GOOD PRACTICE GUIDE 192

2003 Edition

Designing Energy Efficient Multi-Residential Buildings

- Guidance applies to new multi-residential buildings with focus on student accommodation and care homes
- Annual savings of 20% per cent are possible using the recommended standards.
- Integrated package keeps capital costs low and maximises energy efficiency.
- Higher standards of insulation and service controls will reduce the running costs and meet future performance standards.

HOUSING ENERGY EFFICIENCY
BEST PRACTICE PROGRAMME

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1 INTRODUCTION

Demand for multi-residential accommodation - buildings containing separate residential units that share some centralised facilities - is set to grow in coming years. More accommodation will be needed for the growing number of students entering further education, and to meet the demands for sheltered housing and care homes for the ageing population.

This Guide, for designers and their clients, aims to encourage the energy efficient design, construction and refurbishment of all multi-residential buildings. Energy efficient options are illustrated using two standards, 'Good Practice' and 'Best Practice'. These should be considered when addressing the lifetime performance of the building.

The Guide is not exhaustive, and should be used in conjunction with other more detailed publications that are referenced throughout the text.

BUILDING REGULATIONS

Some types of 'multi-residential' buildings are classified under building regulations in England & Wales[1, 2], Scotland[3], and Northern Ireland[4] as 'dwellings' whilst others are 'buildings other than dwellings'. There are different requirements for each classification. This publication primarily considers 'dwellings' but much of the guidance is also suitable for 'buildings other than dwellings'. Following the guidance in this publication will generally result in buildings exceeding the energy efficiency requirements of the building regulations in all countries of the UK but it remains the responsibility of the person carrying out the work to ensure compliance with all aspects of the relevant national regulations.

ENERGY COST BENEFITS

The cost of multi-residential housing varies considerably, but the energy efficiency measures will add very little to the overall project cost. An integrated package of good design and low cost measures can significantly reduce the annual running cost per bedspace. When combined with more efficient heating control systems and higher levels of insulation, this saving can be considerable. Savings of around 15% are achievable for buildings built to the 'Good Practice' standard and savings of over 20% are achievable by following the recommendations of the 'Best Practice' standard.

An energy efficient building:

- reduces energy running costs while maintaining comfort levels
- enables residents to enjoy affordable warmth

- reduces global and local pollution
- preserves non-renewable energy sources.

Construction costs can be kept to a minimum by:

- adopting an integrated package of energy measures
- assessing the costs and benefits of different energy saving features
- carefully choosing designs and constructions
- including energy measures in the 'standard' specification rather than pricing them as extras.

ENVIRONMENTAL CONSIDERATIONS

Burning fossil fuels for heat or to generate electricity causes emissions of carbon dioxide (CO_2), a major 'greenhouse' gas. Energy efficiency reduces emissions of CO_2 and helps to fight climate change. Energy efficiency initiatives over the past 30 years have reduced the energy needed to heat our buildings but initiatives to reduce the impact from construction materials has been comparatively slow.

All building materials have an impact on the environment, particularly during their manufacture and transportation to site. There is growing global pressure to ensure that construction materials are 'sustainable'.

The Green Guide to Housing Specification[5] provides a useful reference for construction products, giving A, B, C environmental ratings for over 250 specifications. This definitive guide, developed over 20 years and supported in its current form by NHBC, is predominantly based on life cycle assessment data from the DETR-supported BRE Environmental Profiles scheme[6]. The Guide contains an extensive list of references to all of its sources of data.

The use of insulation in the building fabric will significantly reduce the operational environmental impact of the building over its lifetime. This benefit will outweigh the embodied environmental impact of the insulation materials. To minimise the embodied impact however, specifiers should avoid foam insulation materials that use blowing agents which cause ozone depletion or global warming, such as HCFCs or HFCs. Alternative blowing agents such as carbon dioxide or pentane are less environmentally damaging.

For best overall environmental performance, look to renewable or recycled materials such as cork, recycled cellulose, flax or sheep's wool, or expanded polystyrene, foams blown using pentane or CO_2 and low density mineral wool or glass wool, which are all good performers in the Green Guide to Housing Specification and have similar insulation properties to mineral wool and expanded polystyrene. Lower density glass and mineral wools should be used in preference to denser ones where possible, as their environmental impact increases proportionally with their weight.

Despite their comparatively low mass, windows and doors typically contribute between 5% and 10% of the embodied environmental impact of a house.

As rated by the Green Guide to Housing Specification, PVC-U windows perform relatively poorly due to the high energy intensity of the materials' manufacture and the fact that they have no recycled input; however the industry is taking steps to encourage the recycling of PVC-U.

Primary aluminium manufacture is also very intensive though much less energy is needed to process recycled aluminium. But although aluminium extrusions contain around 30% recycled aluminium, and are also extensively recycled, the high impacts from primary and secondary aluminium manufacture still result in high overall environmental impact for aluminium windows.

Softwood timber windows, made from renewable material requiring low energy in manufacture, perform well. As with all timber products, specifiers should ensure that the timber is sustainably grown. This is particularly relevant for tropical hardwood windows, which also involve much longer transport distances. Locally grown hardwoods will have similar impacts to softwood. Information on sustainably sourced timber is available from the Forest Stewardship Council (see Useful Contacts on page 34).

REFURBISHMENT OPPORTUNITIES

While new build offers the best opportunity for achieving energy efficiency, significant reductions in energy running costs are available through refurbishment. Most elements of this Guide can be applied to refurbishment, though in a reduced capacity. Measures which can be addressed include:

- roof insulation
- external wall insulation
- cavity wall insulation
- internal wall insulation (dry lining)
- double glazing
- draught-stripping and door closers
- ground floor insulation
- boiler replacement
- heating controls
- lighting controls.

For more information see GPG 155[7].

