Introduction to Energy Efficiency in

Factories and Warehouses

Energy Efficiency Office

DEPARTMENT OF THE ENVIRONMENT

CONTENTS

1

INTRODUCTION

1.1 Who this guide is intended for

This guide is aimed at facilities managers, works engineers and others who have responsibility for energy use in factories and warehouses. It should also be of interest to energy managers in larger organisations.

It is intended to introduce the steps that anyone responsible for energy needs to take in order to control and reduce energy consumption in industrial buildings. It shows how to gain an understanding of how energy is used in industrial buildings and indicates the methods by which savings are likely to be made.

1.2 Use of the guide

This guide is one of a series for different types of building. A full list of titles is given in section 9.4; make sure that you have the guide most suited to your needs. If your building is in the 'factory - office' category (see section 5.2) you should also obtain the 'Offices' guide.

If you are unfamiliar with energy management, you should start with section 2, Energy Management, in order to get an overview of the subject.

- The subsequent sections concern creating and following an action plan (section 3) and implementing measures to achieve energy savings (section 4). Sections 5 to 7 describe methods for assessing energy use in factories and warehouses.
- The case studies (section 8) give examples of industrial buildings where energy saving measures have been successfully implemented.
- Section 9 lists further sources of help and information, including addresses for obtaining copies of the information referred to throughout the guide.

More experienced energy managers or consultants may use the action plan (section 3), or the suggested measures (section 4) as aide-memoires. They may also use the method for calculating performance indices described in section 6 and appendix 1.

A manager responsible for energy on a number of different sites may wish to distribute the guide to the person responsible for energy management at each site.

1.3 Environmental benefits of energy efficiency

Most of the energy used today originates from fossil fuels (gas, oil and coal). Burning fossil fuels emits pollutants, including gases that cause acid rain, and carbon dioxide. As carbon dioxide and other gases build up in the atmosphere, more of the sun's heat is trapped (the greenhouse effect). This could result in the earth becoming hotter (global warming), which may also increase the risk of storms, coastal flooding and drought. Using energy more efficiently is one of the most cost effective means of reducing emissions of carbon dioxide and also helps to conserve finite reserves of fossil fuels.

1.4 Financial benefits of energy efficiency

The cost of energy used in industrial buildings for heating, lighting and other non process applications is over £1 billion per year in the UK. Using simple and cost effective measures, fuel bills in these buildings could be reduced by an average of about 20%. Further savings are possible in new construction and when buildings are refurbished or their services replaced.

Well designed and efficiently managed services not only result in energy savings, but also in an improved and more comfortable working environment. This can give rise to better productivity and reduced absence due to sickness.

Efficiently run buildings also require less manpower to service complaints, providing savings additional to the reduced costs of energy.

1.5 Acknowledgements

This guide was prepared for the Energy Efficiency Office (EEO) by Target Energy Services Ltd. The EEO gratefully acknowledges the assistance given by the following organisations in providing information:

Building Research Energy Conservation Support Unit (BRECSU)

GEC Alsthom Large Machines Ltd

Romford Brewery Co Ltd

Strategy One Ltd

ENERGY MANAGEMENT

2.1 Energy efficiency - a management issue

The aim of energy management is to ensure that energy use and energy costs are as low as possible while standards of comfort, service and productivity are maintained or improved. This requires somebody to be directly responsible for energy efficiency, even if this is only a part of their job:

- As a rule of thumb, organisations or sites with an energy bill over £1 million may justify the employment of a full time energy manager. Otherwise, energy management will normally be combined with other responsibilities.
- Each building should have someone responsible for energy management.
- In larger organisations, energy efficiency should also be managed centrally.
- Energy efficiency must be strongly supported at the highest levels with the authority and resources needed for initiatives to be effective.

Encourage your management board to sign up to the EEO's Making a Corporate Commitment campaign if it has not already done so (see section 9.5).

The duties and functions of an energy manager are discussed here. Section 3 includes a suggested action plan which can be used to get things moving.

