AECB CarbonLite Programme

Delivering buildings with excellent energy and CO_2 performance

VOLUME THREE: THE ENERGY STANDARDS
Prescriptive and performance versions

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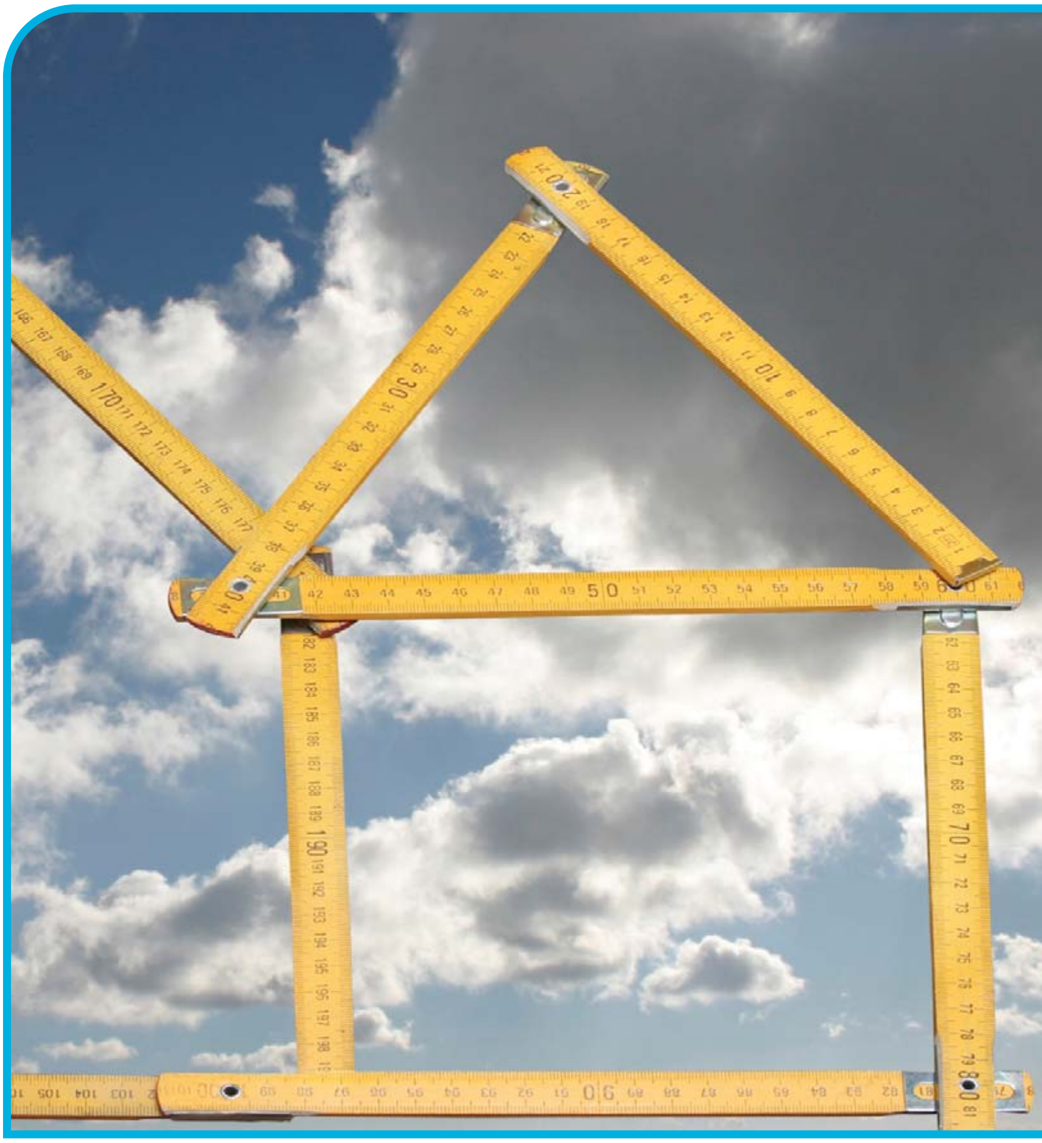

AECB
Carbon Lite

CARBON LITERATE DESIGN AND CONSTRUCTION

Contents

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Introduction

SECTION 1

The AECB Energy Standards is the third in a series of documents published as part of the AECB's CarbonLite Programme. The first document summarises the programme and the second sets out the principles and methodologies upon which the energy performance standards are based. This third document should be read in association with the first two.

The standards are expressed in terms of a combination of limits on space heating energy consumption, primary energy consumption and CO_2 emissions. They can also be expressed as the percentage saving in energy and CO_2 relative to the same building type in the existing building stock. See below.

Table 1. **THE THREE ENERGY STANDARDS AS APPLIED TO A TYPICAL DWELLING**

Standard	Useful space heating energy	Primary energy consumption [1]	CO_2 emissions
Silver	40 kWh/m²yr	120 kWh/m²yr	22 kg/m²yr
Passivhaus Passivhaus in a UK context [2]	15 kWh/m²yr 15 kWh/m²yr	120 kWh/m²yr 78 kWh/m²yr	No explicit limit 15 kg/m²yr
Gold	15 kWh/m²yr	58 kWh/m²yr	4 kg/m²yr

1 These are domestic sector figures, based on a typical-sized dwelling.

2 The requirements in red for Step 2 / Passivhaus in this table and in the tables below are supplementary AECB guidance which is mostly provided to help ensure that such buildings achieve CO_2 emissions consistently lower than Step 1 / Silver. Some of this information is provided to make Passivhaus conventions and requirements more compatible with UK conventions; e.g., the UK and some other countries use air permeability instead of air leakage. *See CLP VOLUME TWO: PRINCIPLES AND METHODOLOGIES - Calculating and minimising CO_2 emissions and heat loss from buildings.*

Table 2. **PERCENTAGE REDUCTION IN CO_2 EMISSIONS RELATIVE TO THE BUILDING STOCK**

Step	Standard	Reduction in primary energy consumption compared to average UK building of that type [1]	Reduction in CO_2 emissions compared to average UK building of that type [1]
One	Silver	70%	70%
Two	Passivhaus	80%	80%
Three	Gold	85%	95%

1 Based on an 80 m² semi-detached house for the domestic sector.

We start with the prescriptive standard. For those not used to thinking about energy in buildings, this is the best introduction to the approach needed. Those who have already designed many successful low-energy buildings may feel comfortable with the performance standards. We suggest that everyone first read the notes attached to the tables in both the prescriptive and performance standards.

Detailed guidance on specific aspects of low energy design, such as passive solar design or daylighting, can be found in the Learning Zone on www.carbonlite.net.

The Prescriptive Version

SECTION 2

This section sets out the details of the prescriptive version of the energy standards. It explains what measures designers and others must implement in order to comply with the standards.

In most countries where advanced energy standards have been tried, designers have wanted some kind of prescriptive standard. It provides them with relatively clear guidance and assurance as to what is likely to be acceptable. By avoiding or reducing the need for calculations, it may also reduce the risk of errors.

The intent is that these prescriptive standards should cover the vast majority of smaller and/or simpler buildings, such as low-rise housing, village halls, blocks of flats, student residences, doctor's surgeries, and care homes. Designers must use the performance version of the standards if any parameters; e.g., the ratio of glazed area to floor area, the orientation, the ratio of glazing area to total window area, etc, are outside the range listed.

Designers are free to use the performance version if they feel their proposal is superior to the requirements listed here. The values listed here represent typical cases of careful design, but they are often not the best possible. For instance, it is feasible to design fenestration whose area is more than 70% glass and less than 30% frame. It is also feasible to design buildings whose unobstructed south-facing glazed area exceeds 10% of floor area.

