GPG 303

The designer's guide to energy-efficient buildings for industry

BEST PRACTICE PROGRAMME

ENERGY EFFICIENCY

ARCHIVED DOCUMENT

EXECUTIVE SUMMARY

This Guide will assist designers in working effectively with their clients to produce energy-efficient buildings through encouraging an integrated approach to the building fabric and building services and by providing a checklist of energy-efficient options. The appraisal procedure for these options will show where it is cost-effective to improve energy efficiency above the minimum required by the Building Regulations.

Almost all energy use results in the production of CO_2, which is the main greenhouse gas contributing to climate change. This fact and the UK Government's commitment to reducing emissions of CO_2 has brought about a sea change within industry, and the businesses that supply them with buildings and building services, that there are sound business and environmental reasons for reducing energy use.

Industrial buildings typically require large areas for storage and production, often having high ceilings and high ventilation rates. Usually there is further 'social' space in areas such as offices, and in many cases the buildings will include canteens or kitchens. With such a range of activities and characteristics, industrial buildings usually have energy requirements that present designers with particular challenges.

This publication contains a number of easy-to-use features that support the design process, including:

- key questions which need to be asked during the development of a design
- fact sheets on energy-efficient solutions
- details of the Climate Change Levy (CCL) and Enhanced Capital Allowances (ECAs)
- nomographs to provide a ready indication of operating costs and savings for various options
- decision trees for the more complex design issues
- advice on setting design targets for energy and environmental performance.

The benefits of using the Guide include:

- quicker decision-making processes during the design stage arising from better understanding between clients and designers
- effective communication of the benefits of energy efficiency to the client
- greater client satisfaction through matching building design to business needs, while improving comfort for occupants
- reduced environmental impact over the lifetime of the building
- lower operating costs for the building owner
- enhanced rent or resale value
- minimising the impact of the CCL
- maximising the benefits of ECAs.

This Guide should be used by designers working with clients. Within the context of the Guide, a designer is any building professional who is involved with the design of a building and its services. This includes architects, mechanical and electrical (M&E) consultants and specialist contractors/engineers with expertise in services such as refrigeration, lighting and heating, ventilation and air-conditioning (HVAC).

The guidance is intended to ensure that energy efficiency is included at the earliest stage of the project brief and that it is fully considered at every stage of the design. It provides the design team and client with energy-efficient options and the consequences of their selection. It is assumed that a professional designer is fully familiar with the topics in the Guide. The value of this document is the provision of comprehensive checklists related to various energy efficiency measures that the design team can use with the client. These checklists are provided from an independent and authoritative source, the Government's Energy Efficiency Best Practice programme.

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CONTENTS

HOW TO USE THIS GUIDE

The structure of this Guide is such that it does not have to read from cover to cover. It is divided into a number of self-contained sections, each of which addresses an element of the design process. The development of a building's design is an iterative process, and it is likely that some of these sections will need to be referred to on several occasions, whereas other sections may only be needed once, if at all.

To enable the reader to quickly locate the relevant sections of the Guide, a route map is provided on a foldout sheet (page 110) from the back of the Guide. This allows the reader to reference the route map while using the Guide.

The colour-coded sections contain key questions and fact files that cover technical design considerations. These are assembled under generic headings such as heating systems, lighting, etc. Each section opens with a series of key questions relating to the design, and these can be answered by referring to the appropriate fact file. Some of the sections also include decision trees to assist with the process. A number of running cost nomographs (RCNs) are also provided in the appendix so that the operating costs of various options can be quickly compared.

There are two sections that are printed on coloured pages. The first of these, on light green pages, is associated with the initial stages of the project, including establishing the brief, setting energy targets, and defining the financial criteria for investment in energy savings. A double-sided briefing sheet, which can be photocopied and used to collate the information required, is inserted in the pocket at the back of the Guide.

The second section, also on light green pages, covers elements that need to be addressed after the initial design process is complete, ie during construction, commissioning and handover.

Most sections include references to further information, which are signposted throughout by the use of a book illustration within a green box. In general, reference should also be made to the CIBSE Guide, 'Energy efficiency in buildings', which provides additional material on all aspects of this Good Practice Guide (GPG).

This Guide is intended for use by designers working with clients. There is a companion volume for building purchasers laid out to the same structure, but written in non-technical language, 'The purchaser's guide to energy-efficient buildings for industry' (GPG 304). Designers should obtain copies of GPG 304 for their clients through the **Environment and Energy Helpline (tel 0800 585794)**.

INTRODUCTION

This Guide will assist designers in working effectively with their clients to design energy-efficient buildings for industry. An integrated approach to the building fabric and building services is encouraged and a checklist of energy-efficient options is provided. The appraisal procedure for these options will show where it is cost-effective to improve energy efficiency above the minimum required by Building Regulations. An essential part of this process is to ensure that energy efficiency is discussed with the client at the earliest stages of the design in order that the implications of design decisions are fully considered and carried through to construction, commissioning and handover.

Many clients are not well informed about energy efficiency and this can often involve the design team in lengthy, and therefore costly, negotiations to develop a cost-effective, energy-efficient design that meets the client's requirements. The purpose of this Guide, and its companion volume for purchasers (GPG 304), is to enable both client and design team to quickly evolve a cost-effective, energy-efficient design, through the provision of a systematic approach within a common framework.

BENEFITS OF USING THIS GUIDE

The benefits of using this Guide include:

- quicker decision-making processes during the design stage arising from better understanding between clients and designers
- communication of the benefits of energy efficiency to the client
- greater client satisfaction through matching building design to business needs while improving comfort for occupants
- reduced environmental impact over the lifetime of the building
- lower operating costs for the building owner
- enhanced rent or resale value
- minimising the impact of the Climate Change Levy (CCL)
- maximising the benefits of Enhanced Capital Allowances (ECAs).

WHY IS ENERGY EFFICIENCY IMPORTANT?

Almost all energy use results in the production of CO_2, which is the main greenhouse gas contributing to climate change. The Government's commitment to reducing emissions of CO_2 has caused an increasing realisation within industry, and the businesses that supply them with buildings and building services, that there are sound business and environmental reasons for reducing energy use. A reduction in energy consumption brought about by improvements in efficiency will reduce running costs and hence raise competitiveness and increase profits.

The government is introducing a package of measures to encourage better use of energy and reduce carbon emissions. These include the CCL, which is a new tax on energy use by industry, commerce, agriculture and the public sector, and ECAs, which will allow 100% capital allowance against tax in the first year for 'eligible' plant and equipment.

Public awareness of environmental issues has also grown and businesses are coming under increasing pressures from their customers and from central government to improve their environmental performance. The energy used within buildings for heating and lighting, etc, accounts for more than 40% of the CO_2 released to the atmosphere in the UK.

All energy costs money. At the time of writing energy prices are rising. As oil and gas stocks diminish, fuel prices are likely to continue to rise at a rate above inflation for the short/medium term. Furthermore, all energy prices are set to increase with the introduction of the CCL. Such pressures to improve energy efficiency are likely to be augmented by further legislation in the future.

INDUSTRIAL BUILDINGS AND ENERGY USE

Industrial buildings typically require large areas for storage and production, with the level of building services required for each activity varying dramatically across industrial classifications. The buildings often have high ceilings and high ventilation rates. Usually there will be further 'social' space in areas such as offices, and in many cases the buildings will include canteens or kitchens. Some of these characteristics have exceptional energy requirements that presents designers with particular challenges.

Industrial buildings are required to serve many purposes, but the principles and benefits of improved energy efficiency remain the same. This Guide aims to ensure that opportunities to save energy are not overlooked during the design process.

THE DESIGN PROCESS

The project brief

Defining usage requirements
Setting a target energy performance
Defining financial criteria

Option appraisal and selection

The building
Heating systems
Hot and cold water
Pipe insulation
Lighting
Power options
Ventilation systems
Cooling and refrigeration

Construction to handover

Quality during construction
Commissioning
Maintenance documentation

THE DESIGN PROCESS

There are three main stages in implementing the design and construction to handover.
These are:

- the project brief
- option appraisal and selection
- construction to handover.

Each stage is considered under generic headings, as illustrated opposite. The same colour coding is used in both Guides for ease of referencing. Important issues arise at each stage, which must involve both the designer and the client.

Note that, while the three key stages are sequential, you must expect to revisit the project brief regularly to ensure that its requirements are being met in practice and/or to modify any parts which are proving to be untenable.

THE PROJECT BRIEF

Every project needs to start with a project brief through which you establish what your client requires from their building. Clients will range from those who are well informed and capable of preparing a detailed brief, to those with little knowledge or in-house capability. Whatever the ability of the client, the process of establishing the brief will be iterative and it is essential that you take an integrated approach to the building fabric and building services, which at the very outset includes energy efficiency.

Clients are interested in fulfilling their building requirements at minimum cost and often do not consider energy efficiency, and may even wish to exclude it on the grounds that they think it will increase their costs. You will need to explain that including energy efficiency in the brief from the outset, and paying attention to the energy performance of the building at every stage of the design, could in fact reduce the overall cost of the building and will definitely reduce the running costs over the lifetime of the building.

A three-step process is proposed to assist you in developing a brief that will produce an energy-efficient building.

1. Establish the client's usage requirements.
2. Agree targets for the building's energy performance.
3. Agree the financial criteria to be used in assessing energy efficiency measures.

DEFINING USAGE REQUIREMENTS

The activities carried out within an industrial building can be very varied and a starting point might be to consider all the activities that will take place. In general, a factory takes in materials and/or components, carries out a process which adds value and then dispatches the products. There will, therefore, be stores for goods inward, possibly a number of process areas, and there may be inspection and packaging areas along with a dispatch function. In addition, there will be administrative functions performed in offices, either within the same building shell, or in a separate office block. There might be kitchens and restaurants and other amenity areas. It will be apparent that these activities require very different types of spaces and building services.

One particular problem in industrial buildings is the impact of the process on the building environment. The process may produce fumes or other noxious materials which require specialist building services to maintain a safe working environment. On the other hand, clean processes may provide opportunities for heat recovery, thus reducing the demand on the heating system.

An integrated design approach is essential in these circumstances. The activity to be carried out in each area of the building will have a significant influence on its layout and the type of heating, lighting, etc, required. It is, therefore, important to define your client's requirements at a very early stage in the design process.

Inserted in the back cover of this Guide is a double-sided loose-leaf briefing sheet which can be used to collate the information required. Photocopy one sheet for each discrete area of your proposed building and complete them in consultation with your client.

A specimen briefing sheet, showing how it may be completed, is given overleaf.

Of course, many industrial buildings are developed speculatively, with their ultimate occupier and end use being unknown at the time of design. This should not inhibit the completion of the briefing sheets, as there will still be a need to define the range of end uses that are to be accommodated by the design.

If there is uncertainty over the proposed use of the building, or it is likely to change on a frequent basis, some degree of flexibility should be incorporated within the building services. For example, the incorporation of extra switches or isolating valves could prove invaluable if future modifications are envisaged.

BSRIA: Design Briefing Manual

SPECIMEN BRIEFING SHEET

Client requirements within defined activity areas		Sheet number	*1 of 12*
Project:	*Acme Anoraks Ltd*	New or existing space:	N / ~~E~~
		Activity/area ref:	*Sewing hall*

Notes

1. These sheets are intended to be completed jointly by the building's purchaser and its designer.
2. Complete one sheet for each discrete activity area of the building.
3. Define requirements by writing in grey data fields and by marking the appropriate tick boxes.

Activity

Purpose of area: *Assembly (sewing) of anoraks*

Number of occupants: *50*

Special requirements (eg minimum height, or access for goods vehicles): *Task lighting at each sewing machine*

Activity level: Strenuous ☐ Average manual ☐ Sedentary ☑

Occupancy

Times:

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Start:	*08.00*	*08.00*	*08.00*	*08.00*	*08.00*	*09.00*	*None*
Finish:	*17.00*	*17.00*	*17.00*	*17.00*	*17.00*	*13.00*	*None*

Pattern of occupancy during working hours: Continuous or frequent ☑ Infrequent ☐

Description of space

Proposed floor area *500 m²* Proposed ceiling or eaves height *3 m*

Access requirements (must comply with fire regulations)

Personnel doors: Number *4*

Goods doors required: Number *2* Size *2.5 x 2.5 m*

Number of goods movements per day: *12* Clearance for goods: *2.25 m*

Glazing: Windows/rooflights *Rooflights* Orientation *North*

Technical services

	Required (Y/N)	Maximum flow rate	Pressure
Compressed air:	*N*		
Steam:	*N*		
Other (define):	*None*		

Climate control

Temperature/humidity requirements:

	Max. during occupancy	Min. during occupancy	Setback condition	Acceptable no. of hours outside limits
Space temperature:	***19 ºC***	***16 ºC***	***12 ºC***	***15 per year***
Humidity:	***60 %***	***40 %***	***N/A***	***None***

Internal heat gains:

Source	kW	Opportunity to recover heat
Sewing machines	***20***	***None***

Ventilation requirements (over and above those required for respiration and comfort cooling):

	Heat removal	Fume control	Humidity control	Estimated extract rate
Nature of requirement:	☑	☐	☐	***400 litres/s***

Lighting requirements

Is there useful natural daylight? Y/~~N~~

Height of working plane	Orientation of working plane	Minimum height for luminaires	Notes on restrictions
0.8 m	***Horizontal***	***2.6***	***Machine locations***

	Lighting levels:	Colour rendering:		
General areas:	***300-500*** lux	☐ Critical	☑ Useful	☐ Unimportant
Task lighting:	***1000*** lux	☑ Critical	☐ Useful	☐ Unimportant
Out of hours security:	***100*** lux			

Power requirements

Process equipment loads – including motive power (machinery, conveyors, etc):

Description	Load (kW)	Voltage
Sewing machines (40 at 0.5 kW each)	***20***	***240 volts***

Technical services:

Lighting	***7***	
Fans	***N/A***	
Pumps	***N/A***	
Compressors	***N/A***	
Other	***N/A***	

Water requirements

Domestic:

No. of basins		No. of WCs	
No. of urinals		No. of showers	
Other			

Process:

Required volume (l/s or m^3/day)	@ Temperature (°C)
None	

THE PROJECT BRIEF

SETTING A TARGET ENERGY PERFORMANCE

At the brief stage of a project it is important to set a target energy performance for the design which will ensure that the building will perform to a good practice standard or better. The good practice benchmarks published as part of the Energy Efficiency Best Practice programme, together with the data collected on each activity area, can be used to calculate an energy performance target as illustrated below.

The good practice benchmarks are published in a number of Energy Consumption Guides (ECONs), but for convenience, benchmark values are included as an insert in the back pocket of this Guide. The benchmarks are updated periodically and the calculations should be based on the latest benchmark values available at the time.

The starting point for setting the target is to find the closest match for the activity areas already identified with the building descriptions given in the ECONs and reproduced in the insert. The benchmark value can then be obtained from the relevant table and, if necessary, adjusted for hours of occupancy and perhaps the degree days expected at the building location. Degree days for all regions of the UK are published in the DETR's journal 'Energy and Environmental Management' and can be found at the Energy Efficiency Best Practice website (www.energy-efficiency.gov.uk).

The calculation of the target energy performance is carried out in simple steps, which are illustrated by reference to a typical factory site. Assume the client has specified a 7500 m² general manufacturing area, 2500 m² of unoccupied warehousing and a 1000 m² naturally ventilated open-plan office block to be located alongside the main factory building.

The ECONs and the tables in the insert break down the electricity use into lighting, fans, pumps and controls and other uses. For each of these end uses, it is, therefore, possible to use the same formula to calculate performance indicators, which can then be set as targets for the design of these services within a building or across the site.

The value of the performance indicator will be indicative of what should be readily achievable through good design for the mix of activities in the proposed building. Recent case studies show that with new technologies and increased insulation levels required by the Building Regulations, consumption values for heating, lighting, etc, can be significantly below the new build benchmark. It is, therefore, recommended that you agree with your client a target energy performance, in kWh per m², which is lower than the indicative value calculated using the method shown here. How much lower depends on the commitment of your client to energy efficiency, but a value 10% lower would not be unreasonable.

The energy targets should be referred to within the operation and maintenance documentation, along with clear guidance on how the building should be operated in order to optimise its energy performance.

THE PROJECT BRIEF

STEP 1

Look up the good practice benchmarks from the tables in the insert.

Activity area	Source of benchmark	Benchmark value kWh/m² per year	
		Electricity	Fossil fuel
Manufacturing area	ECON 18 – new	50	125
Warehouse	ECON 75	3	54
Office	ECON 19 – type 2	54	79

NB These benchmark values may need to be adjusted for hours of occupancy and degree days (see appendix 'How to use the nomographs').

STEP 2

For each area, multiply the treated floor area (in this example the specified areas are used, but treated areas may be less) by the benchmark to calculate a good practice energy consumption target.

Activity area	Treated floor area m²	Good practice energy consumption target kWh per year	
		Electricity	Fossil fuel
Manufacturing area	7500	375 000	937 500
Warehouse	2500	7500	135 000
Office	1000	54 000	79 000

STEP 3

Add up the target figures for each area to obtain good practice energy consumption targets for electricity and fossil fuel for the whole site.

	Treated floor area m²	Total electricity kWh per year	Total fossil fuel kWh per year
Whole site target	11 000	436 500	1 151 500

STEP 4 (OPTIONAL)

A site performance indicator or benchmark for the whole site can be calculated by dividing the total consumption targets by the total treated floor area. This indicator or benchmark in kWh/m2 per year will be the average benchmark for the site weighted according to the treated floor areas and will be useful for comparisons with other sites or other design options.

	Electricity kWh/m² per year	Fossil fuel kWh/m² per year
Whole site target	40	105

It will be apparent that the site benchmark can be calculated directly using the simple formula:

$$\text{Whole site benchmark/ performance indicator} = \frac{\text{Sum of the products of treated floor area and the relevant benchmark}}{\text{Sum of the treated floor areas}}$$

THE PROJECT BRIEF

DEFINING FINANCIAL CRITERIA

Ideally, the financial case for an energy-efficient building should be based on whole life cycle costing of the building. This allows the benefits of lower running costs for an energy-efficient building to be offset against any additional capital investment in energy-saving measures. Unfortunately, the budget holder for capital projects is often not the person who will be responsible for the running costs of the building once completed. Nevertheless, by considering energy efficiency in the brief and design process, lower running costs can be achieved for little or no additional investment. It will certainly be much more expensive to reduce running costs once the building is complete.

POLICY AND LEGISLATIVE BACKGROUND

Before developing the financial case, you need to be aware of government policies and legislation, both existing and pending, which are intended to encourage investment in energy-saving measures.

Building Regulations set minimum requirements for insulation, lighting efficiency, controls, etc, while other legislation sets minimum efficiencies for boiler manufacturers to achieve. The legislation is periodically reviewed, and at each review the requirements for energy efficiency have been increased. For example, the levels of insulation required for walls, roofs and floors have been dramatically increased and further revisions to the Regulations are expected to continue this trend.

From April 2001, the government is introducing a **Climate Change Levy (CCL),** which effectively increases the cost of energy and hence improves the financial case for energy efficiency measures. Some sectors of industry qualify for a rebate on the CCL, but only if they enter into a negotiated agreement to reduce their energy consumption.

Also from April 2001, the government is introducing E**nhanced Capital Allowances (ECAs)*,** which will allow 100% capital allowance against tax in the first year for 'eligible' plant and equipment. Initially ECAs will apply to:

- 'quality' combined heat and power (CHP)
- boiler plant and equipment
- motors
- variable speed drives
- lighting
- pipe insulation
- refrigeration equipment
- thermal screens (for horticulture).

Full details of the current eligibility criteria can be found on the DETR's website. 'The Enhanced Capital Allowances Scheme' – Eligibility Criteria at **www.eca.gov.uk**.

Some sectors of industry carrying out prescribed processes are subject to the EU **Integrated Pollution Prevention and Control (IPPC)** regulations which started to come into effect from October 1999. These now make the efficient use of energy one of the requirements for granting a site operating license.

PUTTING THE FINANCIAL CASE TO YOUR CLIENT

The financial case for energy efficiency that you present to your client needs to be set in the context of the legislative and policy framework as set up by the government and outlined above. The financial case for certain measures, such as CHP and variable speed drives, has become strengthened by the introduction of the CCL and ECAs. It is also apparent that the difference between the minimum required by Building Regulations and good practice is becoming less, so that the on-costs of good practice energy efficiency measures will be lower.

The recommended method of appraising the financial viability of an energy efficiency measure is to calculate the Net Present Value (NPV) of the savings accruing over the lifetime of the measure. This method is described in GPG 165 and CIBSE CA1 (see opposite). For convenience, an example from Good Practice Case Study (GPCS) 390, based on a building management system (BMS) installed at Shell Expro, has been included.

When carrying out an NPV calculation, it is important to include all relevant costs over the lifetime of the project. In 1983, Shell Expro wished to upgrade their building controls and compared the costs of continuing to use standard controls with those of installing a BMS.

* It is anticipated that the legislation to provide for the scheme will be introduced in the Finance Bill 2001. As such, the proposals could be subject to change, and are conditional on the Finance Bill receiving Royal Assent. The details on the website are also subject to the Enhanced Capital Allowances scheme obtaining EU State Aids clearance.

NPV for BMS at Shell Expro

Year	Continue with standard controls		Install BMS		Operating and energy savings	8% discount rate	Discounted saving	Cumulative discounted saving
	Operating costs £'000	Energy costs £'000	Operating costs £'000	Energy costs £'000	£'000		£'000	£'000
1983	588	621	486	599	124	0.926	115	115
1984	588	656	486	630	128	0.857	109	224
1985	588	682	486	550	234	0.794	186	410
1986	588	682	486	550	234	0.735	172	582
1987	588	694	486	560	236	0.681	161	743
1988	588	707	486	573	236	0.630	149	892
1989	588	720	486	586	236	0.584	138	1030
1990	588	733	486	598	236	0.540	128	1158
1991	588	746	486	611	236	0.500	118	1276
1992	588	767	486	631	238	0.463	110	1386
1993	588	756	486	626	232	0.429	100	1486
1994	588	759	486	627	235	0.397	93	1579
1995	588	763	486	630	235	0.368	86	1665
1996	588	766	486	633	235	0.341	80	1745
Net present value (cumulative savings less additional £470 000 capital)								**1275**

Continuing to use standard controls was estimated to require capital investment of £330 000 for replacement units, while a new BMS was estimated to cost an additional £470 000. However, the BMS was forecast to reduce costs through better energy management and also to reduce running costs through lower manpower and maintenance requirements. The actual savings arising from replacing standard controls with the BMS are given in the table above. This illustrates that over the lifetime of the BMS, energy savings combined with reduced running costs generate an NPV of over £1 000 000, thereby justifying the higher capital cost of the BMS. In fact the system has been so successful that it has been upgraded and extended, (see GPCS 390).

The benefit of the NPV calculation is that it allows different types of measures with different lifetimes to be compared. For example, the NPV of the BMS illustrated above could be compared with the NPV from investment in production plant and machinery. The same discount rate should be used for both calculations. In this way it is possible to rank projects for investment purposes in order to make best use of the company's capital resources.

Where applicable, the effect of the CCL and ECAs should be built into the calculations. It is important to realise that ECAs do not apply to measures that are required by the Building Regulations. However, if the NPV for additional measures is greater than that for doing the minimum required by the Building Regulations, then there is a sound financial case for the measures.

This Guide contains Selection Charts and running cost nomographs (RCNs) which will help you to work with your clients to assess the economic costs/benefits of energy-efficient design options. They can also be used to support recommendations to the client.

Good Practice Guide 165 Financial aspects of energy management in buildings
CIBSE CA1 Approving Energy Conservation Investments Using Discounted Cash Flow Techniques
GPCS 390 Building management system in multi-commercial and industrial buildings. Shell UK Exploration and Production – Aberdeen

OPTION APPRAISAL AND SELECTION

Having drawn up the project brief, the next stage is to select the best building and services options to meet its requirements. Options will need to be appraised with regard to technical, operational and financial criteria. From April 2001, ECAs should be taken into account when appraising different options.

An integrated approach is necessary, for example you cannot optimise the building's thermal properties without reference to the type of heating system being used, and vice versa. Be prepared, therefore, for several iterations – changes in one area may well influence the design in others.

This section of the Guide covers eight generic topics and for each one there is a series of fact files to provide practical advice to help speed up your initial option appraisal and selection. (See the diagram below). Each topic is introduced through a series of key questions to guide you through the issues in a systematic way.

Important

This Guide is not intended to provide comprehensive design advice or data – this can be found in a number of the other signposted documents.

The benefit of this Guide is that it provides simple documentation for the initial design process based on indicative data. This is the purpose of this Guide and the information presented must be seen and used in this context.

Final decisions on plant selection, etc, must, therefore, be confirmed by the designer and based on more rigorous assessments and information.

CIBSE Building Services – The Design Process: A Guide for Architects and other Construction Professionals

THE BUILDING

A building's form and constructional details can have a major impact on its energy use. Time spent optimising the design will be well spent. Remember that it will be much harder to improve the building's thermal performance once it has been built.

KEY QUESTIONS

Ask yourself the following key questions, which represent good practice in energy-efficient building design. If you cannot confidently answer 'yes' to any of them, refer to the corresponding fact file to see what opportunities you may be missing.

Is the building correctly orientated with regard to the prevailing wind and sun directions?

Are internal areas arranged to minimise energy requirements?

Fact file B1
Building orientation and layout (page 20)

Have you optimised the insulation to roofs, walls and floors for the fuel and heating system to be used?

Fact file B2
Insulation (page 21)

Have windows been selected to provide the optimum compromise between daylighting and heat loss?

Fact file B3
Glazing (page 23)

Have appropriate steps been taken to minimise air ingress through goods and personnel doors?

Fact file B4
Doors and entrance lobbies (page 25)

Fact File B1
Building orientation and layout

The weather has a major influence on a building's energy needs. Cost savings can be achieved simply by arranging the building with due regard to the prevailing wind, sun directions and topography of the site.

What are the benefits?

A correctly orientated building will offer:

- reduced heating, cooling and lighting demands (annual running cost savings of around 10% are typical)
- improved comfort conditions (for example from a reduction in cold draughts, solar glare or overheating due to solar gains).

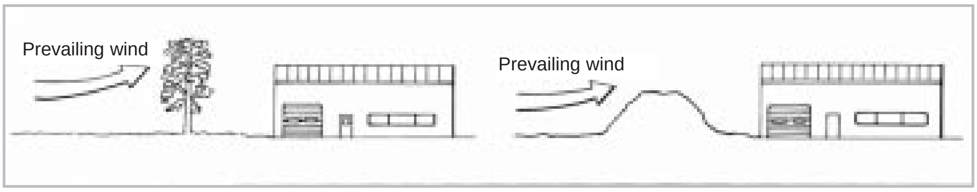
What are the costs?

Essentially, this is a 'zero-cost' opportunity, it just requires some thought and planning. Indeed, the size of heating and cooling plant is likely to be reduced (or in some cases eliminated), which will result in an equipment cost saving.

What needs to be done?