2.2 Actions and measures to save energy

One of your main activities should be to identify areas of energy waste and implement energy saving measures to reduce them. Some waste is simple to diagnose and to correct, for example lighting left on all night in unoccupied areas. Other waste may be more difficult to identify and take more expertise or resources to correct (see section 4).

2.3 Controlling energy use

To control energy consumption and costs, regular and reliable records of energy use should be maintained. Such records will help to identify changes in energy costs and consumption. This is commonly called monitoring and targeting or M&T. The simplest arrangement is a form which can be filled in regularly for each fuel, recording monthly energy use. Alternatively, systems can be based on a computer spreadsheet, or commercially available software systems can be purchased. Computer based systems are essential for effective monitoring of a large estate or site.

An M&T system should:

- Record energy consumption and any other factors that affect energy use (building usage, weather, productivity, etc).
- Compare your energy use to previous years, to other industrial buildings, or to yardsticks representing typical or target energy performance.
- Alert you to sudden changes in energy use patterns as soon as possible, so that any increase can be investigated and corrected if appropriate.
- Produce regular summary reports, especially if there are many sites, to confirm performance and show savings achieved overall.

If fuel bills are not available or some are missing, then duplicates can usually be obtained on request from the relevant fuel supply company. Meters should be checked every few months to ensure that billed readings are correct. In shared or multi - meter sites ensure you are being billed for your use; label your meters.

For further information see:

EEO Practical Energy Saving Guide For Smaller Businesses.

Example recording of monthly electricity use

Period: *JAN-DEC 92* Completed by: *NJK* Date: *10.2.93*

Meter Reading Date	kWh Used	Cost £
8.1.92	*39,700*	*2756.29*
5.2.92	*38,700*	*2653.65*
5.3.92	*31,500*	*2200.35*
9.4.92	*25,000*	*1584.02*

2.4 Getting on the right tariffs

Making sure that fossil fuels and electricity are purchased at the cheapest rates is increasingly important. Considerable cost savings are sometimes possible by changing to more suitable tariffs for electricity, or by making alternative supply arrangements.

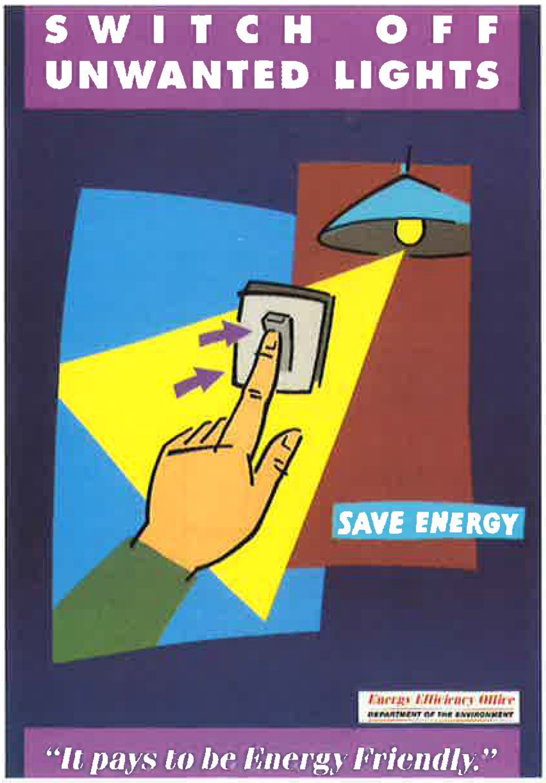
Tariff savings usually incur little or no initial cost and may be used to help finance measures to reduce energy costs further. Reviewing tariffs should therefore be one of your first actions:

- Seek alternative electricity tariffs from your existing supplier.
- Consider using other electricity suppliers in the contract market when the supply is for more than 100 kW (representing a bill of around £30,000 a year).
- Consider a different supplier for oil, or for gas supplies over 70,000 kWh a year (representing a bill of around £1,000 a year).
- For large sites with complicated tariffs and load patterns, it may be worth employing a tariff consultant, although be aware of consultants' costs (contact the Energy Systems Trade Association (ESTA) or the Major Energy Users' Council, see section 9.9).