Table 1. **DETAILS OF THE PRESCRIPTIVE VERSION**

Feature	Step 1 / Silver	Step 2 / Passivhaus	Step 3 / Gold
Design to suit site	Basic passive solar design with principal façade facing within 30° of due S [2] Design all buildings so that daylighting can displace substantial amounts of electric light. Set aside an area of south wall or roof to retrofit solar thermal or photovoltaic panels if ever needed. Provide space to retrofit solar tank if not fitted now.	As Step 1 / Silver but solar water heating would be installed now.	As Step 1 / Silver but solar energy system(s) would be installed now.
U- and y-values if following UK conventions [3]			
Sum of U-value plus y-value [4]			
Roofs	≤0.15 W/m²K [5]	≤0.15 W/m²K [5]	As Step 2 / Passivhaus
External walls	≤0.25 W/m²K	≤0.15W/m²K	
Floor	≤0.20 W/m²K	≤0.15W/m²K	
External opaque doors, uninstalled [6]	≤1.0 W/m²K	≤0.60 W/m²K	
Windows, uninstalled [7]	≤1.40 W/m²K	≤0.8 W/m²K	
Rooflights, uninstalled [8]	≤1.7 W/m²K	≤1.00 W/m²K	
Separating walls in semi-detached and row houses [9]	≤0.5 W/m²K	≤0.3 W/m²K	

Table 1. (cont.) **DETAILS OF THE PRESCRIPTIVE VERSION**

Feature		Step 1 / Silver	Step 2 / Passivhaus	Step 3 / Gold
or U- and ψ-values if following PHI conventions [10]				
U-values				
Roofs		≤0.15 W/m²K	≤0.15 W/m²K	As Step 2 / Passivhaus
External walls		≤0.25 W/m²K	≤0.15 W/m²K	
Floor		≤0.20 W/m²K	≤0.15 W/m²K	
External opaque doors [6]		≤1.0 W/m²K	≤0.65 W/m²K	
Whole windows	Uninstalled	≤1.40 W/m²K	≤0.80 W/m²K	
Whole windows	Installed	≤1.50 W/m²K	≤0.85 W/m²K	
Rooflights	Uninstalled	≤1.70 W/m²K	≤1.00 W/m²K	
Rooflights	Installed	≤1.80 W/m²K	≤1.10 W/m²K	
Separating walls in semi-detached and row houses [9]		≤0.5 W/m²K	≤0.3 W/m²K	
ψ-values				
Around window/door openings		≤0.03 W/mK	≤0.03 W/mK	≤0.03 W/mK
All other		≤0.01 W/mK	≤0.01 W/mK	≤0.01 W/mK
Air leakage per unit of thermal envelope area under pressure [11]		≤3.0 m³/m²hr @ 50 Pa for whole-building mechanical exhaust ventilation. (MEV), ≤1.5 for balanced mechanical ventilation with heat recovery (MVHR).	0.75 m³/m²hr @ 50 Pa	As Step 2 / Passivhaus
Ventilation system [12]		MVHR or MEV. Specific fanpower ≤0.8 W per l/s (MEV) or 1.5 W per l/s (MVHR). Seasonal heat recovery ≥75% excl. fans.	MVHR, specific fanpower ≤1.44 W per l/s. Seasonal heat recovery ≥75% excl. fans but incl. earth preheating tube(s) if fitted.	MVHR, specific fanpower ≤0.8 W per l/s. Seasonal heat recovery ≥85% excl. fans but incl. earth preheating tube(s) if fitted.
Heat loss parameter (HLP) in W/K.m² floor area as a function of building thermal capacity in kWh/K.m² [13]	30	≤0.96	≤0.55	≤0.52
	50	≤0.99	≤0.57	≤0.54
	100	≤1.03	≤0.59	≤0.56
	200	≤1.04	≤0.60	≤0.57
Window solar energy transmittance, incl. frames [14]		≥35%	≥35%	≥35%
Window visible light transmittance, incl. frames [15]		≥50%	≥50%	≥50%
Window area to floor area ratio, incl. frames		18-30%	18-30%	18-30%
Ratio of unobstructed south glazing area, excl. frames to floor area, domestic [16]		≥10%	≥10%	≥10%
Ratio of glazing, excluding frames to wall area [17]		≤30%	≤30%	≤30%
Protection against overheating		Design to avoid overheating in winter and in summer by passive means. Refrigerative cooling systems, incl. reversible heat pumps, are not permitted.		

Table 1. (cont.) **DETAILS OF THE PRESCRIPTIVE VERSION**

Feature		Step 1 / Silver	Step 2 / Passivhaus	Step 3 / Gold
Space heating system [19]		Normally radiators or underfloor pipes. Fed from SEDBUK A-rated mains gas condensing boiler, CHP or, outside the gas supply area, SEDBUK A-rated LPG or oil condensing boiler, earth-source heat pump (seasonal COP ≥3.0) or cleanburning biomass boiler; i.e, one using liquid- or gaseous fuels. Wood pellet boilers are permitted outside the gas supply area but are not encouraged due to the exhaust emissions. Blocks of flats or maisonettes to have a central boiler and/or CHP plant or heat mains connection; i.e. heat distribution within the block rather than individual boilers or electric heating.	As Step 3 / Gold	Normally hot water coil(s) in ventilation ductwork. Circulating pump consumption ≤0.1 W per m² floor area or pro rata; e.g., Grundfos Alpha Pro or equiv. Heat sources as for Silver.
Water heating system		Same as space heating system; plumbing as compact as possible.	As Step 1 / Silver plus solar, min. solar fraction 50% at the design occupancy for that building.	As Step 1 / Silver plus solar, min. solar fraction 65% at the design occupancy for that building.
Hot water system insulation [20]		Tanks ≥100 mm PU foam (λ=0.024 W/mK) or equiv., pipes and valves ≥30 mm mineral fibre (λ=0.04 W/mK) or equiv. and cold pipes to have a vapour barrier.	Tanks ≥100 mm PU foam or equiv, pipes and valves ≥40 mm mineral fibre or equiv. and cold pipes to have a vapour barrier.	Tanks ≥150 mm PU foam or equiv, pipes and valves ≥40 mm mineral fibre or equiv. and cold pipes to have a vapour barrier.
Cooking [21]		No requirement for gas ovens, electric ovens to be A.	As Step 1 / Silver.	Hobs gas, LPG, electric induction or clean-burning biomass - liquids or gases only. Ovens gas, LPG or electric A-rated. Electric min. A+ or A++ if/when such labels are introduced, gas min. A-rated if/when such a label is introduced.
Daylight factor	Domestic	All habitable rooms to have a glazing area excl. frames ≥14% of floor area.	As Step1 / Silver	All habitable rooms to have a glazing area excl. frames ≥16% of floor area.
	Non-domestic	Habitable rooms minimum ≥1%, average ≥2%, plus fenestration and controls to effectively utilise daylight.	Habitable rooms minimum ≥1.25%, average ≥2.5%, plus other measures as Silver.	As Step 2 / Passivhaus