2 DESIGNING FOR ENERGY EFFICIENCY

INTEGRATED DESIGN

Multi-residential projects should be designed so that passive design elements (chapter 3), insulation (chapter 4), heating and ventilation systems (chapters 5 and 6), and lighting (chapter 7) work together. Integrated design ensures that comfort conditions are optimised at minimum cost and minimum energy consumption.

Making energy efficiency an integral part of the design process ensures that appropriate energy features are included as the design proceeds and are not removed by accident or to cut costs.

It is important to think about the management and maintenance of the finished building from the start. Ideally, the design brief should be developed in conjunction with those who will be responsible for managing and maintaining the accommodation.

- Details of any existing energy policy should be sought to ensure that specific objectives are included in the design.
- Ease of maintenance must be considered at all stages. This can range from easy access for cleaning light fittings to providing adequate isolation points for servicing heating installations.
- Where residents are billed, metering and billing arrangements for fuel should be considered, together with any specific requirements for monitoring and targeting energy consumption.

> DESIGN ADVICE SCHEME
>
> The Design Advice scheme is a Government initiative aimed at improving the energy and environmental performance of the building stock. New build and refurbishment projects with a floor area of 500 m^2 or more can benefit from subsidised energy design advice.
>
> Further details can be obtained from Action Energy on 0800 585 794 or www.designadvice.co.uk

The usage pattern should be considered fully, particularly with student accommodation where, for significant periods of time, the accommodation may not be occupied or only partially occupied. Consideration should be given to being able to control the services independently in different zones, as well as the suitability and efficiency of various heating and ventilation systems during low occupancy periods. This situation will be referred to again in the following chapters.

ENERGY ASSESSMENT AND RATINGS

If the insulation levels and layout of a building are known, along with details of the heating and hot water system, it is possible to estimate its future energy consumption and costs using manual calculations or computer based modelling tools. These can be useful decision-making tools when evaluating different design options.

Energy assessments can also be used to set minimum design standards. Performance targets can be set in terms of CO_2 emissions, energy use, or running costs (either per unit floor area, or per bedspace). In self-contained 'dwellings' Standard Assessment Procedure (SAP)[8] and Carbon Index (CI) targets can be used.

The SAP is one of the principal methods of assessing energy performance in dwellings, but the calculation, which assumes a standard occupancy and heating pattern, is not wholly appropriate for multi-residential buildings and care homes. SAP can be calculated manually but a computerised version is preferable.

Computerised energy modelling programs

Programs based on BREDEM (Building Research Establishment Domestic Energy Model) can be used for estimating the energy use, and hence energy efficiency, of self-contained dwellings. There are no BREDEM based software programmes available that are intended specifically for multi-residential buildings.

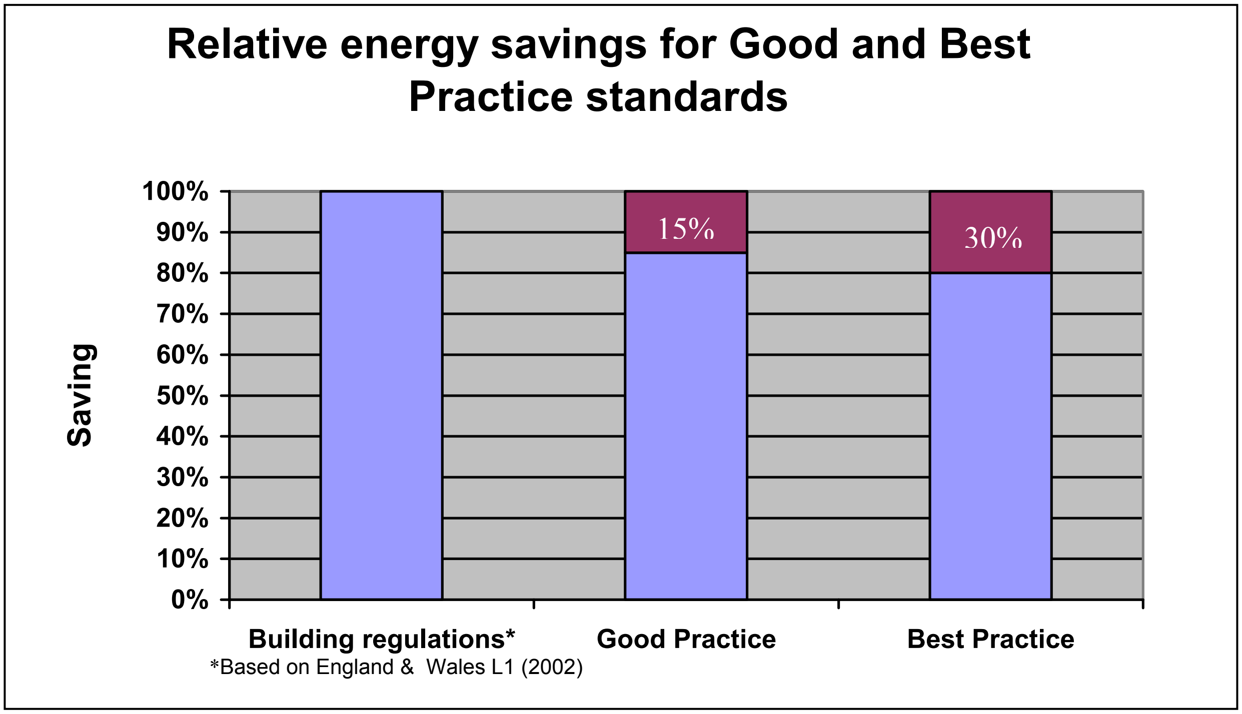
Detailed computer simulation

While not designed specifically for multi-residential accommodation, detailed computer simulation programs are available which can be useful if the design is particularly complex or unconventional. For further information see CIBSE AM11[9].