For further information see:

Fuel Efficiency Booklet 9 - Economic use of electricity in buildings.

Energy Efficiency Poster



2.5 Motivating staff

The greatest possible savings can only be achieved with the cooperation of staff. Foster their support and give them every chance to participate in energy saving initiatives. Feed back information to staff on the results of these initiatives.

Activities could include:

- Providing information about why energy conservation is important, describing practical and environmental benefits
- Setting up an incentive scheme
- Stressing that in many buildings most energy is used by occupants - for lighting, equipment and for maintaining comfortable conditions
- Encouraging staff to switch off equipment and lighting when it is not needed, by providing information and training on how to operate systems and controls, through stickers, posters and articles in staff magazines
- Relating energy use at work to energy use at home.

You should monitor the savings achieved and publicise them to help motivate staff and senior management. Obtaining capital investment for future energy efficiency measures may depend on demonstrating the cost effectiveness and the environmental benefits of measures that have already been completed.

For further information see:

EEO Good Practice Guide 84 - Managing and motivating staff to save energy.

2.6 Energy management in larger organisations

In larger organisations with estates of buildings, an energy manager may be responsible for many separate locations. He or she will have a different role from a site energy manager which is not addressed in detail here.

For further information see:

EEO General Information Report 12 - Organisational aspects of energy management

EEO General Information Report 13 - Reviewing energy management

Making a Corporate Commitment - various guides.

2.7 Responsibilities at larger sites

At larger sites, a number of groups should be involved in energy management:

- Senior management
- Local or departmental management
- Facilities management
- Plant operators
- Security staff
- Maintenance contractors.

You should have regular contact with all of the above and with the individual building occupants. A facilities manager often makes a good energy manager because they already have close contact with staff. You should find out about factors relating to occupants' comfort, including:

- How plant and equipment controls are set and who is responsible for their adjustment
- How comments from occupants are acted on - especially those reflecting dissatisfaction.

2.8 New and refurbished property

Energy efficiency measures are most cost effective when installed in new or refurbished buildings, or while replacing equipment which is at the end of its normal life. New items of of equipment which are required anyway should be as efficient as possible. Additional items to improve energy efficiency can be installed most cheaply during other building work. These special opportunities to incorporate energy efficient design are relatively rare and should not be missed.

You should be involved in decisions about new or refurbished property and should not just be brought in to correct high energy use following decisions made by others. Your knowledge of how the building is used should be drawn on when specifying appropriate levels of services and controls.

When moving or refurbishing premises, take the opportunity to select or specify:

- Energy targets
- Systems which are suitably simple and within the capabilities of the occupants to manage
- High efficiency of major plant and equipment such as boilers or main lighting systems
- Good levels of insulation
- Appropriate controls for the anticipated pattern of use
- Suitable metering and monitoring facilities
- Information, advice and training for staff in the use of new systems.

For further information see:

EEO Good Practice Guide 61 - Design Manual. Energy efficiency in advance factory units

EEO Good Practice Guide 62 - Occupiers Manual. Energy efficiency in advance factory units

EEO Energy Consumption Guide 18 - Energy efficiency in industrial buildings and sites.

2.9 Getting help

Sources of further information are described and listed in section 9.

To obtain further information about possible energy saving measures (see section 4), contact relevant manufacturers, installers or service providers who will advise you of the features of their products. Make sure that these features are relevant and appropriate to your requirements. Gas and electricity suppliers can also offer advice.

If time is not available or if discussions with a selection of competing suppliers do not provide a consistent picture, it may be worth hiring a professional consultant to provide advice or to conduct an energy survey. For organisations with less than 500 employees the EEO's Energy Management Assistance Scheme (EMAS) may offer financial help towards energy consultants' fees (see section 9.5).

If the availability of finance and management time is a problem for opportunities requiring substantial investment, contract energy management (CEM) organisations may provide a solution - they offer a comprehensive service including finance and management responsibility. ESTA can provide a list of companies (see section 9.9).

Refurbishment offers a rare opportunity to incorporate many energy efficiency measures.