This is a fundamental issue and must be addressed at the very earliest stages of design. Follow these principles:

- minimise openings which face into the direction of the prevailing wind (usually SW in the UK) – goods doors are a particular issue
- position goods doors to prevent the creation of internal 'wind tunnels' within the building
- consider the use of trees or banks as windbreaks, either by natural site features or by landscaping
- place areas requiring heating on the southern elevation (to benefit from the sun's warmth), but be aware of potential glare problems
- place areas requiring cooling (eg cold stores, computer suites, etc) on the northern elevation
- position windows serving areas that are sensitive to glare (eg offices with large amounts of IT equipment, studios, workshops, etc) to face east to north west, thereby avoiding exposure to direct sunlight
- use internal partitions to segregate areas with differing heating, cooling or ventilation requirements (either in terms of temperatures required or hours of use)
- locate areas with similar services requirements together – for example, having processes using hot water in the same vicinity is likely to be better than having them scattered throughout the building
- locate central services plant rooms (boilers, air compressors, etc) to minimise distribution runs, but also be aware of the potential benefits of recovering waste heat to neighbouring areas (see fact files H9, V5, PW1 and C6).



Building orientation

Fact File B2
Insulation

A significant part of the energy used in industrial buildings is for space heating – up to 50% in some cases. It is, therefore, essential that the building has an economic level of insulation to the roofs, walls and floors.

What are the benefits?

- Minimum heat losses in winter consistent with economic constraints.
- Reduced heat gains in summer.
- Improved comfort conditions.

These will produce cost savings by:

- allowing the use of smaller heating and/or cooling plant
- reducing annual energy requirements.

Annual savings can be estimated using RCN 1A (appendix).

What are the costs?

Additional costs will only be incurred where the economic thickness of insulation exceeds that prescribed in the Building Regulations. It is possible that in some circumstances additional insulation is viable, especially to pitched and flat roofs, at costs in the order of £5 to £8 per square metre, but this will need to be checked using one of the methods described in Fuel Efficiency Booklet (FEB) 16. When undertaking a financial evaluation it will be necessary to include the impact of the CCL on fuel prices and to determine whether ECAs apply.

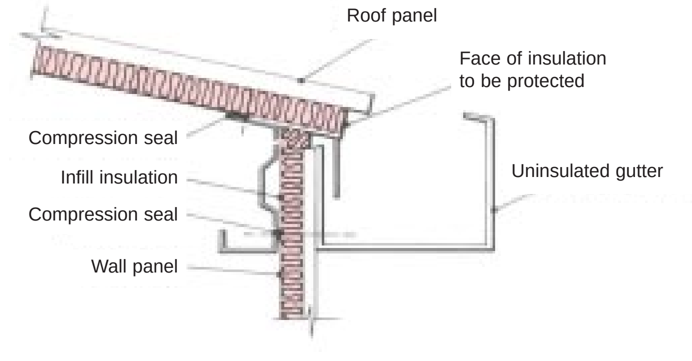
What needs to be done?

Ensure that the U-value of the building as a whole at least complies with the requirements of the Building Regulations. The standard U-values for roofs, walls and floors are currently 0.45 W/m^2°C, but they are likely to be reduced in the near future. Designers wanting to demonstrate good practice should look into providing insulation above that required to meet this minimum standard.

- Choose the optimum insulation thickness. As an initial indicator use RCN 1A (appendix) to estimate the cost of heat losses through floors, walls and roofs.
- Ensure detailing prevents the formation of condensation, which can damage insulation or the roof structure itself.
- Select an appropriate external colour. Pale colours radiate less heat in winter (keeping the building warmer), and absorb less heat in summer (a key issue for areas that require cooling).
- Consider the use of factory bonded composite panels which combine insulant with metal facing panels, ready for direct fixing to the building. While these may appear expensive when compared with site assembled systems, due allowance must be given for their increased speed of installation and generally higher quality standards.

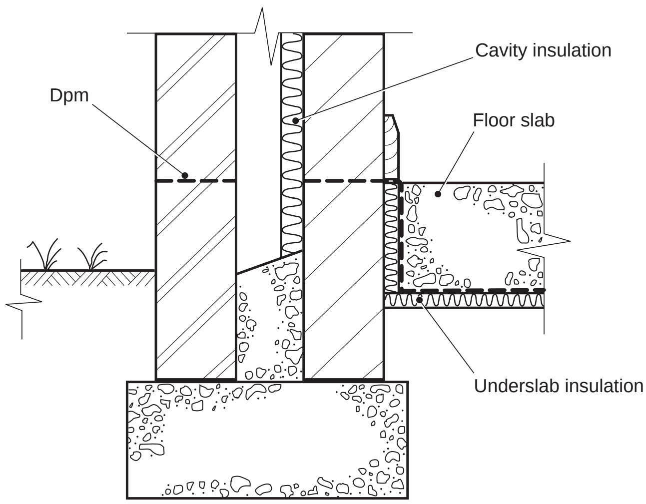
Fact File B2
Insulation

- Where roofs are being refurbished, rather than replaced, the same energy efficiency principles apply. The incorporation of additional insulation above that required by the Building Regulations may be justifiable, but this depends on the fuel used and the heating system. Various methods are available, including under-drawing using insulated 'factory liner' panels, external or internal spray foam coating and the use of ballasted 'upside down' insulation panels on flat roofs.



Consider additional insulation for pitched roofs

- Consider the economics of installing floor insulation, especially edge insulation, even if it is not required by Building Regulations. Typically, slabs of mineral wool or expanded polystyrene are used. As an initial indicator use RCN 1A (appendix).



Consider installing edge insulation around floors

FEB 16 Economic thickness of insulation for existing industrial buildings
CIBSE Guide A3 Thermal properties of building structures
The Building Regulations Approved Document L (defines Building Regulations requirements relating to U-values)

Fact File B3
Glazing

Glazing brings with it the benefits of daylighting and the potential for ventilation. Against this, glazing results in heat loss in winter and solar heat gain/glare in summer. Energy running cost savings can be achieved by attention to:

- *the size and orientation of glazing*
- *the U-value of the glazing system.*

What are the benefits?

Correct window specification will lead to:

- reduced heat losses in winter
- reduced heat gains in summer
- less need to use artificial lighting
- an improved working environment by the elimination of solar glare
- a reduction, or elimination, of condensation.

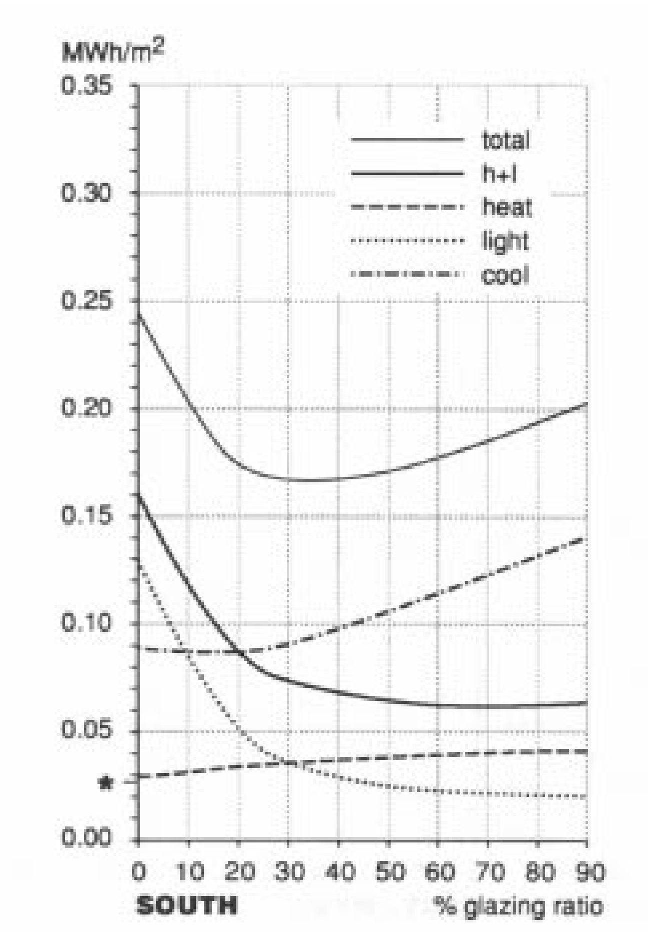
Annual running cost savings resulting from the use of lower U-value glazing systems can be estimated from RCN 1B (appendix).

What are the costs?

The incremental cost of installing lower U-value glazing systems is indicated in the table overleaf.

What needs to be done?

- Optimise the percentage glazing ratio to minimise the combined heating and lighting costs while also avoiding glare and overheating. The LT method or a similar design method, can be used.
- For industrial buildings, wall glazing should not normally exceed 10% of the total external wall area. For factory offices, the optimum amount of glazing is usually around 30% of the external wall area (see illustration right).



Optimise % glazing

Fact File B3
Glazing

- Roof glazing can be an effective way of providing the benefits of natural daylight with less risk of glare problems (particularly if the glazing is installed on a north-facing pitch). Again, these benefits must be weighed against increased heat loss, the optimum amount of glazing usually being around 20% of the total roof area.
- Recognise that in all cases lighting energy benefits will accrue only if:
  – lighting is turned off in response to adequate natural daylight (realistically, this will probably require the installation of automatic controls)
  – windows are positioned to avoid the need for blinds to prevent glare
  – glazing is kept clean.
- Reduce heat losses by specifying double glazing, and consider using low-emissivity surface coatings and/or inert gas fillings. The following table shows typical U-values and incremental costs for various glazing configurations.

Window type	Approximate U-value (glazing only) W/m²°C	Indicative on cost (£/m², year 2000)
Single glazing	5.6	–
Double glazing	3.0	15
Double glazing with surface coating	1.8	22

- Ensure that the overall thermal performance of windows and roof lights is not prejudiced by insufficient attention to frame design and/or installation detailing.

CIBSE Lighting Guide 10 Daylighting and window design
BS8206 Lighting for Buildings: Part 2 – Code of Practice for Daylighting
The LT method version 2.0, Cambridge Architectural Research Ltd (for optimising % glazing ratio in office-type accommodation)

Fact File B4
Doors and entrance lobbies

Easy access is essential in any industrial building, but large goods doors can prejudice energy efficiency and comfort conditions by allowing the uncontrolled ingress of large volumes of fresh air. Running cost savings can be achieved by careful design to minimise these effects.

What are the benefits?

Reducing air infiltration by the proper specification of doors will lead to:

- lower heating and/or cooling costs
- more stable internal air conditions, providing comfort and manufacturing quality benefits
- a reduction in the introduction of grit or other contaminants into the workplace.

What are the costs?

The following indicates typical costs (year 2000) for some of the more common draught control methods:

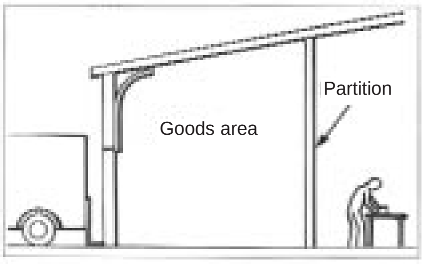
plastic strip curtains	£450	(based on 3 m x 3 m opening)
fast acting (rapid roll) doors	£4500	(based on 3 m x 3 m opening)
vehicle entrance lobbies with two motorised doors	£15 000	(based on 3 m x 3 m opening)

What needs to be done?

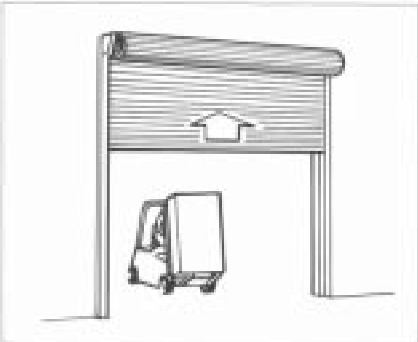
- Ensure the correct orientation of door openings (see fact file B1).
- Consider building a vehicle entrance lobby within the building structure. This will be the most effective solution, but it is also the most expensive. It therefore needs to be discussed with the client in the context of the required factory environment and financial constraints.
- Fit motorised, insulated doors to intermittently used goods entrances, complete with:
  – clear operating instructions
  – an interlock to turn off the heating when the door is open
  – an audible alarm which triggers after the door has been open for a pre-set time.
- Insulate access doors. The standard U-value for vehicle access and similar large doors is currently 0.7 W/m^2°C, but this is likely to be reduced in due course. Designers wanting to demonstrate good practice should determine the economical insulation thickness and where this exceeds that required by the Building Regulations, increase the thickness accordingly.
- Fit plastic strip curtains or fast-acting doors to regularly used goods entrances (typical payback around two years).
- Provide separate personnel access alongside goods doors.
- Provide pneumatic seals around vehicle loading bay doors.

Fact File B4
Doors and entrance lobbies

- Consider pressurising the building using a make-up air heater (see fact file V4).
- If clients request air curtains for ease of access, where possible use warm ambient air from the top of the building and fit interlocks to the fan to ensure it operates only when required. Air curtains are generally not an efficient means of controlling heat losses through large openings.



Entrance lobby



Fast-acting door

Plastic strip curtains

HEATING SYSTEMS

Industrial buildings offer unique challenges when trying to select an effective and efficient heating system. The designer may be faced with high ceiling, intermittent occupancy patterns and processes which give off large quantities of waste heat or require substantial ventilation rates. A wide range of heating plant has been developed in response to these challenges and their correct selection, along with appropriate control systems, can lead to substantial reductions in energy usage.

KEY QUESTIONS

Ask yourself the following key questions, which represent good practice in energy-efficient heating design. If you cannot *confidently* answer 'yes' to any of them refer to the corresponding fact file to see what opportunities you may be missing.

Have you chosen the right fuel?

Fact file H1 Choice of fuel (page 28)

Have you selected the most efficient form of heating for your application?

Fact file H2 Convective systems (page 30)

Fact file H3 Radiant systems (page 32)

Have you located the heating plant in the best position(s)?

Fact file H4 Centralised vs decentralised systems (page 34)

Do you really need to provide flues for your heating appliances?

Fact file H5 Flued vs unflued appliances (page 35)

Have you considered the cost-effectiveness of more efficient boiler plant and equipment?

Fact file H6 Boiler plant and equipment (page 36)

Have you designed in adequate facilities for pipework cleaning and subsequent water treatment?

Fact file H7 Water treatment (page 38)

Have the benefits of using destratification fans been assessed?

Fact file H8 Destratification fans (page 39)

Are you proposing to use waste heat recovered from other plant or processes?

Fact file H9 Use of waste heat (page 40)

Are you specifying the most appropriate control systems?

Fact file H10 Controls (page 42)

Have you confirmed your decisions using the decision tree?

SCIA and SCIB selection chart (page 44)

Fact File H1
Choice of fuel

It must be recognised that some fuels are significantly more expensive than others. The correct choice of heating fuel is therefore essential.

What are the benefits?

- Gas, oil and solid fuel offer significant energy cost and CO_2 emission benefits relative to electricity (as shown in the tables below).
- Gas offers several advantages relative to oil or coal:
  – cleaner combustion
  – greater controllability
  – reduced emissions (CO_2, sulphur dioxide, particulates, etc)
  – lower maintenance costs
  – lower operating costs (fuel ordering, delivery supervision, etc)
  – no fuel storage requirement.
- Using centrally generated hot water or steam as a primary source removes the need to install any boiler plant, significantly reducing installation costs (these central services are often provided to business parks).

What are the costs?

Gas and oil-fired heating plant may be more expensive to install than electric heating. The fuel price differential in favour of gas and oil, however, will usually more than justify their use. The cost of fuel consumed by gas or oil-fired heating plant over its lifetime may be 20 or 30 times the capital cost of the plant, while for electrical systems the figure will be in excess of 100.

What needs to be done?

- Renewable forms of energy have the lowest environmental impact, but for heating the options are largely restricted to biofuels.
- In appropriate circumstances, significant energy use and CO_2 savings can be achieved by on-site generation using a combined heat and power (CHP) unit (see fact file P1).
- If combustible waste is available, this can potentially be used as a heating fuel. This will become more economically viable as landfill taxes increase. Note though:
  – it is always better to minimise the production of waste in the first place
  – the waste materials may require segregation and/or preparation before burning
  – the resulting emissions may be noxious and may require abatement plant
  – the markets for recycled materials are developing rapidly and may represent a better disposal route, if not now then possibly in the future
  – it is sensible to provide standby capability supported by traditional fuels.
- Consider the relative energy costs of alternative fuels.

Fuels	Indicative relative cost (p/kWh)
Coal, fuel oil, natural gas	1
LPG (propane), off-peak electricity	2-3
Day-rate electricity	5-6

Fact File H1
Choice of fuel

- Recognise the relative CO_2 emissions per unit of delivered energy for each fuel type.
- Try to limit the use of electric heating to small-scale local applications. Consider the use of heat pumps in preference to other forms of electric heating as running costs should be less.

Fuel	kg CO_2/kWh	kg carbon/kWh
Gas	0.19	0.052
Oil	0.26	0.071
Coal	0.30	0.082
Delivered electricity (average)	0.44	0.12

Source: DETR – Environmental Reporting Guidelines, June 1999; for update see DETR's website **www.energy-efficiency.gov.uk/document/factfigs/emiss.htm**

Energy conversion factors

Gas/oil: 1 litre = 10.6 kWh
Light fuel oil: 1 litre = 11.2 kWh
Heavy fuel oil: 1 litre = 11.4 kWh

LPG: 1 litre = 6.9 kWh

Natural gas: 1 m^3 = 10.3 kWh
100 ft^3 = 29.3 kWh
1 therm = 29.3 kWh

Coal: 1 kg = 9.7 kWh

Fact File H2
Convective systems

Heating to industrial type buildings may be provided by either convective or radiant means. The correct choice is essential if running costs are to be minimised.

Convective heating systems use the movement of warm air to transfer heat. This air movement can be induced by natural convection or by the use of fans, for example via:
- *fan convectors*
- *floor or ceiling-mounted unit heaters*
- *central air-handling plant.*

For information on radiant systems see fact file H3.

What are the benefits?
Convective heating systems offer the following benefits over radiant types:
- applicable to smaller areas and sensitive applications such as sedentary working and retailing
- warm air can be blown into inaccessible areas, and may increase air pressure within the building to reduce draughts
- the use of fans allows the air delivered to be 'conditioned' (for example by filtration or by the controlled introduction of fresh air)
- fans can often be run in summer to assist ventilation.

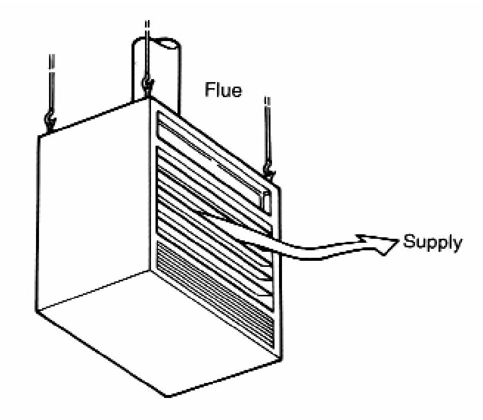
What are the costs?
- When applied to general area heating, convective and radiant heating systems have similar installed costs (comparing similar gas-fired, decentralised plant).
- Energy consumption and hence running costs, can be higher for convective systems than radiant heating systems, as a result of:
  – operation at generally higher air temperatures
  – stratification of warm air at high level (less of an issue in well-insulated buildings and can be overcome using destratification fans – see fact file H8)
  – electrical power consumption through operation of fans.

What needs to be done?
- Refer to selection chart SC1 (page 44) when choosing heating systems
- Compare the relative merits of convective and radiant heating systems.
- Position heaters to prevent discomfort or noise problems which may result from high air movement.
- For fume-laden atmospheres consult manufacturers on suitability of proposed heater.
- Running costs can be compared using RCN 2 (appendix).

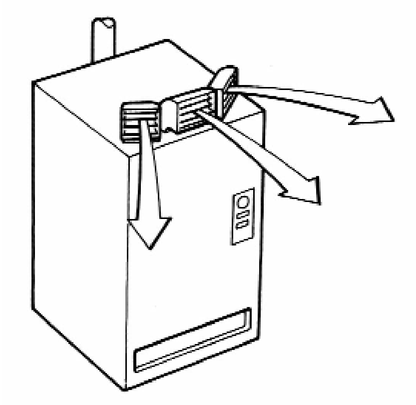
FEB 3 Economic use of fired space heaters for industry and commerce

Fact File H2
Convective systems

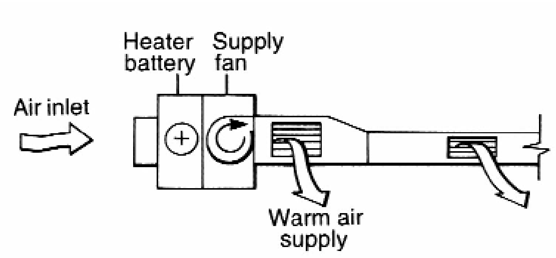
Convective heating systems



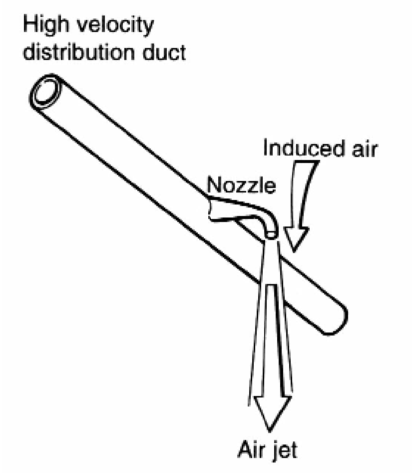
High-level unit heater



Floor-standing warm air heater



Ducted warm air system



Warm air jet/induced jet system

Fact File H3
Radiant systems

Heating for industrial-type buildings may be provided by either radiant or convective means. The correct choice is essential if running costs are to be minimised.

Radiant heating systems use infrared radiation to heat the building's occupants and its fabric directly, without the need for warm air as a transfer medium. They are particularly useful for heating large volumes with high ceilings, typical of industrial buildings. Radiant systems can also provide local 'spot heating', and are also particularly efficient in buildings with high air change rates.

For information on convective systems see fact file H2.

What are the benefits?

Radiant heating systems offer the following benefits relative to convective types and are often the first choice for industrial buildings:

- energy consumption can be lower, as a result of:
  – generally lower air temperatures
  – reduced stratification at high level
- directional output delivers heating directly to where it is needed
- rapid warm-up
- responsive control
- no air movement.

What are the costs?

- When applied to general area heating, radiant and convective heating systems have similar installed costs (comparing similar gas-fired, decentralised plant).
- Energy consumption and hence running costs can be lower than with convective heating systems, as a result of:
  – operation at generally lower air temperatures
  – reduced stratification and hence lower losses through warm air at ceiling level.

What needs to be done?

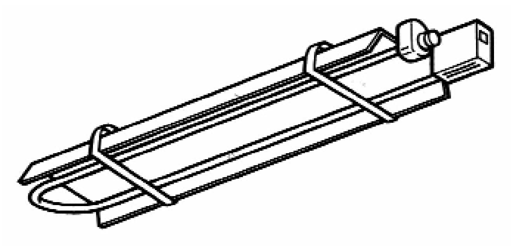
Choose the most appropriate form of radiant heating based on the following table.

System	Emitter temperature (°C)	Mounting height (m)	Application
Centralised plant			
Medium-pressure hot water	110	6	General area heating
Decentralised plant			
Gas-fired tubes	500	3.5-20	General area heating
Gas-fired plaques	900	4-20	Local spot heating
Electric quartz heaters	2000	2-4	Local spot heating

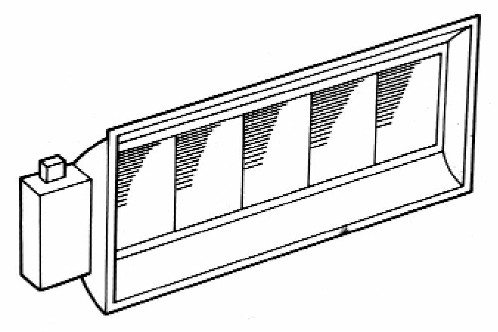
- Refer to selection chart SC1 (page 44) when choosing heating systems.
- Compare the relative merits of radiant and convective heating systems.
- Position heaters to prevent discomfort from high-intensity radiation.
- In noise-sensitive areas, consideration should be given to expansion noises.
- For fume-laden atmospheres, consult manufacturers on suitability of proposed heater.

Fact File H3
Radiant systems

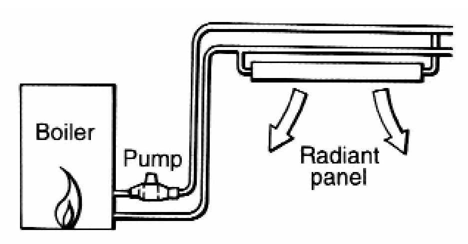
Radiant heating systems



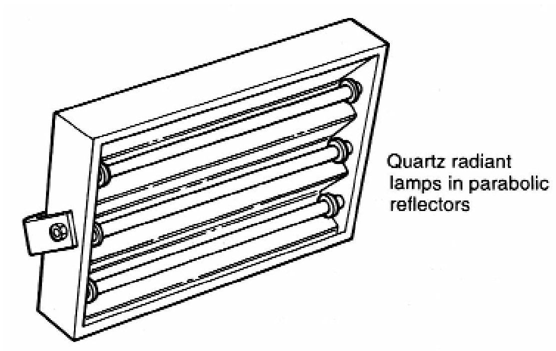
Gas-fired overhead radiant tube heater



Gas-fired radiant plaque heater



Radiant panels served by boiler



Electric radiant heater

BS 6896 – 1991 Specification for the Installation of Gas Fired Overhead Radiant Heaters for Industrial and Commercial Heating (2nd and 3rd Family Gases)

Fact File H4
Centralised vs decentralised systems

Heating plant can either be located centrally (with subsequent heat distribution using hot water, steam or warm air), or distributed throughout the building. Selecting the correct approach will give benefits in running costs, flexibility in use and ease of maintenance.

What are the benefits?

Advantages of centralised systems

- Larger combustion plant (boilers), but fewer of them resulting in:
  - faster payback on high-efficiency plant options (eg oxygen trim combustion control)
  - greater opportunity for multi-fuel capability (including ability to utilise waste fuels)
  - easier provision of standby/backup facilities (both in terms of combustion plant and fuel resources)
  - better suited to waste heat recovery schemes (see fact file H9).
- Some of the heating may be provided by CHP plant with the benefits of reduced energy costs, lower carbon emissions and enhanced security of supply (see fact file P2).

Advantages of decentralised systems

- Lower distribution heat losses than centralised system heat losses are typically 5% of annual consumption, but can be much more, particularly for widely distributed sites.
- Faster warm-up/rapid response.
- Greater flexibility of operation and control to match demand.
- Potentially better space utilisation. Smaller, local heating plant may be accommodated within existing working spaces (for example at high level), without the need for dedicated plantrooms.
- Diversity – the whole site is not exposed in the event of plant failure.
- Generally lower running costs.

What are the costs?

The installed costs of centralised and decentralised heating systems will need to be assessed and compared, depending on specific requirements.

What needs to be done?

- Refer to selection chart SC1 (page 44) to assess the relative merits of centralised and decentralised heating systems (as described above) and compare these with the corresponding budget cost estimates.
- Consider opportunities for CHP plant (see fact file P2), or waste as fuel, as an alternative to traditional boilers.
- Whether centralised or decentralised heating systems are employed, distribution heat losses can be economically reduced by applying thermal insulation in accordance with BS5422 (see fact file PW2).

Fact File H5
Flued vs unflued appliances

The relatively large volume and sometimes high ventilation rates in industrial buildings may offer scope for significant energy cost savings by the use of unflued heating appliances.