SPECIFYING THE OPTIONS

This Guide discusses in detail two energy efficiency options, ('Good Practice' and 'Best Practice'). The Good Practice and Best Practice standards consist of the minimum Carbon Index for different types of commonly used fuels, maximum U-values for all exposed construction elements and various other basic requirements depending on the standard being defined. In addition, there are further recommendations for each standard.

It is both possible and practical to go beyond both these standards and additional information is available on these standards plus an 'Advanced' standard, in GIL 72[10].



THE GOOD PRACTICE STANDARD

Basic requirements

- The dwelling must meet a minimum CI as shown in the following:

Fuel	Minimum CI
Gas / Biomass / CHP / Renewables* / LPG	8.0
Oil	6.8
Electric	6.2

*not including 'green' electricity tariffs

- U-values – The U-values must not be greater than the Elemental U-values of the building regulations in the relevant country (England, Scotland, Wales, Northern Ireland)

- At least 50% of the rooms should be lit by energy efficient lights. When replacing old fittings use fittings specifically for CFLs.

Further Recommended Measures

- Where possible 'A' rated electrical appliances should be supplied.

- A pressure test following the method set out in CIBSE TM 23 'Testing Buildings for Air Leakage'[11], should achieve an air permeability rate of less than 4 $m^3/h/m^2$ for houses with heat recovery ventilation systems and less than 7 $m^3/h/m^2$ at 50 Pa for other houses (GIR 64 Post Construction Testing[12]) .
- A ventilation system should be installed that gives a continuous, controlled supply of fresh air. This can either be a Passive Stack Ventilation system (PSV) or Assisted Passive Stack Ventilation (aPSV) or a Heat Recovery Ventilation system (HRV).

THE BEST PRACTICE STANDARD

Basic requirements

- The dwelling must meet a minimum CI as shown in table.

Fuel	Minimum CI
Gas / Biomass / CHP / Renewables* / LPG	8.6
Oil	7.4
Electric	6.8

*not including 'green' electricity tariffs

- The U-values must not be greater than those set out in the following table:

Element	Maximum U-value (W/m^2K)
Roof	0.13
Walls, including basement walls	0.25
Floors, including ground floors and basement floors	0.20
Windows doors and rooflights (area-weighted average)	1.80

Basic requirements (continued)

- A pressure test following the method set out in CIBSE TM 23[11] should achieve an air permeability rate of less than 3 $m^3/h/m^2$.
- A ventilation system should be installed that gives a continuous, controlled supply of fresh air. This can either be a Passive Stack Ventilation system (PSV) or Assisted Passive Stack Ventilation (aPSV) or a Heat Recovery Ventilation system (HRV) (note 1 below).

- If a central heating system is used, it should comply with the CHeSS HC4 or HR4 specification (GIL59 Central Heating Systems Specifications[13]).
- Other heating systems should have time and temperature controls equivalent to the CHeSS specification (note 2).
- At least 80% of rooms should be lit by dedicated energy efficient lights.
- A ventilated space for clothes drying should be provided inside the house (note 3).
- Where electrical appliances are being supplied, they should be ‘A’ rated (note 4).

Further Recommended Measures

- A thermographic survey should be considered as a useful technique for identifying missing insulation.
- Low water use appliances should be used. The WC should use no more than 4 litres. Showers should use less than 8 litres/min. Where specified washing machines should have a water consumption of less than 50 litres per wash; consumption for dishwashers should be less than 16 litres (as specified on the energy label). Care should be taken to avoid excessive ‘dead legs’. It is recommended that the maximum length of dead leg should contain no more than 1.5 litres of water. This is equivalent to a 10 m length of 15 mm diameter copper pipe. If mains pressure hot or cold water is used, outlets should be fitted with dynamic flow regulators.

Notes (Best Practice standard)

1 If PSV or aPSV is used, both the supply and exhaust vents should be humidity controlled. If fans are used in the ventilation system, the total fan power should be less than 2W per l/s of extract air. If heat recovery is to be used the efficiency of the heat exchanger should be greater than 70% as measured by BS EN 13141/7/8 (CEN TC 156/WG2/AH7 Component/products for residential ventilation[14])

2 For non-central heating systems the following requirements should be met.

- Non-electric systems. If gas room heaters are used, their efficiency should not be less than the standard set out in BS EN 613[15] 'Independent gas-fired convector heaters' (soon to be superseded). The heaters should have individual room temperature control. If hot water storage is used, it should a) be insulated to CHeSS HR4 and b) have time and temperature control.
- Electric systems. Storage heaters should have automatic charge control. Fan assisted storage heaters are recommended. On-peak heaters should have time and individual room temperature control. Hot water systems should have cylinder heat losses less than 1.33*(0.02 + 0.051*V2/3) as measured by BS 1566, 'Copper indirect cylinders for domestic purposes'[16]. This equates to a heat loss of 2.4 kWh over 24 hours for a 210 litre cylinder, or 1.7 kWh for a 120 litre cylinder. BS 1566 requires these heat loss figures to be marked on cylinders.

3 The clothes drying space should either have an exhaust vent from the whole house heat recovery ventilation system or an exhaust terminal from the PSV system or should be fitted with a room heat recovery ventilator.

4 Where electrical appliances are not supplied, occupants should be given information on the benefits of energy efficient appliances.

3 PASSIVE DESIGN

Passive design seeks to exploit the use of solar energy for heating and lighting, and utilises natural ventilation. However, maximum energy savings can only be achieved if passive design is fully integrated into the design strategy at the beginning.

Good passive design should be a central part of any overall energy efficiency strategy. As well as encouraging buildings to trap and store solar energy for heating, it aims to:

- improve daylighting in the buildings,
- encourage the use of natural ventilation,
- avoid overheating,

all of which will reduce running costs and need not increase the cost of the building.

