overall rating for the home. Minimum standards for energy and water efficiency at every level of the Code were introduced, with minimum standards for compliance set above Building Regulation requirements.

The overall sustainability performance of a new home is assessed using a rating system of 1 to 6, with level 6 representing the highest standard that can be achieved. Assessment is carried out during the design stage, and is then followed up with a further assessment at completion to verify 'as built' compliance.

Figure 1: The nine design categories (in order of significance)

Code category	Maximum points
1. Energy	36.4 points
2. Health and well-being	14.0 points
3. Ecology	12.0 points
4. Management	10.0 points
5. Water	9.0 points
6. Materials	7.2 points
7. Waste	6.4 points
8. Pollution	2.8 points
9. Surface water run off	2.2 points
<b>Total</b>	<b>100 points</b>

A more detailed overview of the points available in each category is provided in Appendix A, along with a possible route to compliance at each code level.

The relatively broad scope of the Code provides a range of design options to achieve the stated number of points at each level; however the mandatory requirements for energy and water limit flexibility in these categories, particularly at higher code levels. Energy and CO<sub>2</sub> is the highest scoring of the nine categories, attracting up to 36.4 of the 100 available points.

The Energy and CO<sub>2</sub> category points are further subdivided between a maximum of 18.8 mandatory points awarded for specific improvement over Part L of the Building Regulations at each code

level (largely fabric related), and a further 17.6 non-mandatory points available in eight sub-categories (see Figure 2). This publication focuses on achieving the mandatory points in the energy category using concrete and masonry construction.

Figure 2: Energy and CO<sub>2</sub> sub-categories

Energy and CO <sub>2</sub> sub-category	Maximum points
<b>1. Mandatory improvement on Part L target emission rate (TER)</b>	<b>18.8 points</b>
2. Reduced fabric heat loss parameter	2.5 points
3. Energy efficient internal lighting	2.5 points
4. Low/zero carbon energy	2.5 points
5. Eco-labelled white goods	2.5 points
6. Energy efficient external lighting	2.5 points
7. Cycle storage	2.5 points
8. Provision of drying space	1.3 points
9. Home office space	1.3 points
<b>Total</b>	<b>36.4 points</b>

The percentage improvement required over the target emissions rate (TER) required by Part L is shown in Figure 3. Code level 3 needs a 25% TER improvement, i.e. CO<sub>2</sub> emissions set at least 25% lower than basic Part L compliance. Similarly, code level 4 needs a 44% improvement on Part L, and requires 10.04 points. The design measures needed to achieve code levels 5 and 6 with regard to energy are essentially the same for all types of construction, requiring significant use of renewable energy in conjunction with a very high standard of fabric performance.

Figure 3: Anticipated mandatory improvement in CO<sub>2</sub> emissions

Code level	Percentage improvement over TER required by Part L1A (2006)	Points required	Government target for regulatory introduction
1	10% (EST 'Good Practice' level)	1.25	-
2	18%	3.77	-
3	25% (EST 'Best Practice' level)	6.28	2010
4	44% (similar to 'Passiv Haus' standard)	10.04	2013
5	100% (zero emissions: heating, hot water, ventilation and lighting)	17.57	-
6	≈ 140% (zero net emissions from all energy use in the home)	18.83	2016

**Note:**

The Callcutt Review [1] of house building contains a diagram showing the critical path to delivery of zero carbon homes up to 2016 and beyond (see Figure 25 on page 95 of the review which can be downloaded at [www.communities.gov.uk/documents/housing/pdf/callcuttreview](http://www.communities.gov.uk/documents/housing/pdf/callcuttreview))

# Achieving Mandatory Energy and CO<sub>2</sub> Requirements

There are a number of different routes to achieving the Code's mandatory energy and CO<sub>2</sub> requirements, combining different fabric and services options to provide the most appropriate solution for each housing development. Work was undertaken to establish routes to achieve the necessary energy/CO<sub>2</sub> savings using currently available fabric and services systems. The results are summarised on pages 6-7 and are applicable to all forms of construction (e.g. concrete, masonry, timber, steel etc).



Jetfloor construction can greatly reduce U-values of ground floors. Courtesy of Hanson.

## Background assumptions

Whilst the flexibility permitted in Part L (2006) allows for a good deal of variation in design, options become more limited in the Code, particularly at the higher levels. Figure 4 (pages 6-7) shows the ability of various fabric and services options to meet the specific improvement in performance required at each code level. Six dwelling types are considered in combination with four fabric specifications. All calculations were undertaken using the BRE-approved SAP 2005 software JPA Designer version 4.02.

Services options include use of a high performance gas boiler with radiators; mechanical ventilation with heat recovery (MVHR); solar hot water; photovoltaics and a ground source heat pump. Variations in fabric performance largely focus on the air leakage rate and U-values for external walls, which are of particular relevance to this guide. Specifications One, Two and Three represent a standard of construction broadly appropriate up to code level 4, while Specification Four is more appropriate to code levels 5 and 6.

**Specification One** has an external wall U-value of 0.28 W/m<sup>2</sup>K. This can typically be achieved in a cavity of 100mm or less. The details for Specification One are shown below:

- Wall : U = 0.28 W/m<sup>2</sup>K
- Roof : U = 0.11 W/m<sup>2</sup>K
- Floor : U = 0.18 W/m<sup>2</sup>K
- Openings : U = 1.5 W/m<sup>2</sup>K
- East/west orientation
- Thermal bridging y-value: 0.04 W/m<sup>2</sup>K
- Air leakage: 5m<sup>3</sup>/(h.m<sup>2</sup>) at 50 Pa
- Boiler SEDBUK value: 90% (with zone control)
- 100% energy efficient lighting
- 50mm cylinder insulation

The assumed east/west orientation reflects situations where a more southerly aspect is not possible. The effect of orientation on a dwelling's performance is discussed under the heading 'Orientation' in this guide. Similarly, the thermal bridging y-value and use of 100% energy efficient lighting are discussed elsewhere in this guide.

**Specification Two** is the same as Specification One, but with external walls that have a lower U-value of 0.2 W/m<sup>2</sup>K. In cavity walls this can typically be achieved with a cavity of around 120mm to 140mm.

**Specification Three** is the same as Specification Two, but with the addition of MVHR and an assumption that there is no secondary heating in the dwelling. The rationale for this, explained under the heading 'Secondary Heating', reflects likely changes to Part L of the Building Regulations.

**Specification Four** differs from Specifications One, Two and Three in several areas, and broadly reflects Passiv Haus standards in terms of air leakage and insulation. The details for Specification Four are shown below:

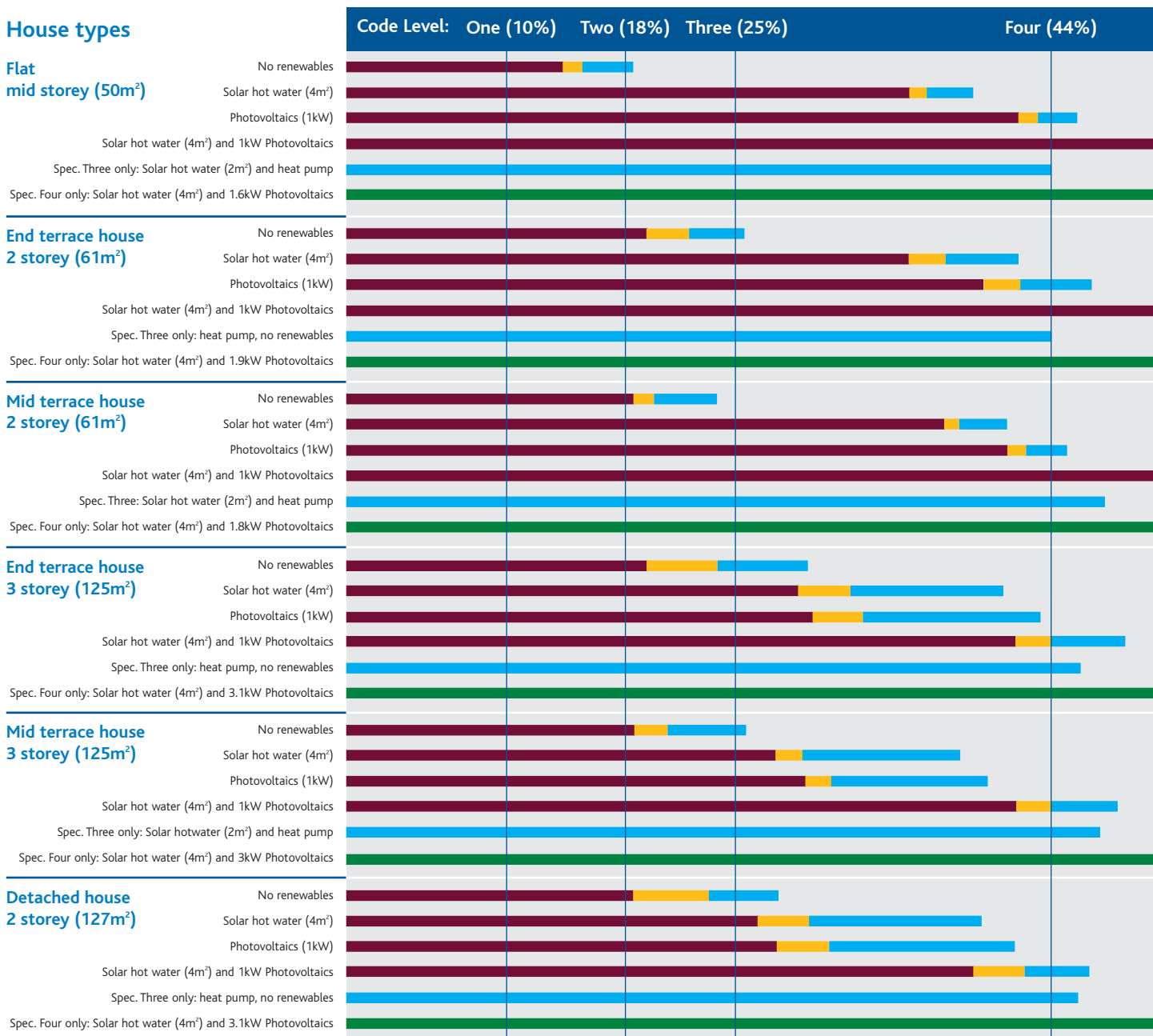
- Walls : U = 0.15 W/m<sup>2</sup>K
- Roof : U = 0.11 W/m<sup>2</sup>K
- Floor : U = 0.15 W/m<sup>2</sup>K
- Openings : U = 0.8 W/m<sup>2</sup>K
- Southern orientation with optimised glazing
- Thermal bridging y-value: 0.04 W/m<sup>2</sup>K
- MVHR with air leakage of 2m<sup>3</sup>/(h.m<sup>2</sup>) at 50 Pa
- No secondary heating
- Ground source heat pump with zone control
- 100% energy efficient lighting

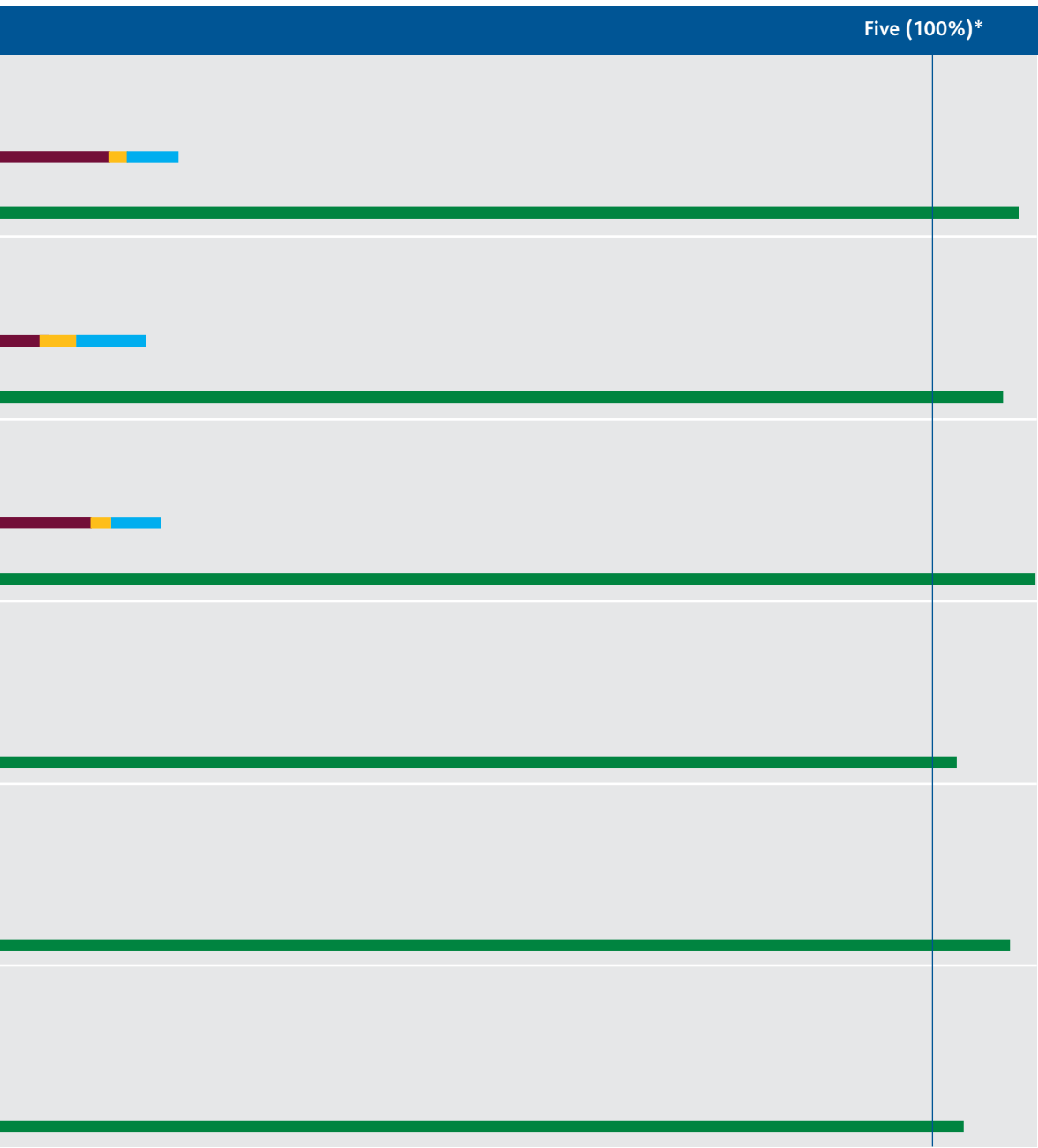
It is possible to achieve the wall U-value of 0.15 W/m<sup>2</sup>K used in Specification Four with a 150mm partial fill cavity. Specification Four can be used to achieve code level 5 performance when used in combination with a solar hot water system and a relatively large photovoltaic array (approximately 1.6kW to 3.1kW depending on dwelling type), for which the orientation is optimised for best performance. With the addition of more extensive renewable technology, Specification Four may also be appropriate for code level 6 performance, an area beyond the scope of this guide.