What are the benefits?

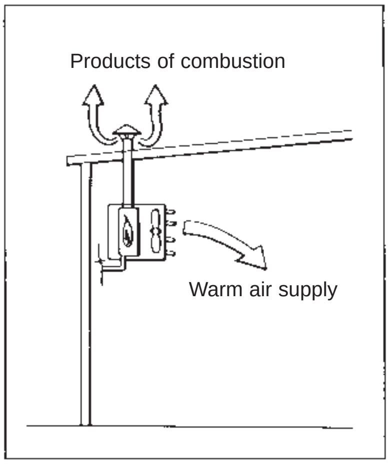
- Most gas-fired heating appliances have a thermal efficiency of around 80%, the balance of heat input being lost as hot flue gases.
- If it is possible to operate gas-fired heating appliances without a flue, simply discharging the products of combustion into the working space, this will improve their thermal efficiency to around 95%.

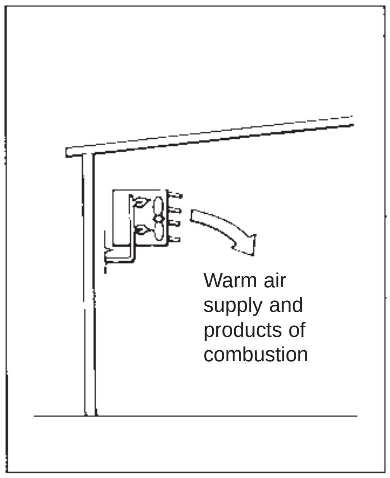
What are the costs?

Unflued heating appliances are, by their nature, cheaper to install than those requiring a flue, so a cost saving will result.

What needs to be done?

- The use of unflued appliances requires:
  – an adequate building volume
  – a sufficient provision of fresh air (building air change rate).
- For most modern, well-sealed industrial type buildings, the internal air change rate will be too low to allow the use of unflued appliances. Exceptions are:
  – small, local spot heaters located within much larger buildings (eg warehouses)
  – industrial-type buildings with high process ventilation requirements; the tempering of make-up air supplies (see fact file V4), can be an ideal application for unflued warm air heaters.
- Note that it is a false economy to artificially increase ventilation rates to a well-sealed building, just to allow the use of unflued appliances – use flues instead.





Flued and unflued appliances

FACT FILE H6

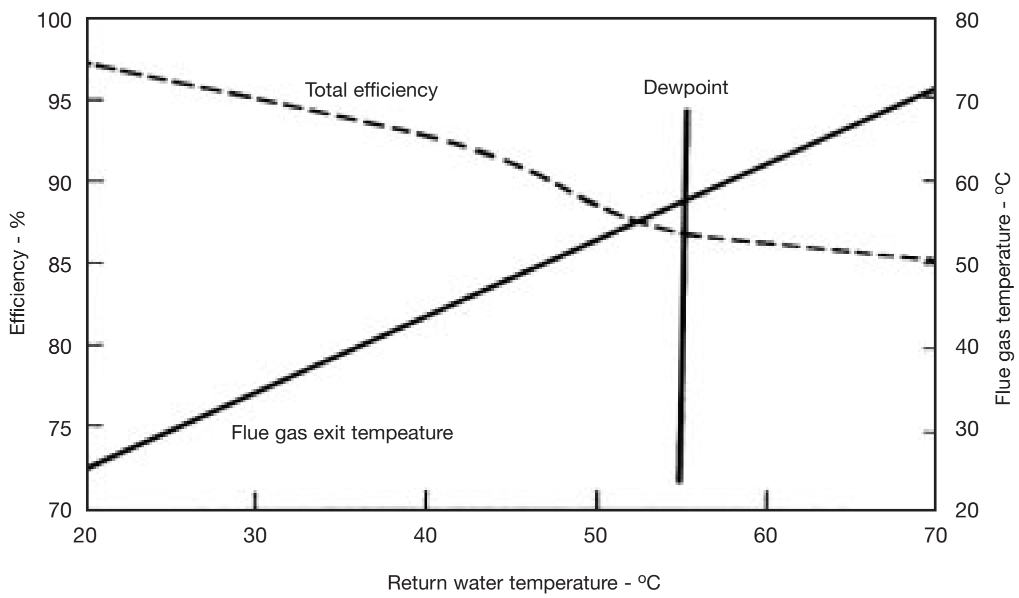
Fact File H6
Boiler plant and equipment

Boilers sold in the UK must, by law, comply with minimum efficiency standards. These minimum standards vary with the type of fuel and type of boiler and will only be achieved if the plant is designed to be operated in an energy-efficient manner. There are a number of energy-saving measures which should be incorporated at the design stage and many of these qualify for ECAs (see DETR's ECA ***website www.eca.gov.uk****). Where practicable, it is important to extract as much heat as possible from the flue gases using condensing economisers or condensing boilers. All boilers up to 400 kW qualify for ECAs if they are classified as gas condensing boilers.*

What are the benefits?

Each of the energy-saving measures, such as digital controls, flue gas economisers, oxygen trim controls, sequence controls, automatic flow valves, heat recovery from boiler blowdown, re-use of flash steam, automatic TDS control, condensate return systems and flue shut off dampers can improve efficiency by between 1% and 5%. Where return water temperatures are low enough for condensation, the use of condensing economisers or condensing boilers can improve efficiency by as much as 10% (see diagram below)

Condensing boiler efficiency



The graph illustrates how the boiler efficiency increases as more heat is extracted from the flue gas, so reducing its exit temperature, especially if the flue gas is cooled below the dewpoint so that both sensible and latent heat are recovered.

Fact File H6
Boiler plant and equipment

What are the costs?

The approximate price differential of condensing systems over non-condensing is shown in the following table.

Output (kW)	Budget cost (year 2000)	
	High-efficiency boiler (£)	Condensing boiler (£)
25	900	1400
50	1200	2000
100	1500	3100
150	1800	3900
200	2100	4500

What needs to be done?

- Undertake a feasibility study to ascertain whether CHP would be cost effective (see also fact file P2).
- Select a boiler system, possibly in conjunction with CHP, that will meet the factory's heat demand in the most efficient manner, incorporating appropriate energy-saving measures (see GPG 30 and DETR's ECA website).
- Where fuel type and operating condition are suitable, specify condensing boilers as the first choice, especially for 'lead' boilers for low-temperature applications.
- Where condensing boilers are used only for weather-compensated (variable temperature) heating circuits (see fact file H10), the boiler flow temperature set point should match the compensated flow temperature.
- Recognise the need to provide condensing boilers with a route to drain for their condensate – ideally this should be by gravity, but may be pump-assisted.
- Assess running costs by using RCN 2 (appendix).
- As well as choosing the correct type of boiler plant, it is important to ensure that it is correctly sized. In general, boilers operate less efficiently at reduced load and so over-sized plant will cost more to run as well as to buy. Consider using modular boilers.

The Boiler (Efficiency) Regulations 1993: Statutory Instrument SI 1993/3083
Condensing Boilers CIBSE Application Manual AM 3
GPG 30 Energy Efficient Operation of Industrial Boiler Plant

Fact File H7
Water treatment

Effective water treatment is essential to ensure optimum energy efficiency and longevity from any new or refurbished wet heating system.

What are the benefits?

Water treatment will prevent corrosion, scaling and build up of other chemicals within boilers and heating systems. This will:

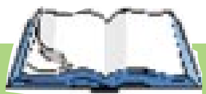
- maintain peak efficiency (severe scaling can reduce boiler efficiency by at least 10%)
- increase the working life of the installation by many years.

What are the costs?

In very general terms, water treatment facilities should add less than 2% to the installed cost of a heating system.

What needs to be done?

- All new or refurbished wet heating systems should be subject to:
  – a fresh water flush to remove loose debris
  – a chemical clean to de-grease and/or remove scaling
  – chemical dosing to inhibit subsequent corrosion and/or microbiological infection.
- Designers should provide adequate facilities to allow these procedures to be carried out, which should include:
  – sufficient high-velocity flushing points, air vents and drain points
  – bypass facilities around sensitive equipment such as control valves and heating coils
  – a dosing pot to facilitate ongoing water treatment
  – replaceable insulation on fittings where access is frequently required.
- When extending existing circuits, particular attention should be paid to ensure that the new system does not become contaminated. Thorough cleansing of the existing system is important, but may require specialist on-line techniques if (as is often the case), insufficient flushing points were originally installed.
- The selection of chemicals for cleaning and treatment should be referred to specialists having due regard to:
  – age and condition of pipework, etc
  – materials of construction
  – raw water quality.



BSRIA Application Guide 8/91: Pre-commission Cleaning of Water Systems

Fact File H8
Destratification fans

Hot air rises, and in high-roofed industrial buildings this can lead to layers of very warm air at high level. These higher temperatures significantly increase the amount of heat lost through the building's roof, and reduce the benefits of heating to the occupants.

What are the benefits?

- Destratification fans blow high-level layers of warm air back down towards the working plane, causing it to mix with the cooler air below. This will lead to:
  – reduced heat loss through the building's roof
  – more uniform heating and hence improved comfort
  – faster warm-up
  – protection of ceiling finishes and high-level lighting from thermal degradation.
- Destratification fans can be run during the summer to provide cooling by enhanced air movement.
- In high-bay applications, the fans can be sleeved so that the warm air is returned at ground level.

What are the costs?

- A typical installed cost is around £5/m² (year 2000), based on a 6-10 m ceiling height.
- The value of the heat savings far exceeds the cost of electricity required to operate the fans.

What needs to be done?

- Estimate the temperature gradient produced by the type of heating system proposed.

Type of heating	Temperature gradient
Fan convectors, warm air heaters	2-2.5°C/m height rise
Radiators	1.2-1.7°C/m height rise
Radiant heating	0.2-0.4°C/m height rise

- Use RCN 3 (appendix) to assess the running cost savings from using destratification fans
- Consider the use of appropriate controls, including:
  – time switches
  – thermostats
  – variable fan speed
  – manual override (eg for summer operation).

Fact File H9
Use of waste heat

There may be opportunities for heating parts of the building using waste heat recovered from its nearby processes or other services.

What are the benefits?

- Waste heat is effectively free and will reduce annual running costs if used to displace purchased fuels.
- An example of the value of the waste heat available from an air compressor is shown in the graph opposite, although waste heat may be available from other industrial processes.

What are the costs?

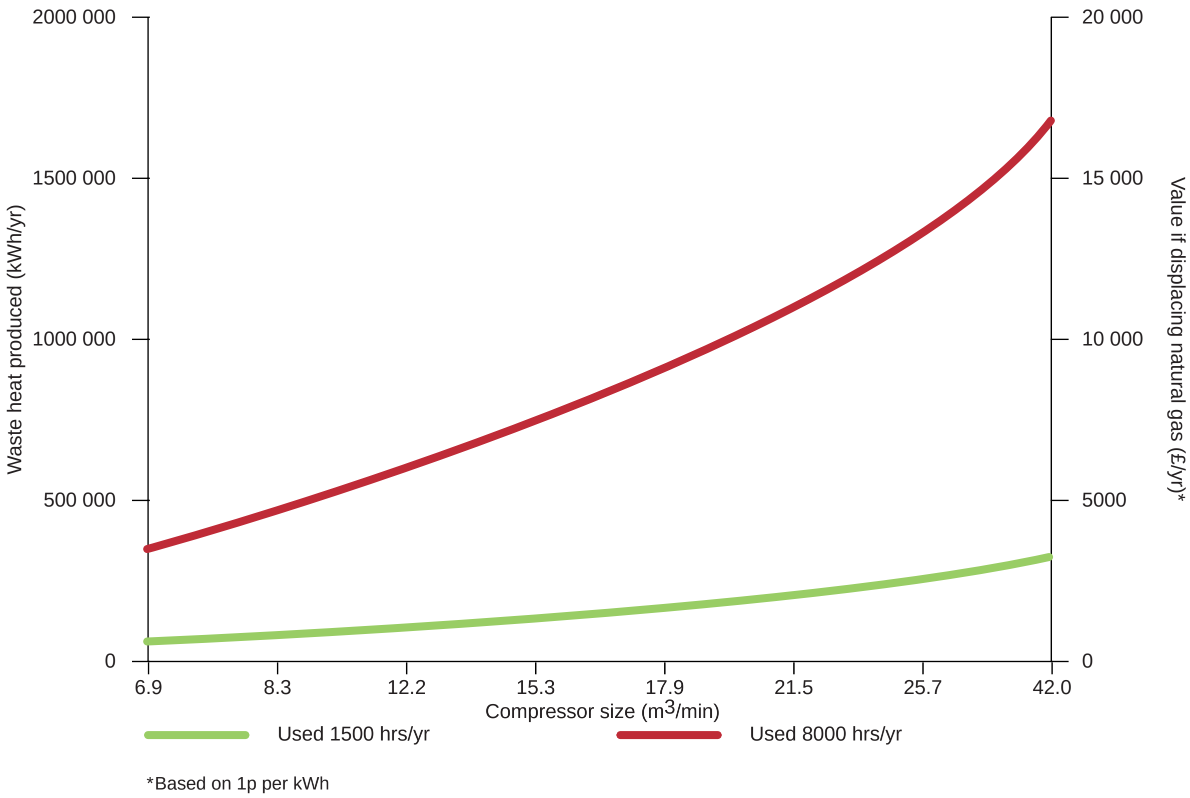
The cost of recovering waste heat can be minimal or very significant, depending upon the engineering required. In general, the simplest systems are the most cost-effective.

What needs to be done?

- Before considering recovery, always ensure that the source process has been optimised to minimise the generation of waste heat.
- There are three main requirements for an effective scheme:
  – location – the heat source and the recipient area should be close together
  – temperature – waste heat needs to be available at a higher temperature than the recipient area needs
  – timing – there must be a match between the timing of heat availability and demand.
- The most widespread opportunity relates to air compressors, because approximately 90% of the electricity that they consume is rejected as waste heat. Air compressors are either:
  – water or oil cooled, in which case a hot water supply (for process or domestic use) can be generated by heat exchange with the compressor's cooling circuit
  – air cooled, in which case the hot air produced can be simply ducted to an adjoining area; bypass dampers will be required to allow the hot air to be dumped outside the building during the summer.

Fact File H9
Use of waste heat

The following graph illustrates the cost saving potential of waste heat recovery from an air compressor.



- Also consider other opportunities for heat recovery, including:
  – process plant (eg dryers, ovens, furnaces, etc)
  – hydraulic and other power systems
  – hot effluent streams
  – ventilation plant (see fact file V4)
  – chillers (see fact file C3).
- Where heat from process plant within the same building is being considered, leaving process pipes uninsulated is often not the most efficient means of extracting heat from the system and may create risks from personnel inadvertently coming into contact with them (see fact file PW4).

GPG 41 Waste heat recovery in the process industries

Fact File H10
Controls

Whatever type of heating plant is selected, it is important to ensure that it is properly controlled with respect to both temperature and time of operation.

What are the benefits?

Properly controlled heating plant will:

- reduce energy usage and costs
- respond to weather conditions
- enhance comfort conditions
- protect building fabric, plant and materials from condensation/frost damage
- ensure that energy savings accruing from any improvements to the building fabric are fully realised.

What are the costs?

Costs will vary depending upon the degree of sophistication provided. The table on page 43 indicates minimum control standards which have been found to be cost-effective.

What needs to be done?

- Design heating systems to allow control at differing temperatures dependent on the requirements of each area. The temperature may be dictated by the product being manufactured or stored. If this is not the case refer to the following table for recommended maximum internal air temperatures.

Type of activity	Dry resultant temperature (°C)
Factory production area – occupied	
■ Sedentary work (generally seated, bench work)	19
■ Light work (light bench work, walking)	16-19
■ Heavy work (heavy bench work, strenuous activity)	13-19
■ Stores	15-19
Factory production area – unoccupied (night set-back)	
■ Minimum for frost protection	5
■ Minimum for condensation protection	10
Office area	
■ General (seated at desk)	19

- It is important to provide separate heating zones for those parts of the building that have differing:
  – internal heat gains (eg from solar, process, etc)
  – temperature requirements
  – heating time requirements.
- In each case there are three types of heating control to be considered:
  – space temperature controls
  – time controls
  – heating plant capacity controls.

Fact File H10
Controls

The following minimum control standards are recommended:.

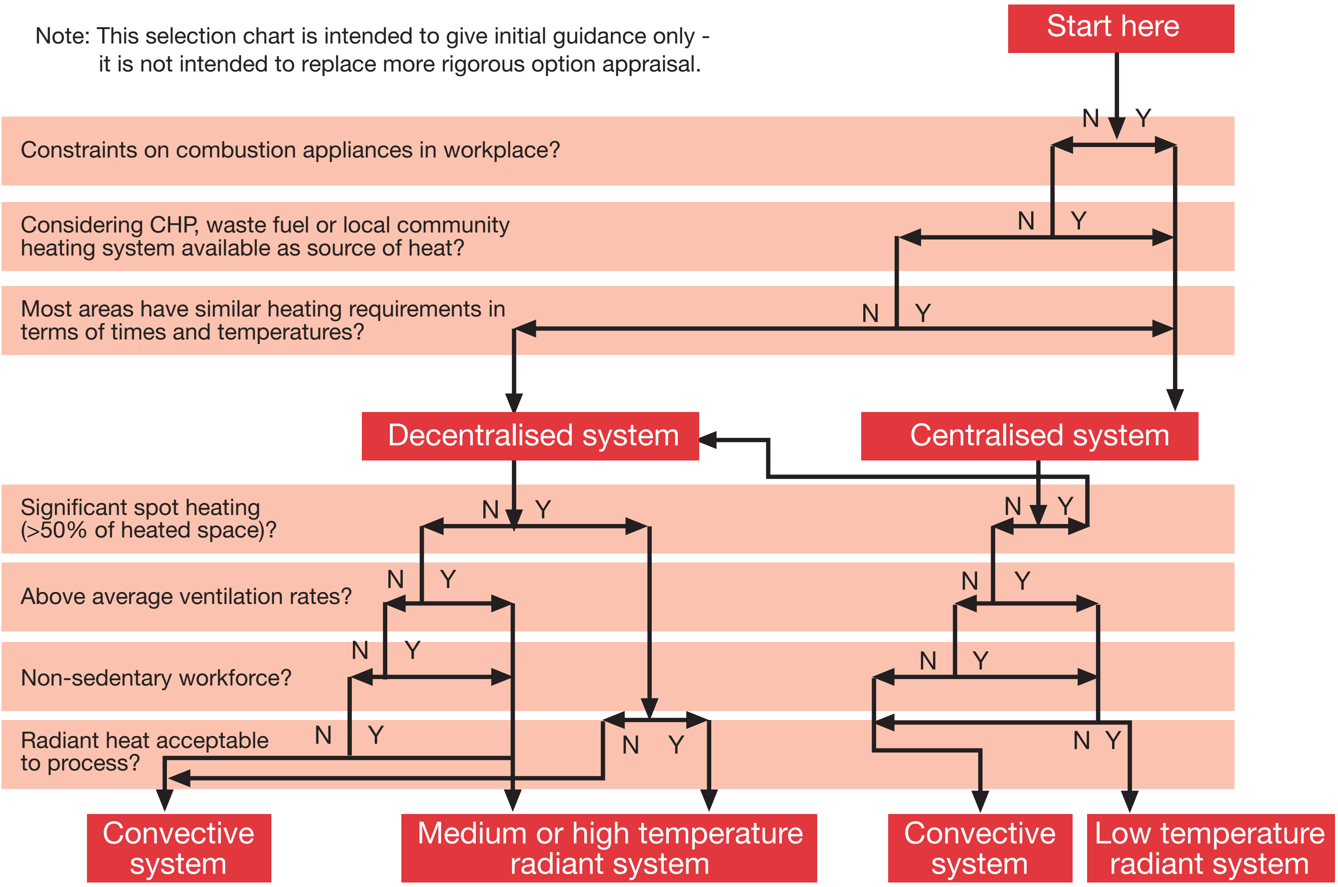
Category	Heating system	Recommended controls
Space temperature	■ Unit heaters (convective) ■ Radiant heaters ■ Radiators -- system control -- individual control ■ Intermittently occupied areas	■ Electronic thermostat ■ Black bulb sensor/thermostat ■ Weather compensation ■ Thermostatic radiator valves ■ Electronic setback thermostat ■ Zone controls
Time	■ Up to 30 kW capacity ■ 30-100 kW capacity ■ Over 100 kW capacity ■ Intermittently occupied areas	■ Time switch allowing separate time programmes for each day of the week; resolution better than 15 mins; spring reserve/battery back-up ■ Optimum start recommended ■ Optimum start required by Building Regulations ■ Occupancy-sensing controls or push-button timer. Consider switching between three temperature levels: -- occupied -- unoccupied during working hours (setback) -- unoccupied out of hours (frost protection)
Capacity control	■ Boilers/air heaters -- up to 100 kW -- above 100 kW -- above 500 kW ■ Multiple boiler installations	 ■ On/off control ■ Consider high/low/off control ■ Consider fully modulating control ■ Sequence (step) control ideally combined with automatic means of flue and/or hydraulic isolation for the offline boiler(s); sequence control is a requirement of the Building Regulations where heat loads exceed 100 kW

- Some process and storage applications require close control of the air's relative humidity (eg in the textiles, pharmaceuticals, tobacco and foodstuff industries). Again, effective reliable control is essential if energy use is to be minimised and proper air conditions maintained.

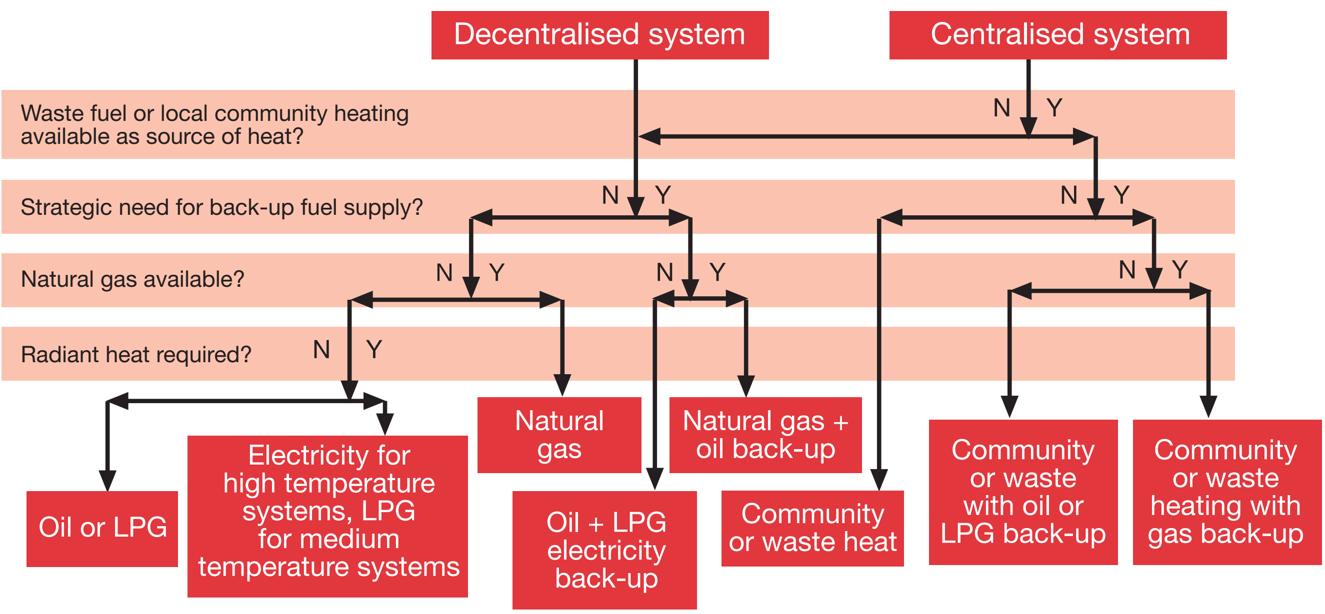
Automatic Controls: CIBSE Applications Manual AM1
GIR 40 Heating systems and their control
GPG 132 Heating controls in small, commercial and multi-residential buildings

Selection Chart SC1A – Heating Systems

Note: This selection chart is intended to give initial guidance only - it is not intended to replace more rigorous option appraisal.



Selection Chart SC1B – Fuel Selection



HOT AND COLD WATER

The costs associated with hot and cold water usage are often much lower than those associated with other aspects of building energy use. It is therefore easy for the designer to become complacent about hot and cold water services and for simple efficiency improvements to be overlooked.

KEY QUESTIONS

Answer the following key questions, which represent good practice in the design of hot and cold water services. If you cannot confidently answer 'yes' to any of them refer to the corresponding fact file to see what opportunities you may be missing.

Have you selected the most appropriate means of generating hot water, including heat recovery from a manufacturing process when practicable?

Fact file W1
Hot water generation
(page 46)

Have you specified the most appropriate controls, particularly at the point of water use?

Fact file W2
Controls (page 47)

Have you considered what impact your design will have on the building's water and sewerage tariffs?

Fact file W3
Water, effluent and sewerage tariffs (page 48)

Have you confirmed your decisions using the decision tree?

Selection chart SC2
Hot water generation
(page 49)

Fact File W1
Hot water generation

Hot water can either be generated centrally (and pumped around the building), or locally at the point of use. In either case, effective design will yield energy cost savings.

What are the benefits?

A correctly designed hot water system will lead to:

- lower energy and water use
- lower maintenance costs
- improved water hygiene.

The efficiencies of alternative types of water heater will vary – check manufacturers' data to confirm. The running costs associated with different efficiency heaters can be estimated from RCN 4 (appendix).

What are the costs?

The installed costs of centralised and decentralised hot water systems will need to be assessed and compared, depending on specific requirements.

What needs to be done?

- Decide whether hot water is to be generated centrally or locally at the point of use, and which fuel type should be used. Selection chart SC2 (page 49) addresses the factors that assist with these decisions.
- Assess whether it is feasible to generate hot water by recovering waste heat from air compressors (see fact file P3) or refrigeration plant (see fact file C3).
- In all cases be aware of the design, commissioning and maintenance requirements needed to avoid the risk of bacteriological infection (eg legionella requirements (GPG 132)).

Centralised plant. Key energy efficiency issues include the following.

- Ensure that hot water storage volume is matched to demand. Avoid excessive storage volumes that will lead to high standing heat losses and increased risk of bacteriological infection.
- In general, ensure that hot water is produced independently of the building's heating system (for example by using a separate water heater).
- Plate heat exchangers, or copper fin water heaters, transfer heat more effectively than traditional storage-type water heaters. They are more expensive, but they can be very cost-effective where larger quantities of hot water are required, for example for process use, and reduce the requirement for storage.
- In hard water areas consider base exchange water softeners and other means to prevent scale formation.
- Ensure distribution pipework and valves are well insulated. Avoid 'dead legs' where water can stagnate, eg long distribution runs that serve outlets with low or intermittent utilisation.
- Ensure the system is adequately controlled with regard to operating times and temperature (see fact file W2).

Avoid using electricity for centralised hot water production, due to its relatively high cost, both financially and environmentally (see fact file H1).

Local plant. Electricity is often the best choice for local water heating due to its low installation/maintenance costs. Its high unit price is less of an issue, provided that water use is low. Local gas heaters can also be used where there are widespread gas distribution mains.