Site location and layout of buildings

The energy implications of the building site, location, form and orientation should be considered at the planning stage. Decisions that result in wasted energy are difficult to amend once planning permission is granted or the master plan agreed. If the opportunity exists during the selection of the site, consider:

- access to daylight
- protection from winds
- orientation for solar gain.

If site location is predetermined, try to relate the above issues to the building orientation.

Where possible, orientate one of the longest facades of the building within ±30° of south. Avoid overshadowing within ±45° of south.

To maximise solar gain, buildings should be spaced more than twice their height apart from north to south, with lower buildings on the south edge of the site and taller buildings on the north. Further information on this issue is contained in 'Site layout planning for daylight and sunlight: a guide for good practice' BR 209[17].

SHELTERING AND OPENINGS

- On exposed sites reduce exposure by using existing shelter or by planting tree shelter belts.
- Reduce ventilation heat loss by positioning buildings to avoid openings in exposed facades.

- Avoid planting trees on south sides, or plant deciduous trees without dense foliage to allow sun penetration, particularly in spring, autumn and winter.

BUILDING FORM

Design first for minimal heat loss and then consider solar improvements. But remember that fabric heat loss is only one element of the total energy consumption of a building. Building form should be integrated with other factors such as solar gain and daylighting.

Factors that can reduce heat loss include:

- terraced units
- a compact building shape
- enclosed porches and external draught lobbies.

To maximise solar gains, bedrooms and communal living areas should be south-facing. Service areas, e.g. stairways and kitchens, should generally be on the north facade.

A long thin room with the short wall to the exterior minimises heat loss, but a shallow plan room with a wide external wall can enjoy more daylight. A compromise solution is to use the former shape and locate areas requiring daylight, such as desk space, adjacent to the window. Long thin rooms may be essential to reduce heat losses, especially if electric heating is being considered (see section on Fuel Choice).

Conservatories

Conservatories can provide pleasant and popular additional space, particularly in care homes. However, they should not be heated. They should have high levels of insulation and double glazing with low emissivity coatings, and should be separated from other living spaces by doors to avoid excessive heat loss in winter. Although conservatories can provide useful solar gain at particular times, they are not overall energy saving features.

DAYLIGHTING

Daylighting reduces lighting costs and provides a pleasant environment. The need for sufficient window area, however, must be balanced against the desire for privacy. If residents feel exposed in a room they may draw curtains and switch on lights, causing energy consumption to rise. Venetian blinds can aid privacy while still admitting daylight.

Raising the height of the window head increases penetration of daylight, and splaying the window reveals can enhance its distribution. Glazing below normal sill height (0.8-1.0 m) provides little useful daylight and can severely affect privacy.

Rooflights can improve daylighting in rooms and corridors on top floors. This is particularly useful for internal bathrooms, kitchens and large rooms where more light may be needed than can be provided by windows. However, there is a greater heat loss through a rooflight than its equivalent as a window in a wall so a good U-value for rooflights is particularly important. Alternatively, light pipes can be used to bring light into areas where electric lighting is likely to be on during the day.

SOLAR GAIN

It is not necessary to have especially large windows on the south-facing elevations for energy saving reasons. Simply rearranging room layout to put the rooms with the larger glazed areas i.e. the main living rooms and main bedrooms on the south side of a building will naturally displace those with smaller windows to the north side. This will make the most of passive solar gains whilst not having a serious impact on the architecture and will not significantly increase the risk of overheating.

Shading should be provided where glare and overheating may be a problem, for example in conservatories or highly glazed communal living areas. Projecting external shading on south facades can cut out high summer sun and allow low winter sun to enter the building but in most cases internal blinds will provide an adequate solution.

Further information on this is given in 'Solar shading of buildings' BR 364[18].

4 INSULATION AND FABRIC ISSUES

INSULATING THE BUILDING ENVELOPE

As part of an integrated energy efficient design, all exposed (and 'semi-exposed') elements should be insulated to produce a fully insulated building envelope. Attention should be paid to avoiding thermal bridging (see section on Thermal Bridging, page 17). For all aspects of the fabric (walls, floors, roofs, and windows & doors, the Good Practice standard will be met so long as the U-value is no worse than the appropriate U-value in the Elemental Method for the building regulations of the relevant country.

EXTERNAL WALLS

Filling cavity walls with insulation is one of the most cost-effective options. Fully filled cavity walls will resist rain penetration except in very severe exposure areas, mainly found in Wales, Scotland, and the west of England and parts of Northern Ireland. Maps are available which divide the UK into zones according to exposure to wind-driven rain. It is important to take local conditions into account and calculate a driving rain index using BS 8104[19]. Further information on cavity fill and its suitability can be found in GPG 26[20] and GIL 23[21].

Other forms of construction including partial fill masonry, timber framed construction, and external wall insulation can all achieve very good insulation standards. Construction methods other than fully filled cavities should allow a minimum 50 mm clear residual cavity.

Care should be taken to choose insulation products with the least environmental impact (see Environmental Considerations, page 4).

Care homes

Care homes and sheltered accommodation are likely to have heating switched on for long periods. The building should therefore be highly insulated. This will greatly reduce fuel bills and help to ensure comfortable conditions for occupants.

Student accommodation

The heating pattern in student accommodation may be intermittent and therefore it should be possible to heat the room quickly. A lightweight form of construction will improve the thermal responsiveness of the building.

ROOFS, CEILINGS AND FLOORS

For conventional pitched roofs, an insulation depth of around 300mm can be expected for normal insulation quilt material for the 'Best' Practice standard. This should be laid in layers, one between the joists and the others across the joists to prevent thermal bridging. A gap at the eaves allows ventilation and prevents condensation. If necessary, battens should be used to raise access walkways above the insulation. Where space is of a premium, for example in flat roofs or where insulation follows the pitch of the roof, a higher insulating value material will be needed to achieve the required U-value within the space available.