# The Code Challenge

The challenge is the same for the whole construction sector. The figure below shows generic solutions for achieving energy/CO<sub>2</sub> requirements at each level of the Code and is relevant to all building materials.

**Figure 4:** Code compliance of common house types with varying thermal performance, use of renewables and services





Specification One



Specification Two



Specification Three



Specification Four

**\*Note:**  
Moving from code level 5 to 6 requires greater use of renewable technology, and is essentially not a building fabric issue.

## Conclusions from Figure 4

It is clear that there is no single solution that can be applied to all dwelling types. Those with a large exposed area, such as detached houses, will benefit more from improved U-values than smaller mid terrace units. Conversely, it appears that smaller attached units will benefit more from the introduction of limited renewable energy. This is demonstrated by the ability of the flat, end terrace house (61m<sup>2</sup>) and mid terrace house (61m<sup>2</sup>) to comfortably exceed code level 4 using Specification One in combination with limited renewables. This is not possible with the other types of dwelling, particularly the detached house, which requires the higher performance of Specification Three to achieve the same result.

### Achieving code level 3

Improving U-values and airtightness alone may not be sufficient to achieve code level 3. For example, lowering the U-value of external walls from 0.28 to 0.2 W/m<sup>2</sup>K (i.e. moving from Specification One to Two) results in a modest improvement to performance, but is not enough to achieve code level 3 without enhancements to the heating and ventilation systems (the basis for Specification Three) or the addition of renewables.

Specification Three is sufficient to reach code level 3 without the need for renewables or heat pump technology in four of the six dwelling types considered.

### Achieving code level 4

With the addition of solar hot water and a heat pump, Specification Three can achieve code level 4 without the need for photovoltaic panels. Alternatively, Specification Three in combination with judicious use of solar hot water and photovoltaics achieves the same result.

### Achieving code level 5

Specification Four shows that additional improvements to fabric and services, combined with greater use of photovoltaics, is one route to code level 5. However, the required panel area is relatively large and may come up against both practical and financial limitations. This problem may reduce in the future as the scale of panel production and operating efficiency continues to improve.

## Points to note

**Hot water tank heat loss factor** – The CO<sub>2</sub> emissions from hot water have become a significant contributor to the overall emissions in low energy dwellings. Improving the heat loss factor for the hot water cylinder to 1.97 [2] from that provided by say 50mm of tank insulation can provide a CO<sub>2</sub> saving greater than moving the wall U-value from 0.17 to 0.15 W/m<sup>2</sup>K. Viewed another way, it could also enable the use of a full fill cavity wall instead of a more expensive partial fill cavity, without increasing CO<sub>2</sub> emissions.

**Biomass** - Where planning and fuel availability allows, biomass as a district or stand-alone scheme potentially represents an attractive option for carbon reduction for code levels 5 and 6.

**Heat Loss Parameter (HLP)** – Credits are available in the non-mandatory part of the Energy and CO<sub>2</sub> category for a low HLP (1 credit for an HLP smaller than or equal to 1.3, increasing to 2 credits for a value of 1.1 or lower). Whilst these credits are achievable in highly insulated dwellings, it may require smaller windows to reduce heat loss, which could in turn impact on the credits available in the Health and Wellbeing category of the Code for a good standard of daylighting. Smaller windows may also impact on the energy savings that can be achieved through passive solar design (see page 13).



Ground source heat pumps are an effective way of reducing CO<sub>2</sub> emissions from heating and hot water. Courtesy of Kensa Heat Pumps.

# Design Considerations

## Airtight construction

Appropriately designed and constructed masonry dwellings can achieve levels of air leakage below  $2\text{m}^3/(\text{h}\cdot\text{m}^2)$ .

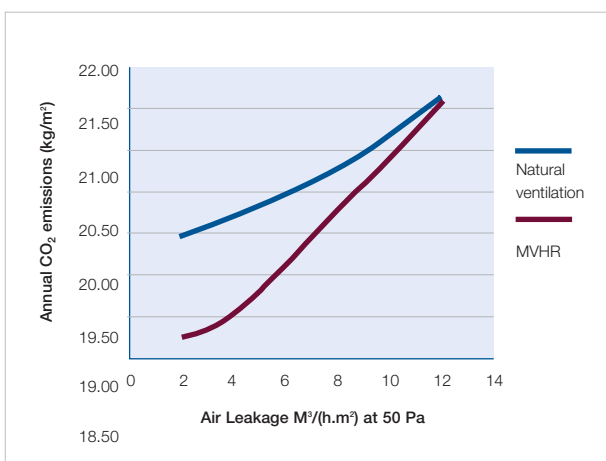
Air leakage from the uncontrolled movement of air through joints and gaps in the building fabric can be a significant source of heat loss, particularly in a well insulated home where the impact will be proportionately higher. The units of measurement are  $\text{m}^3/(\text{h}\cdot\text{m}^2)$  at 50 Pa. This is the volume of air in cubic metres replaced every hour per square metre of floor, at a fixed difference between the internal and external pressure of 50 Pascals. The introduction of the  $10\text{m}^3/(\text{h}\cdot\text{m}^2)$  limit in Part L has gone a long way towards ensuring a minimum standard of airtightness in all new dwellings, but better performance will help towards achieving code compliance, particularly at the higher levels. At code levels 3 and 4, an air leakage rate of  $5\text{m}^3/(\text{h}\cdot\text{m}^2)$  or better is a good performance target (see Figure 5).

The routes for air leakage can be complex. Careful attention should be paid to the following areas[3]:

- Plasterboard dry-lining on dabs or battens.
- Cracks, gaps and joints in the structure (due to shrinkage, settlement, or perpend joints in brickwork).
- Joist penetrations of external walls (especially inner leaves of cavity walls).
- Service entries and ducts (gas, water, drainage pipes, cabling).
- Areas of unplastered/unparged masonry wall (e.g. intermediate floors, behind baths etc.).

Figure 5: Influence of air leakage on CO<sub>2</sub> emissions

Two storey, end terrace house (61m<sup>2</sup>) conforming to Specification One detailed on page 5.



The primary air barrier is central to any airtightness scheme. It needs to be impermeable, continuous and durable. Typically the simplest solutions are the most buildable and durable. There are essentially three ways of creating a primary air barrier in masonry construction:

- **Dry-lining** can be used to form the air barrier through careful edge sealing around perimeters and junctions. To achieve this, plasterboard is mounted on a continuous perimeter ribbon of adhesive. With a high standard of workmanship, dry-lining can be reasonably effective at meeting the requirements of a pressure test, with anecdotal evidence suggesting air leakage rates as low as  $2.5\text{m}^3/(\text{h}\cdot\text{m}^2)$  [4]. However, compared to other options, it may not offer such a robust, long-term solution to airtightness. Another limitation is that air can still permeate the blockwork and potential leakage paths may remain behind the board, allowing air to pass into ceiling cavities, floor voids and partitions [5].
- A **paring coat** is basically a sand and cement render which, when applied, seals the blockwork, creating a primary air barrier. Once applied, the wall can then be dry-lined in the usual way. Edge sealing of the plasterboard may further reduce air leakage, although this is likely to be limited if the paring coat has been effectively applied.
- **Wet plastering** will seal the blockwork to provide an effective air barrier. An air pressure survey [6] of masonry housing showed that, of the houses tested, those built in the 1980s, when dry-lining was not ubiquitous, tended to perform better than newer homes built in the 1990s which were all dry-lined. It was also found that the best performing masonry dwellings in a 1984–1994 sub-set performed as well as the best of the framed houses with an air leakage index of 3 to  $4\text{m}^3/(\text{h}\cdot\text{m}^2)$ .