1. FEB 8 'The economic thickness of insulation for hot pipes'
2. GPG 132 'Controls for wet heating systems in small commercial and multi-residential buildings'

Fact File W2
Controls

Ensuring that hot and cold water systems are adequately controlled with respect to both their operating times and temperatures will avoid costly energy wastage.

What are the benefits?

Properly controlled water systems will lead to:

- lower water use and costs (savings of over 50% are not uncommon)
- lower energy use and costs
- higher standards of water hygiene.

What are the costs?

Most water system controls cost under £100 and will pay for themselves in less than 12 months.

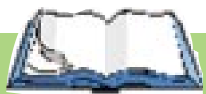
What needs to be done?

Hot water

- Controls should be provided for:
  – operating times of water heaters, circulating pumps and other ancillary equipment
  – water temperature.
- Where hot water is produced using a boiler and storage cylinder, a control interlock should be provided to turn the boiler off when the storage cylinder is up to temperature. This will prevent any wasteful 'on/off cycling' of the boiler, which can otherwise occur when there is no heat load.
- Where electric immersion heaters are used, time switches should be set to provide full heating of the storage calorifier(s) using cheap rate, off-peak electricity. Subsequent 'boosts' can be provided during the day if necessary.
- Hot water should ideally be stored at the lowest temperature compatible with maintaining water hygiene (eg 60°C for controlling legionella). If some water is required at a higher temperature (for example for a process application), consideration should be given to providing a separate system for this requirement.

Cold water

- Controls should be provided to minimise wastage and should include:
  – urinal flush controls, to limit automatic flushing in line with actual use (as required by current Water Regulations), low volume cisterns (6.5 litres), and percussive taps for hand basins
  – service valves to all taps to allow flow adjustment and provide isolation, when required for maintenance
  – sprung-loaded trigger nozzles on any hoses (to prevent them from being left running when unattended).



GPG 143 Upgrading controls in domestic wet central heating systems – a guide for installers
Water (Water Fittings) regulations 1999 (explains current legal requirements relating to water efficient urinals, water closets, etc)
HS(G)70 The Control of Legionellosis Including Legionnaires' Disease

Fact File W3
Water, effluent and sewerage tariffs

Water costs can be reduced by establishing the correct supply infrastructure at the design stage.

What are the benefits?
Establishing the correct water supply infrastructure and basis for charging will ensure the lowest water costs for the future.

What are the costs?
There should be only limited additional cost involved – in fact, in some cases, the avoidance of over-sized supplies could actually lead to a saving in the installed cost.

What needs to be done?
Consider the following.

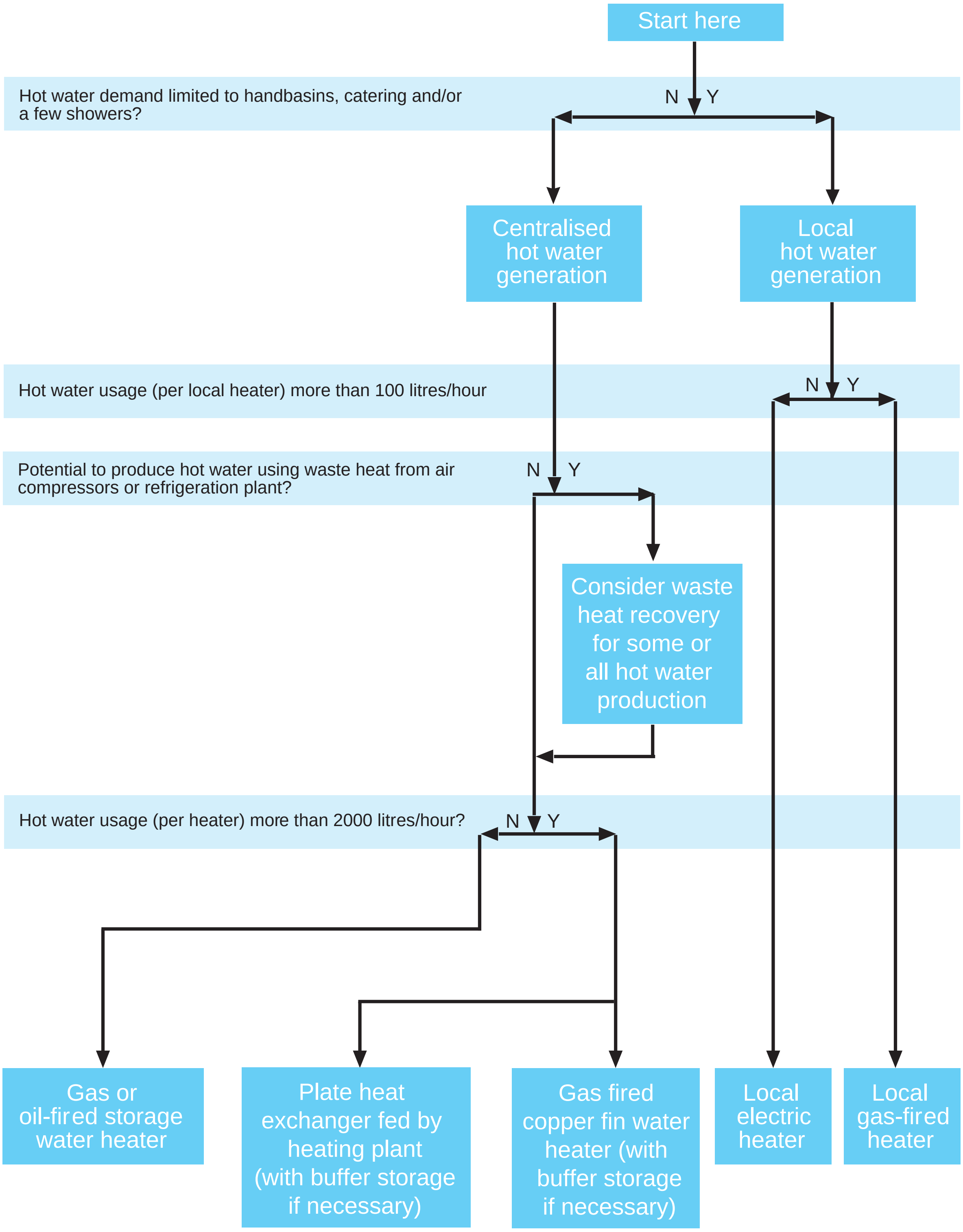
- Make a realistic assessment of the building's water demand, making due allowance for any storage provided.
- Water meter size – annual standing charges will be levied which will increase with meter size. It is therefore costly to specify a supply that is too large.
- Non-return to sewer allowances (NRTSA) – sewerage charges are normally charged on the basis that the volume returned to sewer equals the volume of fresh water supplied. Where significant quantities of water are not returned to the sewer, rebates can be obtained. Typical ways in which water can be 'lost' include:
  – incorporation into product, eg food or drink
  – evaporation from hot processes, dryers or evaporative cooling towers
  – watering of grounds or livestock.

The process of obtaining a sewerage rebate will be made easier by the incorporation at the design stage of low-cost sub-meters to allow the direct quantification of the water 'lost'.

- Surface water drainage – some water companies levy a charge for the removal of rainwater from buildings and grounds. In some circumstances these charges can be avoided by providing your own means of disposal (for example into a local watercourse or soak-away).
- Trade effluent charges – some processes will require trade effluent consents, and for other processes trade effluent charges will cost less than domestic sewerage disposal. Consideration should be given to providing additional treatment in order to reduce ongoing effluent charges (which are related to the degree of contamination remaining in the sewerage – settleable solids and biological oxygen demand being the most important). On-site treatment may be required to meet the terms required by the local water authority. Specialist advice should be sought, and water companies can be a useful source of information.

Selection Chart SC2 — Hot Water Generation

Note: This selection chart is intended to give initial guidance only — it is not intended to replace more rigorous option appraisal.



PIPE INSULATION OPTIONS

When considering energy efficiency measures, pipe insulation ranks with some of the very best options for both financial and environmental benefits. Temperature gradients handled are often amongst the largest in the built environment and the materials typically used for pipes are excellent thermal conductors.

BS 5970, together with BS 5422 (1990) and its subsequent revisions, are key standards in defining the most appropriate pipe insulation levels in industrial buildings.

KEY QUESTIONS

Ask yourself the following key questions, which represent good practice in the design of pipe systems in industrial facilities. If you cannot confidently answer 'yes' to any of them, refer to the corresponding fact file to see what opportunities you may be missing.

Have you minimised your requirement for pipe runs in the building by assessing the energy efficiency of alternative system configurations?

Fact file PW1
Minimising pipe runs
(page 52)

Have you sized the pipes correctly for the flow of fluid anticipated in the system?

Fact file PW2
Sizing of pipes (page 53)

Have you selected the most appropriate pipe insulation material for your application?

Fact file PW3
Selection of materials
(page 54)

Have you selected the most appropriate thickness of pipe insulation material for your application?

Fact file PW4
Thickness requirements
(page 55)

Have you assessed whether your current selection could still give you further cost-effective environmental benefits?

Fact file PW5
The bigger picture-
CO_2 emissions (page 56)

Have you confirmed your decisions using the decision tree?

Selection chart SC3
Pipe insulation selection
(page 58)

Fact File PW1
Minimising pipe runs

The simplest way of minimising heat loss or heat gain from a pipe run is to make it shorter. This may seem obvious but can be overlooked in the haste to provide practical linkages between other pieces of energy-efficient equipment. However, care must be taken to assess the full impact of any changes in design. The debate outlined between centralised and decentralised systems in fact file H4 is a good example of the issues that need to be considered. When considering pipe layouts, these should always be viewed only as part of a larger system – the basis for all true comparison.

What are the benefits?

Properly conducted system comparisons that include pipe insulation ensure:

- that the potential losses from the distribution system are understood
- that the system consumes as little energy as possible while meeting all the performance requirements
- that material costs are minimised while ensuring key performance characteristics are achieved.

Higher than necessary material costs can arise from using too much pipe, using the wrong type of insulation (see fact file PW3) and from applying the insulation to an unnecessary thickness (fact file PW4).

What are the costs?

The cost of carrying out system comparisons will depend on the approach taken. Clearly, if every potential variable were separately modelled, the work required would be too costly both in terms of time and money. However, once the basic options are established (eg from fact file H2), the assessment can be limited to perhaps six models based on different options available. It is normal that the effect of variables becomes fairly rapidly understood once the model is derived.

What needs to be done?

- Decide which of the following criteria – protection against freezing, condensation control, personnel protection, energy saving, CO_2 emission reduction and cost-effectiveness – are to be used to assess performance.
- Assess a number of alternative solutions against the chosen criteria, including the implications for pipe layout, sizing and flow rates.
- Options should be selected on the basis of their investment cost, likely running costs and, where appropriate, the potential to minimise CO_2 emissions based on the fuel selected (see fact file H1).
- Where appropriate, assess the benefits derived from the pipe insulation in order to provide a lifetime cost or saving per tonne of CO_2 saved annually using the methodology set out in fact files PW4 and PW5.

Fact File PW2
Sizing of pipes

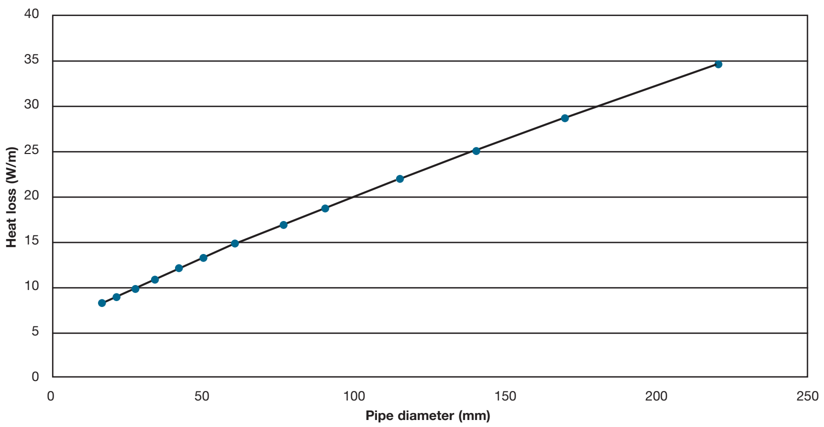
Although the discussion goes well beyond the scope of this Guide, the sizing of pipes can have a dramatic effect on the heat losses experienced along a pipe run. The heat loss or heat gain of a pipe is proportional to the area of the surface of the pipe. Even with the best insulation materials, it is impossible to achieve the same level of heat loss or gain on a large pipe as a small pipe (see below). Small pipes are, therefore, preferred (hence the use of micro-bore systems in some domestic heating systems). However, care must be taken to avoid undue pressures that can in turn cause increased energy use in pumps. Smaller pipes are also more prone to blockages and can be more difficult to clean.

What are the benefits?

Smaller pipes can provide the following benefits:

- lower investment cost both in terms of the pipe and the thermal insulation
- lower heat losses, as shown by the graph below.

Increase in heat loss with pipe diameter for commercial heating pipe at 75°C insulated to revised BS 5422 requirements

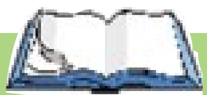


What are the costs?

There may be some incremental costs for larger pump sizes.

What needs to be done?

- Flow calculations need to be carried out based on the rate of fluid delivery required.
- An assessment of investment cost benefits and drawbacks needs to be made.
- This assessment needs to be weighted against the heat loss reductions achieved when insulating to BS 5422 (1990) or its subsequent revisions.



BS 5422 (1990) Specification of thermal insulation materials for pipes, tanks, vessels, ductwork and equipment
BS EN ISO 12241 Methods of heat loss calculation for pipes

Fact File PW3
Selection of materials

The specific requirements of an application define the key performance criteria of the insulation. Where refrigerated and chilled applications are being considered, vapour-impermeable insulation systems are essential and high-emissivity surfaces can be beneficial. In high-temperature applications, where energy savings predominate, the prime issues can be thermal conductivity and maximum operating temperature.

As BS 5422 is a standard based on economic thickness, it should be noted that not all insulation materials specified save the same amount of energy (and CO_2).

What are the benefits?

The correct selection of insulation material type will provide:

- optimum energy savings for a specific pipe size/temperature combination
- longevity of performance both in terms of moisture resistance and high temperature degradation
- cost-effectiveness
- appropriate reaction-to-fire characteristics
- resistance to other adverse conditions (eg vibration)
- best utilisation of available space.

What are the costs?

The market for thermal insulation products is highly competitive. Accordingly, the costs of different insulation choices are generally comparable when applied to a given standard. However, it is not always the case that the performance against specified criteria is equivalent. Hence it is usually best to cost each material type against the specific performance objectives required in an application.

What needs to be done?

- Define application of the pipework in question and specify performance objectives (eg commercial heating).
- A shortlist of potential materials needs to be defined. Frequently used materials are as follows:
  – rock mineral wool
  – glass mineral wool
  – expanded nitrile rubber
  – polyethylene foam
  – phenolic foam
  – polyisocyanurate (PIR) foam
  – polyurethane foam
  – polystyrene (both expanded and extruded)
  – cellular glass
  – calcium silicate
  – others (microporous silica, magnesia, ceramic fibre).
- Individual product offerings need to be established by consultation with relevant suppliers.
- These should include appropriate facings and coatings (eg foil or mastic) where required.
- Specific performance objectives need to be verified and their cost-effectiveness determined.

BS 5970 Code of Practice for thermal insulation of pipework and equipment
BS 5422 (1990) Specification of thermal insulation materials for pipes, tanks, vessels, ductwork and equipment
BS EN ISO 12241 Methods of heat loss calculation for pipes

Fact File PW4
Thickness requirements

Thickness requirements are driven by the key performance objectives of the application in question. These can include:

- *protection against freezing*
- *condensation control*
- *personnel protection*
- *energy saving and CO_2 emission reduction*
- *cost-effectiveness.*

Specification of appropriate thickness can be calculated from first principles (see BS EN ISO 12241) but it is more common to use the thickness specification tables set out in BS 5422 (1990) or later revisions.

What are the benefits?

Insulation specified to the thickness determined by such an approach will provide:

- the required performance objective (from the list above)
- an ability to cite an appropriate British Standard compliance (reference to the table used should be made)
- significant energy saving and CO_2 emission reduction in many applications
- in the case of insulation primarily installed for energy-saving purposes, potential eligibility for ECAs which will optimise cost-effectiveness (revised BS 5422 only – see below)
- assured performance and minimised liability claims.

What are the costs?

No inherent on-costs should arise from applying the appropriate standard to the definition of insulation thickness since, with the exception of energy-saving measures, tables are derived to provide minimum requirements for compliance against performance objectives. Alternative approaches can be taken, but these run the risk of falling short of long-term energy consumption targets. For energy-saving measures, the 'economic thickness' approach ensures that an element of balance is maintained between the monetary value of the energy saved and the initial cost of the insulation measure. Typically, BS 5422 (1990) takes a five-year view of this balance – a method also adopted in the Government's Energy Efficiency Best Practice programme document FEB 8.

It should be noted that future revisions of BS 5422 are likely to move to an environmental or ecological thickness methodology based on the assurance that selection of any insulation type will provide equivalent levels of energy saving (not so in the current standard). The overall levels of insulation will be based primarily on the cost-effectiveness of CO_2 emission abatement, but will also consider practical constraints such as space requirements. This approach is expanded in fact file PW5.

What needs to be done?

- Define application of the pipework in question (eg commercial heating)and specify performance objectives.
- The thermal conductivity of the insulation material to be used needs to be determined from suppliers at the temperature of application.
- Consult relevant tables within BS 5422 (1990) or its subsequent revisions (eg personnel protection and energy saving).
- Use the specific performance objective requiring the highest thickness of insulation as the basis of selection.

BS 5970 Code of Practice for thermal insulation of pipework and equipment
BS 5422 (1990) Specification of thermal insulation materials for pipes, tanks, vessels, ductwork and equipment
BS EN ISO 12241 Methods of heat loss calculation for pipes
FEB 8 The economic thickness of insulation for hot pipes

Fact File PW5
The bigger picture – CO_2 emissions

Standards such as BS 5970 and BS 5422 (1990) only provide minimum requirements for meeting individual specific performance objectives. In the area of energy saving and CO_2 emission reduction, further savings will always be possible, albeit with poorer cost-effectiveness. The relative cost-effectiveness of further insulation measures should be assessed against other CO_2 reduction measures as part of the company's corporate strategy for meeting its commitments to reduce emissions.

This will be of increasing importance to organisations entering into negotiated agreements with government in order to qualify for a discount on the CCL. Also, pipe insulation which meets the revised BS 5422 will be eligible for ECAs (see DETR's ECA website ***www.eca.gov.uk****).*

What are the benefits?
Increased insulation will generally lead to greater energy savings. The prime benefit from considering the 'bigger picture' is that the most cost-effective measures for CO_2 emission abatement can be implemented first.

What are the costs?
Any measure that moves beyond normal cost-effectiveness criteria will have an associated incremental cost. Each measure needs to be considered on its merits relative to other options available.

What needs to be done?
- Establish whether a wider CO_2 emissions reduction strategy exists, for example to reduce a facility's overall emissions in order to qualify for a discount on the CCL.
- Compare the cost-effectiveness of increased insulation with that of other CO_2 emission abatement options, using a consistant method of calculation. Your client may not know the cost of other abatement options and it may be necessary to adopt a simple estimating procedure. For example:

$$\textbf{Cost per tonne of } \mathbf{CO_2} \textbf{ saved annually} = \frac{\textbf{Lifetime cost}}{\textbf{Annual savings of } \mathbf{CO_2} \textbf{ resulting}}$$

where

Lifetime cost
= **initial investment cost**
+ **maintenance costs**
+ **manpower costs**
– **discounted value of energy savings accruing over the lifetime**

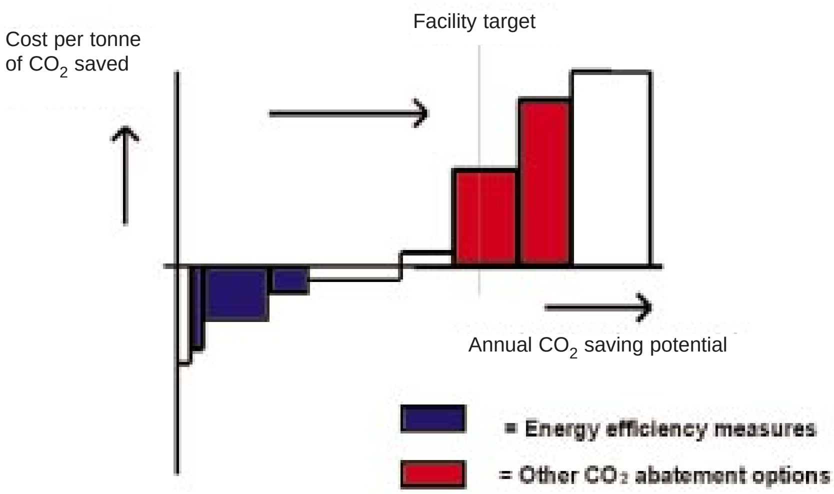
and where the discount rate used to calculate gross present value is the same for all measures

(See also page 16 'Putting the financial case to your client'.)

Fact File PW5
The bigger picture – CO_2 emissions

Illustrative example

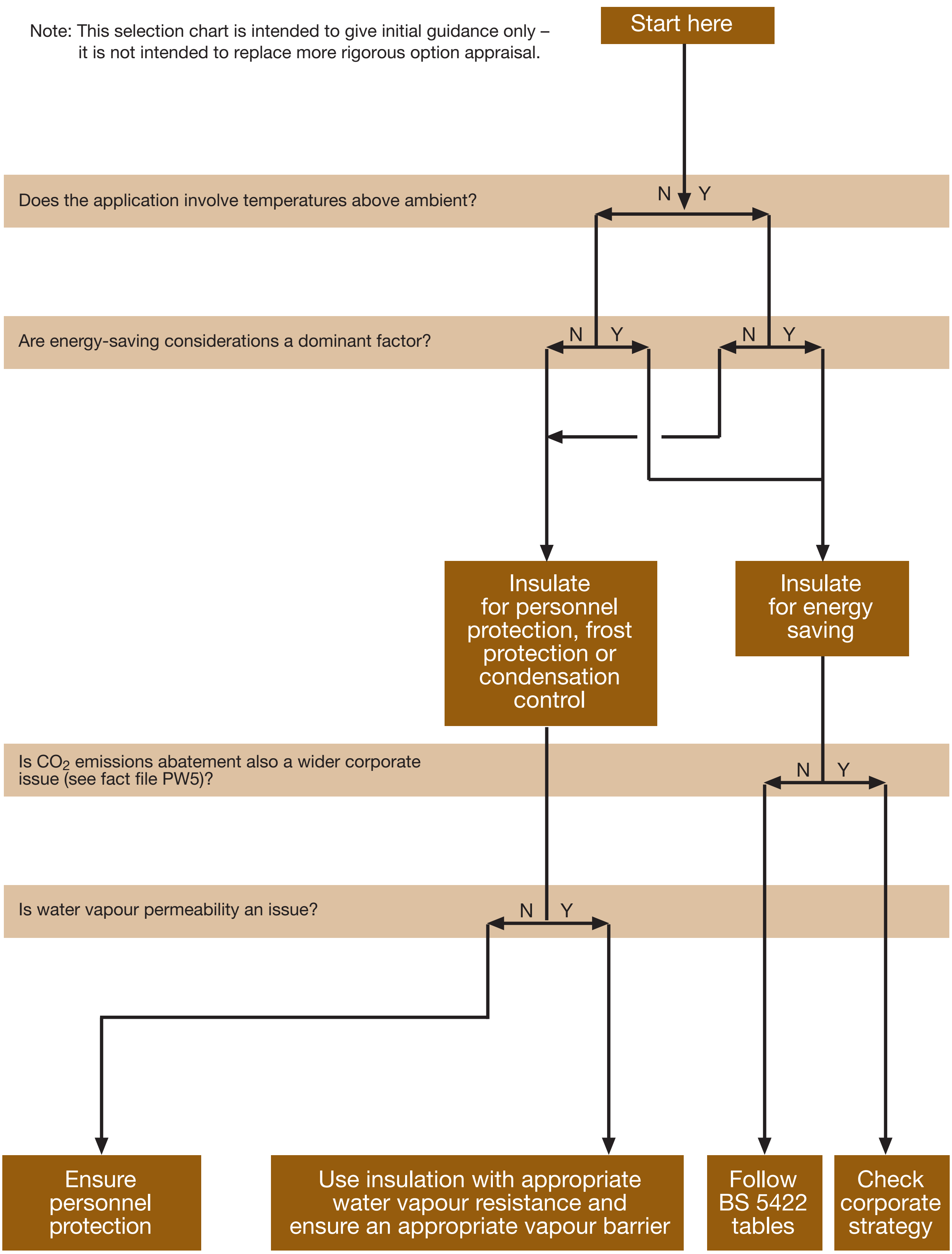
It will be apparent that some measures will have a negative cost where savings exceed costs, while others will have a positive cost. Sufficient measures need to be implemented to achieve the emission target for the facility, as illustrated schematically below:



- Install further insulation where this is cost-effective relative to other measures and necessary to achieve the facility target. Where applicable, remember to include any rebate on the CCL when assessing cost-effectiveness.

SELECTION CHART SC3

Selection Chart SC3 – Pipe Insulation Selection



LIGHTING

Industrial buildings impose particular demands on the lighting designer to provide lighting that contributes to a safe and productive workplace.

Lighting requirements, eg illuminance, colour rendering and appearance, contrast, type of visual environment, etc, vary according to the visual task(s) in, and/or the general usage of, each area to be lit. Additionally, the designer must fulfil these requirements in the most energy-effective manner practical.

KEY QUESTIONS

Answer the following key questions that represent good practice in lighting design. If you cannot confidently answer 'yes' to any of them, refer to the corresponding fact file to see what opportunities you may be missing.

Have you specified, or designed for, the optimum lighting requirements?

Fact file L1
Getting the basics right
(page 60)

Have you selected the most efficient type of lamp suitable for the application?

Fact file L2
Lamp types (page 62)

Have you chosen the most efficient type of luminaire suitable for the application?

Fact file L3
Luminaire types (page 64)

Have you determined, and included for in the calculations, an appropriate maintenance schedule?

Fact file L4
Maintenance matters
(page 65)

Are you sure that the general lighting installation is as efficient as is practical?

Fact file L5
Installed load efficacy
(page 66)

Have you ensured that the switching arrangements match the operating needs of the building and the availability of daylight?

Fact file L6
Switching and circuit configuration (page 68)

Are you making the best use of manual and automatic lighting controls?

Fact file L7
Automatic controls (page 69)

Fact File L1
Getting the basics right

Efficient and suitable lighting systems can increase productivity and consequently the efficiency with which all forms of energy are used in manufacturing and associated services. The lighting system efficiency depends on the combination of the light fitting, lamp and control gear and it is therefore important to get the basics right at the design stage. Those systems which achieve specified efficiencies will qualify for ECAs (see DETR's ECA website: ***www.eca.gov.uk****).*

The design of new buildings should take into account the potential for reducing electric lighting through an appropriate 'daylight design' policy that takes account of the interrelated aspects of window performance such as solar gain and winter heat loss.

What are the benefits?

- Suitable and sufficient lighting systems lead to higher productivity and improved quality.
- Efficient lighting systems minimise electricity costs.
- Efficient lighting systems generate lower internal heat gains to be removed through ventilation or cooling.

What are the costs?