For most types of flooring, insulation in the order of 100mm should be anticipated, depending on the standard being considered, the shape and type of the floor, and the material chosen. Particular attention also needs to be given to avoiding thermal bridging at the floor edges. (see section on Thermal Bridging).

WINDOWS

Double glazing with low emissivity (low-e) glazing is now standard in much of the UK but different types of low-e coating, and gas filling are also available. These improve performance further and can be used when aiming for higher standards, or increasing the window areas are desirable without increasing overall heat loss. The Best Practice standard requires U-values no worse than 1.8 W/m^2K. The table below shows the U-values of some typical frame/glazing combinations.

U-values of different frame and glazing combinations					
Frame	Glazing	Coating	Gas fill	Gap	U-value
Timber/PVC-U	Double	Clear	Air	16+	2.7
Timber/PVC-U	Double	Low-e, hard (0.15)	Air	16+	2.0
Timber/PVC-U	Double	Low-e, hard (0.15)	Argon	12	1.9
Timber/PVC-U	Double	Low-e, soft (0.10)	Air	16+	1.9
Timber/PVC-U	Double	Low-e, soft (0.10)	Argon	12	1.9
Timber/PVC-U	Double	Low-e, soft (0.0.5)	Air	16+	1.8
Timber/PVC-U	Double	Low-e, soft (0.05)	Argon	12	1.7
Metal (4 mm break)	Triple	Low-e, hard (0.15)	Air	16+	2.0
Metal (4 mm break)	Triple	Low-e, soft (0.05)	Argon	12	1.8

When selecting double or triple glazing, specify:

- units fitted in accordance with the Glass and Glazing Federation Manual[22],
- units 'kite marked' to BS 5713[23],
- trickle ventilators in the top of the frame (unless full mechanical ventilation is provided)

- thermal breaks, if metal frames are used
- draught-stripped frames appropriate for the exposure rating.

Care homes

Day rooms with large areas of wall and roof glazing are present in many care homes. As these rooms are usually heated and constantly occupied it is worth considering installing a higher standard of glazing to improve thermal performance and the comfort of residents.

THERMAL BRIDGING

Heat loss from thermal bridging occurs where one element of the building fabric is poorly insulated, and thus colder, than the other parts. This usually occurs when elements pass through the insulating layer. The thermal bridge is not always the shortest heat loss path and will also depend on the conductivity of the material bridging the insulation.

Condensation can be a result of thermal bridging. This usually occurs around windows, doors, and at the junctions between external walls, floors and roofs.

It is best to avoid thermal bridging by maintaining continuity of insulation. Where this is not possible:

- overlap the insulating layers to prevent a direct thermal bridge
- use a material with good insulating properties to bridge the gap between the construction layers.

For further information on the application of insulation and good detailing see 'Thermal insulation: avoiding risks'[24]; and 'Robust Details'[25].

AIR LEAKAGE

Air leakage is of considerable importance when considering energy efficiency and is measured in terms of permeability of the building fabric. An air permeability rate is a measure of the 'leakiness' of a building and a fan pressurisation test can be used to determine whether a given standard has been achieved.

The importance of air leakage is reflected in the air permeability rates for both 'Good' and 'Best' Practice standards. Ventilation should be controllable and only provided by means of purpose designed openings (see the chapter 6, Ventilation).

Standard	Air permeability rate
Good Practice	4 $m^3/h/m^2$ - full mechanical ventilation 7 $m^3/h/m^2$ – other ventilation
Best Practice	3 $m^3/h/m^2$

The main air leakage paths in dwellings are:

- joints around components, e.g. windows
- gaps between one building element and another
- holes where services pass through the construction.

Care should be taken to ensure that these areas are well detailed and sealed.

For further information on reducing air leakage and good detailing see ‘Thermal insulation: avoiding risks’[24]; and ‘Robust Details’[25].

5 HEATING

FUEL CHOICE

The choice of fuel for heating must be considered at the initial planning stage and will be based on the fuels available on site. The level of CO_2 and other emissions, capital cost, plant maintenance and running costs over the life of the building must also be considered. Natural gas, where available, is the preferred fuel for wet-heating systems due to its significantly lower carbon content.

Where mains gas is not available, oil - likely to be comparable in running cost - should be considered.

Further information on fuel choice is given in GPG 301[26].

Various heat emitters can be used with both oil and gas systems and some advantages and disadvantages of the different types of heat emitters used are listed below.

Advantages and disadvantages of alternative emitters for wet heating systems.		
	Advantages	Disadvantages
Radiators	• Flexible layout • Relatively cheap to install • Low maintenance • Occupants familiar with system from domestic use	• Care must be taken to ensure that touch temperatures are not too high. Particularly important in care homes as the elderly are more susceptible to burns
Finned tubes	• Take up relatively little space • Provide an even distribution of heat • Fan assisted units can provide increased heat dissipation	• Units prone to damage
Underfloor	• Provides even distribution of heat • No risk of damage by occupant • No restriction on room layout • Low water and touch temperatures	• Slow to respond to temperature control • Expensive to install • A leak can cause extensive disruption

Electrical heating equipment is cheap to install and maintain, but running costs and environmental impact are higher. However, in some circumstances it may be a viable option. As well as its low capital cost, ease of installation and low maintenance requirements, electric storage heating needs no central plant and billing residents is easy.

On the other hand storage systems cannot respond quickly to changes in solar gains and, even using off-peak tariffs, heating costs will be higher than with gas systems. In addition, the thermal charge can be depleted too quickly if the manual controls are not understood and a secondary (usually on-peak) electric system is usually required.

Buildings with electric heating will need to have better insulation levels. Only the small sheltered dwellings, e.g. flats and mid terrace properties are likely to meet the relevant minimum CI rating given in the Good and Best Practice standards using the maximum U-values given in the standards. For 'buildings other than dwellings' where the CI targets do not apply, electric heating should only be used if the fabric U-values are no worse than those given in the Best Practice standard.