Although wet plastering traditionally takes longer than dry-lining, projection systems which spray-apply the plaster can significantly increase productivity and are growing in popularity. A design consideration for any plaster finish is the routing of services which, without the convenience of a dry-lining cavity, is less straightforward. To tackle this some developers are starting to use surface mounted trunking - a tried and tested system in commercial buildings. In addition to providing a convenient means of distributing all types of cabling, trunking assists the ongoing integrity of the plaster air barrier by helping to avoid the need for chasing and drilling when new cabling or additional sockets are required.

## Air leakage – insulating concrete formwork (ICF)

ICF construction is capable of providing a low level of air leakage due to the sealing effect of the concrete pours and the low permeability of the insulating formwork. This combination provides a highly effective air barrier that is capable of achieving an air leakage rate of around  $2\text{m}^3/(\text{h}\cdot\text{m}^2)$  or better [7]. The simplicity and robust nature of ICF will help ensure that the integrity of the air barrier is maintained over the life of the building.

## Stamford Brook development

Leeds Metropolitan University recently undertook an extensive study into buildability and performance issues at Stamford Brook, a development of 700 highly insulated and airtight masonry houses on the National Trust's Dunham Massey Estate in Cheshire. After extensive monitoring of the construction process and pressure testing of the completed houses, the analysis demonstrated that cavity masonry construction is perfectly capable of delivering  $5\text{m}^3/(\text{h.m}^2)$ , even in dwellings with more complex forms [8]. This level of performance was achieved through the application of a thin parging layer to the inner leaf of all external and separating walls to seal the blockwork to form a primary air barrier. In addition, the plasterboard dry-lining was edge sealed to form a further air barrier from the ground floor to the uppermost ceiling. Careful attention was also paid to sealing around windows, service penetrations and joists etc.

Achieving such consistently low levels of air leakage was found to depend as much on good site practice as on buildability and detailed design. A high standard of communication and feedback, along with care over sequencing and the implementation of a quality system, all played an important part. A key recommendation of the study is that the quality system should specify the location of the primary air barrier, identify any potential discontinuities in the barrier and provide information on what measures need to be adopted on site to ensure the barrier's continuity during construction [9]. As mentioned, the airtightness work at Stamford Brook demonstrated that masonry construction is perfectly capable of delivering  $5\text{m}^3/(\text{h.m}^2)$ , and that when the issues outlined above are appropriately managed, parged masonry walls linked to airtight top floor ceilings and ground floors were shown to achieve a pressure test result below  $2\text{m}^3/(\text{h.m}^2)$  [8].

It was generally felt by the university research group that a parging layer is an effective means of providing a primary air barrier, and offers a much more robust solution than relying solely on dry-lining to perform this task.

Practical feedback on the Stamford Brook development, can be found using the following link:  
[www.leedsmet.ac.uk/as/cebe/projects/stamford/](http://www.leedsmet.ac.uk/as/cebe/projects/stamford/)



Window fitted and sealed to parging layer at the Stamford Brook development. Courtesy of Leeds Metropolitan University.



Built in joists with parging layer into the intermediate floor void, excess around the joists struck off and sealant applied (Stamford Brook development). Courtesy of Leeds Metropolitan University.



Plastic joist seals are another option for reducing air leakage associated with built timber joists. Courtesy of Manthorpe Building Products Ltd.

## Mechanical ventilation with heat recovery (MVHR)

MVHR can help in achieving higher code level performance where the air leakage rate is around  $5\text{m}^3/(\text{h}\cdot\text{m}^2)$  or less.

Airtight construction reduces heat loss, but with minimal background infiltration, ventilation becomes more critical and must be carefully controlled if this benefit is to be realised. Passive ventilation from windows and trickle vents may not provide a sufficient level of control, leading to excessive heat loss or insufficient fresh air. To counter this problem and optimise energy efficiency, an MVHR system can be used. This supplies air at a controlled rate into the dwelling and extracts stale air at a similar rate. A simple plate heat exchanger inside the unit takes heat from warm, moist air extracted from 'wet' rooms, and uses it to preheat the incoming fresh air. The energy saved through heat recovery will be greater than that used to power the unit providing it is correctly sized, installed and maintained. The length of the heating season and regional climatic conditions will also influence overall effectiveness. To maximise efficiency, the fan power should be around  $1\text{W}/\text{l/s}$  or lower, and the heat recovery efficiency should be 85% or higher.

As a rule of thumb, worthwhile energy saving benefits of MVHR are only realised in properties with an air leakage rate of around  $5\text{m}^3/(\text{h}\cdot\text{m}^2)$  or lower, where nearly all of the ventilation air will pass through the heat exchanger [10]. Without a good standard of airtightness, the use of MVHR can add to the natural infiltration rate [11], reducing energy efficiency.

## Low energy lighting

The increased use of low energy lighting can provide a significant opportunity for additional  $\text{CO}_2$  reductions.

Lighting is becoming an increasingly significant component of  $\text{CO}_2$  emissions as dwellings become more highly insulated. For example, lighting accounts for 15% of the emissions in a 2006 compliant gas heated semi-detached house with 30% low energy lighting [12]. This means that increased use of this technology could provide a significant opportunity for additional  $\text{CO}_2$  reductions. As the technology has matured rapidly in recent years, the government will be investigating the possibility of allowing the percentage of low energy lighting to be varied in the standard assessment procedure (SAP) calculation [12]. This is currently limited to a maximum of 30%, but the Code offers two points for values greater than 75%. Based on the likelihood that the CLG will permit higher values in the next revision of SAP, and the current inconsistency between SAP and the Code on this issue, the dwellings investigated in Figure 4 were assumed to have 100% low energy lighting.

## Secondary heating

The concept of secondary heating may no longer be appropriate as dwellings become more highly insulated.

The 2006 edition of Part L of the Building Regulations assumes that householders use some secondary heating with a higher carbon burden than the main heating system. Consequently, the SAP calculation makes an allowance for 10% of the heating load to be met by electric secondary heating, unless specific provision is made for a fixed secondary system. However, as dwellings become better insulated, dependence on the primary heating system is likely to decrease, with greater reliance on secondary heating systems. In response to this, the CLG forward look [12] at future energy efficiency requirements suggests a possible change to the rules on secondary heating. The point is made that in some highly insulated dwellings, usage of the secondary heating system could be as high as 100%, effectively replacing the primary system and leading to a situation where the concept of secondary heating no longer applies. On this basis, it has been assumed that there is no secondary heating in Specifications Three and Four detailed in Figure 4.

## Thermal bridging (non-repeating)

The development of new Enhanced Construction Details by the Energy Saving Trust will significantly reduce the impact of non-repeating cold bridging in all forms of construction.

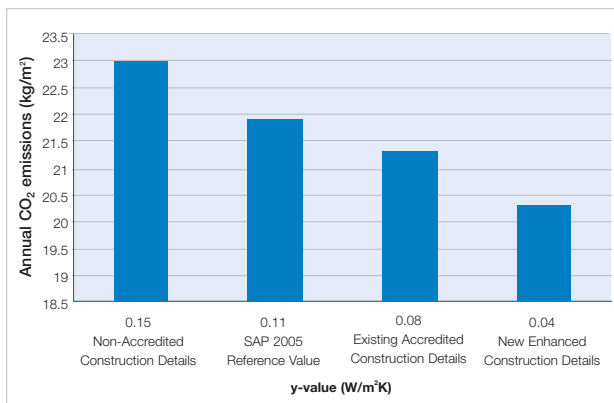
The ongoing improvements to the standard of insulation required by Part L has increased the proportion of total heat loss from thermal bridging, making it more important to reduce its impact. Since the introduction of SAP 2005, non-repeating thermal bridges e.g. those that occur at junctions, corners and lintels have been included in the calculation of transmission heat losses. Repeating thermal bridges such as wall ties and mortar joints are already accounted for in the U-value calculation: see Thermal bridging (repeating).