Ideally cost comparisons of different systems should be made on whole life costs and not solely the initial purchase price. The cost of electricity to provide lighting over the lifetime of the system will be many times greater than the initial purchase price. If there are additional capital costs for more efficient designs, these can be rapidly recovered through lower running costs. Getting the basics right will reduce running costs and can often reduce installation costs.

What needs to be done?

The designer needs to provide the most efficient combination of lighting fittings, lamps and control gear that fulfils the requirements.

- Consider relevant design options:
  - either general lighting to provide the required standard maintained illuminance on a horizontal plane throughout the interior
  - or provide a lower standard maintained illuminance on a horizontal plane throughout the area and supplement this with local lighting at each machine or workstation
  - or, where luminaires are positioned relative to the workstations, use localised lighting to provide the required task illuminance and lower illuminance in the areas between workstations.
- Where it is known that high machinery, conveyors, racking, ducting, etc, will be installed in an interior, 'tailor' the layout of the general lighting installation accordingly. For example, when lighting vertical racking, use luminaires which effectively distribute the light along the aisles (see fact file L3).
- Avoid over-lighting. Where a number of visual tasks require different illuminances, which could change, provide flexibility by using movable or interchangeable luminaires, multi-lamp luminaires with separately controlled circuits or dimmable fluorescent luminaires.
- Include switching arrangements and controls to allow electric lighting to be regulated according to the daylight available and occupancy patterns (see fact files L6 and L7).
- Provide light sources which provide light of a colour appearance appropriate to the function of the space and which will render the colours of surfaces accurately if that is critical to the tasks to be performed. Colour appearance is described as warm, intermediate or cold depending on the lamp's correlated colour temperature, while the CIE general colour rendering index can be used to group tasks into colour rendering groups (see the table opposite). The designer will need to refer to these CIE colour rendering indices when selecting appropriate lamp types (see fact file L2).

Fact File L1
Getting the basics right

Correlated colour temperature (CCT)	CCT Class
Below 3300 K	Warm
3300 K to 5300 K	Intermediate
Above 5300 K	Cold

Colour rendering group	Colour rendering index (*Ra*)	Typical application
1A	$Ra \geq 90$	Wherever accurate colour matching is required, eg colour printing inspection
1B	$90 \geq Ra \geq 80$	Wherever accurate colour judgements are necessary or good colour rendering is required, including the recognition of safety colours
2	$80 \geq Ra \geq 60$	Wherever moderate colour rendering is required
3	$60 \geq Ra \geq 40$	Wherever colour rendering is of little significance but marked distortion of colour is unacceptable
4	$40 \geq Ra \geq 20$	Wherever colour rendering is of no importance at all and marked distortion of colour is acceptable

Table 1.1 from CIBSE Code for interior lighting 'Correlated colour temperature classes and colour rendering groups used in the code for interior lighting'

- Match the lamps to luminaires which direct the light where required and result in a low installed power density per 100 lux for the system (see fact files L3 and L5).
- Check that the design complies with the Building Regulations and also achieves the level of efficiency requires to qualify for ECAs. Further guidance is contained in the documents listed below and can be used to group tasks into colour rendering groups (see the table above).

CIBSE Code for Interior Lighting
CIBSE Lighting Guide No. 1 The Industrial Environment
Health & Safety Guidance Note 38 Lighting at work
GPG 300 The installer's guide to lighting design (under preparation by BRECSU)
Building Regulations Part L

Fact File L2
Lamp types

The energy efficiency of a lighting installation is primarily determined by the circuit efficacy (lumens per Watt) of the lamps type(s) used and it is therefore essential to select the most efficient lamp type suitable for the application. High-efficacy lamps qualify for ECAs (see DETR's ECA website ***www.eca.gov.uk****)*

Whether or not a lamp type is suitable for an application is determined by many factors. Some, such as colour appearance and colour rendering, relate to the lighting result, others to practical and operational needs, eg dimensions, wattage ratings and permissible operating positions.

What are the benefits?

- Correct lamp selection contributes to the provision of good lighting.
- Selecting the most efficient type of lamp, from those that are suitable, results in the lowest electricity consumption and cost, and it can also result in a reduction in the number of luminaires required with a consequent reduction in initial cost.

What are the costs?

In those cases where the more efficient lamp type has a higher price, it is usually more than offset by the reduced electricity consumption and possible lower initial installation cost.

What needs to be done?

- Select the most efficient lamps that provide light of a colour appropriate for the area and have a colour rendering ability suited to the task.
  - The choice of colour appearance of the light source is determined by the function of the room and may involve psychological aspects of colour impression. The tendency is to use intermediate colour lamps for working areas and warm colours for leisure and social areas, eg rest and eating areas.
  - The colour rendering ability of a lamp can be important for some industrial tasks. For example, light from high-pressure sodium lamps can result in light grey metal finishes tending to look like copper; this may result in reduced contrast in visual tasks that include copper, other non-ferrous metals and material having a light grey finish.
  - Nevertheless, high-pressure sodium lamps, because of their very high efficacy, are commonly used in industry where colour rendering is not critical, but a degree of colour discrimination is required.

The table overleaf lists some common lamp types with details of their colour appearance, colour rendering ability and efficacy.

- Try to select lamp types that qualify for ECAs. These are listed on the website and include self-ballasted compact fluorescent lamps (CFLs) as replacements for filament lamps, and T8 (26 mm diameter) and T5 (16 mm) linear fluorescent lamps as replacements for T12 (38 mm diameter) tubes.
- Use high-frequency (HF) operation of fluorescent lamps as this results in efficacies 15-20% higher than when operated at 50 Hz.
- Frequency of switching is an important design consideration. In test programmes, what is described as 'cold start' HF control gear for fluorescent lamps reduces average lamp life by 30% when compared with operating with 'warm start' HF control gear. 'Cold start' should therefore only be specified for applications with infrequent switching (once or twice per 12 hours) and should not be used in luminaires switched by presence or photocell controls.
- Where colour rendering is not important, for example security lighting, consider low-pressure sodium lamps as these are the most efficient, but produce monochromatic yellow light which does not provide colour recognition.

Fact File L2
Lamp types

- Select lamps that also satisfy practical and operational requirements such as dimensions, lumen output, wattage rating and permissible operating positions. This will be important where the type and size of the luminaire is determined by the application, eg in areas classified as hazardous or flameproof. The website provides wattage ratings and sizes of lamps qualifying for ECAs.
- Other lamp types that can be the most efficient and suitable for specific applications include the following.
  – Compact fluorescent lamps (non-self-ballasted types, ie not 'plug-in') from 5 W to 55 W. Circuit efficacies are from 38 lm/W to 81 lm/W when operated on HF control gear. Typical applications include indoor and outdoor amenity lighting, and local lighting units. The higher wattages, 36 W to 55 W, include types suitable for use in 600 mm square luminaires and are more efficient than the 600 mm linear 18(16) W fluorescent lamps that are commonly used in such luminaires.

Lamp type	Control gear	Colour rendering	Colour appearance (CCT*)	Circuit efficacy (lumen/W)
Deluxe tubular fluorescent	50 Hz	1A	Various 3000-6500 K	circa 52 (36-70 W ratings)
	High frequency			circa 66 [36 (32)-58 (50) W ratings]**
Triphosphor tubular fluorescent	50 Hz	1B	Various 2700-6500 K	circa 75 (36-70 W ratings]
	High frequency			89 [36 (32)W-70 (60)W ratings]**
Metal halide	50 Hz	1B and 2	Various 3000-5000 K	70-85 (250-400 W ratings)
High-pressure sodium deluxe (comfort)	50 Hz	2	c.2200 K	74-92 (150 W - 400 W ratings)
High-pressure sodium (plus)	50 Hz	4	c.2000 K	94-125 (150-400 W ratings)

Circuit efficacy, which includes control gear losses, values for guidance. Please refer to manufacturers' data.

N.B. Metal halide and high-pressure sodium lamps have a 'run-up' time of between three and eight minutes after switch-on before 80% of full light output is achieved.

* CCT = correlated colour temperature; the absolute temperature of a blackbody whose colour appearance most closely resembles that of the lamp.

** Standard T8 (26 mm) krypton fluorescent lamps operate at reduced wattage when operated on HF control gear, eg 36 W, 58 W and 70 W operate at 32 W, 50 W and 60 W respectively.

Lighting Industry Federation Lamp Guide

Fact File L3
Luminaire types

Choose the most efficient suitable luminaire. The luminaire should be of a type that directs the maximum amount of the light (lumens) emitted by the lamps towards the surfaces to be illuminated, while complying with any other criteria, eg maximum luminance, discomfort, glare, etc, and is suitable for the type of environment in which it is to operate.

*Luminaires that meet minimum efficiency requirements qualify for ECAs. The DETR's ECA website (**www.eca.gov.uk**) specifies maximum light fitting efficiency codes (LFECs) that determine which fittings qualify when used with particular lamps.*

What are the benefits?

The correct choice of luminaire will lead to:

- a more efficient lighting installation
- lighting that contributes to overall productivity
- lower electricity consumption and costs.

What are the costs?

Selecting the optimum luminaire does not necessarily incur additional costs. Higher efficiency minimises electricity consumption and cost and may also result in a lower installation cost because fewer luminaires are required. In any case, decisions should be made on whole life costs.

What needs to be done?

- From these luminaires which are suitable for the environment and the application, and are capable of achieving the desired overall lit appearance of the interior, select the one with the highest utilisation factor (UF).
- Check that the combination of lamp and the selected luminaire will qualify for ECAs. The website shows how to obtain the light fitting efficiency code (LFEC) from the UF or other manufacturers' data. Depending on the lamp type and application, maximum LFECs (minimum efficiencies) are specified in order to qualify for ECAs.
- Select luminaires that are designed to have a relatively high luminaire maintenance factor (LMF); this is particularly important in atmospheres that are not 'clean'. See CIBSE 'Code for Interior Lighting' for information on luminaire maintenance categories.
- When lighting has to be 'tailored', eg the lighting of areas that include significant obstructions to the general flow of light or designing for vertical illuminance, ensure that the luminaires have an appropriate luminous intensity distribution. For example, when lighting the vertical surfaces at the sides of narrow aisles between storage racks, use specially designed reflector luminaires which produce a narrow luminous intensity distribution on the plane transverse to the aisles and a wider distribution along the main axis.
- Select luminaires that utilise good quality reflectors and/or prismatic controllers or diffusers that retain their reflective and transmission performances.
- Luminaires for fluorescent lamps should be equipped with HF control gear. The benefits when compared with standard 50 Hz operation are:
  – 15-20% higher lamp circuit efficacy
  – lower maintenance costs (extended tube life)
  – enhanced working environment (no subliminal flicker)
  – reduced risk of stroboscopic effects with rotating machinery
  – dimming capability.

Fact File L4
Maintenance matters

The designer needs to advise the client of the maintenance schedule on which the design calculations are based and that it must be implemented if the objective maintained illuminance, which is considered necessary for productivity and safety to be achieved.

What are the benefits?
A well-maintained lighting installation will ensure that the designed lighting result is provided and should also minimise the problem of 'dark zones' resulting from individual lamp failures.

What are the costs?
The cost of cleaning lamps and luminaires and replacing failed lamps can be considerable. It may be more economical to group change the lamps at specific intervals, combined with a luminaire cleaning operation, rather than incurring the relatively high labour cost of changing individual lamps on failure.

What needs to be done?
- The maintenance factor used in the design calculations should be based upon a practical and economic maintenance schedule. The schedule should take account of:
  – the depreciation rate of light output from the lamps before changing, ie the lamp lumen maintenance factor (LLMF)
  – the effect of accumulation of dirt, etc, in/on luminaires between cleaning operations by applying a suitable LMF
  – the effect of dirt on room surfaces using a room surfaces maintenance factor (RSMF).
- Ensure that lamps and fittings are easily and safely accessible.
- Provide the client with a maintenance manual that details the lamp type(s), luminaire type(s), relevant spares and the recommended cleaning and re-lamping schedule.

Further details are provided in the CIBSE code for interior lighting.

CIBSE Code for interior lighting

Fact File L5
Installed load efficacy

The installed load efficacy is traditionally measured as the power density per 100 lux. For general lighting installations, 'benchmark' values can be calculated based on the most efficient and suitable combinations of lamps, luminaires and control gear. These benchmarks can be used to assess the performance of existing installations, or proposed replacement and new installations, and hence identify scope for improvements and savings.

The installed load efficacy in W/m^2 per 100 lux is not used directly to assess whether lighting installations qualify for ECAs. Instead, high-efficacy lamps are specified, while a light fitting efficacy code is introduced for luminaires (see footnote).

What are the benefits?
Comparing installed load efficacies with benchmark values identifies opportunities to increase efficacy of both proposed and existing new general lighting installations.

What are the costs?
Where an existing or proposed lighting installation has an installed load efficacy significantly higher than the benchmark (eg 25%), additional costs may be incurred in upgrading the lamps, luminaires or control gear. However, this additional cost will generally be recovered in a relatively short time through lower running costs.

What needs to be done?
- For new general lighting installations calculate the installed power density per 100 lux in W/m^2/100 lux using data for the designed horizontal maintained illuminance, total area and total installed load.
- For existing general lighting installations, calculate the power density per 100 lux, to identify savings that could be made by replacing existing equipment with more efficient alternatives. To calculate the average maintained illuminance use the method described in section 4.5.3 of CIBSE's 'Code for Interior Lighting'
- Compare the calculated power density for the proposed design with the target values given in table 2.2 of the CIBSE code which includes maintenance factors (see fact file L4). Bearing in mind that these targets were set in 1994 and are likely to be revised downwards in the next edition of the code, it is recommended that the target for the new designs should be the bottom end of the ranges in the CIBSE code. For convience the table overleaf reproduces the bottom of the range values from the CIBSE code.
- If the installed power density per 100 lux for the proposed installation or an existing installation is more than 25% above the target in the table, then there is probably scope for further improvement (but there may be special factors – see below)
- Some lighting recommendations/requirements necessitate the use of lamps and/or luminaires that are less efficient than the optimum, eg the use of less efficient Group 1A colour rendering lamps in applications where colour recognition is critical. In such cases the need to provide correct lighting takes precedence.

Fact File L5
Installed load efficacy

CIE colour rendering group	Target working plane power density W/m²/100 lux*		
	Room index		
	K = 1	K = 2.5	K = 5
High bay industrial - reflectance C,W,F, = 0.5, 0.5, 0.2, to 0.3, 0.3, 0.1			
2	2.6	2.1	2.0
3	2.4	2.0	1.9
4	1.4	1.2	1.1
Low bay industrial - reflectance C,W,F = 0.7,0.5, 0.2 to 0.3, 0.5, 0.2			
1b	2.5	1.9	1.6
2	2.9	2.3	2.1
3	2.7	2.1	2.0
4	1.8	1.3	1.3
Commercial - reflectance C,W,F = 0.7, 0.5, 0.2, to 0.5, 0.5, 0.2			
1b	2.7	2.2	2.1
2	3.4	2.8	2.6
3	3.8	3.1	2.9
4	2.4	2.0	1.9

* Target values are based on the surface reflectances shown for ceilings (C), walls (W) and floors (F) and also good maintenance programmes

Table taken from CIBSE 'Code for interior lighting' table 2.2 Targets for installed power density per 100 lux maintained illuminance for general lighting installations in W/m²/100 lux.

Footnote: Qualifying criteria for ECAs (see DETR's ECA website www.eca.gov.uk for the latest information)

Lamps Lamps that can be substituted for existing, less efficient types on a one for one basis. These include:
i) self-ballasted compact fluorescent lamps (CFLs) as replacements for ordinary filament lamps; and
ii) high-efficiency fluorescent lamps as replacements for T12 (38 mm diameter) lamps, where the ballast type allows it.

Light fittings A light fitting efficacy code (LFEC) is introduced based on the utilisation factor (UF) of a light fitting in a standard room. The LFEC is derived from the UF value value for a room with surface reflectances of 0.7, 0.5 and 0.2 for ceilings, walls and floors respectively and a room index of 3.0. Depending on the lamp type and application, there is a specified maximum LFEC (minimum efficiency) for a luminaire to qualify for ECAs.

CIBSE Code for Interior Lighting
Lighting requirements of Building Regulation Part L
GPG 199 Energy Efficient Lighting – a guide for installers
GPG 300 The installer's guide to lighting design (in preparation by BRECSU)

Fact File L6
Switching and circuit configuration

The most cost-effective way of reducing lighting running costs is usually to ensure that it is switched off when not required. It should also be appreciated that productivity and safety will be affected if lighting is not switched on when necessary.

To achieve this requires the provision of easy-to-use and effective switching arrangements, which may qualify for ECAs (see DETR's ECA website ***www.eca.gov.uk****).*

What are the benefits?

Providing appropriate switching arrangements will allow lighting to be turned off when not required or when daylight is sufficient. This will lead to:

- lower energy use and costs (just turning off for one extra hour per day will typically reduce lighting energy costs by over 10%)
- lower maintenance costs through increased intervals between lamp replacements.

What are the costs?

The simple expediency of providing a few extra light switches to allow more flexible lighting control will incur negligible extra cost if incorporated at the design stage. Trying to provide additional switching once the building is complete, however, may be prohibitively expensive.

What needs to be done?

- Ensure that a sufficient number of independent circuits are provided and arranged to match the needs of the building and its occupants and to take full advantage of daylight. Consider:
  - – the proximity of windows or other sources of natural daylight – ensure those fittings closest to windows are on a separately switched circuit from those further away
  - – shift patterns – ensure lighting to areas working different patterns can be separately controlled
  - – frequency of use – intermittently occupied areas should be separately circuited from those requiring longer hours of use; warehouses in particular should have sufficient lighting circuits to allow intermittently visited areas to be switched separately from those which are visited more regularly
  - – separate provision for circulation areas – providing separate circuits for circulation routes will allow the lighting in other areas to be turned off without prejudicing safe access; think particularly about how the building will be lit out-of-hours, perhaps for security staff or cleaners.
- Note the recommendations in Health & Safety Guidance Note 38 'Lighting at work' regarding minimum illuminances and maximum ratios of maximum to minimum illuminances with respect to health and safety.

Health and Safety Guidance No. 38 Lighting at Work

Fact File L7
Automatic controls

The essential precursor for energy-efficient lighting is the provision of sufficient independent circuits and switching points (see fact file L6). Almost inevitably, however, the use of some form of automatic control will also be cost-effective. Such controls, which ensure lighting equipment is only switched on when needed, qualify for ECAs (see DETR's ECA website ***www.eca.gov.uk****).*

What are the benefits?

- Maintaining staff motivation to turn off lights when they are not required is difficult. The selective use of automatic controls will overcome this and lead to lower energy consumption and reduced costs.
- Automatic control of luminaires can ensure that the lighting provision is sufficient to meet productivity and/or health and safety recommendations.

What are the costs?

The installed costs for automatic lighting controls will typically be £50-£250 per device. The payback on their use in industrial-type buildings is often very attractive as single control devices can be used to switch relatively large numbers of light fittings.

What needs to be done?

- Do not be over-ambitious, but limit the use of automatic controls to strategies that are workable and easily understood by those that have to live with to them.
- The following automatic control equipment should be considered:
  – time controller to automatically switch lighting 'on' and/or 'off' at predetermined times
  – presence detector controller to automatically detect occupancy or movement in an area to switch lighting 'on' and 'off' accordingly
  – daylight detector and switching controller to monitor daylight in an area and switch lighting 'on' or 'off' according to occupants' needs
  – daylight detection and regulation controller to monitor daylight in an area and regulate the electric lighting level to that sufficient to supplement the available daylight
  – central control unit to provide overall management of a lighting system utilising some or all of the control elements listed above; such a control unit may form part of a building management system (BMS).
- Incorporate time delay logic or switch on/switch off offsets to avoid nuisance switching.

GPG 160 Electric Lighting Controls – a guide for designers, installers and users

POWER OPTIONS

With day-rate electricity costs being typically five times as high as gas or oil, electrical plant is likely to have the greatest impact on the building's energy running costs. Careful design of the supply infrastructure and associated plant is therefore essential.

KEY QUESTIONS

Answer the following key questions, which represent good practice in energy-efficient design of general electrical services. If you cannot confidently answer 'yes' to any of them, refer to the corresponding fact file to see what opportunities you may be missing.

Have you got the supply infrastructure right, including issues such as supply capacity, supply voltage and power factor?

Fact file P1
Supply infrastructure (page 72)

Have you considered the benefits of on-site generation, either using CHP plant, or by using standby generators for 'peak lopping'?

Fact file P2
On-site generation (page 74)

Have all opportunities been taken to optimise compressed air generation and usage (in line with its high cost as a utility)?

Fact file P3
Compressed air (page 76)

Has advantage being taken of the benefits offered by higher-efficiency motors and variable speed drives?

Fact file P4
Motors and drives (page 78)

Fact File P1
Supply infrastructure

Electricity costs can be reduced by establishing the correct supply infrastructure at the design stage.

What are the benefits?

Establishing the correct electricity supply infrastructure and basis for charging will ensure the lowest electricity costs for the future.

What are the costs?

In general, there should be no additional costs involved, and in many cases the avoidance of over-sized supplies could actually lead to a saving in installed cost.

What needs to be done?

The following issues need to be considered at the design stage.

Supply voltage

It is likely that industrial buildings with a design electrical load of 250 kVA or more will be provided with a dedicated high voltage incoming supply. By supplying and maintaining your own transformers, there is an opportunity to reduce costs through the lower tariffs that apply to high voltage supplies, and installation costs for smaller internal distribution cables. Be aware of the need for suitably qualified and authorised staff to maintain and operate high voltage transformers and switchgear.

Transformer configuration

Transformer configuration is only an issue if you are responsible for high voltage distribution at your site. The electrical efficiency of transformers is a function of their load. Where multiple transformers are installed, consideration should be given to the optimum number and sizes provided. Ring distributions offer greater flexibility in operation.

Supply capacity

When requesting a new electrical supply you will need to agree an authorised supply capacity with your local electricity company. As a designer, you will need to ensure that sufficient capacity is made available to meet the immediate and planned future needs of the building. Care must be taken not to over-specify, however, as over-sized supplies will impose an unnecessary cost penalty, both in terms of any initial capital contribution and the monthly supply capacity charges (which are typically £1.00-£1.50/kVA/month). Once a supply capacity has been officially requested it is not normally possible to negotiate a reduction for several years (typically five years or more).

Power factor

The use of inductive electrical loads such as electric motors will cause the building's power factor to decrease. A power factor of below 0.9 can cause excessive running currents which overloads switchgear, and is often penalised through supply tariffs. It is, therefore, important to ensure that the building's power factor is maintained at 0.95 or above by the installation of capacitors. These capacitors can be of a fixed rating to match the inductive load of a large item of equipment, or can be a bank of capacitors, which are switched by automatic controls.

Fact File P1
Supply infrastructure

Sub-metering

The most cost-effective time to incorporate electricity sub-meters is during initial design and construction. Sub-meters should be specified for all main distribution panels and should incorporate a pulsed output facility to enable remote reading if required at a later date.

- The data provided by the meters will prove invaluable for:
  – energy management
  – monitoring and targeting
  – recharging of internal costs
  – technical investigations into internal electrical loads, etc.
- Sub-metering and subsequent monitoring will be made easier if dedicated distribution boards are provided for:
  – lighting
  – general power
  – air compressors
  – major process plant and equipment.

FEB 9 Economic use of electricity in buildings (for information on power factor correction and metering)
GPG 112 Monitoring and targeting in large companies (for advice on metering and strategies and regular monitoring)
GPG 125 Monitoring and targeting in small and medium sized companies (for advice on metering and strategies and regular monitoring)

Fact File P2
On-site generation

*On-site electrical generation may be considered within the scope of CHP plant or where standby generators are required simply as a back-up power supply. In either case, significant electrical running cost savings can be obtained by ensuring that the generation equipment is correctly specified and operated. The government has set up a Quality Assurance Programme for CHP (CHPQA – **www.chpga.com**) for assessing whether or not CHP schemes are 'good quality'.*

What are the benefits?

- On-site generation of electricity can lead to increased security of supply. In addition, using CHP to provide on-site generation can provide: reduced electrical supply costs, reduced emissions of CO_2, and a source of low-cost heat.
- Assessment and certification under the CHPQA Programme will determine the eligibility of CHP schemes for Climate Change Levy exemption, ECAs, and exemption of plant and machinery from business rating.

What are the costs?

Investment costs can be substantial, so a rigorous financial and technical appraisal is essential. Installed costs for CHP typically range from £600-850/kW of electrical output capacity, depending on the size of plant being installed. However, investment in 'good quality' CHP installations, ie those which utilise most of the recovered heat, will be exempt from the CCL and qualify for ECAs*. As an alternative to raising the capital, the installation of a CHP unit can be financed by its supplier or an energy services company who will then retain a share of the savings achieved, yet still be able to supply the building with cheaper electricity and/or heat.
For comparison, the cost of standby generators is typically £200-£500/kW.

What needs to be done?

Consider the following.

Combined heat and power (CHP)
CHP is the generation of thermal and electrical energy in a single process. CHP units use a prime mover(s) (usually either a gas-fired reciprocating engine or turbine) to drive a generator. The heat generated in this process is recovered to produce hot water or steam. Unlike standby generators, CHP plant always incorporates control equipment to ensure that the electrical output is synchronised with the incoming mains. There are a number of prime movers and electrical generator options whose characteristics are summarised in the table on page 75.
CHP schemes should be designed to meet the 'good quality' criteria laid down in the CHPQA Standard (available from **www.chpqa.com**) in order for the whole capacity to qualify for the benefits listed above.

- CHP normally provides an acceptable economic return on sites that have a simultaneous demand for heat and power over a prolonged period of time, at least 4500 hrs/yr, although CHP can sometimes be cost-effective with fewer operating hours.
- Because of the way electricity tariffs are structured, the greatest electricity cost savings are available for 17 hours per day (nominally 07.00 to 24.00 hrs) throughout the year. Turbines are better suited to continuous operation (ie several hundreds of hours at a time), whereas reciprocating engines are more tolerant to regular (eg daily) switching.
- The most likely circumstances in which CHP can be applied to industrial-type buildings is where the building houses a process which has a year-round demand for either hot water or steam. However, CHP can be economically viable in sites that have only a seasonal demand for heat.
- CHP can also be appropriate for industrial buildings which have extensive cooling or air-conditioning requirements, in which case the heat generated can be used to provide cooling via an absorption chiller (see fact file C2).
- CHP can be a cost-effective alternative to the provision of traditional standby generators and will provide significant environmental benefits through reduced emissions of CO_2.
- Further information can be obtained from the CHP Club website on **www.chpclub.com.**

*Subject to EU State Aid Clearance

Fact File P2
On-site generation

Type of plant	Typical output range	Typical fuels	Typical heat to power ratio	Grade of heat output
Gas turbine	0.5 MW upwards	Natural gas Gas-oil, landfill gas, biogas, mine gas	1.6:1 Up to 5:1 with supplementary firing	High
Compression -ignition engine	2 MW upwards	Natural gas + 5% gas-oil Heavy fuel oil	1:1 to 1.5:1 Up to 2.5:1 with supplementary firing	Low and high
Gas engine	Up to 4 MW	Natural gas, landfill gas, biogas, mine gas	1:1 to 1.7:1	Low and high
Steam turbine	0.5 MW upwards	Any, but converted to steam	3:1 to 10:1	Medium
Combined cycle	10 MW	As gas turbine	Down to 0.7:1	Medium

Table taken from 'The Managers guide to Custom Built Combined Heat and Power systems', Table C5 'Summary of prime mover/electrical generating characteristics

Standby generation

- Emergency standby generators can represent significant capital investment, which normally provides little or no return. If correctly engineered, however, they can be used to produce significant electricity cost savings by 'peak lopping' in conjunction with suitable electricity supply tariffs.
- The true cost of generating electricity in power stations (and of distributing it around the country), is seasonal. The most expensive times are weekday evenings (roughly between 16.00 and 19.00 hrs), during the months of November to February. It is possible to choose an electricity supply tariff which charges peak rates at these times in exchange for lower prices elsewhere (often called seasonal time of day (STOD) tariffs). Under these circumstances, it can be cost-effective to operate standby generation plant during the peak hours in order to reduce the building's electrical load.
- The economics require careful consideration. Controls to ensure that the standby generator operates in parallel with the normal mains supply are expensive. If standby generators are sized to match specific loads then it may be more economic to control the generators manually to meet these loads in isolation.