On-peak electric non-storage heating should be used only in well insulated rooms occupied for short periods.

Whichever system is chosen, it is important to ensure that the controls are accessible and easily understood by those operating them.

Further information on choosing a heating system can be obtained from GPG 284[27].

Billing

The arrangements for billing could influence the plant installed. For example, where residents will be billed for fuel directly, it may be more appropriate to install individual systems in each unit. This will simplify metering. Where occupants are not billed for heating and hot water, such as in care homes, centralised plant may be a more efficient option.

HEATING PLANT

Whether heating and domestic hot water is supplied from a central boiler house or a series of local decentralised units will depend on site characteristics and other factors (see table below). Heating systems must be sized to meet reasonable maximum demand using a sizing method based on the Domestic Heating Design Guide[28]. Oversizing can lead to unnecessary capital cost and, with some boilers, less efficient operation.

If the base load of the development is large enough, combined heat and power (CHP) plant may be considered[29] possibly as part of a community heating system. When looking at large or centralised plant options, consideration should be given to the user patterns of the building and periods when there may be only a few or no residents in occupation. In such situations large plants may be inefficiently running at over capacity. Hybrid or multiple boiler systems may prove to be more efficient.

Combined heat and power (CHP)

CHP offers a very efficient way of producing heat and electricity. To provide an acceptable financial payback, however, requires a fairly continuous accessible heating requirement and electricity demand. This may only be achievable for some large care homes and sheltered housing. It may also be viable in buildings that are part of a larger site.

Advantages and disadvantages of centralised and decentralised plant

	Advantages	Disadvantages
Central boiler house	• Easy maintenance as there is only one main plant area • Provides flexibility to run multiple boiler installation at near 100% output giving good operating efficiencies • Possibility of heat recovery or CHP Installation • Simplified fuel supply	• Failure could cause major disruption • Increased capital costs for boiler house etc • Increased capital costs due to larger pipework distribution • Less control for local user • Additional plant room space (cupboards etc) for zone control • Energy loss from distribution mains and additional pump power • Difficult to meter the supply for individual payment
Decentralised boilers	• No main boiler house and associated flue required • Small boilers general make less noise • Increased user control to determine on/off times of heating system • Failures create only local disruption	• Individual fuel supplies must be provided • Large number of units to service

Most gas or oil boilers are categorised as regular or combination. Each of these may be either condensing or non-condensing. Condensing boilers are always more efficient.

Domestic boilers are now classified with a seasonal efficiency rating (SEDBUK) and 'banded' A – G (see www.boilers.org.uk for further details). It is recommended that all single boiler installations should use ‘A’ (preferably) or ‘B’ rated boilers, however in order to meet the Carbon Index targets for Good and Best Practice

Domestic type systems

The simplest method of specifying domestic type systems is to use the recommendations given in GIL 59[12].

standards (Specifying the options, page 7) a lower efficiency boiler can be used if insulation standards are improved.

Maximum efficiency depends on correct sizing and system layout. Instead of one single boiler, the use of multiple smaller units could be preferable. For instance, when there is lower demand for heating in the summer, the secondary boilers can be shut down, requiring the lead boiler to run at maximum efficiency supplying the hot water requirements. A multiple boiler system will also enable some heating to be supplied if one boiler fails. For multiple boiler installations it is recommended that a minimum of 50% of installed capacity is condensing so long as boilers are sequenced so the condensing boilers always fire first. Where this is not the case all boilers should be condensing.

Care homes

Space heating in care homes can be in use for up to 24 hours per day during the heating season. Careful zoning should be arranged so that unused areas are not being heated at night. The use of night setback programmers will also reduce the heating costs without undue discomfort to the occupants. Controls should also be installed to prevent the whole system firing up at night when a single small demand for heat or hot water is made[30].

DOMESTIC HOT WATER

Domestic hot water (DHW) is likely to be a major energy user in multi-residential buildings, and plant sizing must be based on a realistic hot water usage profile. This will involve an evaluation of the daily and annual usage pattern.

The main options for DHW production are:

- centralised production combined with the space heating system
- centralised production separate from space heating
- localised production with some storage
- localised instantaneous hot water production with no storage.

If space heating is decentralised and the individual boilers are relatively small, a combination boiler may be the most efficient method of providing heating and hot water. It may also be worth considering a hybrid system. For example, if there are very long pipe runs it may be more efficient to install instantaneous DHW heaters in those areas while retaining centralised production elsewhere. If washing machine points are supplied they should have hot and cold feed points. If mains pressure hot and cold water is used, outlets should be fitted with dynamic flow regulators.

Care homes

A hot water temperature of above 50°C at the tap prevents the proliferation of legionella (see below), but it can present a risk of scalding to the elderly. It is recommended that fail safe, thermostatically controlled mixing valves are used. These valves are not affected by changes in water pressure and will shut off the hot water supply if the cold water pressure drops. This will allow the hot water system to operate at above 50°C while allowing lower temperatures to be delivered at the tap, where 43°C is required to avoid the risk of scalding[30].

Legionnaire’s disease

Attention must be given to avoiding the risk of legionella when designing hot and cold water services. This is particularly relevant for care homes, where occupants may be more susceptible. The Health and Safety Executive recommends:

- hot water storage (calorifiers) at 60°C
- hot water delivered to the tap at 50°C within one minute
- cold water storage and distribution below 20°C.

For further information see ‘Legionnaires disease: the control of legionella bacteria in water systems’[32].

HEATING CONTROLS

An energy efficient heating system will realise its potential only if the control regime is appropriate, understood and used. Simple control systems often provide a more efficient solution than more complex arrangements. Basic points to be addressed before a system is designed include:

- the level of automation required
- user access to, and understanding of, controls
- the level of centralised control required.