Table 1. (cont.) **DETAILS OF THE PRESCRIPTIVE VERSION**

Feature	Step 1 / Silver	Step 2 / Passivhaus	Step 3 / Gold
Lighting [22]	Electronically-ballasted CFLs, T5 or T8 everywhere bar cupboards. All table, desk and floor lamps to have CFLs or equiv. LEDs acceptable if/when their efficacy reaches that of CFLs. Domestic: Weighted average lamp and luminaire efficiency sufficient to give ≥45 lm/circuit W; e.g., a combination of 75 lm/W lamps and 60% efficient luminaires. Non-domestic: Weighted average lamp and luminaire efficiency sufficient to give ≥56 lm/circuit W.	Light sources as Step 1 / Silver. Domestic: Weighted average lamp and luminaire efficiency sufficient to give ≥50 lm/circuit W. Non-domestic: Weighted average lamp and luminaire efficiency sufficient to give ≥64 lm/circuit W.	Electronically-ballasted CFLs, T5 or T8 (all hard-wired) everywhere bar cupboards and floor/table lamps. All table, desk and floor lamps to have electronically ballasted CFLs, T5s or equiv. LEDs acceptable if/when their efficacy reaches that of CFLs. Domestic: Weighted average lamp an luminaire efficiency sufficient to give ≥55 lm/circuit W. Non-domestic: Weighted average overall lamp and luminaire efficiency sufficient to give ≥72 lm/circuit W; e.g., a combination of 85 lm/W lamps and 85% efficient luminaires.
'Cold' electrical appliances [23]	Minimum A+	Minimum A++	The top five or top 50% listed on www.topten.ch, whichever is the greater number.
'Wet' electrical appliances	The top 50% of the A class.	Washing machines minimum A+ on energy and A on spin and wash efficiency. Dishwashers minimum top 50% of A class.	Washing machines minimum A+ on energy and A on spin and wash efficiency. Dishwashers minimum the top 50% of the A class. Both to be hot fill. Minimum A+ and then A++ when these grades become available.
Clothes dryers	Gas, LPG, electric heat pump or integrated with MVHR or MEV system. Last two arrangements usually need condensate drain.	Gas, LPG, electric heat pump or integrated with MVHR system.	Integrated with MVHR system; i.e. a drying closet fitted with an exhaust vent.
TVs [24]	Screens to be LCD or CRT. If LCD, choose from all models on www.topten.ch. If CRT, choose any model with an electricity consumption equal to or lower than these LCD models.	As Step 1 / Silver	The best 50% or the best five for that screen size on www.topten.ch, whichever number is the greater.
Major office electrical equipment [25]	Anything listed on www.topten.ch	As Step 1 / Silver	The best 50% or the best five listed on www.topten.ch, whichever number is the greater.

Table 1. (cont.) **DETAILS OF THE PERFORMANCE VERSION OF THE STANDARDS**

Feature	Step 1 / Silver	Step 2 / Passivhaus	Step 3 / Gold
Lifts [26]	Energy-efficient models	As Step 1 / Silver	As Step 1 / Silver
Small electrical appliances or office equipment [27]	No requirement	No requirement	Those listed on www.topten.ch, if applicable. Otherwise not regulated for the time being.
On-site or dedicated renewable electricity generation [28]	No requirement	No requirement	Enough to offset the building's CO_2 emissions due to its electricity use for HVAC pumps, fans & controls, lighting and most electrical appliances / equipment.
Embodied energy	No requirement	No requirement	No requirement
Monitoring	Smart meter	Smart meter	Smart meter
Maintenance and commissioning [30]			
Post-occupancy survey [31]			

NOTES TO TABLE 1:

1 Pre-approved combinations will be issued by the CarbonLite Programme later in its schedule which are deemed to satisfy the requirement of the standard for different types of small building; e.g., detached bungalows, semi-detached houses and flats, without the designer doing any significant further calculations.

If the requirements for a particular parameter are not stated here, they are the same as the minimum in the Building Regulations for that region or country; e.g., Scotland, Northern Ireland, the Isle of Man, Jersey and the other Channel Islands, England and Wales.

If a designer proposes dwelling(s) with integral garage(s), the opaque thermal envelopes of both the dwelling and the integral garage must meet the above thermal insulation and thermal bridging requirements. This is to ensure that any future conversion to residential use does not materially worsen the thermal performance of the building.

In such cases, the air permeability of the garage and the U-values of its windows and doors are not regulated. It is assumed that these would and could be remedied during any future residential conversion.

Attached garages are exempt from this requirement. So clearly are detached garages. Both layouts are actually preferable if a garage is needed. This is because exhaust fumes are less likely to enter the dwelling and because the dwelling itself remains simpler in shape, giving a thermal envelope with a smaller area and with fewer non-repeating thermal bridges.

2 A housing layout which looked random to residents and visitors, but was geared to effective use of passive solar, was demonstrated at; e.g., the Pennyland Project, Milton Keynes, 1977. This estate was monitored by the Open University. Other developments showed effective means to achieve this end; e.g. the Solar Courtyard houses, Milton Keynes, 1986 and the development of 700 homes underway at Stamford Brook, Cheshire, 2007.

Buildings served by heat mains are exempt from any requirement to leave space to retrofit a solar tank or to retrofit solar collector(s). This can be done more easily and cost-effectively on a central basis.

3 The elemental U-values must be met by all elements which separate a heated volume from an unheated space; e.g., from a porch, a cold cellar or an attached garage, or which separate it from the outside air. The U-values of elements which are adjacent to such spaces may not be increased.

The limiting U-value for floors includes not just ground floors. Floors above unheated spaces; e.g., some stairwells in blocks of flats, or floors above the open air, are also covered by this requirement.

4 Under UK conventions, the elemental U-value includes all repeating thermal bridges and the y-value is a correction which is applied to elemental U-values to account for the impacts of nonrepeating point and linear thermal bridges. Conventionally, y = +0.08 W/m^{2}K if one is using accredited details. The y-value is in effect spread uniformly over the whole area of the building, although in reality the thermal bridges are usually concentrated in certain areas of the building.

y can be further reduced by using details which are specifically designed to limit thermal bridging. *See CLP VOLUME TWO: PRINCIPLES AND METHODOLOGIES - Calculating and minimising CO2 emissions and heat loss from buildings.*

5 The Step 1 / Silver, Step 2 / Passivhaus and Step 3 / Gold opaque U-values listed are maxima. To meet the other limits; e.g., the heat loss parameter, most buildings with a high surface area-to-volume ratio; e.g., small or medium-sized detached houses, and some semi-detached houses, will need to utilise lower opaque U-values. In buildings such as flats, offices or compact row houses these U-values generally suffice.

The heat loss parameter (HLP) must be calculated using the ventilation rate for the design occupancy level; e.g. 2.56 people in a 80 m^2 semi-detached house, pro rata for dwellings of other sizes. One must use effective U-values for the ground floors which include the impact of heat transfer via the soil.

6 Most suppliers of certified Passivhaus windows can also supply thick insulated external doors, with a whole-door U-value of around 0.6 W/m^{2}K. After correcting for the thermal bridging due to the installation detail, the effective heat loss is higher. If one is following PHPP conventions, the installed U-value is limited to 1.05 W/m^{2}K for Step 1 / Silver and 0.65 W/m^{2}K for Step 2 / Passivhaus or Step 3 / Gold. There are many suppliers of external doors with a U-value of ≤1.0 W/m^{2}K - usually North American or Scandinavian imports.

7 Broadly speaking, a window U-value of 1.4 W/m^{2}K, or 1.5 W/m^{2}K including the thermal bridge due to the installation detail, can be reached by:

a) low-e argon-filled double glazing (warm edge; e.g. Thermix, Superspacer, Swisspacer) in wood or GRP frames; or

b) low-e air- or argon-filled triple glazing (cold edge) in wood or GRP frames, plus window installation details which exclude the use of significant amounts of steel, other metals, concrete or dense masonry and exclude the use of excessive amounts of solid timber in the plane of the window. *See CLP - Silver Standard Design Guidance.*

Manufacturers normally quote U-values for a single-light window measuring 1230x1480 mm. Certified Passivhaus windows have U ≤ 0.8 W/m^{2}K for a window of this size. A window U-value of 0.8 W/m^{2}K, or 0.85 W/m^{2}K including the installation detail, normally requires triple glazing with krypton or argon gas fill, two low-e coatings, warm edge spacers and insulated GRP, plastic or wood frames.