Renewable energy

It is unlikely that it will be economic to generate electricity on site using renewable forms of energy, but make clients aware that some electricity suppliers sell electricity generated using renewable sources.

GPG 43 Introduction to large scale combined heat and power
GPG 200 Financing large scale CHP for industry and commerce
GPG 227 How to appraise CHP. A simple investment appraisal methodology
CIBSE AM12 Small Scale Combined Heat and Power for Buildings
Web page of the EEBPp CHP Club **www.chpclub.com**
The Managers Guide to Custom Built Combined Heat and Power Systems, available through the Energy Efficiency Best Practice programme CHP club
A Quality Assurance Programme for Combined Heat and Power; DETR, July 2000 – CHPQA Standard (available from **www.chpqa.com**)

Fact File P3
Compressed air

Compressing air is an energy-intensive process with around 90% of the electrical input being released as heat. It is, therefore, essential that the compressor system is designed for maximum efficiency, and that compressed air is only used where the cost is justified.

What are the benefits?

A properly engineered compressed air system will lead to:

- a more stable air supply
- reduced air losses
- lower electricity use and costs
- lower maintenance costs.

What are the costs?

The design stage is the most cost-effective time for incorporating energy-efficient features. Trying to correct an inadequately designed system at a later date will be much more expensive.

What needs to be done?

The following issues need to be considered.

Siting of the air intake

This should be sited to take in cool air if possible, eg north-facing wall of a building.

Plantroom ventilation

Air compressors should be installed within well-ventilated plantrooms, preferably with large direct openings to the outside air.

Pipework design

- Compressed air distribution pipework must be adequately sized to suit demand.
- Pipework should be designed to minimise pipe runs, but avoid 90° bends. The end use will determine whether a ring main or branch line is the best solution.
- Pipe materials – seek advice for your application, eg hygiene requirements and the need for flexibility (a modular arrangement may be the best long-term option).

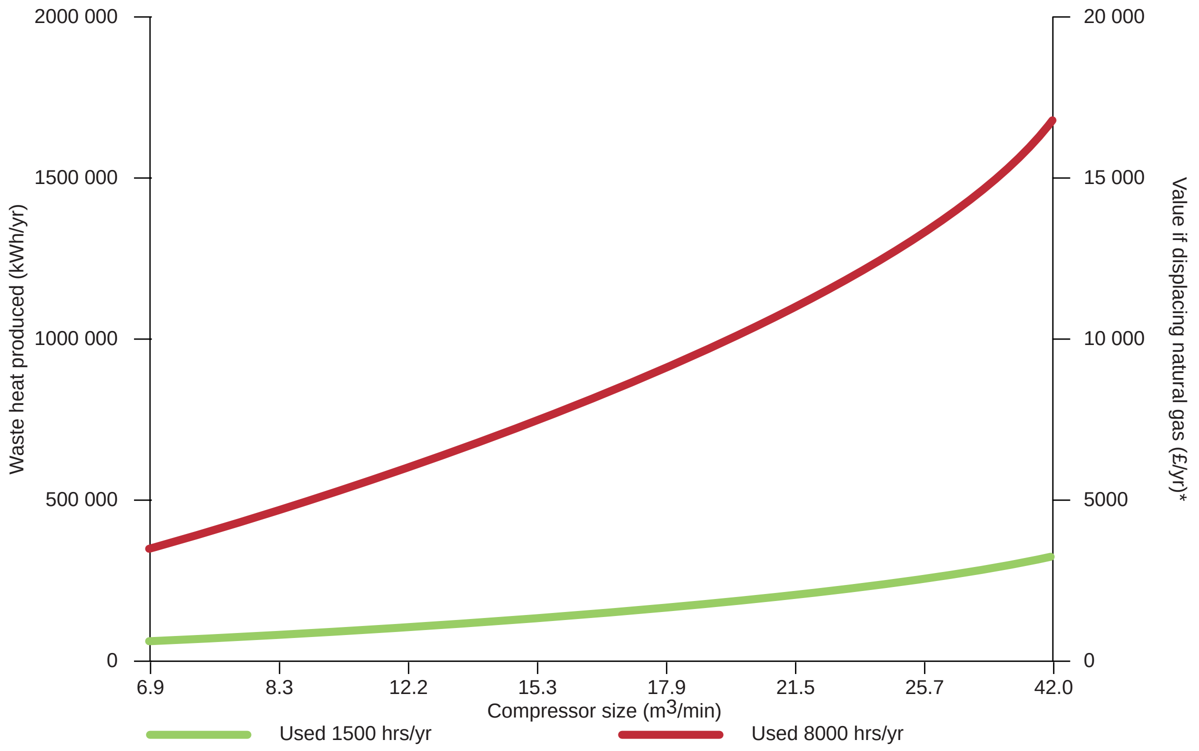
Compressor efficiency

- Compressor efficiency decreases markedly at low loads, therefore the demand will dictate how many compressors, and of which size, are installed. Consideration should be given to choosing appropriate sequence controls and timers.
- For varying air demand with occasional peaks, it may be appropriate to consider installing a variable speed compressor. The variable speed drive (VSD) may qualify for ECAs (see fact file P4). However, variable speed should not be used in installations running for long periods at full load.

Fact File P3
Compressed air

Heat recovery

Ninety percent of the electricity consumed by air compressors is turned into unwanted heat. This heat can sometimes be usefully used either to produce hot water or to provide warm air for space heating or drying purposes (see fact file H9).



*Based on 1p per kWh

GPG 238 Heat recovery from air compressors
GPG 241 Energy savings in the selection, control and maintenance of air compressors
FEB 4 Compressed air and energy use
GIL 45 Air compressors with integral variable speed control
Installation Guide – Guide to selection and installation of compressed air services (available from British Compressed Air Society, 33-34 Devonshire Street, London, W1N 1RF, tel (020) 7935 2464, fax (020) 7935 3077)
Plant Engineer's Reference Book, edited by Dennis A. Snow, published by Butterworth & Heineman for Institute of Plant Engineers ISBN No. 0-7506-1015-8

FACT FILE P4

Fact File P4
Motors and drives

The value of the electricity consumed by an electric motor over its life is typically 100 times the purchase price of the motor itself. It is, therefore, important to ensure that the motors (and their associated drives), are as efficient as possible. Motors that reach specified efficiency standards qualify for ECAs. Where a motor is subject to a variable load, energy can be saved by using variable speed drives (VSDs), which may also qualify for ECAs.

What are the benefits?
Electricity savings will range from 1-3% for higher-efficiency motors (HEMs) relative to standard versions, to potentially over 50% by the use of VSDs in the right application.

What are the costs?
HEMs can be purchased for no additional cost, whereas VSDs will require significant expenditure. In the right applications, however, they can pay for themselves in a matter of months.

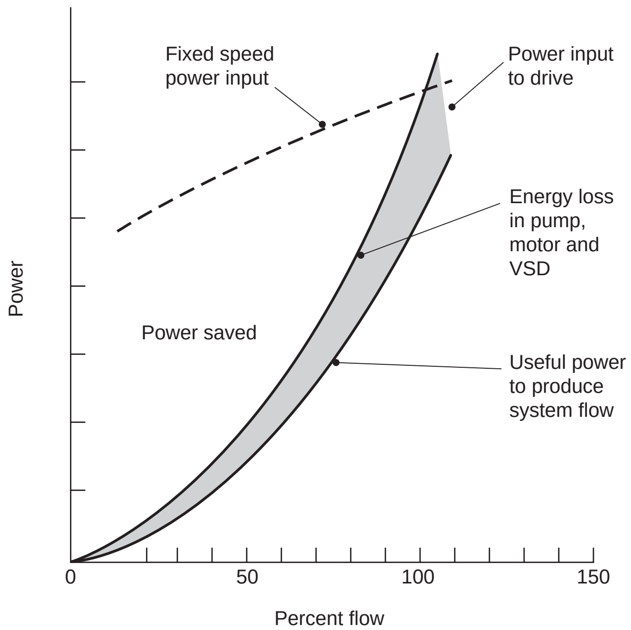
What needs to be done?
Consider the following.

Higher-efficiency motors (HEMs)
- Different makes and designs of electric motors have efficiencies that vary by a few percentage points. HEMs generally use better quality materials and have enhanced design features.
- As the market for HEMs has developed, their price has become broadly comparable with that for 'standard' motors (even allowing for bulk purchasing discounts). The EU has produced a motor classification scheme and, other than 4-pole motors below 11 kW, Efficiency 1 classified motors should always be specified. Further information is contained in GIL 56.
- Consult DETR's ECA website for the minimum efficiencies the motors must achieve to qualify for ECAs (**www.eca.gov.uk**)

Variable speed drives (VSDs)
- The traditional method of providing flow control for pumps and fans is to throttle their output using valves and dampers respectively. Unfortunately, this method wastes a lot of energy across the throttling device. A much more energy-efficient form of control is to vary the flow rate by altering the speed of the pump or fan itself. The load on the drive varies approximately as the cube of the flow rate, so that reducing the speed can significantly reduce the input power (see figure opposite). Ventilation fans and heating/cooling water pumps can often be successfully run at reduced speeds for much of the year, when typical loads are less than the design condition.
- Modern electronic 'frequency inverter' VSDs provide cost-effective, infinitely variable speed control for standard squirrel cage electric motors.
- Consult DETR's ECA website for details of VSD controllers eligible for ECAs.

Two-speed motors
The use of two-speed motors is a cost-effective and efficient way of providing a degree of speed control for fans and pumps. They are most typically applied to air-handling plant to provide either a boost or a setback facility.

Fact File P4
Motors and drives



Power consumption using a VSD and power saved (GPG 14)

GPG 2 Energy savings with electric motors and drives
GIL 56 Energy savings from motor management policies
GPCS 266 Higher efficiency motors on HVAC plant
GPCS 219 Two-speed motors on ventilation fans
GPCS 88 Variable speed drives on water pumps
GPG 14 Retrofitting AC variable speed drives

VENTILATION SYSTEMS

Ventilation rates within industrial-type buildings are often much higher than found elsewhere. This ventilation may be required to remove process heat or to provide dust and fume control. In either case, these high ventilation rates will lead to excessive heat loss (and hence energy usage), unless appropriate measures are incorporated within the design.

KEY QUESTIONS

Answer the following key questions, which represent good practice in energy-efficient ventilation design. If you cannot confidently answer 'yes' to any of them, refer to the corresponding fact file to see what opportunities you may be missing.

Has every opportunity been taken to make use of natural ventilation strategies?

Fact file V1
Natural ventilation (page 82)

Have mechanical ventilation systems been designed to provide the required air change rates with minimum energy use?

Fact file V2
Mechanical ventilation (page 83)

Have make-up air systems been specified to provide the optimum building pressure balance?

Fact file V3
Make-up air and pressure balance (page 84)

Is the heat contained within any exhaust air being recovered for re-use?

Fact file V4
Heat recovery (page 85)

Have variable speed or other advanced control techniques been adopted?

Fact file V5
Controls (page 87)

FACT FILE V1

Fact File V1
Natural ventilation

Natural ventilation strategies that reduce or eliminate the need for mechanical services plant can lead to cost and operating benefits. Natural ventilation can be particularly effective in industrial buildings due to their relatively high ceilings.

What are the benefits?

Designs that utilise natural ventilation can provide the following advantages:

- lower capital costs
- lower energy costs
- lower maintenance costs
- improved user satisfaction (through more direct control).

What are the costs?

- Simple natural ventilation designs (those capable of dealing with internal heat gains of up to 20 W/m^2) should cost less to install than those relying on mechanical plant.
- More sophisticated natural ventilation designs (those capable of dealing with internal heat gains of up to 40 W/m^2), may cost more to install than those relying on mechanical plant, but this is frequently justified by reduced running costs.

What needs to be done?

- Minimise heat gains to extend the scope for natural ventilation and reduce the need for mechanical cooling. These gains include contributions from:
  – solar gain
  – process plant (or desk top equipment in factory offices)
  – hot distribution pipes
  – electric lighting
  – personnel.
- Another useful approach can be the grouping together of energy-intensive process equipment into a few mechanically ventilated areas, allowing the rest of the industrial building to be naturally ventilated.
- Consider alternative mechanisms to drive natural ventilation:
  – wind pressure
  – stack effect (warm air rises).
- In areas where openings are only on one wall, wind pressure ventilation will be limited to a room depth of around 6 m. With openings on opposite walls, cross-ventilation occurs and can be effective in areas up to 12 m wide. Similarly, stack effect ventilation can be effective for horizontal distances up to 12 m between the wall opening and roof opening. Most effective natural ventilation will be achieved by using a combination of low-level openings (eg windows) and some at high level (eg roof vents).
- For optimum energy efficiency, ensure that any natural ventilation is controllable, as natural air change rates in industrial buildings can be quite high (particularly if goods doors, etc, are left open). The correct strategy is to design the building to be as airtight as possible, and then provide the required amount of ventilation by controllable means.

CIBSE Applications Manual AM10 Natural Ventilation in Non-Domestic Buildings.
CIBSE Guide A4 Air Infiltration and Natural Ventilation.
BS5925 Code of Practice for Ventilation Principles and Designing for Natural Ventilation.
GIR 59 Natural ventilation for commercial and public buildings – good practice in the UK.
GPG 290 Ventilation cooling option appraisal – a client's guide
GPG 291 A designer's guide to the options for ventilation and cooling

Fact File V2
Mechanical ventilation

Some amount of mechanical ventilation is an almost inevitable requirement for many industrial buildings, either for providing cooling or for fume/dust extraction. Proper design will reduce running costs and may result in lower installation costs.

What are the benefits?

Well-designed mechanical ventilation plant will lead to:

- more effective fume or dust capture
- greater comfort and an improved working environment
- more stable conditions for process operations
- reduced energy running costs.

What are the costs?

None, in fact effective design is likely to reduce the size of ventilation plant required and hence should lead to lower installed costs.

What needs to be done?

Select the system that meets the business need with minimum energy use.

- For general factory ventilation, consider the use of high-level extract fans (either roof or wall mounted). These are very effective at removing heat, but are ineffective at fume extraction, etc.
- Fume or dust removal is best achieved using local extraction facilities. This also has the benefit of lower air extraction rates, resulting in reduced heating costs. Consideration should be given to balance ventilation to avoid introducing contamination by creating a negative pressure in a space with a number of extracts.
- Seek specialist advice for the design of extraction hoods, as this will be critical for optimum performance, particularly where hazardous materials are involved. The designer should ensure that the necessary test points, etc, are provided.
- Where extract rates are variable (eg the user determines when extract hoods or fume cupboards operate), ensure that the supply air volume can be reduced to meet these needs. This can result in a saving in fan power (see fact file V5), but the most significant improvement in energy efficiency is due to the reduced volumes of make up air which require heating or cooling.
- Consider providing all mechanical ventilation systems with back-draught shutters (or dampers), to prevent air infiltration when the fans are not in use.
- Prevent excessive fan power requirements by ensuring that all ductwork is adequately sized. As a guide, aim to incur a pressure drop of no more than 1 Pa/m. This usually equates to an air velocity of around 10 m/s in main ducts and 4 m/s in branch ducts. However, higher velocities may be required for fume or dust transfer.
- Avoid the use of over-sized fans that may operate well away from their optimum efficiency point and/or may require throttling with a damper (itself a source of energy wastage), in order to provide the suction or air flow rates required.
- Recognise that any air extracted from a building will inevitably be replaced by fresh air drawn in from outside. The means by which this make-up air is introduced will have an impact on energy efficiency, comfort conditions and in some cases, the safety of heating appliances (see fact file V3).
- Provide adequate automatic controls (see fact file V5).

GPG 257 Energy efficient mechanical ventilation systems

Fact File V3
Make-up air and pressure balance

In the absence of make-up air to a building, extract fans will cause it to operate at a negative pressure. This will draw cold, uncontrolled volumes of fresh air in through any openings in the building fabric, causing cold draughts and increased heating costs. The introduction of controlled quantities of conditioned make-up air can alleviate these effects.

What are the benefits?

- Cold draughts can be minimised by:
  – careful siting of the source of make-up air
  – providing a tempered fresh air supply into the building to restore the pressure balance.
- Providing properly controlled make-up air to replace that removed by extract systems will lead to:
  – lower heating costs
  – more stable internal air conditions providing comfort and manufacturing quality benefits.

What are the costs?

Each system must be assessed on its own merits.

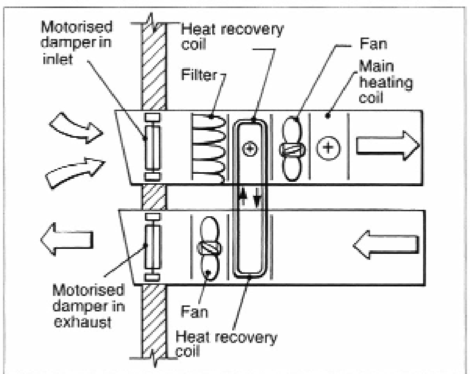
What needs to be done?

- Where fresh air is being provided solely to meet the respiration needs of staff, use the following table to determine the volumes required.

Condition	Fresh air supply (litres/sec/per person)
No smoking	8
Some smoking	16
Heavy smoking	24
Very heavy smoking	32

CIBSE guide volume B, table B2.2

- Consider the use of direct gas firing (see fact file H5), as this can be a particularly efficient method of tempering large volumes of incoming fresh air.
- Be aware that negative building air pressures can also present a particular hazard if traditional flued heating appliances (or process equipment) are installed: the negative pressure can prevent the flue from functioning correctly and can cause potentially harmful products of combustion to be drawn into the workplace.
- Recognise that, in some instances, a positive building pressure can be beneficial, particularly where highly uniform heating is required throughout the building and/or the ingress of untreated external air is unacceptable.



Balanced ventilation (with heat recovery coils)

Fact File V4
Heat recovery

Ventilation to heated areas inevitably leads to increased heating energy use. This cost penalty can be reduced by recovering heat from warm exhaust air and using it to temper the incoming, cold, makeup air.

What are the benefits?

- Heating plant may not be required for some of the heating season.
- Energy running costs are reduced.

What are the costs?

The cost of heat recovery systems depends critically on whether the supply and extract ducts are adjacent (see table below) and each case will need to be assessed on its merits.

What needs to be done?

- Before considering heat recovery, make sure that ventilation rates have been minimised and can be adequately controlled.
- Consider the relative merits of alternative methods of heat recovery as presented in this table.

System	Advantages	Disadvantages
Partial air recirculation	▪ Controllable ▪ Able to recover both sensible and latent heat components ▪ Efficient	▪ Supply and extract ducts must be adjacent ▪ Risk of cross-contamination
Plate heat exchanger	▪ Simple, static device ▪ Low risk of cross-contamination between air streams	▪ Supply and extract ducts must be adjacent ▪ Efficiency typically less than 50% ▪ Bulky
Thermal wheel	▪ Controllable ▪ Able to recover both sensible and latent heat components ▪ Efficiency 65-80%	▪ Supply and extract ducts must be adjacent ▪ Risk of cross-contamination between air streams ▪ Difficult to clean ▪ Bulky
Run-around coils	▪ Controllable ▪ No risk of cross-contamination between air streams ▪ Supply and extract ducts need not be adjacent	▪ Efficiency typically less than 65% ▪ Frost protection required
Heat pipes	▪ Simple, static device ▪ Low risk of cross-contamination between air streams ▪ Efficiency up to 75% ▪ Compact	▪ Supply and extract ducts must be adjacent

FACT FILE V4

Fact File V4
Heat recovery

- Where the extracted air is only contaminated with particles, it may be possible to filter it and then return it to the workplace. This approach eliminates the heat losses normally associated with ventilation, but maintenance requirements may be more stringent. If the recycled air is hot, consider discharging it back into the workplace at low level during the winter. Ductwork should also be provided to allow the hot air to be dumped to outside during the summer.
- If any form of heat recovery is being considered, the use of centralised supply and extract plant will assist its installation and economics. Be aware, however, that this may prejudice the controllability of the ventilation (see fact file V5).

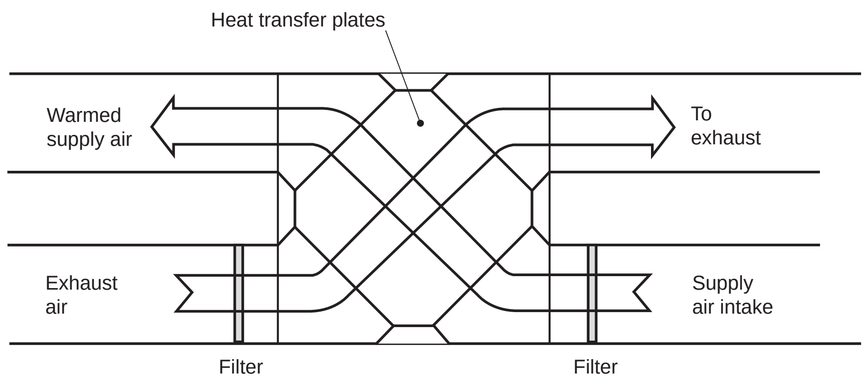


Plate heat exchanger for heat recovery

Good Practice Guide 141 Waste heat recovery in the process industries

Fact File V5
Controls

Ventilation systems must be well controlled to minimise energy waste due to excessive ventilation rates, temperature fluctuations or fan motor use.

What are the benefits?

Close control of ventilation will lead to:

- optimised heating costs
- improved comfort conditions, by reducing draughts
- reduced maintenance costs as the result of shorter plant running hours.

What are the costs?

The costs involved will vary depending on the scale and complexity involved. The simplest improvements will cost only a few pounds and pay for themselves within a matter of weeks. Adequate controls are essential if savings are to be maximised from other energy efficiency improvements.

What needs to be done?

Consider three forms of control:

- time control
- temperature control
- air flow rate control.

Time control

- Ventilation plant can be time controlled by a variety of methods:
  – manual switching (requires an easily accessible, well-labelled on/off switch)
  – time switch
  – push button or automatic presence detection, allowing preset timed operation (useful for intermittently occupied areas)
  – electrical interlock to associated production machinery (for dedicated extract systems).
- Larger centralised ventilation systems should be zoned (using local motorised isolation dampers), if parts of the system are required to operate at differing times.

Temperature control

If using ventilation plant to provide heating or cooling ensure the following:

- frost protection facilities are correctly adjusted and commissioned (if heating/cooling coils are provided), to prevent unnecessary operation
- sufficient control deadbands are provided to prevent simultaneous operation of heating and cooling coils within individual air-handling units
- supervisory control is provided to prevent neighbouring air-handling units from providing simultaneous heating and cooling.

FACT FILE V5

Fact File V5
Controls

Air flow rate control

- Ideally, ventilation rates should be varied in line with actual requirements. Depending on the purpose of the ventilation, 'demand' can be sensed by measuring:
  – air temperature
  – contaminant concentration
  – number of production machines in operation
  – duct pressure (where zone isolation dampers are used on a centralised system).
- Air flow rates can be regulated using dampers, but a more energy-efficient technique is to use two-speed motors or, better still electronic VSDs, to vary fan speeds (see fact file P4).
- When contemplating reducing air flow rates on process extract systems, be aware that limits may be imposed by the need to maintain a minimum duct velocity (particularly when handling dust-laden air streams).

GPCS 164 Variable speed drives on a flour mill extract
GPCS 219 Two-speed motors on ventilation fans
GPCS 232 Variable speed drives on wood dust extract fans

COOLING AND REFRIGERATION

Cooling in industrial buildings may be required by the process, or it may be provided for the comfort of the occupants. Where the manufacturing process requires close control of air temperatures, for example to prevent the thermal degradation of produce, then inevitably some form of cooling plant will be required with potentially high energy consumption. By comparison, the need for comfort cooling may be avoidable through attention to the design of the building, but where this is not possible the required cooling can often be provided by simple mechanical ventilation.

KEY QUESTIONS

Answer the following key questions, which represent the good practice approach to solving cooling problems. If you cannot confidently answer 'yes' to one or more of them, refer to the corresponding fact file to see what opportunities you may be missing.

Have you considered all means of reducing heat gains and cooling loads, in order to lessen the need for cooling?

Fact file C1
Reducing heat gains (page 90)

Have you selected the most energy-efficient means of cooling and considered the use of 'free cooling'?

Fact file C2
Methods of providing cooling (page 91)

Have you considered opportunities for recovering the heat given off by a cooling system for re-use elsewhere?

Fact file C3
Heat rejection (page 94)

Have you specified the most efficient controls for all components in the cooling system?

Fact file C4
Controls (page 96)

Fact File C1
Reducing heat gains

Mechanical cooling plant has high capital costs and is expensive to run. Wherever possible the requirement for mechanical cooling should be eliminated through attention to the building design. Where some degree of cooling is unavoidable, the cooling load needs to be minimised by reducing internal heat gains as far as practicable.

What are the benefits?

Reducing the need for mechanical cooling will lead to:

- reduced capital cost for plant
- lower energy use and costs
- lower maintenance costs
- lower potential environmental impact, through lower emissions (mainly CO_2); and reduced inventory of potentially environmentally damaging refrigerants.

What are the costs?

Much can be achieved at no capital cost, simply by making the correct design decisions. Other opportunities may require expenditure, but this is frequently offset by a corresponding reduction in the capital expenditure on cooling plant.

What needs to be done?

Recognise that as internal heat gains increase, more sophisticated cooling facilities will be required. The following table illustrates this for rooms with a ceiling height of approximately 3 m (ie typical of factory offices or low-bay production/storage areas). Larger heat gains can be tolerated in production/storage areas with higher ceilings and these should be assessed on an individual basis.

Heat gain (W/m^2 floor area)	Method of cooling
Up to 20	Simple natural ventilation strategy
20-40	Sophisticated natural ventilation strategy
40-80	Mechanical ventilation
Over 80	Mechanical refrigerated cooling

Consider reducing heat gains by:

- optimised orientation and shading of windows (see fact file B1)
- locating high-power-consumption activity on the north side of a building
- improved roof insulation (see fact file B2)
- using a pale-coloured external roof finish (see fact file B2)
- increasing the thermal mass of the building and allowing this mass to cool overnight
- avoiding the running of hot service pipes through 'heat-critical' areas
- ensuring that hot service pipework and valves are well insulated
- selecting energy-efficient lighting and other equipment
- partitioning off hot processes and providing dedicated ventilation plant to serve them.