The rate of heat loss for a non-repeating thermal bridge is determined by its linear thermal transmittance or  $\psi$  in W/mK. When the value of  $\psi$  is known, it can be multiplied by the length (L) of the bridge to give the heat loss from the thermal bridge ( $H_{TB}$ ). In other words:  $H_{TB} = \Sigma (L \times \psi)$ . If Enhanced Construction Details are used, default values of  $\psi$  can be applied. However, an alternative, and typically more practical approach, is to use a default heat loss coefficient known as the y-value (W/m<sup>2</sup>K) to give an estimation of the overall heat loss in a dwelling from non-repeating cold bridging. The y-value is simply multiplied by the total area of exposed elements in the dwelling. In other words:  $H_{TB} = y \times \Sigma A_{exp}$ . Providing Enhanced Construction Details are used, the y-value is assumed to be 0.08. If Enhanced Construction details are not used a y-value of 0.15 must be used.

New Enhanced Construction Details currently being developed will enable a lower y-value of 0.04 to be used, offering a means of further reducing fabric heat loss. As a consequence, a y-value of 0.04 has been assumed in all the specifications detailed in Figure 4. The new Details will include the use of separate lintels in masonry construction and improved performance at wall to ground floor junctions, and wall to ceiling insulation at gable ends. The significance of the y-value on CO<sub>2</sub> emissions is shown in Figure 6.

Figure 6: Influence of y-value on CO<sub>2</sub> emissions

Two storey, end terrace house (61m<sup>2</sup>) conforming to Specification One detailed on page 5.



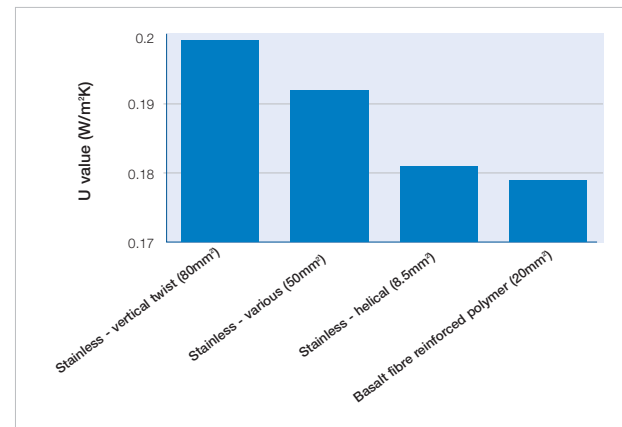
## Thermal bridging (repeating)

The use of low conductivity wall ties can significantly improve the thermal performance of walls with larger cavities.

Repeating thermal bridges are those that occur regularly in all construction elements. They include ceiling joists, studwork in walls, mortar joints in lightweight blockwork and wall ties. The effect of conventional wall ties on U-values is negligible in cavities of 100mm or less. However, the more substantial ties typically required in cavities of 100mm or more can increase heat loss. To a limited extent this undermines the benefit of the thicker insulation made possible by a larger cavity. To counter this, low conductivity wall ties made from various types of plastic can be used. However, the market for low conductivity ties is currently limited in the UK, although it is anticipated this will change in the near future as demand increases in response to the Code.

One product that is available in the UK is a basalt fibre reinforced polymer wall tie, which was developed in Russia. It is used in the same way as conventional ties but has a thermal conductivity of only 0.8 W/mK, around 20 times less than stainless steel. Another option is stainless steel helical ties, which have a relatively small cross sectional area of around 8mm<sup>2</sup> and consequently conduct very little heat. Figure 7 shows the comparative thermal performance of various wall ties in a 150mm cavity.

Figure 7: Influence of wall ties on the U-value of a full fill brick and block cavity wall (150mm cavity)



Images courtesy of Leeds Metropolitan University.

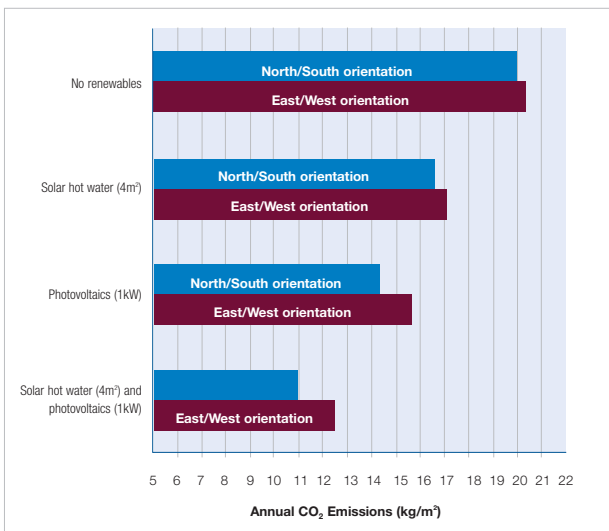
## Orientation

Optimising orientation will reduce a dwelling's heating energy requirement and can improve the performance of solar hot water and photovoltaic systems.

A southern orientation can reduce heating energy requirements, particularly in masonry and concrete dwellings which offer useful levels of thermal mass to maximise the storage of solar gains (passive solar design). However, Specifications One, Two and Three in Figure 4 are based on an east/west orientation, which is not the most favourable in terms of CO<sub>2</sub> emissions, but reflects the lack of choice that often exists over this design issue. Where a southern aspect is possible, an additional reduction in emissions can also be achieved through more advantageous positioning of photovoltaic and solar hot water panels. Figure 8 shows the reduction in CO<sub>2</sub> emissions that a southern orientation can provide in a two storey end terrace house, where approximately two thirds of the glazing is located on the south façade (in Specifications One, Two and Three the glazing area was divided evenly between the east and west facade).

Figure 8: Influence of orientation on CO<sub>2</sub> emissions

Two storey, end terrace house (61m<sup>2</sup>) conforming to Specification One detailed on page 5, with two thirds of glazing on the south façade, and one third on the north.



The ability of the thermal mass in masonry and concrete dwellings to store heat enables the benefit of solar gain to be maximised during the heating season. However, SAP currently assumes a fixed level of thermal mass for all types of construction, so this benefit is not fully reflected in Figure 8. A revision of the SAP methodology is currently under way, which the government has stated will include a fresh look at the treatment of thermal mass in a summer and winter context [12]. This should lead to the benefits of passive solar design being more accurately calculated. More information on passive solar design and using thermal mass in dwellings can be found in a free publication from The Concrete Centre entitled *Thermal Mass for Housing*. This can be downloaded from The Concrete Centre's website ([www.concretecentre.com/publications](http://www.concretecentre.com/publications)).

## U-values - external walls

A 350mm partial fill cavity wall (150mm cavity) can achieve a U-value of 0.15 W/m<sup>2</sup>K using phenolic insulation and aircrete blockwork.

U-values corresponding to the main types of external concrete and masonry walls are detailed in Figure 9. These are not exhaustive, as numerous permutations exist, however they do give a good indication of what can be achieved using standard forms of construction. The wall thicknesses shown are for corresponding U-values of between 0.3 and 0.15 W/m<sup>2</sup>K. Similarly, U-values are shown for walls with a range of thicknesses between 270mm and 415mm. It can be seen that a 350mm partial fill cavity wall (150mm cavity) wall can achieve a U-value of 0.15 W/m<sup>2</sup>K through the use of phenolic insulation and aircrete blocks for the inner and outer leaf.