As of 2007, there are over 45 relevant products from at least seven countries, namely Finland, Sweden, Norway, Germany, Austria, Switzerland and Canada. Most are inward-opening, tilt-andturn; the Canadian windows are outward-opening, top-hung. In addition, suitable window installation details are needed, as for Silver.

The total glazing area in the building must be ≥70% of the total window area. The frame and sash area combined must be ≤30% of the total window area. Measure the frame and sash area from the edge of the glass to the edge of the structural opening – or as far as the edge of the wall insulation, if this overlaps the frame when viewed in elevation. If these criteria are not met by the proposed building, use the performance version of the standard.

By following the above rules, it is expected that the U-value for the actual mix of windows installed in a building, including the installation thermal bridge, can normally be kept to ≤0.85 W/m^{2}K. If experience shows that this limit is not being met, AECB will modify this guidance.

8 No mass-produced rooflights yet meet the Passivhaus or Gold standards. A few could possibly meet Silver. Some site-built sloping glazing systems could meet Silver. At least two experimental site-built rooflights in Canada and the UK have met Gold, but may not yet be ready for mass application.

European manufacturers' stated U-values for manufactured rooflights are usually the U-value of the glazing alone, or the glazing and frame alone, installed in a vertical configuration. This gives an inaccurate picture of the overall U-value which the glazing will achieve in a sloping position and with extensive thermal bridging at the rooflight kerb.

The 2005 ASHRAE Handbook of Fundamentals, pp. 31.8-32.9 has realistic but indicative U-values for sloping glass systems, using all the main generic glazing and frame types. Until further notice, most designers who want to use sloping glazing should follow the performance version of the standard and use the above U-values as guidance in the early stages, replaced by fully-calculated U-values and ψ-values as a project progresses.

Such designers need to provide adequate winter heating system capacity below such rooflights, to combat downdraughts. They may wish to slope rooflights to the north, to reduce the potentially overwhelming summer heat gains. When more rooflights meeting the prescriptive standards become available, designers can more easily use the prescriptive version.

9 Separating walls are walls between separate dwelling units, or between rental units in some non-domestic buildings. They are often called party walls. Such walls must be sufficiently insulated that an attached dwelling or other building can still be heated if adjacent dwelling(s), or other building(s), is/are unoccupied for a prolonged period. Designers can relax these U-values by up to 10% if they wish, but they remain responsible for the satisfactory performance of the resulting dwelling(s). This may require larger heating systems.

In cases where; e.g., a row of houses is stepped down a hill, a separating wall may become an external wall near roof level and may again become an external wall below ground level. The top of such a wall must meet the upper limit to external wall U-value. The base of such a wall must meet the upper limit to wall U-value, taking into account the effect of the earth contact.

10 The U-value calculated by PHI using PHPP includes the same components as in the UK, but the elemental areas are measured with reference to external dimensions. Using these conventions, all thermal bridges whose ψ-value is ≤0.01 W/mK with reference to external dimensions may be omitted.

The PHI procedure overestimates heat loss. With good detailing, most ψ-values are negative when they are expressed with reference to external dimensions.

If they wish, designers who use external areas may add up the ψ-value of all the individual thermal bridges. This is considerably more work. However, because the ψ-value of the thermal bridges are negative, it permits them to use slightly thinner insulation and there may be a sufficient cost saving on large projects to justify the extra design work.

11 The Passivhaus Standard requires air leakage of ≤0.6 ac/h at 50 Pa. The UK limit is expressed as an air permeability in the same units as UK Building Regulations; i.e., in m^3/m^2hr at 50 Pa. By regulating air permeability rather than air leakage, the thermal envelopes of all buildings have to be designed to be equally airtight and anomalies are reduced.

Note, UK air permeabilities for attached dwellings are calculated by dividing the total airflow by an “envelope area” including the separating walls and floors, not just the external elements. This convention can give misleading results. If the separating walls and/or floors are fairly airtight, as they must be for acoustic insulation, using this approach has the effect of increasing the permitted total air movement through unit area of thermal envelope at 50 Pa. AECB requires designers to divide total airflow by thermal envelope area (based on internal areas). For detached houses, there is no ambiguity; the total surface area equals the thermal envelope area.

To reach the Silver Standard permeability of ≤3.0 or ≤1.5 m^3/m^2hr at 50 Pa under UK conditions is moderately easy if a design and building team have understood the principles and gained experience, from the testing of real buildings. The transition will be smoother if they adopt plastered masonry construction with concrete intermediate floors, as used on mainland Europe; timber-frame construction with Canadian-type airtight construction details of the last 30 years, as used in the R-2000 Program; or most forms of concrete construction.

New German and Swiss buildings tend to meet this level of airtightness without extraordinary efforts, so long as windows and external doors are of good quality and incoming services are sealed. These buildings are customarily constructed from plastered load-bearing masonry with in situ or precast concrete intermediate floors.

Reaching the Gold Standard air permeability of ≤0.75 m^3/m^2hr at 50 Pa has proved difficult and challenging under UK conditions unless:

a) at least one team member has enough experience to avoid materials, detailing and procedures which are prone to leak initially or prone to open up as the building ages;

b) all components, including windows and doors, are good quality; and

c) the building is constructed with great care.

Please note the potential difficulties with Gold early on and plan your project accordingly, *based on sound experience*. This is summarised below.

Construction details which are used for airtightness must be designed to stay airtight over time. Some UK buildings which have been re-tested became 30-50% leakier over the space of just 3-4 years. Some timber-frame houses which were constructed in the Orkney Islands in 1993 became three times leakier over 4 years.

We know with some confidence what is likely to be adequate in timber-frame construction, because Canada has published design guidance in this field for 30 years. It no longer recommends some of the airtight construction details which were published in the late 1970s. Similarly Sweden. The procedures which have worked best are where a heavy-duty membrane is used as an air barrier, it is sealed at seams and the seams are all clamped between two solid materials.

Owing to wind pressures, even the Canadian approach of a heavy-duty, protected, sealed and clamped membrane is not today considered adequate in buildings of more than four storeys. So these buildings need to use other materials/systems in order to produce a durable air barrier.

Many continental European countries have experience with solid masonry, concrete-floored construction. Airtightness is easier to achieve here; solid “all-wet” construction is relatively tight if the plaster layer is continuous and if in situ concrete floors, which continue the air barrier between floors, are used. But great care is still needed at all services openings, window and door openings, joints between pre-cast concrete elements and joints of masonry and pre-cast concrete.

Timber roofs in masonry and concrete buildings need sealing as described for timber buildings. Masonry or concrete elements which crack will leak. Cracking must be prevented by measures such as sealed movement joints and/or bed-joint reinforcement.

Steel-frame non-domestic buildings can be hard to make airtight. Buildable solutions to this problem have not been widely-reported. Where possible, we suggest concrete-frame construction as a practical alternative; buildable solutions already exist. *See CLP VOLUME FIVE: STEP TWO/THREE DESIGN GUIDANCE – Passivhaus/Gold Standard.*

Separating walls between attached dwellings must be designed to be airtight and designed to avoid other heat loss mechanisms; e.g., convective bypasses. In other words, assuming that adjacent buildings are at the same temperature, the measured heat loss of the separating wall must be zero. Most separating walls built today comply with Part E but do not meet the requirements of good thermal envelope design, which is an implicit requirement of Part L. This leads to elevated heat loss.