GIR 31 Avoiding or minimising the use of air-conditioning – a research report from the EnREI Programme. BRECSU
Passive Ventilation Guide
FEB 8 The economic thickness of insulation for hot pipes.

Fact File C2
Methods of providing cooling

There is more than one way of providing cooling. Some methods have much lower energy requirements than others, but they may not guarantee precise temperature levels during hot weather. Whatever the method, there are energy saving measures that can be introduced at the design stage, many of which qualify for ECAs (see below). A building employing good practice will utilise the most energy-efficient temperature control strategy consistent with its particular cooling demands.

What are the benefits?

- Choosing the best method of cooling will lead to:
  – lower energy use and costs
  – lower maintenance costs
  – lower potential environmental impact, due to a reduction in the inventory of refrigerants
- The running costs of providing cooling using plant of differing efficiency, as indicated by the coefficient of system performance (COSP), can be estimated using RCN 6 (appendix). The COSP is defined as the amount of heat removed per unit of energy consumed by the whole cooling system, taking account of auxiliaries such as fans and pumps as well as the compressor. The higher the COSP over the operating season, the more efficient the cooling system.

What are the costs?

The correct choice of cooling method will be influenced by capital cost, running cost and technical considerations. Any financial evaluation should consider the effect of the Climate Change levy. ECAs may be applicable to investment in efficient systems, providing a further financial incentive to consider energy efficiency at the design stage (see DETR's ECA website **www.eca.gov.uk**).

What needs to be done?

- As a first step, compare centralised and decentralised systems in a similar manner to that used for heating (see fact files H4 and PW1).
- You need to consider the following alternative methods of providing cooling, starting with low-energy options.

FREE COOLING

Full outside air ventilation

The simplest example of 'free cooling' is the opening of a window to cool a room. Where glazing is fixed, free cooling is still possible by changing mechanical ventilation air damper settings. The main opportunities for 'full outside air' ventilation occur during spring and autumn, when outside air is often at about the right temperature to keep the building cool without having to start up the mechanical cooling equipment (eg the chillers).

Evaporative cooling ('wet cooling')

- The evaporation of water produces a cooling effect – the final water temperature being determined by the wet-bulb temperature of the ambient air. This effect can be harnessed by using an evaporative cooling tower to remove heat from a recirculating flow of cooling water.
- Energy requirements are much lower than those of other cooling options, being limited to the cooling tower fans and water pumps. As these components are usually also required by other cooling methods, evaporative cooling is often referred to as 'free cooling'.
- The major limitation of using evaporative cooling is that in summer cooling water temperatures may be limited to a minimum of around 20°C. This is likely to be too high for many applications, but for much of the year it can cool water to +10°C or lower, which is low enough to satisfy building cooling needs directly.
- Evaporative cooling is usually the first choice for the direct cooling of many industrial processes and associated services plant (eg grinding mills, air compressors, etc). It may also be adequate, however, for general comfort cooling duties in production areas or factory offices, provided a large enough heat transfer area is used. Typically this would entail the use of over-sized coils in air-handling units, or alternatively large chilled beam/ceiling panels may be more suitable. There is usually a need to provide water treatment to the evaporative cooling circuit, to prevent Legionella and other bacterial growth(see fact file W2).

Fact File C2
Methods of providing cooling

Thermosyphon

- A further refinement of evaporative cooling is the Thermosyphon concept. This development of the standard refrigeration circuit for water chilling has the advantage of keeping the tower water and chilled water systems segregated.
- A thermosyphon refrigeration circuit has an evaporator where refrigerant boils to cool water, and a remote condenser mounted higher up in the building, in which the refrigerant vapour condenses. In normal refrigerating mode, the circuit operates just as a standard chiller, with the compressor raising the pressure of the vapour. In cool weather, however, as long as the ambient wet bulb temperature is low enough, the circuit runs in thermosyphon mode: a valve is opened which allows the vapour from the evaporator to bypass the compressor and flow directly to the condenser, being driven by the condenser-evaporator pressure differential.
- Thermosyphon chillers have been installed to serve a number of major mainframe computer data processing centres. Typically, full free cooling is achieved for 40% of the year – and year-round average COSPs well above 10 have been achieved.

Ground water cooling

Many long-established industrial sites have boreholes. Borehole water temperatures are near-enough constant – across the UK the figure is ~+10°C, which is undoubtedly low enough to suit some cooling techniques (see the next section). Moreover, it is often possible to first use borehole water to perform a cooling duty, and then for it to be used elsewhere as a substitute for mains water. In some situations it can be re-injected.

Designing with free cooling in mind

The key to maximising the energy-saving opportunities is to design the equipment with free cooling in mind. Generally, the higher the cooling water supply temperature that can be tolerated, the better; so large heat transfer surface areas are needed. Investing capital in over-sized coils in air-handling units, or chilled beams/ceiling panels, or heating/cooling coils embedded in floor slabs and/or walls, is substituting expensive low-depreciation plant for cheaper, high-depreciation chillers with high running costs.

HEAT-DRIVEN COOLING

Desiccant cooling and adiabatic cooling

There is a connection between these two technologies. Both are linked with 'full outside air' air-conditioning.

- With adiabatic cooling, the nominally +20°C/50% relative humidity (RH) air which is extracted from a building is sprayed with water to bring it down to its saturated condition, which is +10°C/100% RH, which is then discharged into the cooled space via mixing boxes/ducts and diffusers. It then passes through a heat recovery wheel, and this pre-cools the incoming ambient air, with an efficiency of between 70% to 80%. In winter, the same heat recovery wheel is used 'dry' to pre-heat incoming air.
- Desiccant cooling uses a wheel containing a moisture-absorbing matrix (such as silica gel). Ambient air passes through the wheel, and in the process it is dried down to a very low relative humidity. It next passes through a spray cooler, leaving it in the desired cooled condition (typically +10°C/100% RH). The moisture-absorbing matrix is 'regenerated' as the wheel rotates through a segment in which hot air is circulated. The heating energy can be from any source – solar-heated hot water and waste heat from CHP systems often find favour.

Absorption chilling

- Absorption chilling uses heat to provide its cooling effect. Less efficient than mechanical vapour compression, absorption chilling typically has a COSP of only 1, or less (although this can be improved by using 'multiple effect' machines). It has the advantage, however, of being able to use energy sources which are cheaper than electricity (ie natural gas or recovered waste heat). Generally, absorption cooling is only viable where there is a source of low cost or waste heat, eg from a CHP generating engine. Indeed, absorption chillers, by creating a summertime heat load, can strengthen the case for a CHP installation (see fact file P2).

Fact File C2
Methods of providing cooling

'CONVENTIONAL' COOLING

Mechanical vapour compression

- Currently the most widespread method of providing refrigeration and air-conditioning, this technique almost invariably uses electrically driven compressors to drive a volatile refrigerant around a boiling/condensing cycle. The compressors may be used in chillers to produce chilled water; or they can provide direct expansion (DX) cooling without the use of chilled water as an intermediary (as in 'packaged' air-conditioning). COSPs are typically 2 to 3, but when the efficiency with which electricity is generated and the associated cost are taken into account, mechanical vapour compression can result in the highest overall running costs and the greatest emission of CO_2 into the atmosphere.
- DX cooling has installation cost advantages in small applications and can be the only way of providing the lower temperatures required in some process applications. However, running refrigerant through extensive pipework systems increases the risks of fluid leakage, and the regulations covering high-pressure pipework must be adhered to.
- Chilled water systems make it easier to provide close temperature control and are potentially safer, as all refrigerant can be contained within remotely located chiller plant. Operating temperatures for chilled water systems are usually in the range +4 to +10°C, although anti-freeze additives permit lower temperatures.

Specifying chilling equipment

Many refrigerants if released into the atmosphere, act as greenhouse gases and cause ozone depletion. For new equipment refrigerants with zero ozone depletion potential should be specified. Furthermore, specifying energy-saving plant reduces the consumption of fossil fuel and hence reduces the emission of CO_2.

The key to efficient refrigeration is to minimise the 'temperature lift' (condensing temperature – evaporating temperature); and to optimise performance for average cooling duties and average ambient conditions.

- Systems should operate with the highest possible evaporating temperature – a 1°C increase in evaporating temperature improves refrigeration energy efficiency by around 3%. Controls should accordingly let the chilled water temperature 'float' as high as possible, 6°C may be essential in summer, but 11°C might suffice over the winter.
- Design to operate at the lowest practical condensing temperature – a 1°C decrease in condenser temperature typically increases energy efficiency by around 3%°C. Some specialists advocate 'over-sized' condensers, but greater financial returns may be obtained on better controls (such as electronic expansion valves – see fact file C4), or substituting evaporative condensers (which qualify for ECAs) for air-cooled condensers. Alternatively, consider using liquid pressure amplification (LPA), more generally described as liquid refrigerant pressure boosting, which allows the condensing pressure and temperature to drop as the ambient temperature falls. The capital, installation and commissioning costs of LPA systems qualify for ECAs.
- Consider installing automatic air purgers, as this will avoid the loss of efficiency that occurs if non-condensing gases are allowed to build up in the system. Automatic purgers meeting certain criteria qualify for ECAs.

More detailed guidance is available, ring the Environment and Energy Helpline on 0800 585794

GPG 278 Purchasing efficient refrigeration – the value for money option
GPG 279 Running refrigeration plant: energy efficient design
GPG 280 Energy efficient refrigeration technology – the fundamentals
GPG 283 Designing energy efficient refridgeration plant
GPG 236 Refrigeration efficiency investment – putting together a persuasive case
GPG 256 An introduction to absorption chilling
GPCS 301 Use of larger condensers to improve refrigeration efficiency
HS(G)70 The Control of Legionellosis including Legionnaires Disease.
Refrigeration and Air Conditioning: HCFC Controls URN 25/525

Fact File C3
Heat rejection

The heat extracted by any refrigeration or cooling system has to be rejected. An industrial building employing energy efficiency good practice will seek to re-use this rejected heat, for example to provide space heating or to produce hot water for process or domestic use. Running cost savings can be achieved by choosing the correct method of heat rejection.

What are the benefits?

Choosing the right method of heat dissipation will lead to:

- possible re-use of rejected heat
- improved overall energy efficiency
- lower energy use and costs
- improved hygiene and safety.

What are the costs?

Choosing the correct method of heat rejection can reduce running costs without necessarily incurring higher capital costs.

What needs to be done?

Consider the three principal methods of heat dissipation:

- recovery to a process or to provide space heating and/or hot water
- dissipation by air blast
- dissipation by water evaporation.

Heat recovery

- The recovery and re-use of the heat rejected by cooling systems should always be the first choice, where viable.
- The rejection of heat from the refrigerant used in a mechanical vapour compression chiller is a three-stage process:
  – de-superheating of hot refrigerant vapour (~15% of total heat energy)
  – condensing (vapour into liquid: ~75% of total heat energy)
  – sub-cooling of the liquid refrigerant (~10% of total heat energy).
- Each occurs at a successively lower temperature. De-superheating can be used to produce hot water at around 60°C, but the other processes occur at much lower temperatures and hence are less useful. For this reason heat recovery is often limited to de-superheating only. As with any heat recovery scheme, the availability of heat must be matched to the demand for it, both in terms of quantity and timing.

Air blast condensers

- The refrigerant can be condensed by passing it through an air-cooled heat exchanger.
- Advantages:
  – relatively low capital cost
  – none of the hygiene risks associated with evaporative cooling towers.
- Disadvantages:
  – condensing temperature can be no lower than the ambient air's dry bulb temperature; this has an adverse effect on refrigeration efficiency and hence compressor energy consumption (see fact file C2)
  – the physical disadvantages are that air-cooled condensers have quite short operating lives (typically 10 years); they take up a lot of space (especially low-noise models); and they are susceptible to fouling, blockage and corrosion caused by atmospheric pollution.

Fact File C3
Heat rejection

Water-cooled condensers and evaporative condensers

- Many larger refrigeration and air-conditioning systems are 'wet cooled' – either the chillers have a water-cooled condenser connected to a cooling tower, or they use an evaporative condenser, where the condenser tubes are directly spray-cooled.
- Advantages:
  – the condensing temperature is determined by the wet bulb temperature of the air; in summer this is typically 5-10°C lower than the dry bulb temperature, and it is much more stable. Hence, in UK applications, changing from air-cooled condensers to wet cooling should improve compressor energy consumption by at least 20%.
- Disadvantages:
  – hygiene risk and stringent water treatment requirements
  – frost protection facilities required.

Notes on 'wet-cooled' equipment

- Installing 'wet-cooled' equipment is usually more involved than fitting an air-cooled condenser. A water supply is required, as is a drain connection. There is also a need to provide chemical and/or electronic/magnetic water treatment to prevent legionella; and to protect the equipment against other bacterial growth, corrosion, and water hardness.
- There is a perception in the building services business that wet-cooled equipment requires more maintenance than air-blast cooling equipment; and that the Legionella problem is insuperable. In fact, a huge amount of electricity is wasted each year because air-blast equipment is not cleaned regularly – condenser faults are at the root of half of all service calls. On the other hand, Legionella outbreaks are extremely rare because they are the result of a chain of maintenance failures. This explains why evaporative cooling is usually the first choice for the direct cooling of many industrial processes and associated services plant (eg grinding mills, air compressors, etc).
- Correct location of any heat rejection plant is particularly important to prevent re-entrainment of the warm discharge air.

GPG 278 Purchasing efficient refrigeration – the value for money option
GPG 280 Energy efficient refrigeration technology – the fundamentals.
GPG 283 Designing energy efficient refrigeration plant.

Fact File C4
Controls

The use of enhanced controls on cooling plant can lead to significant running cost savings.

What are the benefits?

Properly controlled cooling plant will lead to:

- lower energy use and costs (through allowing the design objectives to be achieved)
- lower maintenance costs
- enhanced comfort conditions.

What are the costs?

Much control optimisation work does not involve capital expenditure. It is very often a question of re-configuring the existing control design or installation. Even if money has to be spent, much can be achieved with only limited expenditure.

What needs to be done?

Consider controls to ensure the following.

Plant capacity matches demand

- It is essential to ensure that the operation of refrigeration plant is matched to demand.
- In steady load applications (eg process cooling) a single chiller with a single compressor may be acceptable, but typically multiple chillers (or a chiller with multiple compressors) should be used in conjunction with capacity and step/sequence controls.
- Avoid capacity control based on hot gas bypass or suction gas throttling.
- Under certain operating conditions, cooling towers may provide adequate cooling to allow the chillers to be bypassed. If this is the case, ensure that the controls are designed to allow such a mode of operation.
- Consider also control of cooling tower fans to optimise overall system performance, including:
  – on/off switching
  – two-speed motors (see fact file P4)
  – variable speed drives (see fact file P4)
  – variable speed control of chilled water pumps (see fact file P4)
  – raising the temperature of any chilled water circuits when demand is low.

Plant only operates when required

Consider:

- time switches
- interlocks to heat-producing plant or processes
- thermostatic control to inhibit operation when room conditions are satisfied (suggested maximum set point temperatures are 25°C for sedentary personnel and 23°C for active personnel, but comfort is very much dictated by air movement and relative humidity at higher dry bulb temperatures)
- 'day economisation' thermostatic control to inhibit operation when the ambient temperature air falls below a pre-set value (at which point refrigerated cooling should not be required).

Fact File C4
Controls

Evaporation and condensing pressures are optimised

For mechanical vapour compression plant there are three options, all of which qualify for ECAs:

- using balanced port valves, which are a more sophisticated type of thermostatic expansion valves to provide more accurate control
- fitting electronic expansion valves in preference to thermostatic expansion valves will permit lower condensing temperatures/pressures to be used (resulting in 3% efficiency gains for every 1°C reduction achieved)
- an alternative approach is to fit liquid refrigerant pressure boosting pumps which provide another way of letting condensing temperatures/pressures fall (see fact file C2).

Minimise operation of defrost system

Install monitoring equipment and controls to ensure defrost system does not operate unless necessary. Such controls qualify for ECAs.

Proactive controls

Consider installing a proactive controller to monitor and optimise system parameters to ensure the most efficient operation. These controllers qualify for ECAs.

Automated permanent refrigerant leak detection systems

System performance can be seriously degraded by loss of refrigerant. Installing an automated permanent leak detection system (which qualifies for ECAs) provides early warning of refrigerant leaks.

GPCS 089 Variable speed drives on cooling water pumps
GPCS 124 Variable speed drives on secondary refrigeration pumps
GPCS 270 Variable speed drives on a cooling tower induced draught fan
GPCS 302 Improving refrigeration performance using electronic expansion valves
GPG 280 Energy efficient refrigeration technology – the fundamentals

CONSTRUCTION TO HANDOVER

Buildings will only perform well if they are constructed, commissioned and operated to a high standard. Surveys show that energy-saving measures included at the design stage (which the client will have paid for) are frequently not properly installed. The position is often made worse by inadequate operating and maintenance (O&M) documentation, with the result that the building is not operated as intended, generally resulting in higher than necessary energy consumption.

MONITORING CONSTRUCTION

The building construction or refurbishment needs to be monitored to ensure that it is carried out to the full design specification. Points to watch for are:

- structure is airtight as far as practicable
- insulation is installed to the thickness specified, with no gaps or thermal bridges
- plant specifications are not changed, leading to undersizing or oversizing
- energy-saving measures are not omitted to reduce costs
- control strategies are not compromised.

COMMISSIONING

Commissioning must include comprehensive testing to demonstrate that all elements of the building are performing to the design requirements. The designer must clearly define what performance standards are required – for example where air extraction is critical, then the volume flow rates must be clearly and unambiguously stated.

The commissioning engineer should be instructed to produce documentary records of all tests and, once again, these should form part of the final O&M documentation. Building occupiers or nominated representatives should witness these tests.

The following tests should be considered.

Building infrared thermography

An infrared scanner can be used to detect infrared radiation emitted by objects and services on a cold day. This enables visualisation of missing or defective insulation, and cold bridging caused by poor workmanship.

Boiler efficiency

A boiler's combustion efficiency can be readily determined by measuring its flue gas temperature and basic chemical composition. The necessary test equipment is standard issue for commissioning engineers.

Controls

Possibly the most critical element of commissioning works. Many energy-saving features, such as increased standards of thermal insulation, will not save energy unless the controls work effectively. Heating and cooling should not be allowed to work against each other, and 'deadbands' of 4°C or more should be applied. A second commissioning check (typically six months later) will allow settings to be 'fine tuned' in the light of operating experience.

Ductwork and pipework

Air and water flow rates must be balanced and set to the design levels. Leakage from ductwork must be contained within acceptable limits, particularly where safety is an issue (eg fume extraction plant). All pipework should be pressure tested before insulation is applied in order that any leaks may be identified and repaired. Pipework carrying natural gas is subject to statutory requirements regarding its purging and testing which must be undertaken by a CORGI-registered contractor.

Water treatment

New heating systems should be thoroughly flushed and dosed with corrosion inhibitors to ensure their long-term, energy-efficient operation. Cooling water and domestic hot/cold water systems have specific requirements to prevent the risk of bacteriological infection. Again, these works need to be rigorously undertaken and the results documented.

OPERATING AND MAINTENANCE DOCUMENTATION

The purpose of O&M documentation is to inform the occupants how their building and its services are designed to operate. This might need to be referred to in an emergency, or because the occupants want to understand how their systems work. In either event, it should be a clear and comprehensive document, and not just a collection of commissioning and installation certificates, equipment data sheets, maintenance schedules, and 'as fitted' drawings.

CONSTRUCTION TO HANDOVER

No matter how thorough the documentation, it is important to specify that the installing contractor must provide on-site training on energy-efficient plant operation for the building's occupiers and maintenance staff.

Emergencies

The O&M documentation should contain clear directions on action that should be taken in an emergency. The response time to a leak can be vastly improved if appropriate 'as installed' drawings are framed and displayed in appropriate plantrooms or switchrooms with clearly labelled valves and a valve schedule.

The document should include details of warranties, and outline procedures for dealing with faults during the defects liability period, particularly where such faults might require an immediate out of hours response.

Information on building services

The owners/users of the building need to be made aware of the intended mode of operation of their buildings' systems. Often the information provided is little more than a collection of literature from manufacturers on the performance of each component in isolation. The 'operating' components of the O&M manuals have historically been limited to how to turn the plant on and off.

What is needed are clear instructions on how to operate the building and its services in an energy-efficient manner as intended by the designers. This information should include reference to the energy targets that were set during the early stages of the design, and suggested procedures for monitoring and targeting, so that any adverse energy performance is promptly identified.

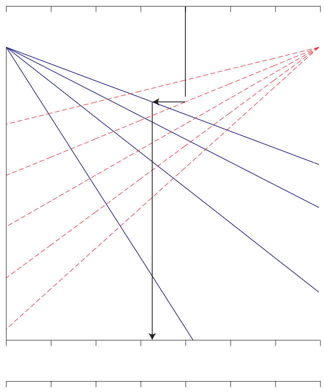
A management system is required to keep a careful record of changes to control settings and the reasons for those changes, if controls are to succeed in operating as they were intended to during the design stages.

Designers must strike a balance between technical features and ease of use, particularly with control systems that must match the end user's technical expertise. 'Maintainability' can be improved by avoiding over-complex plant, using standard components where possible and by ensuring easy access for subsequent maintenance. The need for adequate access has been reinforced by the introduction of the Construction (Design and Management) Regulations 1994.

CIBSE Building Services – The Design Process: A Guide for Architects and other Construction Processes (describes the overall design process)
Building Research Establishment Information Paper IP/790: An Introduction to Infra-red Thermography for Building Surveys.
CIBSE Commissioning Code B: Boilerplant (for information on measuring boiler efficiency
CIBSE Commissioning Code C: Automatic Controls
CIBSE Commissioning Code A: Air Distribution Systems
BSRIA Commissioning of Air Systems in Buildings
HVCA DW/143 Practical Guide to Ductwork Leakage Testing
CIBSE Commissioning Code W: Water Distribution Systems
BSRIA Commissioning of Water Systems in Buildings
I Gas E: IGE/UP/1 Soundness Testing and Purging of Industrial and Commercial Gas Installations
BSRIA AG8/91 Pre-commission Cleaning of Water Systems

APPENDIX HOW TO USE THE NOMOGRAPHS

TYPE 1



RCN 1A – BUILDING FABRIC

1 Identify U-value for floor, wall, roof or weighted average U-value
2 Move vertically down to temperature line
3 Move horizontally to hours line
4 Move vertically down to axes and read off heat loss and cost (through element selected at 1)
5 Multiply scale cost by price of fuel in pence per kWh
6 Apply regional degree day correction using table on top right of this page

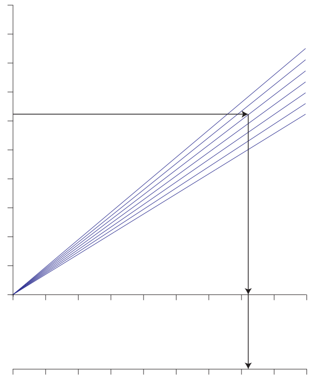
RCN 1B – GLAZING

1 Identify U-value for glazing
2 Move vertically down to temperature line
3 Move horizontally to hours line
4 Move vertically down to axes and read off heat loss and cost
5 Multiply scale cost by price of fuel in pence per kWh
6 Apply regional degree day correction using table on top right of this page

RCN 3 – DESTRATIFICATION FANS

1 Identify heating type and select ceiling height
2 Move vertically down to roof U-value line
3 Move horizontally to running hours line
4 Move vertically to axes and read off heat savings and cost savings
5 Multiply scale cost by price of fuel in pence per kWh
6 Apply regional degree day correction using table on top right of this page

TYPE 2



RCN 2 – HEATING

1 Identify annual heating load
2 Move horizontally to seasonal efficiency line
3 Move vertically down to axes and read off fuel consumption and cost
4 Multiply scale cost by price of fuel in pence per kWh

RCN 4 – HOT WATER

1 Select hot water temperature
2 Move horizontally to seasonal efficiency line
3 Move vertically down to axes and read off energy used and cost
4 Multiply scale cost by price of fuel in pence per kWh

RCN 5 – LIGHTING

1 Identify installed lighting load
2 Move horizontally to hours per year line
3 Move vertically down to axes and read off electricity consumption and cost
4 Multiply scale cost by price of fuel in pence per kWh

RCN 6 – COOLING

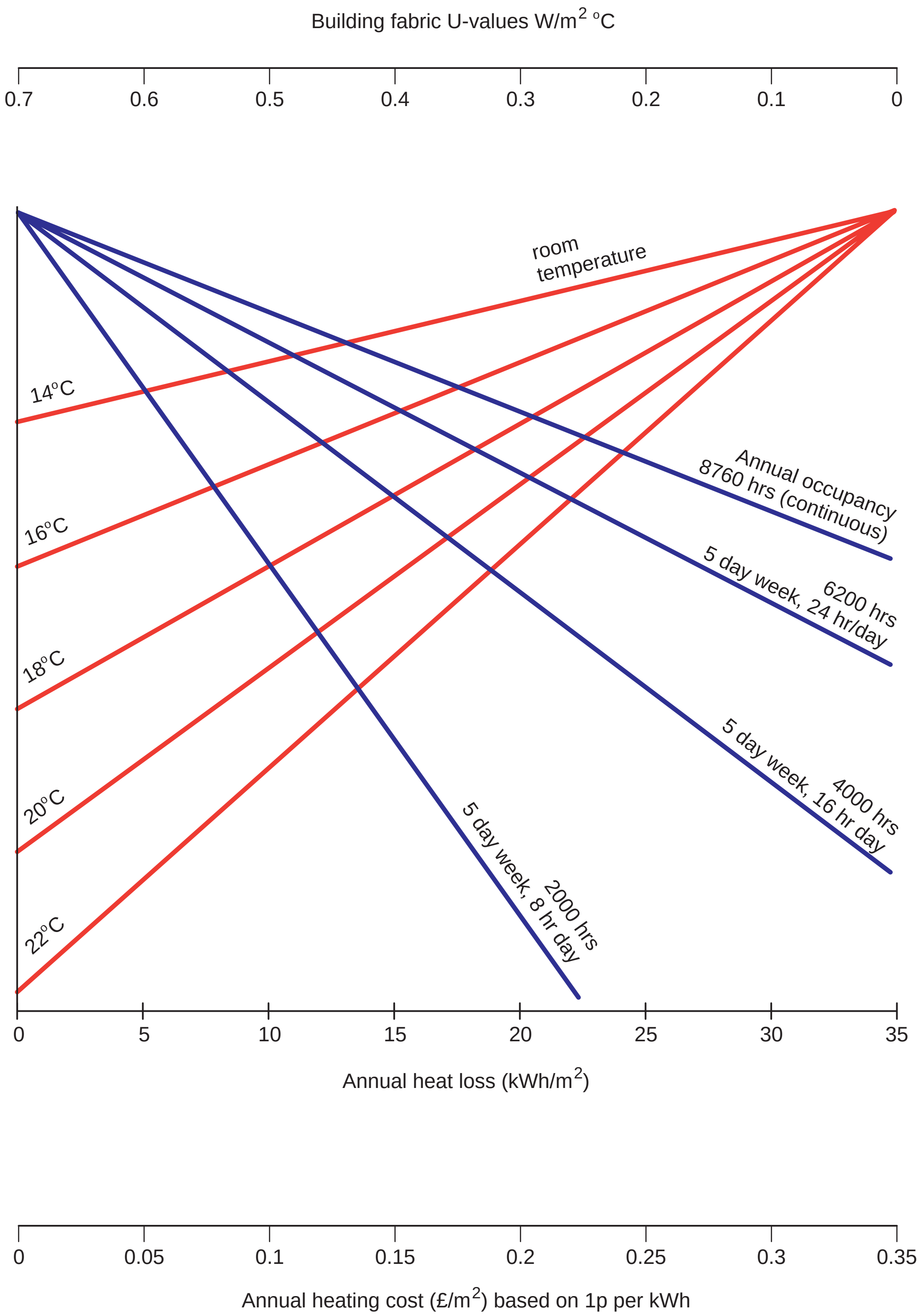
1 Identify cooling load
2 Move horizontally to COSP line
3 Move vertically down to axes and read off electricity consumption and cost
4 Multiply scale cost by price of fuel in pence per kWh

REGIONAL DEGREE DAY CORRECTION FACTORS	
Thames Valley	0.80
South East	0.90
Southern	0.89
South West	0.75
Severn Valley	0.76
Midlands	0.97
West Pennines	0.92
North West	0.99
Borders	1.03
North East	0.99
East Pennines	0.96
East Anglia	0.94
West Scotland	1.03
East Scotland	1.07
North East Scotland	1.11
North West Scotland	1.05
Wales	0.90
Northern Ireland	0.98

Based on 20-year regional average (1999) relative to a standard 2462 degree days assumed in ECONs. Typically degree days can vary about the average by ±10% depending on exposure and a further ±10% year-on-year.