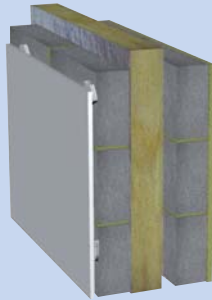
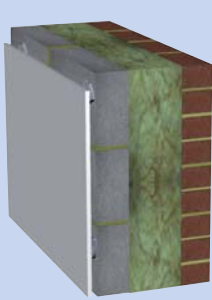
Alternatively, a combination of thin joint aircrete blocks for the inner leaf and facing bricks for the outer leaf can achieve the same result. Similar levels of performance are also possible with solid masonry walls, precast concrete sandwich panels and insulating concrete formwork.

If a wet plaster finish is used as an alternative to plasterboard there is a small increase in the U-value, which becomes less significant as the level of insulation is increased. This slight increase in U-value should be evaluated alongside the potential for any reduced air leakage associated with a plaster finish, as this may well be more significant in terms of minimising heat loss. A plaster finish will also help to maximise the thermal mass that can be provided by a concrete inner leaf. For an aircrete inner leaf, the change in thermal mass when moving from plasterboard to wet plaster is less significant than for denser concrete, since the plasterboard and air gap is less of a bottle neck to the lower rate of heat flow and thermal capacity of aircrete. In practical terms, the use of aircrete with plasterboard will provide around twice the thermal mass of an alternative light weight construction system, increasing to around three times as much thermal mass with a plaster finish. Similarly, dense concrete with plasterboard will provide around three times as much thermal mass as an alternative lightweight construction system, increasing to approximately seven times as much with a plaster finish [13].

For clarity, the number of material options shown in Figure 9 is limited, and a plaster finish is not included. However, the following example illustrates the minimal impact it can have on a highly insulated wall: An all aircrete 350mm partial fill cavity wall can achieve a U-value of 0.15 W/m<sup>2</sup>K with plasterboard on dabs and also with a wet plaster finish.

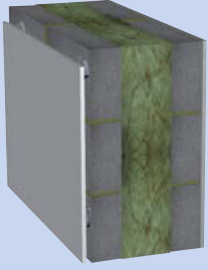

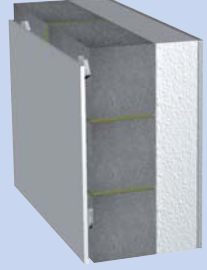


# Code Solutions for External Walls

Figure 9: U-values for external walls in concrete and masonry

<b>Partial fill cavity wall: Brick and 100mm block (aircrete)</b>	<b>Partial fill cavity wall: Brick and 100mm block (aggregate)</b>	<b>Partial fill cavity wall: 100mm block and 100mm block (aircrete) with render</b>	<b>Full fill cavity wall: Brick and 100mm block (aircrete)</b>
 <p>Aircrete block (<math>\lambda = 0.15</math>) Phenolic insulation (<math>\lambda = 0.021</math>) 50mm air gap</p>	 <p>Aggregate block (<math>\lambda = 1.13</math>) Phenolic insulation (<math>\lambda = 0.021</math>) 50mm air gap</p>	 <p>Aircrete block (<math>\lambda = 0.15</math>) Phenolic insulation (<math>\lambda = 0.021</math>) 50mm air gap</p>	 <p>Aircrete block (<math>\lambda = 0.15</math>) Mineral wool (<math>\lambda = 0.033</math>)</p>
<ul style="list-style-type: none"> <li>• 295mm wall (45mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 300mm wall (50mm insulation) <math>U = 0.26 \text{ W/m}^2\text{K}</math></li> <li>• 330mm wall (80mm insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (100mm insulation) <math>U = 0.17 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (100mm insulation) with low conductivity wall ties <math>U = 0.16 \text{ W/m}^2\text{K}</math></li> <li>• 360mm wall (110mm insulation) with low conductivity wall ties <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (100mm insulation) large format thin joint blocks (<math>\lambda = 0.11</math>) <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> </ul>	<ul style="list-style-type: none"> <li>• 300mm wall (50mm insulation) <math>U = 0.30 \text{ W/m}^2\text{K}</math></li> <li>• 305mm wall (55mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 340mm wall (90mm insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (100mm insulation) <math>U = 0.19 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (100mm insulation) with low conductivity wall ties <math>U = 0.17 \text{ W/m}^2\text{K}</math></li> <li>• 370mm wall (120mm insulation) with low conductivity wall ties <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> </ul>	<ul style="list-style-type: none"> <li>• 285mm wall (35mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 300mm wall (50mm insulation) <math>U = 0.24 \text{ W/m}^2\text{K}</math></li> <li>• 320mm wall (70mm insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (100mm insulation) <math>U = 0.16 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (100mm insulation) with low conductivity wall ties <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> </ul>	<ul style="list-style-type: none"> <li>• 285mm wall (85mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 300mm wall (100mm insulation) <math>U = 0.25 \text{ W/m}^2\text{K}</math></li> <li>• 335mm wall (135mm insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (150mm insulation) <math>U = 0.19 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (150mm insulation) with low conductivity wall ties <math>U = 0.18 \text{ W/m}^2\text{K}</math></li> <li>• 380mm wall (180mm insulation) with low conductivity wall ties <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> </ul>

Notes for Figure 9:

- Indicated U-values and wall dimensions are for guidance only.
- Dimensions are rounded to the nearest 5mm, and do not include finishes.
- Results have been obtained using BRE U-Value Calculator version 1.2.
- With the exception of the sandwich panel, the internal finish is assumed to be plasterboard on dabs.

Full fill cavity wall: 100mm block and 100mm block (aircrete) with render	Solid masonry wall: 215mm block (aggregate) mineral fibre insulation and reinforced render	Solid masonry wall: 215mm block (aircrete), extruded polystyrene and reinforced external render	Insulating concrete formwork (ICF) with brick slips (150mm concrete)	Precast concrete sandwich panel (70mm/125mm concrete)
 <p>Aircrete block (<math>\lambda = 0.15</math>) Mineral wool (<math>\lambda = 0.033</math>)</p>	 <p>Aggregate block (<math>\lambda = 1.13</math>) Mineral fibre (<math>\lambda = 0.04</math>)</p>	 <p>Aircrete block (<math>\lambda = 0.15</math>) Extruded polystyrene (<math>\lambda = 0.029</math>)</p>	 <p>Insitu concrete (<math>\lambda = 1.75</math>) Expanded polystyrene (<math>\lambda = 0.034</math>)</p>	 <p>Dense concrete (<math>\lambda = 1.83 - 2.0</math>) PIR Insulation (<math>\lambda = 0.023</math>)</p>
<ul style="list-style-type: none"> <li>• 275mm wall (75mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 300mm wall (100mm insulation) <math>U = 0.22 \text{ W/m}^2\text{K}</math></li> <li>• 325mm wall (125mm insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (150mm insulation) <math>U = 0.18 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (150mm insulation) with low conductivity wall ties <math>U = 0.17 \text{ W/m}^2\text{K}</math></li> <li>• 375mm wall (175mm insulation) with low conductivity wall ties <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> </ul>	<ul style="list-style-type: none"> <li>• 335mm wall (120mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (135mm insulation) <math>U = 0.25 \text{ W/m}^2\text{K}</math></li> <li>• 395mm wall (180mm insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 415mm wall (200mm insulation) with aircrete block <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> <li>• 455mm wall (240mm insulation) <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> </ul>	<ul style="list-style-type: none"> <li>• 275mm wall (60mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 300mm wall (85mm insulation) <math>U = 0.22 \text{ W/m}^2\text{K}</math></li> <li>• 315mm wall (100mm insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (135mm insulation) <math>U = 0.16 \text{ W/m}^2\text{K}</math></li> <li>• 360mm wall (145mm insulation) <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> <li>• 390mm wall (175mm insulation) with aggregate block <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> </ul>	<ul style="list-style-type: none"> <li>• 285mm wall (105mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 300mm wall (150mm insulation) <math>U = 0.2 \text{ W/m}^2\text{K}</math></li> <li>• 280mm wall (130mm extruded polystyrene insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (200mm insulation) <math>U = 0.16 \text{ W/m}^2\text{K}</math></li> <li>• 330mm wall (180mm extruded polystyrene insulation) <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> <li>• 360mm wall (210mm insulation) <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> </ul>	<ul style="list-style-type: none"> <li>• 270mm wall (75mm insulation) <math>U = 0.28 \text{ W/m}^2\text{K}</math></li> <li>• 300mm wall (105mm insulation) <math>U = 0.21 \text{ W/m}^2\text{K}</math></li> <li>• 305mm wall (110 insulation) <math>U = 0.20 \text{ W/m}^2\text{K}</math></li> <li>• 345mm wall (150mm insulation) <math>U = 0.15 \text{ W/m}^2\text{K}</math></li> <li>• 350mm wall (155mm insulation) <math>U = 0.14 \text{ W/m}^2\text{K}</math></li> </ul>