Separating floors within blocks of flats or maisonettes must also be airtight and must be designed to avoid unwanted heat loss mechanisms. Convective bypasses are a risk in hollow-core precast concrete floors, unless precautions are taken.

12 Passivhaus or Gold Standard ventilation could be either:

a) a very efficient air-to-air heat exchanger or

b) a marginally less efficient heat exchanger plus earth tube(s) to preheat the ventilation air an equivalent amount.

Strategy (a) requires an effective defrosting mechanism to be provided in the heat exchanger. Warm moist air which passes through a high-efficiency heat exchanger more often reaches the dewpoint than if it passes through a lower-efficiency exchanger. In severe weather, the condensate could freeze. Where this is a problem, use solutions approved by PHI which do not materially worsen the seasonal heat recovery efficiency or the specific fanpower.

Silver Standard ventilation in blocks of flats or row houses, with a low surface/volume ratio, could sometimes be met by whole-house MEV and still meet the requisite heat loss parameter. MEV costs less than MVHR and may use little more primary energy, especially if buildings meet a permeability of 3 m/hr. It has been and is widely-used in Sweden.

The Silver Standard does not at present permit passive stack ventilation (PSV), because PSV does not appear capable of providing fresh air with the same precision as well-designed and well-maintained MEV or MVHR systems. However, this policy will be kept under review and will be informed by results from adequately-monitored case studies.

13 The heat loss parameter (HLP) is the building's specific heat loss divided by the building's floor area, measured internally. If buildings are following the prescriptive standards, they must meet both the heat loss parameter and the elemental U-values. The limit to HLP varies slightly with building thermal capacity. The variation listed is based on results of PHPP simulations, a tool which is itself calibrated using the results of earlier dynamic thermal simulations. All values relate to a building whose south-facing glazing area, excluding frames, equals 10% of floor area. Caution is advised for lightweight buildings; see note 16.

Lighweight: a thermal capacity of 30 Wh/Km^2 is typical of timber-frame or SIP buildings whose thermal capacity is limited to the plasterboard or timber panelling and the building contents. 50 is typical of such buildings if they are modified by; e.g., using double plasterboard throughout and/or a thin ceramic tile finish on much of the floor area.

Intermediate: 100 is typical of single-storey timber structures with a concrete ground floor, insulated below the slab.

Heavyweight: 200 is typical of buildings with dense masonry external walls, pre-cast concrete intermediate floors, lightweight partitions and timber roofs. 400 can be reached or exceeded by buildings with dense masonry or concrete external walls, in situ concrete intermediate floors, dense masonry partitions and concrete roofs.

Interpolate linearly for intermediate amounts of thermal capacity. If in doubt, meet the lower HLP of the two alternatives.

Buildings with higher HLPs are not ruled out. Very high-capacity south-facing buildings, including earth-sheltered buildings, may use very little space heating energy, despite a slightly higher HLP than the ranges given in the prescriptive standards. However, they must be justified using the performance version of the standard.

14 The g-value or total solar energy transmittance is a weighted average for all the windows and glazed doors in the proposed building, including frames plus glazing. The g-value of the glazing of most Silver Standard windows is 60-65%. Care is needed with Passivhaus or Gold Standard windows, whose glazing g-value is in the region of 50-55%. 50% is the minimum for residential buildings because the glazing plays a role in heating the building. Buildings which use lower g-values must follow the performance version of the standards.

15 Visible light transmittance is important to daylighting in all building types. The limit is a weighted average and applies to the whole window, including sashes, frames and couplings between windows in curtain walling-type systems. Measure window sizes to the outside of the structural openings.

16 Includes only buildings whose principal, most highly-glazed façade is within 30° of due south and is shaded by no more than the equivalent of a continuous row of houses 7 m high, located 40 m to the south and on flat ground. Anyone who needs to exceed these glazing ratios or has to deal with worse overshading must do their own calculations and use the performance version of the standards.

For thermally very lightweight buildings; e.g, timber-frame or SIPs with no more thermal storage than the plasterboard lining alone and the building contents, proceed with caution until AECB issues more detailed guidance. If in doubt, use slightly less unshaded south-facing glass than 10%.

For all construction types, reduce the HLP by 0.015 per percentage point by which the ratio of unshaded south-facing glazing area, excluding frame, to floor area falls below 10%. So for a ratio of 8%, reduce the HLP by 0.03; for a ratio of 5%, reduce it by 0.075.

In a passive solar context, south means the principal façade of the building. Depending on the individual circumstances, it may face due south or within 30° of south.

17 This limit is significant for reducing the risk of summer overheating but is usually only approached on flats or large non-domestic buildings. Anyone who wishes to exceed the ratio must do their own calculations and follow the performance version of the standards.

18 Overheating falls into two different categories:

a) Summer overheating even when windows are open, due to prolonged heatwave conditions plus solar gains and/or internal gains, and;

b) Late winter overheating, usually in February or March when windows are closed. Accentuated by large areas of south-facing glazing and low-angle sunshine overwhelming a lightweight building's thermal mass. Rarely recorded in the UK, due to high heat loss, overshading and the low number of entirely lightweight buildings, but often observed in the past in the USA, Canada, Norway and Sweden.

Summer overheating is accentuated by large areas of unshaded west- or east-facing glazing. The sun's rays in the morning and afternoon are incident at a low angle and are hard to block by external shading. Do not use large areas of east or west glass unless effective shading can be provided; e.g., by deciduous trees or by other buildings.

The acceptability or otherwise of a design with substantial areas of south, east or west glass can be assessed with *PHPP*, using 25°C as the maximum comfort temperature and providing moveable summer-only shading if needed. *PHPP* contains weather data for Glasgow, Manchester, Birmingham, London and Plymouth and also many nearby weather stations in other countries. Use the geographically closest weather data for summer overheating calculations; e.g., for Milton Keynes, use London; for Worcester, use Birmingham; for Anglesey, use Dublin; for Dover, use Ostend. AECB will publish deemed-to-satisfy combinations for dwellings which are satisfactory for summer and winter performance without the need for further calculations.

Buildings which intend to use refrigerative space cooling systems, including reversible heat pumps, are not covered here. They must use the performance route to compliance.

19 The space heating system must be sized and designed to utilise circulating water at supply and return temperatures of ≤60/40°C under design conditions. So if the building has radiators or underfloor heating, these water temperatures would occasionally be reached in very cold weather. If the building is heated via the MVHR system, the water circulated through the plumbing coil(s) in the ductwork would occasionally reach these temperatures.

The reason for installing internal heat distribution systems which are capable of utilising low-grade heat and requiring central heating in blocks of flats is to preserve future fuel flexibility. The above temperatures have been mandatory since 1980 in Sweden and Denmark. For user comfort in buildings where heating is delivered via the MVHR system, the peak temperature of the supply air under design conditions must be ≤50°C.

It is assumed that the space heating system is operated continuously at least under severe weather conditions; i.e., with precise temperature controls but with no time controls. With Steps 2 or 3, there may be no zone controls either, because temperatures within the thermal envelope tend to equalise. In fact, the cost of zone controls may be less effective - in p/kWh of energy saved - than spending the same budget on further improvements to the thermal envelope. Attempts to operate the space heating system intermittently in buildings to Steps 2 or 3 should be approached with caution. Such buildings cool down very slowly if the heat is turned off and they warm very slowly, under the influence of a low-powered heating system. However, some projects have utilised intermittent heating.