Zone, temperature, timing and boiler interlock controls are a requirement of the building regulations in all parts of the UK. While groups of rooms may be considered as one supply zone, each room should have its own temperature controls. Thermostatic radiator valves (TRVs) alone are not sufficient for boiler interlock.

The boiler interlock is the electrical wiring of controls designed to prevent the boiler firing up when there is no call for heat.

If zone controls are properly integrated they will allow heating to be adjusted in response to solar gain and usage patterns in different areas of a building. For this reason areas with different levels of solar gain e.g. different sides of a building, should be zoned separately.

A programmer may also give the option of night set-back, which allows the space or water temperature to fall to a specified minimum during the night.

Care homes

Heating in care homes will usually be centralised. Staff will generally be responsible for adjusting the heating system in response to residents' requests. Some local temperature control, such as room thermostats or TRVs, should be provided for extra control[29].

Student accommodation

The intermittent heating pattern of student accommodation requires controls to be very responsive, so that students can obtain heat almost immediately on entering the room. The problem, as far as energy efficiency is concerned, is to ensure that the heating is turned down again when the student leaves the room. Heating control systems that respond automatically to room occupancy are available and may be appropriate in this type of accommodation.

Installing optimised start control can produce savings in multi-residential buildings, as well as improving comfort. The control monitors internal and external temperatures and adjusts the length of the warm-up period of the heating to reach the desired temperature at the appropriate time. Significant savings will be made during fluctuating temperatures, particularly in the spring and autumn seasons, without having to adjust the winter on/off time setting (although clocks will still need adjusting for summer and winter clock changes).

Primary control can be achieved with wall-mounted thermostats by averaging several units through an intelligent controller or building management system (BMS). Secondary local control relies on thermostatic radiator valves (TRVs) or dampers for finned tube emitters. BMS systems can also monitor the performance of the heating system, which will help to confirm the results of adjustments made during occupation.

More information on controls for multi-residential buildings can be obtained from the GPG132[33]. For further information on heating and fuel for domestic buildings can be found in GPG 284[27], GPG 301[26], and GPG 302[34].

6 VENTILATION

The principle behind ventilation is the rapid removal of moisture at its source and the provision of controllable background ventilation.

Effective ventilation is best provided by reducing air leakage (see section on Air Leakage p17) and installing purpose-designed openings over which there is some control. Air tightness, when combined with controllable ventilation will improve the energy efficiency of the building.

In reasonably airtight buildings a ventilation system should be installed that gives a continuous, controlled supply of fresh air. This can either be a Passive Stack Ventilation system (PSV) or Assisted Passive Stack Ventilation (aPSV) or a Heat Recovery Ventilation system (HRV).

Total ventilation rates of between 0.5 and 0.75 air changes per hour (ach) are recommended[35] for residential accommodation.

PASSIVE STACK VENTILATION

In many cases adequate ventilation can be achieved at low capital cost by PSV, an arrangement of ducts running from kitchens and bathrooms to vents on the roof. This reduces the need for extract fans, thereby reducing electricity consumption.

The ducts extract air by the stack effect, the upward movement of air caused by the temperature inside the building being higher than that outside, and the suction caused by wind flows over the roof. Airflow is controlled by humidity sensitive dampers on duct inlets. Fresh air enters the building via trickle ventilators and other openings. PSV can only be used effectively in buildings up to 4 storeys[36].

'Assisted passive stack ventilation' (aPSV) is similar to a central extract system but where humidity control is provided at each air inlet.

WHOLE BUILDING VENTILATION WITH HEAT RECOVERY (MVHR)

In whole building ventilation systems, fresh air is distributed via a duct system throughout the building with air being extracted by fans from kitchens, bathrooms and WCs. A heat exchanger is usually incorporated to extract heat from the exhaust air and warm the incoming air. A well-sealed building is essential.

Savings in space heating can be offset by the cost of electricity required to run the fans. However, MVHR may be cost-effective if the heating fuel is expensive, e.g. electricity. Regular maintenance is required and system failure may have serious consequences if there is no back-up. MVHR systems rely on a well sealed and controlled environment, which may not be possible if individuals are free to open windows. Also, the efficiency of a whole house ventilation system needs to be considered over an annual period where there may be extended periods of low occupancy where the running cost per occupant will be relatively high.

However, whole house mechanical ventilation reduces the risk of condensation if well installed and maintained[37].

7 LIGHTING

Lighting can form a sizeable part of total fuel costs. It is therefore important to reduce the energy consumed by the lighting system.

Key areas to address when considering lighting installation are:

the use of daylighting (see section on Daylighting)

- lighting design
- luminaire and lamp choice
- lighting controls.

LIGHTING DESIGN

Careful consideration is needed to balance the functional needs of the user with the aesthetics of the space. The three different types of lighting commonly referred to by designers are general, task and atmospheric (decorative) lighting. Matching the type of lighting to the room requirements can help reduce energy use. Particular care should be given to the lamp colour of fluorescent lamps and residential applications a lamp colour of 2700K is recommended. GIL 20[38] gives more information on this issue.

LAMP AND LUMINAIRE (LIGHT FITTING) CHOICE

The effectiveness or 'efficacy' of a light source is given by the light output in lumens divided by the power consumed in Watts. This power consumption can be for the lamp itself, lamp and control gear, or for the whole luminaire. For 'dwellings' an energy efficient lamp can be categorised as a one that has an efficacy greater than 40 lumens per Watt. For multi-residential 'buildings other than dwellings' an efficacy of 50 lumens per Watt including control gear is used. Most compact and tubular fluorescent lamps will be energy efficient.

For accommodation classified as 'dwellings' the Good and Best Practice standards require 50% and 80% of rooms to be lit using energy efficient lighting. For accommodation classified as 'buildings other than dwellings' it is recommended that 95% of all installed lighting capacity (Watts) is provided using lamps given in the table below.