# Conclusions

It is clear that there is no single solution that can be applied to all dwelling types. Those that have greater exposed areas, e.g. detached houses, will benefit more from improved U-values than smaller mid terrace units or flats. Conversely, smaller attached units benefit more from the introduction of renewable energy. In most types of dwelling, level 3 can be achieved without renewables, and in all cases level 4 is reached through the addition of limited renewables.

## Optimising wall thickness

For external walls, a U-value of between 0.28 and 0.2 W/m<sup>2</sup>K was found to be appropriate for code levels 3 and 4. At the present time a 150mm cavity is felt to represent the upper threshold of mainstream cavity wall construction. This may increase in the future as larger cavities become more commonplace accompanied by greater availability of suitable cavity closers and low conductivity wall ties etc. Equally, it may be felt that a cavity of 150mm is typically all that is necessary to meet future requirements, since it can already provide a U-value of around 0.15 W/m<sup>2</sup>K in a 350mm masonry wall built with high performance insulation and aircrete blocks (see page 13). This level of performance approximates to the Passiv Haus standard and is suitable for the highest levels of the Code. U-values below this level (using currently available forms of insulation) are unlikely to be cost competitive with other means of reducing CO<sub>2</sub>.

However, there is an argument that the cost of the additional insulation required in a super insulated home (U-value ≈ 0.1 W/m<sup>2</sup>K) is offset by eliminating the need for a space heating system. Calculations may show this to be true, but the expectations of householders should also be considered, many of whom will want to retain a heating system regardless of fabric performance. In reality, a U-value of around 0.17 W/m<sup>2</sup>K for the highest code levels may currently represent the optimal balance between overall CO<sub>2</sub> reduction and insulation costs [14]. Much less than this can incur disproportionate additional cost and much more, a missed opportunity to reduce CO<sub>2</sub> emissions. This level of performance can be readily achieved with a 150mm cavity in virtually all forms of masonry wall using a broad range of materials.

## Minimising air leakage

Standards of air leakage are improving rapidly in concrete and masonry construction as lessons learned from pressure testing are fed back into the design and construction process. Test results from a recent study of new masonry housing [8] show that cavity masonry construction can readily deliver 5m<sup>3</sup>/(h.m<sup>2</sup>), and the use of parged masonry walls linked to airtight top floor ceilings and ground floors can achieve an air leakage rate below 2m<sup>3</sup>/(h.m<sup>2</sup>). Anecdotal evidence also suggests that with a good standard of workmanship, airtightness levels as low as 2.5m<sup>3</sup>/(h.m<sup>2</sup>) are being achieved in conventional dry-lined masonry construction [4]. As an alternative to using parging and/or dry-lining as an air barrier, a wet plaster finish could become an increasingly popular option (see page 9). In addition to providing a simple means to minimise air leakage, this solution can also help maximise the thermal mass available in masonry and concrete construction.

## Code levels 5 and 6

The design measures needed to achieve code levels 5 and 6 with regard to energy are essentially the same for all construction systems, requiring significant use of renewable energy. Beyond level 5, opportunities for further cost effective reductions in CO<sub>2</sub> emissions through additional enhancements to the performance of the fabric are limited.

## Environmental performance

In the Materials category of the Code the majority of concrete and masonry walling systems currently score an 'A+' rating for their relatively low environmental impact (based on the Green Guide to Specification Online - May 2008). It is worthy of note that an 'A' rating for three of the five key construction elements (roof, external walls, internal walls, floors and windows) will only score an additional 1.8 points over elements with a 'D' rating.



Moving above level 4 requires greater use of renewables and is essentially not a building fabric issue. Courtesy of Gusto Homes.

# Potential changes to Part L1



Areas to be addressed include the development of new procedures for handling the effects of thermal mass in summer and winter.

In the recent Energy White Paper [15] the Government signalled its intention to significantly reduce energy use in buildings as an important element in its climate change strategy. Future revisions to Part L of the Building Regulations are one of the mechanisms through which these reductions are to be achieved (which will in turn have direct implications for the Code). In July 2007 the CLG published a forward look [12] at what Part L standards may be in 2010 and 2013. This provides an early indication of the changes that will probably be needed to meet future targets for energy efficiency. However, as required by the Building Act 1984, there will be full consultations before any changes are made to the Building Regulations.

Discussion on some of the specific changes can be found in this guide under the headings 'Low energy lighting', 'Secondary heating' and 'Orientation'. However, from a concrete and masonry perspective, perhaps the most significant area to be addressed is the development of new SAP procedures which are likely to take more account of the effects of thermal mass in summer and winter. At present, SAP assumes a fixed level of thermal mass for the winter heating calculation, which can result in an overestimation of the fuel required in medium to heavyweight dwellings with a southern orientation [16, 17]. In other words, the contribution thermal mass can make to passive solar design is not fully recognised. Until recently, this was of relatively little consequence, but the move towards a much higher standard of fabric performance has made the issue more significant.

From a summertime perspective, the current SAP overheating check takes limited account of thermal mass, with an associated maximum reduction in the peak internal temperature of just 1°C. In many cases the reduction associated with thermal mass will be higher, and may reach as much as 5 or 6°C in some heavyweight dwellings [18].

The extent to which these issues are addressed will strongly determine the ability of SAP to more accurately account for passive heating and cooling in buildings, and will have important implications for all heavyweight construction materials.

## Appendix A: Code for Sustainable Homes [19] interpreted

An interpretation of the Code, showing a possible route to compliance at each level.