One argument against intermittent heating is that condensing boilers or heat pumps in a well-designed system are less efficient at full load; i.e., with a high return temperature, than at part load; i.e., with a low return temperature. Intermittent heating needs a larger heating system, costing money which could otherwise be spent on fabric insulation measures. The extra fuel consumption due to the reduced plant efficiency with intermittent heating could exceed the fuel saving arising from a slightly lower mean daily internal temperature.

For thermally-lightweight non-domestic buildings which are unoccupied for long periods, there may be net benefits to intermittent heating. But such buildings represent a small minority of all projects.

Space heating via plumbing coil(s) in the ventilation ducts is the Passivhaus or Gold Standard norm & helps to keep down overall costs. The standards do not require this integration per se but it is likely to happen anyway; it is the cheapest way to meet the target.

Sparsely-occupied buildings with a high surface/volume ratio; e.g., some detached houses, may need more heating power than the ventilation air alone can provide. If so, the usual solution is a coil in the ductwork plus a few strategically-sited radiators in living rooms, bathrooms and similar spaces, or radiators alone sited so that air movement caused by the MVHR system distributes the heat and so that living rooms and bathrooms are acceptably warm.

Single-room through-the-wall MVHR systems are very prone to short-circuiting and are not encouraged. However, even ducted whole-building MVHR systems can give short-circuiting if not designed with care. The supply and exhaust terminals must be laid out to avoid short-circuiting and avoid all risk of condensation and mould growth.

PHPP calculations allow for the presence of some solar gains even under design conditions. These are significant enough to supply a small percentage of a building's heat.

The standards do not permit the use of electric resistance space and water heating, as it cannot utilise low-grade energy resources. Heat pumps which are sized and designed to avoid use of electric resistance backup heat are accepted outside the gas supply area. Minor resistance heat backup for *legionella* control only is acceptable. The seasonal average COP for space and water heating combined must be ≥3.0, including the impact of the resistance heating with its effective COP of 1.0.

Within the gas supply area, CHP and district heating is a more flexible long-term option. It can utilise low-grade energy sources in the form of industrial waste heat, large-scale solar or geothermal wells, not just energy in the form of electricity. With present technology, 1 kWh of lowgrade heat from a medium to large gas-fired CHP plant - 100s of kW(t) to 100s of MW(t) - emits one-fifth to one-third as much CO_2 as 1 kWh of heat from an electric heat pump. The performance version of the standards enables credit to be obtained for use of CHP systems.

20 Viessmann and other companies make storage tanks with insulation of 100 mm PU foam. These would meet Steps 1 or 2. In case of problems sourcing storage tanks for Step 3, one might build a larger enclosure than the bare tank, fill it with the necessary thickness of loose-fill insulation and rest the tank base on sufficient rigid insulation. This approach could also be used to meet the Silver or Passivhaus Standards.

Treat 150 mm PU/PI foam with lambda ≤0.024 W/mK as equivalent to 240 mm expanded polystyrene or other loose-fill material with lambda ≤0.038 W/mK. Treat 100 mm PU foam as equivalent to 160 mm expanded polystyrene beads or similar loose-fill material.

21 Cooking with gas (LPG) typically emits 60-70 (50-60)% less CO_2 than electric cooking. The Gold Standard discourages electric cooking for the same reasons that it restricts electric resistance heating; the peak loads are quite severe and pose added difficulties in running the electric grid on renewables in the long term.

Gas ovens today are unlabelled and data on running costs is limited. Energy efficiency requirements will be introduced when labels are introduced.

Induction hobs and/or A-rated electric ovens are allowed instead of gas or LPG in situations where a gas or LPG supply is considered unsafe or is illegal; e.g. blocks of flats. They are also allowed in buildings heated by CHP plant with annual outputs of ≥30% electricity, ≥55% heat (HCV) and heat distribution efficiency ≥90% - or equivalent parameters. If other projects wish to use electric cooking, they must follow the performance version of the standard and take account of the higher CO_2 emissions.

22 Just as designers and builders must ensure adequate performance of the insulation system, and the fixed lighting, the occupants of a dwelling must fit energy-efficient table and floor lamps and the occupants of an office or school must fit energy-efficient background and task lighting. Otherwise buildings will consume more energy than expected. If there is doubt that this will happen - there may be for social housing - the designer must use the performance version of the standard and presume that the occupants will fit standard inefficient light sources; e.g., incandescent and/or

halogen lamps. In these circumstances, he/she might decide to compensate for this worsening of energy performance by taking any or all of the following steps:

(a) an improved thermal envelope;

(b) improved passive solar features;

(c) use of CHP, not gas for space and water heating and

(d) fitting a solar water heating system.

There are other options but these four are likely to be strong contenders to improve a building's performance.

The required efficacy in lm/W (Lumens/Watt) refers to the total lighting installation, including emergency and external lighting. Standby power used by lighting controls, etc must be included in the overall efficacy where applicable. Lighting in common or external areas of flats; e.g. unheated stairwells, must meet the same standard as lighting within individual units.

23 If the designer, builder or developer of housing provides and installs major appliances; e.g., refrigeration, washing machines and TVs, he/she must specify energy-efficient models. If the occupants choose the appliances, they must purchase energy-efficient models. If there is doubt over this, the designer must use the performance version of the standards and use input data which presumes that the occupants will fit appliances of normal UK energy efficiency. See note 22.

24 The top five TVs with a specific screen size on www.topten.ch are acceptable. There are three size classes, the smallest being <66 cm (<26 inch) and the largest being >90 cm (>36 inch). Any other models on the market with a lower or identical total consumption, relative to these five are acceptable. Large LCD screens often use 60% less electricity than plasma screens of the same size - typically, 140 W versus 350 W. However, the consumption of both types of screen varies widely.

The top five are defined as those with the lowest total electricity consumption in active and standby mode combined. Using the listed active and standby consumption, assume that a TV is in the active mode for 5 hours/day and the standby mode for 19 hours/day. So a model using 90 W in active mode and 3 W in standby uses (0.09x5)+(0.003x19) = 0.51 kWh/day.

25 Major office equipment comprises ICT equipment, photocopiers, laser printers, inkjet printers, fax machines, business mobile phones, etc. Choose from the lists on www.topten.ch under the heading “Büro”. The best models are defined as those with the lowest lifetime electricity cost, which is given in Swiss Francs. The top five models or the top 50% of all models on the list are acceptable, whichever number is the greater. If any other models on the market and not listed on www.topten.ch have a lower total consumption, or an equal consumption, these are acceptable. This requirement must also be met by office equipment which is installed in a domestic environment; e.g., PCs, faxes, photocopiers, laser and inkjet printers.

26 Lifts are routinely used in offices and high-rise flats. The UK Building Regulations now de facto require them in non-domestic buildings of two storeys upwards. There is often scope to save 50% or more of electricity consumption in low-rise buildings, whose lifts tend to be particularly energy-inefficient. For Step 1, lifts installed must be from the top 50% of a supplier's range, measured in terms of kWh/passenger journey. For Step 2, lifts installed must be the most energy-efficient in a supplier's range. For Step 3, lifts installed must be the most energy-efficient models available from the top two suppliers.

For their own health, occupants should be encouraged to use the stairs whenever possible. So staircases must be accessible and welcoming. Lifts in two- and three-storey buildings must be readily accessible for use by the disabled, but signs should indicate that they are not for regular use by the able-bodied.

27 Small electrical appliances are defined as all other devices; e.g., including but not limited to vacuum cleaners, irons, toasters, mobile telephones, coffee makers, hi-fi

systems, electric toothbrushes, electric lawnmowers, other garden machinery, medical instruments and specialised laboratory equipment. Small appliances are normally all provided by the occupants of a building who must purchase electricity-efficient models.