For ease of copying, black and white versions of the nomographs are included in the inside back pocket of this Guide.

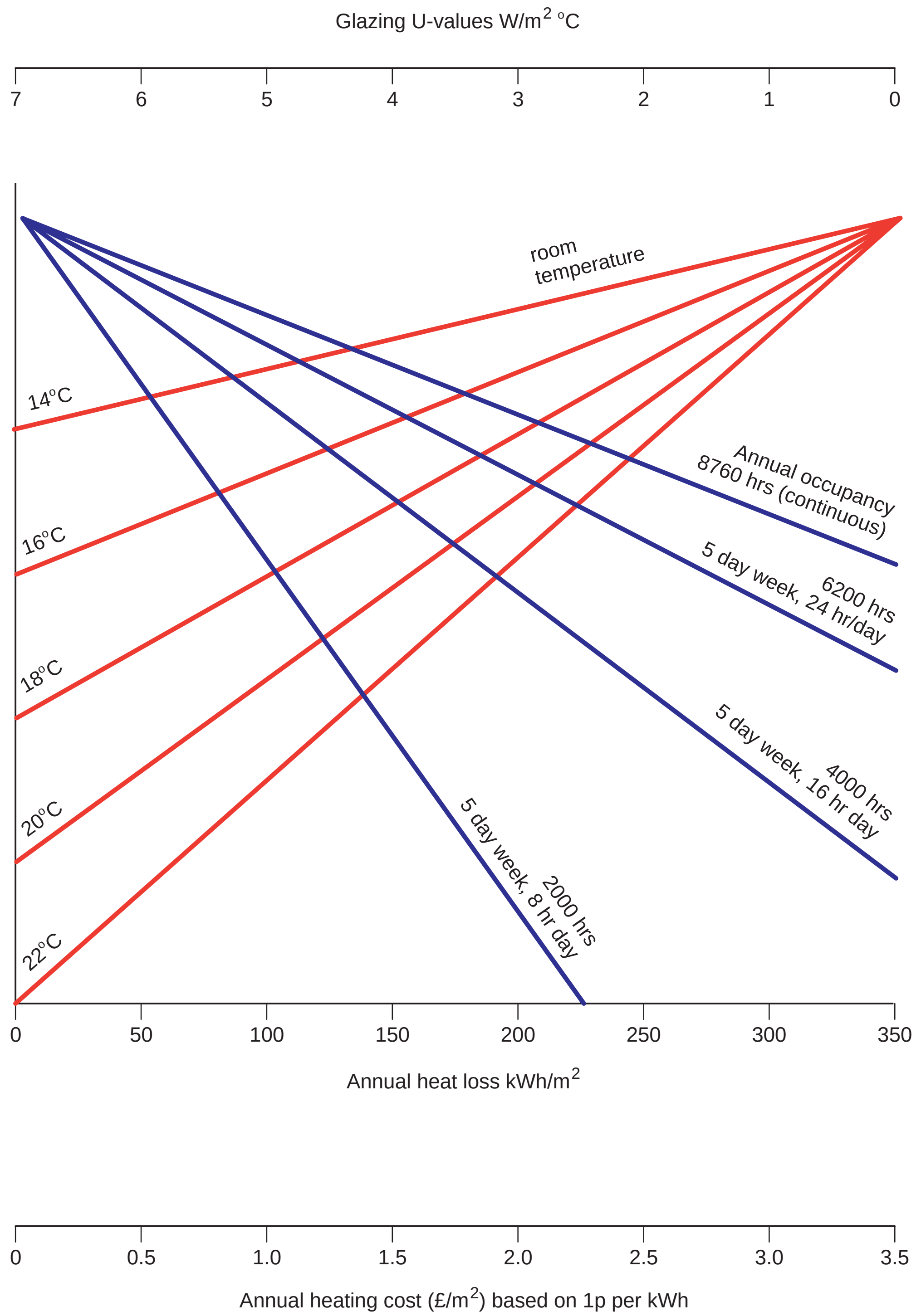
RCN1A: COST OF BUILDING FABRIC HEAT LOSSES



Actual Cost
To calculate actual cost, multiply scale reading by cost of fuel in pence per kWh and apply regional degree day correction factor.

Note
1. Assumes heating plant efficiency of 80%.
2. Assumes typical internal heat gains equivalent to offices or light manufacturing.
3. Based on 2462 degree days with allowance for preheat for intermittent heating.

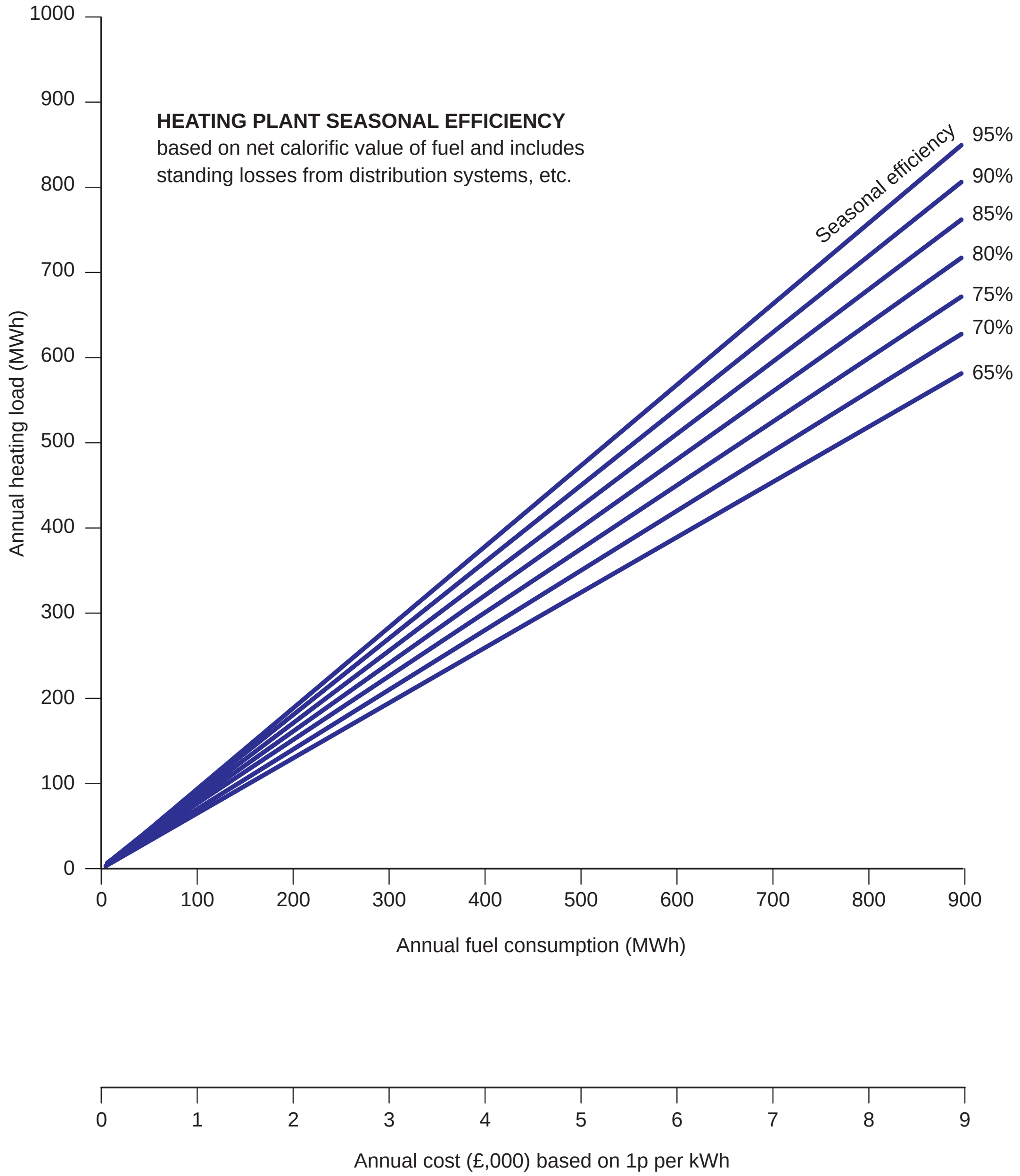
RCN 1B: COST OF GLAZING HEAT LOSSES



Actual Cost
To calculate actual cost, multiply scale reading by cost of fuel in pence per kWh and apply regional degree day correction factor.

Note
1. Assumes heating plant efficiency of 80%.
2. Assumes typical internal heat gains equivalent to offices or light manufacturing.
3. Based on 2462 degree days with allowance for preheat for intermittent heating.

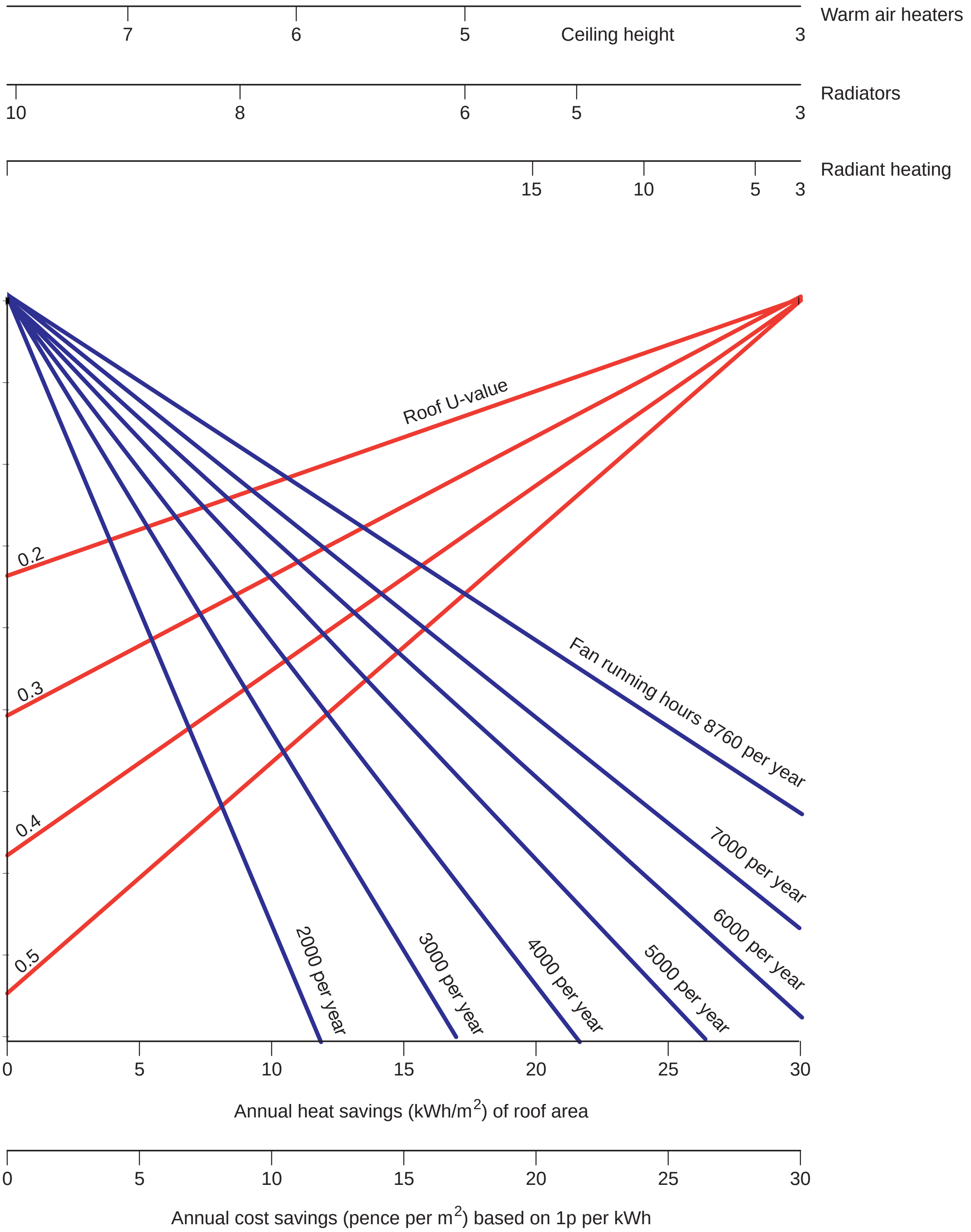
RCN 2: COST OF PROVIDING HEATING



Actual Cost
To calculate actual cost, multiply scale reading by cost of electricity in pence per kWh.

Note
1. Assumes heating plant efficiency of 80%.
2. Assumes typical internal heat gains equivalent to offices or light manufacturing.

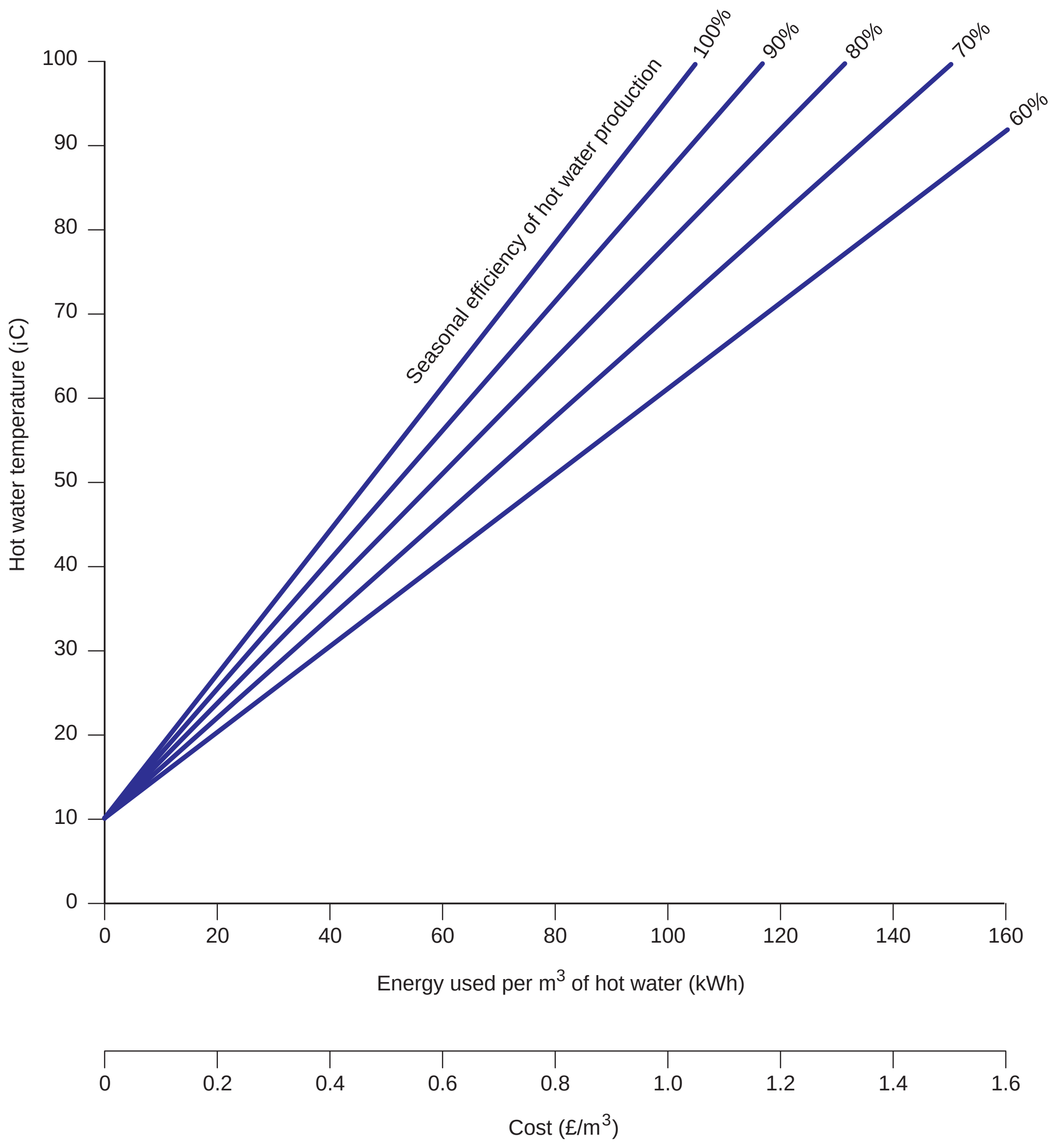
RCN 3: BENEFITS OF DESTRATIFICATION FANS



Actual Cost
To calculate actual savings, multiply scale value by cost of fuel in pence per kWh and apply regional degree day correction factor.

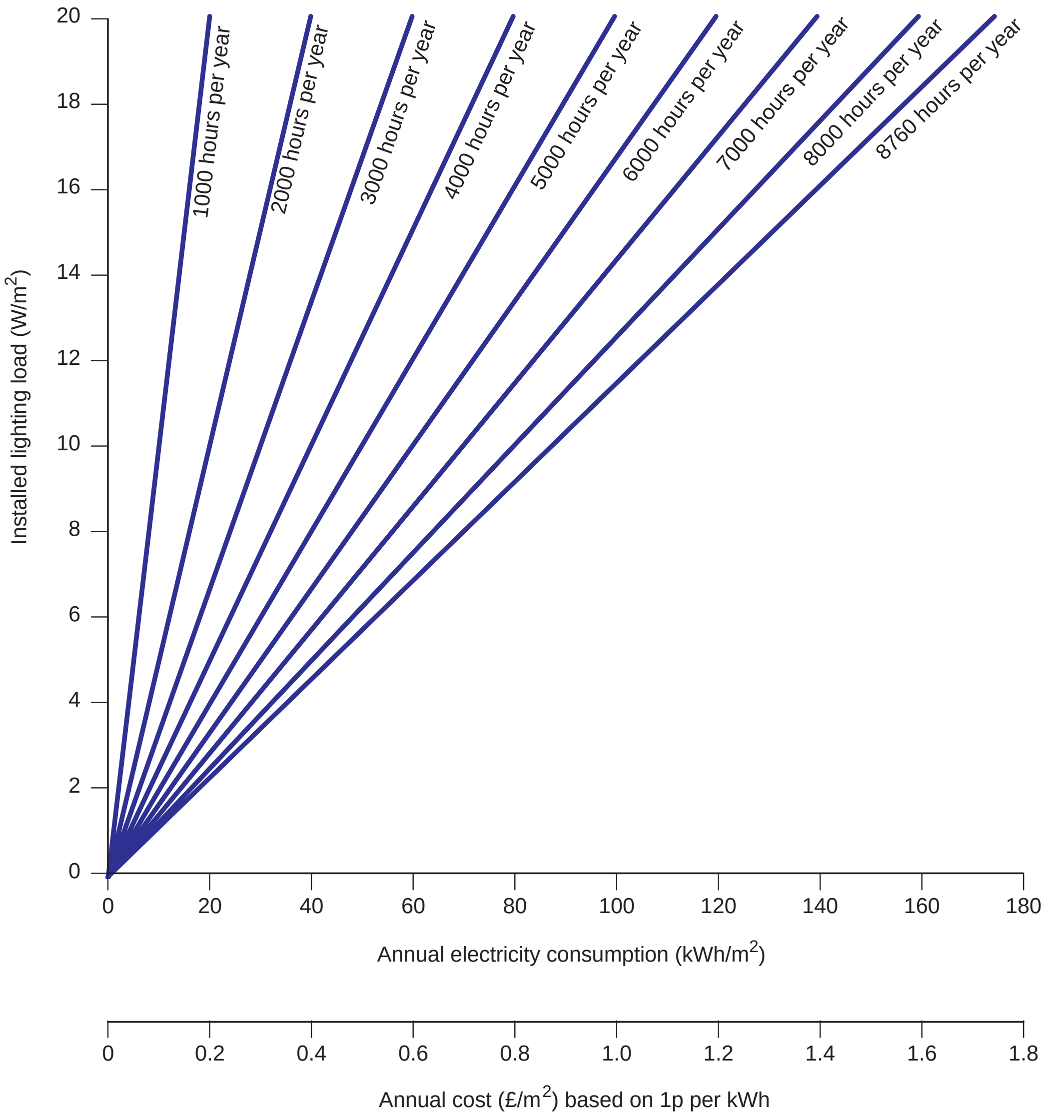
Note
1. Assumes heating plant efficiency of 80%.
2. Assumes typical internal heat gains equivalent to offices or light manufacturing.
3. Based on 2462 degree days with allowance for preheat for intermittent heating.

RCN 4: COST OF PROVIDING HOT WATER



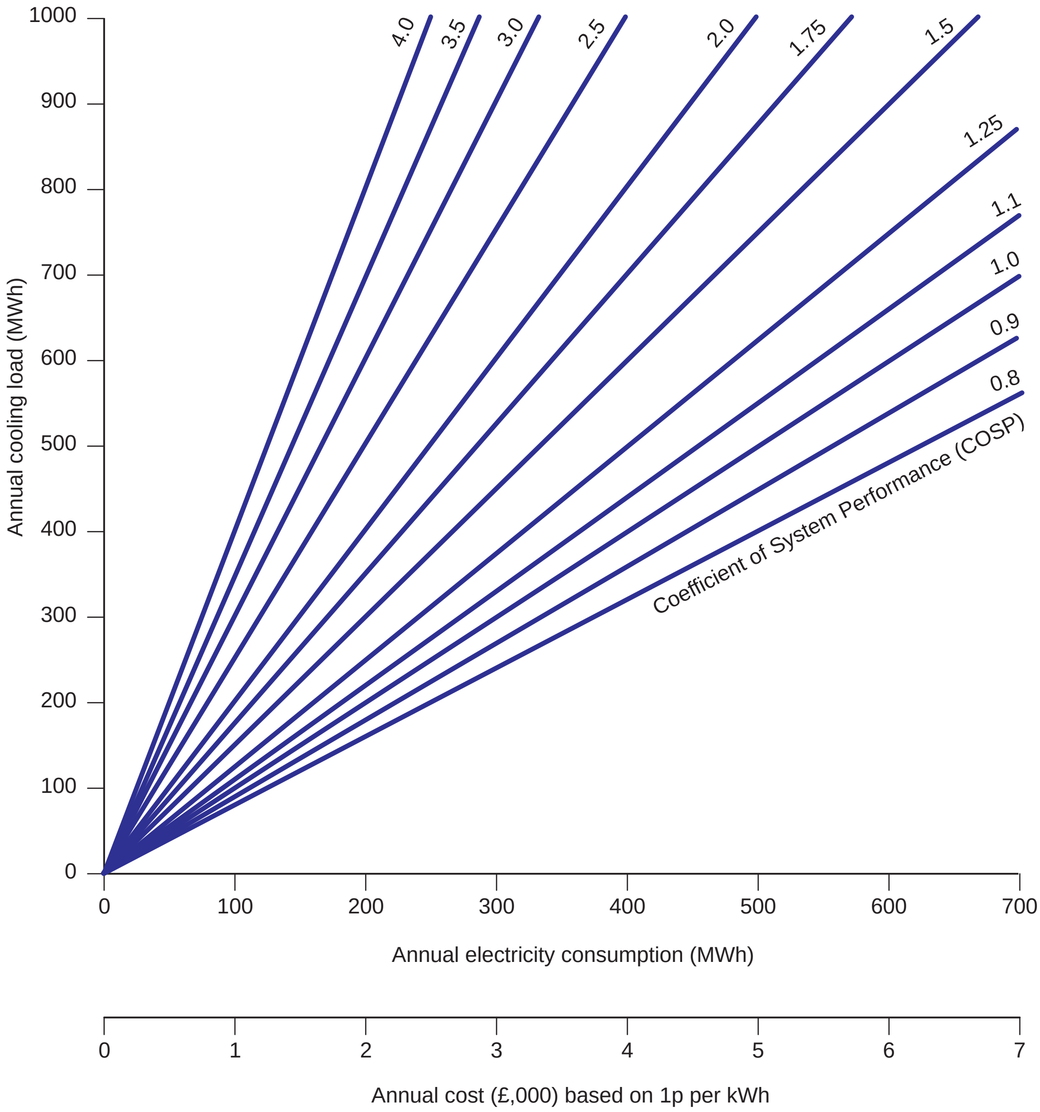
Actual Cost
To calculate actual cost, multiply scale reading by cost of fuel in pence per kWh.

RCN 5: LIGHTING RUNNING COSTS



Actual Cost
To calculate actual cost, multiply scale reading by price of electricity in pence per kWh.

RCN 6: COST OF PROVIDING COOLING



Actual Cost
To calculate actual cost, multiply scale reading by price of electricity in pence per kWh.

ROUTE MAP

THE DESIGN PROCESS

There are three main stages in implementing the design and construction to handover.

These are:

- the project brief
- option appraisal and selection
- construction to handover.

Each stage is considered under generic headings, which are colour coded throughout the Guide.

GPG 303

The designer's guide to energy-efficient buildings for industry

The pocket of this Guide contains the following inserts:

- **RUNNING COST NOMOGRAPHS**
- **ENERGY CONSUMPTION BENCHMARKS FOR SETTING GOOD PRACTICE DESIGN TARGETS**
- **BRIEFING SHEET**

SOURCES OF FURTHER INFORMATION

BUILDING RESEARCH ESTABLISHMENT
Bucknalls Lane, Garston, Watford WD25 9XX
Tel 01923 664258. Fax 01923 664787

CHARTERED INSTITUTION OF BUILDING SERVICES ENGINEERS (CIBSE)
Delta House, 222 Balham High Road, London
SW12 9BS
Tel 0208 675 5211. Fax 0208 675 5449
Website www.cibse.org

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under contract to BRECSU for the Energy Efficiency Best Practice programme.

The Government's Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

Visit the website at **www.energy-efficiency.gov.uk**

For further information on:

Buildings-related projects contact:
Enquiries Bureau
BRECSU
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E-mail brecsuenq@bre.co.uk

Industrial projects contact:
Energy Efficiency Enquiries Bureau
ETSU
Harwell, Oxfordshire
OX11 0RA
Tel 01235 436747
Fax 01235 433066
E-mail etsuenq@aeat.co.uk

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy-efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R&D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting, etc.