Category	Credits	Weight	Issue	Issue Credits	Issue Points	Code Year	1	2	3	4	5	6	
							2007	2010	2013	2016 'True' Zero Carbon			
1 Energy & Emissions	29	36.4	Points for code level rating				36+	48+	57+	68+	84+	90+	
			Ene 1.01 Dwelling Emission Rate (DER) - Mandatory	15	18.83	Minima	1.26	3.77	6.28	10.04	17.57	18.83	
			Percentage of minimal points required				3.47	7.85	11.01	14.76	20.92	20.92	
			Improvement on SAP 2005 Target Emission Rate				10%	18%	25%	44%	100%	100% or higher	
			Ene 1.02 Building Fabric Heat Loss Parameter	2	2.51					1.26	2.51	2.51	2.51
			HLP <sub>≤1.3</sub> = 1 of 2 Credits										2.51 - With a Heat Loss Parameter probably below 0.8
			HLP <sub>≤1.1</sub> = 2 of 2 Credits										
			Ene 1.03 Internal Lighting	2	2.51		2.51	2.51	2.51	2.51	2.51	2.51	2.51
			≥ 40% energy efficient = 1 of 2 Credits										
			≥ 75% energy efficient = 2 of 2 Credits										
			Ene 1.04 Drying Space - Internal or External	1	1.26		1.26	1.26	1.26	1.26	1.26	1.26	1.26
			Ene 1.05 Eco-labelled White Goods	2	2.51		1.26	1.26	1.26	1.26	2.51	2.51	2.51
			information only = 1 of 2 Credits										
			some efficient appliances = 1 of 2 Credits										
			all efficient appliances = 2 of 2 Credits										
			Ene 1.06 External Lighting	2	2.51		1.26	2.51	2.51	2.51	2.51	2.51	2.51
			efficient space lighting = 1 of 2 Credits										
			efficient security lighting = 1 of 2 Credits										
			or no security lighting = 1 of 2 Credits										
Ene 1.07 Low or Zero Carbon Energy Technologies	2	2.51					1.26	2.51	2.51	2.51	2.51		
10% reduction in emissions = 1 of 2 Credits											2.51 - With all energy used in a home resulting in Zero Net Greenhouse Gas Emissions		
15% reduction in emissions = 2 of 2 Credits													
<b>For heating, hot water, ventilation and lighting</b>													
Ene 1.08 Cycle Storage	2	2.51		1.26	1.26	2.51	2.51	2.51	2.51	1.26			
smaller storage space = 1 of 2 Credits													
larger storage space = 2 of 2 Credits													
Ene 1.09 Home Office	1	1.26		1.26	1.26	1.26	1.26	1.26	1.26	1.26			
2 Water	6	9	Wat 2.01 Internal Potable Water Use - Mandatory	5	7.5	Minima	1.5	1.5	4.5	4.5	7.5	7.5	
Water use in litres/person/day							120	120	105	105	80	80 or lower	
Wat 2.02 External Water Use	1	1.5		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
rainwater collection system = 1 of 1 Credits													
or if no gardens = 1 of 1 Credits													
3 Materials	24	7.2	Mat 3.01 Environmental Impact - Mandatory	15	4.5	Entry	Zero	0.3	0.9	1.8	2.7	4.5	
Three of the five key elements of roof, external walls, integrated walls, floors and windows achieve A+ to D ratings from 'The Green Guide 2007', BRE weighted and assuming a 60 year study period							3 x D	4 x D	3 x B	3 x A	3 x A+	5 x A+	
Mat 3.02 Responsible Sourcing - Basic elements	6	1.8		0.3	0.6	0.9	1.2	1.5	1.8	1.8	1.8	1.8	
Mat 3.03 Responsible Sourcing - Finishing elements	3	0.9		0.15	0.3	0.45	0.6	0.75	0.9	0.9	0.9	0.9	
4 Surface Water Run-off	4	2.2	Sur 4.01 Surface Water Run-off from Site - Mandatory	2	1.1	Entry	1.1	1.1	1.1	1.1	1.1	1.1	
from hard surfaces = 1 of 2 Credits													
from roofs = 1 of 2 Credits													
<b>Reduction of peak and annual water run-off rates</b>													
Sur 4.02 Flood Risk Reduction	2	1.1		0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	
medium to high flood risk = 1 of 2 Credits													
low flood risk = 2 of 2 Credits													
5 Waste	7	6.4	Was 5.01 Household Waste Facilities - Mandatory	4	3.66	Entry	1.82	3.66	3.66	3.66	3.66	3.66	
limited recycling bin space = 2 of 4 Credits													
recycling and waste bin space = 4 of 4 Credits													
<b>Household waste storage space required</b>													
Was 5.02 Construction Waste - Mandatory	2	1.83	Entry	0.91	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	
minimise waste = 1 of 2 Credits													
and sort, reuse and recycle = 1 of 2 Credits													
<b>Site Waste Management Planning</b>													
Was 5.03 Composting	1	0.91		0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	
6 Pollution	4	2.8	Pol 6.01 Global Warming Potential of Insulators ≤5	1	0.7		0.7	0.7	0.7	0.7	0.7	0.7	
Pol 6.02 NOx Emissions from building services	3	2.1		0.7	1.4	1.4	1.4	1.4	1.4	2.1	2.1	2.1	
≤ 100 Dry NOx level (mg/kWh) = 1 of 3 Credits													
≤ 70 Dry NOx level (mg/kWh) = 2 of 3 Credits													
≤ 40 Dry NOx level (mg/kWh) = 3 of 3 Credits													
7 Health & Well Being	12	14	Hea 7.01 Daylighting	3	3.5			1.16	1.16	2.33	2.33	3.5	
kitchen daylight factor 2% = 1 of 3 Credits													
habitable room daylight factor 1.5% = 1 of 3 Credits													
80% of kitchen with sky light = 1 of 3 Credits													
Hea 7.02 Sound	4	4.67		1.16	1.16	1.16	1.16	1.16	3.5	3.5	3.5	3.5	
achieve airborne sound insulation values 3dB higher and impact sound insulation values 3dB lower than Approved Document E 2004 = 1 of 4 Credits													
achieve airborne sound insulation values 5dB higher and impact sound insulation values 5dB lower than Approved Document E 2004 = 3 of 4 Credits													
achieve airborne sound insulation values 8dB higher and impact sound insulation values 8dB lower than Approved Document E 2004 = 4 of 4 Credits													
detached dwellings = 4 of 4 Credits													
attached dwellings with separation = 3 of 4 Credits													
Hea 7.03 Semi-Private Outdoor Space Provision	1	1.17		1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	
Hea 7.04 Lifetime Homes as a 16 point design guide	4	4.67		4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	
8 Management	9	10	Man 8.01 Home User Guide	3	3.33		2.22	2.22	2.22	3.33	3.33	3.33	
individual Home User Guide = 2 of 3 Credits													
and neighbourhood User Guide = 1 of 3 Credits													
Man 8.02 Considerate Constructors Scheme	2	2.22		1.11	1.11	1.11	2.22	2.22	2.22	2.22	2.22	2.22	
regularly audited scheme = 1 of 2 Credits													
regularly audited enhanced scheme = 2 of 2 Credits													
Man 8.03 Construction Site Impacts	2	2.22		1.11	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	
2 of 6 site impact procedures = 1 of 2 Credits													
4 of 6 site impact procedures = 2 of 2 Credits													
Man 8.04 Secured by design as a police standard	2	2.22		2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	
9 Ecology	9	12	Eco 9.01 Ecological value of site reporting	1	1.33			1.33	1.33	1.33	1.33	1.33	
Eco 9.02 Ecological enhancement proposal	1	1.33		1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	
Eco 9.03 Protection of Ecological features	1	1.33		1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	
Eco 9.04 Change of Ecological Value of site	4	5.33		2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	
minor negative change = 1 of 4 Credits													
neutral = 2 of 4 Credits													
minor enhancement = 3 of 4 Credits													
major enhancement = 4 of 4 Credits													
Eco 9.05 Building Footprint	2	2.67		2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	
Net Internal Floor Area: Net Internal Ground Floor Area over 2.5:1 for houses and 3:1 for flats = 1 of 2 Credits												1.33	
Net Internal Floor Area: Net Internal Ground Floor Area over 3:1 for houses and 4:1 for flats = 2 of 2 Credits													
<b>Totals</b>	<b>104</b>	<b>100%</b>		<b>104</b>	<b>100</b>		<b>36.76</b>	<b>48.11</b>	<b>57.18</b>	<b>68.19</b>	<b>84.91</b>	<b>90.37</b>	
Version created in February 2008, by Ian Abley, Audacity (www.audacity.org)							1	2	3	4	5	6	

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