Until further notice, use www.topten.ch and treat the top five appliances listed of each category as acceptable, or the top 50%, whichever number is the greater. If a category of small appliance is not listed on www.topten.ch it is unregulated for the time being.

28 This requirement covers electricity-specific uses. It covers cooking or clothes drying only if these services are wholly provided by electricity; gas cookers and gas clothes dryers are excluded.

So a dwelling which uses 1,400 kWh/year for lighting, appliances and ventilation under standard occupancy conditions, and has gas space and water heating, cooking and clothes drying needs a dedicated or on-site wind, photovoltaic, hydro and/or other renewable electricity system which generates 1,400 kWh/yr, plus an allowance for 10% grid losses in electricity which is exported and used elsewhere. This makes 1,400/0.90 = 1,555 kWh/yr.

Similarly, a block of 60 flats with electric cooking, consuming 700 kWh/yr for each unit, plus 1,100 kWh/yr each for lights, appliances and ventilation, needs a system which generates at least (42,000+66,000)0.9 = 120,000 kWh/yr. A school which uses 34,000 kWh/yr of electricity for lighting, ICT, ventilation, etc would need to generate 37,400 kWh/yr from its own dedicated renewable capacity.

The allowance for grid losses, etc is under review.

The renewable electricity generated by or for the building must be additional to renewable electricity generation plant which is planned anyway. So, electricity which has been or will be credited via any other mechanism; i.e., the Renewables Obligation, the Climate Change Levy and so-called “green tariffs” offered by electricity suppliers over and above the RO and CCL, does not count towards the requirement.

This rule is subject to review as and when OFGEM clarifies its views on the matter.

29 Of the total energy consumed by a building over a 100 year life, embodied energy appears to be 5-7% of the total for a building of current UK construction and 8-10% for a dwelling of Passivhaus construction. The rest is operational energy. This is based on central European-type construction of externally-insulated masonry or concrete walls, heavyweight partitions, concrete intermediate floors and timber roofs.

Some UK efforts to reduce embodied energy could increase a building’s lifecycle energy usage. In particular, increasing its thermal capacity may raise its embodied energy but reduce its operational energy use for heating and for cooling. Proposals to regulate embodied energy would be counterproductive if they lead to buildings using more energy for space heating and/or cooling over their lifespan. We shall reassess this point once more work has been done to clarify the subject.

30 Clear instructions are required to the homeowner, tenant or non-domestic building owner for the setting-up and maintenance of MEV & MVHR systems and all other alterations to mechanical services. To be in accordance with CIBSE guidance on building logbooks. Provide English language version of the standard booklet on www.passiv.de, revised as needed for Steps 1 and 3.

Standard user manuals for low energy buildings will be published by the CarbonLite Programme later in its schedule.

31 Post-occupancy surveys and analysis of energy performance of non-domestic buildings are to be in accordance with documents published by William Bordass Associates and/or the Usable Buildings Trust. This guidance should be used to enable designers to establish whether deviations from the expected energy and CO_2 benchmarks are due to lower or higher levels of energy efficiency, or are due to non-standard occupancy conditions.

The Performance Version

SECTION 3

This section sets out the details of the performance version of the energy standards. It explains the underlying objectives but it does not state in detail what one must do to meet these objectives.

Performance standards appeal mainly to building designers who want greater freedom than the prescriptive version of a standard allows. They allow designers who cannot meet one or more elements of the prescriptive version of the standards; e.g., a maximum ratio of glazing to wall area, or a principal facade orientated within 30° of due south, or windows with a low frame fraction, to trade off these parameters against others to a limited extent.

The performance version of the standards still sets upper limits to some parameters which cannot easily be upgraded later, such as floor, wall, roof and window U-values and air permeability. This is to ensure that the building's CO_2 emissions are minimised without reliance on extra highperformance heating and ventilation systems, or solar panels on the roof; i.e., equipment which could later be removed or whose performance could later degrade. These minimum levels help to ensure that CO_2 emissions are more reliably reduced in the long term.

Table 1. **DETAILS OF THE PERFORMANCE VERSION OF THE STANDARDS**

Feature		Step 1 / Silver	Step 2 / Passivhaus	Step 3 / Gold
Design to suit site		Basic passive solar design, subject to site limitations. Design the building so that daylighting can displace substantial amounts of electric light. Set aside an area of wall or roof to retrofit solar thermal or photovoltaic panels if ever needed. Provide space to retrofit solar tank if applicable [2].		
U- and y-values if following UK conventions [3]				
Upper limit to sum of elemental U-value plus y-value				
Roofs		≤0.15 W/m²K [5]	≤0.15 W/m²K [5]	≤0.15 W/m²K
External walls		≤0.25 W/m²K	≤0.15W/m²K	≤0.15 W/m²K
Floor		≤0.20 W/m²K	≤0.15W/m²K	≤0.15 W/m²K
External opaque doors, uninstalled [4]		≤1.0 W/m²K	≤0.75 W/m²K	≤0.75 W/m²K
Windows, uninstalled		≤1.45 W/m²K	≤0.9 W/m²K	≤0.9 W/m²K
Rooflights or rof windows, uninstalled		≤2.0 W/m²K	≤1.20 W/m²K	≤1.20 W/m²K
Separating walls in semi-detached and row houses		≤0.5 W/m²K	≤0.3 W/m²K	≤0.3 W/m²K
U- and ψ-values if following PHI conventions				
Upper limits to elemental U-values				
Roofs		≤0.15 W/m²K	≤0.15 W/m²K	≤0.15 W/m²K
External walls		≤0.25 W/m²K	≤0.15 W/m²K	≤0.15W/m²K
Floor		≤0.20 W/m²K	≤0.15 W/m²K	≤0.15W/m²K
U-values				
External opaque doors	Uninstalled	≤1.0 W/m²K	≤0.75 W/m²K	≤0.75 W/m²K
	Installed	≤1.1 W/m²K	≤0.80 W/m²K	≤0.80 W/m²K
Windows	Uninstalled	≤1.45 W/m²K	≤0.95 W/m²K	≤0.95 W/m²K
	Installed	≤1.5 W/m²K	≤1.00 W/m²K	≤1.00 W/m²K
Separating walls in semi-detached and row houses		≤0.5 W/m²K	≤0.3 W/m²K	≤0.3 W/m²K
ψ-values				
Junction of window, rooflight or external door with external wall or roof		≤0.03 W/mK	≤0.03 W/mK	≤0.03 W/mK
All other non-repeating thermal bridges		≤0.01 W/mK	≤0.01 W/mK	≤0.01 W/mK
Air leakage per unit thermal envelope area under pressure		≤3.0 m³/m²hr @ 50 Pa for wholebuilding mechanical exhaust ventilation (MEV), ≤1.5 for balanced mechanical ventilation with heat recovery (MVHR).	≤0.75 m³/m²hr @ 50 Pa	As Step 2 / Passivhaus.
Ventilation		Whole building MEV or whole building MVHR	Whole building MVHR	Whole building MVHR