External lighting needs to be effective for safety and identification purposes. It should have control mechanisms to ensure it automatically switches off when there is sufficient daylight or when not required at night. Energy efficient lamps should be considered in all situations where lighting is required for long periods. High pressure sodium lights should not be used in conjunction with passive infrared (PIR) presence detectors. Fluorescent lighting should only be used with PIRs when the control is set to stay on for periods of around 20 minutes (see controls, below).

Suitable light sources with efficacies greater than 50 lumens/Watt	
Light source	**Types and ratings**
High pressure sodium	All types and ratings
Metal halide	All types and ratings
Induction lighting	All types and ratings
Tubular fluorescent	26mm diameter (T8) lamps, and 16mm diameter (T5) lamps rated above 11W, provided with high efficiency control gear. 38mm diameter (T12) linear fluorescent lamps 2400mm in length.
Compact fluorescent	All ratings above 11W
Other	Any type and rating with an efficacy greater than 50 lumens per Watt

CONTROL SYSTEMS

Choosing appropriate controls should ensure that artificial lighting is used only where and when it is required.

Options include:

- manual switching
- photocell control
- time zone
- dimming
- occupancy sensors
- key fob switches.

Waste can be avoided by ensuring that every light point has an independent, easily identifiable switch. In particular, separate switches should be provided for lights close to windows.

Where lighting is controlled by manual switches these should be positioned at all exits doors. In large rooms such as communal dining areas switching (automatic or manual) should be provided within 8 metres of the luminaire (measured on plan) or three times the ceiling height. In bedrooms, switches should be provided near beds.

If safety permits, push-button switches should be used in cupboards and corridors where lights are frequently left on unnecessarily They should not be used near staircases.

The life of fluorescent lamps without electronic control is significantly shorter where there is frequent switching. For this reason they should not be used with PIR controls which are set to remain on for less than approximately 20 minutes. This is much less of an issue for lamps with electronic control gear.

For more information on choosing luminaires, lamps and control systems, see GPG199[39], and GPG 160[40].

8 CONSTRUCTION AND HANDOVER

CONSTRUCTION

Only when the well designed and constructed building has been correctly handed over will the full energy efficiency of the project be realised.

The design documents should provide the contractor with both technical guidance on the installation and the operating intent and rationale of any novel features in the design.

Provision must be made for inspection and testing. It is difficult to carry out remedial work to bring a failed building up to meet its targets, and early identification and correction of potential problems is vital.

COMMISSIONING

Infiltration rate tests and infrared thermographic surveys enable straightforward and accurate checking of the design and construction standard of any heated building.

It is preferable to commission many aspects of a building when it is in use. This allows systems to be tailored more closely to the requirements of users. Settings may need to be adjusted over a period of occupation to find the optimum levels that suit the user profile and improve on the energy efficiency. BMS systems will help in monitoring performance and feed back from changes made.

AS-BUILT INFORMATION AND HANDOVER

Changes are often made to the detailed design of a building during construction. These must be documented to provide a complete and accurate ‘as-built’ record. This is required for operating the building effectively, and becomes essential when refurbishing or altering.

Comprehensive and accessible manuals are required for each aspect of a building and its services. The components installed and the operating instructions and standard control settings for all services equipment must be clearly and accurately communicated. Cross referencing with layout and schematic drawings is also required to aid full understanding of the design intent.

Information about the appliances supplied or required, should also be included with an explanation of their importance to the energy efficient running of the building.

Staff should be trained in the correct use of the energy efficiency measures and the concept behind them. A member of staff should also be appointed as an 'Energy Manager' to be responsible for co-ordinating the efficient running of the building.

FURTHER READING

The following related publications are available from the Housing Energy Efficiency Best Practice programme (HEEBPp). Tel 01923 664258 or www.housingenergy.org.uk

ECON 57 Energy consumption guide for nursing and residential homes.

GIL 20 Low Energy domestic lighting - a summary guide.

GIL 23 Cavity wall insulation : unlocking the potential in existing dwellings.

GIL59 Central Heating Systems Specifications.

GIL 72 Energy Efficiency Standards – new and existing dwellings.

GIR 64 Post-construction testing.

GPG 26 Cavity wall insulation in existing housing.

GPG 155 Energy efficient refurbishment of existing housing.

GPG 199 Energy efficient lighting - a guide for installers.

GPG 284 Domestic central heating and hot water: systems with gas and oil-fired boilers - guidance for installers and specifiers.

GPG 301 Domestic heating and hot water - choice of fuel and system type.

GPG 302 Controls for domestic central heating and hot water - guidance for specifiers and installers.

The following publications are available from Action Energy. Tel. 0800 57 58 94 or www.actionenergy.org.uk

GPG 132 Heating controls in small commercial and multi-residential buildings.

GPG 234 Guide to community heating and CHP - commercial; public and domestic applications.

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USEFUL CONTACTS

British Standards Institution (BSI)
Tel 020 8996 9000
www.bsi-global.com

Building Research Establishment (BRE)
Tel 01923 664000
www.bre.co.uk

Chartered Institution of Building Services (CIBSE)
Tel 020 8675 5211
www.cibse.org

Forest Stewardship Council (FSC)
Tel 01686 413916
www.fsc-uk.demon.co.uk

Glass and Glazing Federation (GGF)
Tel 020 7403 7177
www.ggf.org.uk

Health and Safety Executive (HSE)
Tel. 08701 545500
www.hse.gov.uk

Thermostatic Mixing Valve Manufacturers Association (TMVA)
Tel 020 7793 3008
www.tmva.org.uk

The Stationery Office (TSO)
Tel: 0870 600 5522,
www.tso.co.uk

The Government's Housing Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in housing. This information is disseminated through publications, together with seminars, workshops and other events.

Visit the website at **www.housingenergy.org.uk**
Call the Housing Helpline on **01923 664258**

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