Table 1. (cont.) **DETAILS OF THE PERFORMANCE VERSION OF THE STANDARDS**

Feature		Step 1 / Silver	Step 2 / Passivhaus	Step 3 / Gold
Protection against overheating [5]		Design to avoid overheating in winter when windows are normally closed all the time and in summer when windows are normally opened part of the time.	As Step 1 / Silver.	As Step 1 / Silver.
Space and water heating system		SEDBUK A-rated mains gas condensing boiler, combined heat and power (CHP) or, outside the gas supply areas, a SEDBUK A-rated LPG or oil condensing boiler, electric heat pump or clean-burning biomass; i.e, liquid- or gaseous-fuelled condensing boiler. Wood pellet boilers are permitted outside gas supply area, but are not encouraged due to the exhaust emissions. Max CO_2 emissions per unit of low-grade heat to be 0.28 kg/kWh.	As Step 1 / Silver.	As Step 1 / Silver except that renewable water heating is likely to be needed to meet the energy and CO_2 targets.
Space heat distribution		Any system compatible with a source of low-grade heat and based upon circulating hot water supply and return temperatures of ≤60°/40°C under design conditions. Examples include (a) large radiators,(b) underfloor heating pipes (c) hot water coil(s) in the ventilation system.	As Step 1 / Silver but hot water coil(s) in the ventilation system normally suffice.	As Step 2 / Passivhaus
Useful space heating energy consumption per unit treated floor area		≤40 kWh/m²yr	≤15 kWh/m²yr	≤15 kWh/m²yr
Monitoring		Smart meter	Smart meter	Smart meter
Primary energy consumption				
Dwellings Surface-to-volume ratio =	0.6	≤125 kWh/m²yr	≤83 kWh/m²yr	≤65 kWh/m²yr
	1.0	≤121 kWh/m²yr	≤81 kWh/m²yr	≤62 kWh/m²yr
	1.5	≤118 kWh/m²yr	≤79 kWh/m²yr	≤60 kWh/m²yr
	2.0	≤116 kWh/m²yr	≤78 kWh/m²yr	≤58 kWh/m²yr
	2.5	≤113 kWh/m²yr	≤77 kWh/m²yr	≤57 kWh/m²yr
	3.5	≤109 kWh/m²yr	≤75 kWh/m²yr	≤55 kWh/m²yr
	5.0	≤105 kWh/m²yr	≤72 kWh/m²yr	≤52 kWh/m²yr
Non-domestic [9]		Reduction ≥70% vs. the existing stock of that building type	Reduction ≥80% vs. same baseline	Reduction ≥85% vs. same baseline

Table 1. (cont.) **DETAILS OF THE PERFORMANCE VERSION OF THE STANDARDS**

Feature		Step 1 / Silver	Step 2 / Passivhaus	Step 3 / Gold
CO_2 emissions				
Dwellings	0.6	≤25 kg/m²yr	≤17 kg/m²yr	≤4.8 kg/m²yr
Surface-to-volume ratio =	1.0	≤24 kg/m²yr	≤16 kg/m²yr	≤4.4 kg/m²yr
	1.5	≤23 kg/m²yr	≤15 kg/m²yr	≤4 kg/m²yr
	2.0	≤22 kg/m²yr	≤15.5 kg/m²yr	≤3.8 kg/m²yr
	2.5	≤21.5 kg/m²yr	≤15 kg/m²yr	≤3.6 kg/m²yr
	3.5	≤21 kg/m²yr	≤14.5 kg/m²yr	≤3.4 kg/m²yr
	5.0	≤20.5 kg/m²yr	≤14 kg/m²yr	≤3.2 kg/m²yr
Non-domestic [6]		Reduction ≥70% vs. the existing stock of that building type	Reduction ≥80% vs. same baseline	Reduction ≥95% vs. same baseline

NOTES TO TABLE 1:

1 Calculations using the performance version of the standards must normally be performed using PHPP. This is available directly from the Passivhaus Institut. PHPP-2007 fully covers domestic and most small to medium non-domestic buildings. More sophisticated simulation tools may be used for larger and/or more complex non-domestic buildings. Use Manchester weather data, which is close to the UK average, for complying with overall energy targets.

If, using PHPP or a more advanced tool, the predicted primary energy use and CO_2 emissions are both ≥15% below the limit for that building type and size, designers may describe the project as follows: “Exceeds the minimum requirements of the AECB Silver [or Gold] Standard”.

2 Calculations using the performance version of the standards must normally be performed using PHPP. This is available directly from the Passivhaus Institut. PHPP-2007 fully covers domestic and non-domestic buildings of various types.

3 For further details of U-values, please see the footnotes to the prescriptive standards. The procedures for calculations of space heating energy consumption are set out in *CLP VOLUME TWO: PRINCIPLES AND METHODOLOGIES - Calculating and minimising CO_2 emissions and heat loss from buildings.*

The first group of U-values is based on the UK convention of measuring elemental areas internally and expressing the additional impact of the non-repeating thermal bridges as a y-value. The second group of U-values presupposes the use of “thermal bridge-free” construction and the practice of measuring elemental areas externally, as in PHPP.

4 The uninstalled and installed U-values for external doors and windows are weighted averages for the whole building. The weighted average can be calculated using PHPP for the proposed window sizes and styles.

Because the glazing edge and frame U-values exceed the centre-of-glass U-value, buildings with many small windows, or windows with many divided lights, have a higher window U-value than buildings with larger single-light windows from the same manufacturer, even though all these windows have exactly the same frame and glazing type. Fenestration made from certified Passivhaus windows but containing large numbers of transoms and mullions can have U-values of >>0.90 W/m²K.

5 The acceptability or otherwise of a design can be assessed with PHPP. Use 25°C as the maximum comfort temperature. Use the geographically closest weather station for overheating calculations; see notes to the prescriptive standard.

For other building types, use internal gains of:

	Internal gains in W/m		
Steps	Schools	Offices	Care homes
Step One (Silver)	3.1	3.85	4.5
Step Two (PH)	2.8	3.50	4.1
Step Three	2.5	3.15	3.7

Other buildings need a more precise calculation; see PHPP-2007.

To meet the limit, buildings with a high surface-to-volume ratio; e.g., small detached and semidetached houses, need U-values below the maximum.

All individual dwelling units in a group of attached dwellings must meet this limit to useful space heating energy. So under Steps 2 or 3, the average dwelling in a row of houses, or in a block of flats or maisonettes, will normally use less than 15 kWh/m^{2}yr, but the most exposed dwellings in the block will use very close to 15 kWh/m^{2}yr. The weighted average for the block of flats or the row of houses, if the block or the row is viewed as one building, will be less than 15 kWh/m^{2}yr.

6 For non-domestic buildings, use as the reference building one which just meets the energy benchmarks published by the Carbon Trust (CT). These are available from www.carbontrust.co.uk. The reference building represents the weighted average for the whole existing stock of that building type; e.g., all cellular offices, all open-plan offices, all primary schools or all acute hospitals.

CT's benchmarks are based on energy consumption with reference to treated floor area, not with reference to total floor area. For definitions, please see PHPP Manual. Some of the CT benchmarks are based on energy per person and one of them is based on energy consumption per unit of treated building volume, measured in m3, so care is needed in applying them.

Benchmarks are currently available from the CT for the following non-domestic building types:

a) Four principal types of private sector office building;

b) Central government office buildings;

c) Primary schools;

d) Secondary schools with and without swimming pools;

e) Acute, teaching, cottage and long-stay hospitals;

f) Sports and recreational buildings of different types, including local authority | leisure centres;

g) Magistrates, county, crown and combined court buildings;

h) Central government laboratories;

i) High-security, open and other types of prison;

j) Three different generic types of hotel;

k) Local authority buildings including offices, residential care homes, sheltered housing, hostels for homeless people, museums, libraries, community centres, day centres and depots;

l) Industrial offices.

For building types for which no benchmark is yet available; e.g., churches, village halls, follow the prescriptive version of the standards for the time being. In the event that more than one CT publication is in print giving energy benchmarks for that building type, use the most modern one.

Examples of the procedures to use are provided in *CLP VOLUME TWO: PRINCIPLES AND METHODOLOGIES - Calculating and minimising CO_2 emissions and heat loss from buildings.*