For further information see:

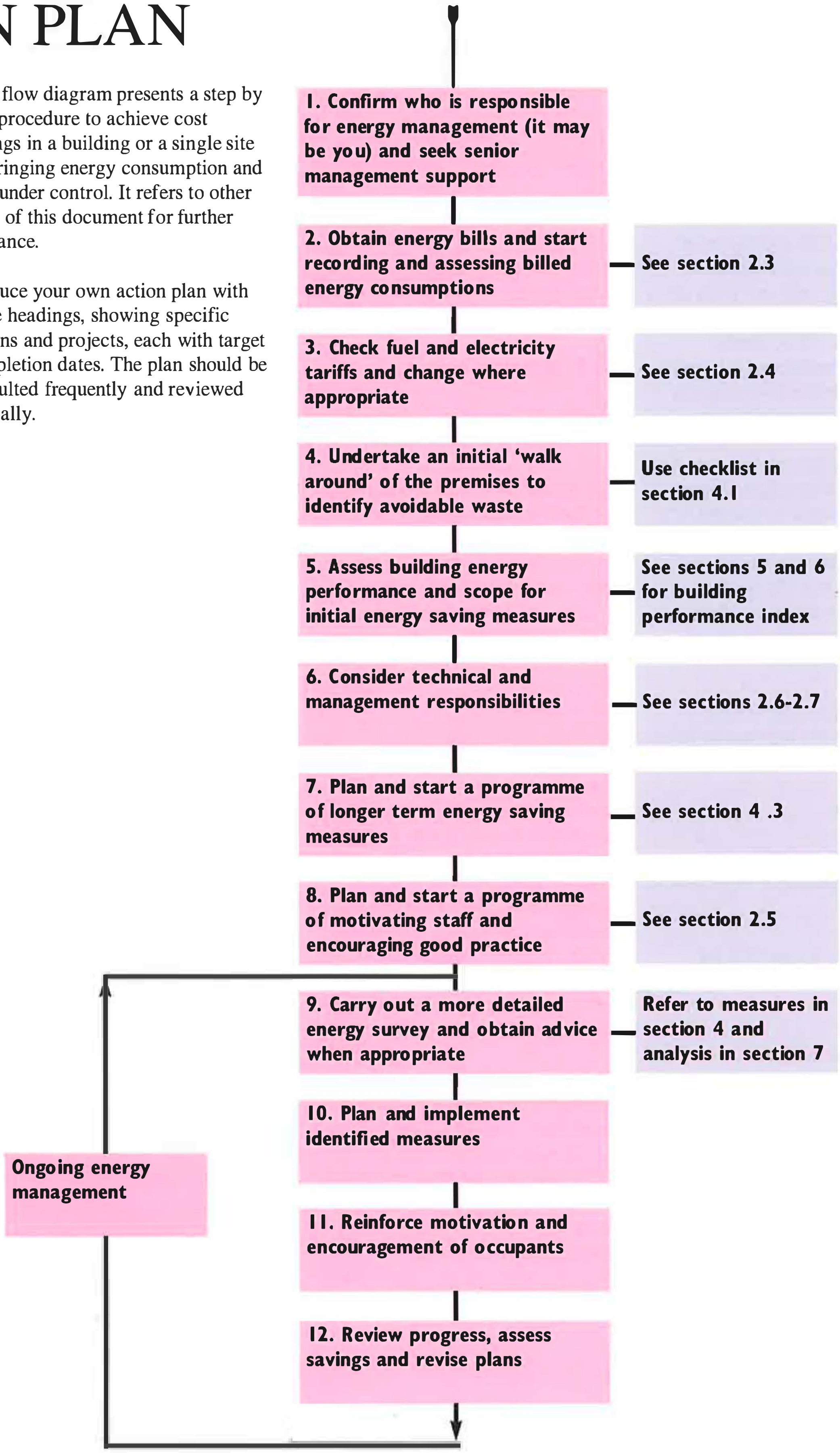
Choosing an Energy Efficiency Consultant (EEO).

3

ACTION PLAN

This flow diagram presents a step by step procedure to achieve cost savings in a building or a single site by bringing energy consumption and cost under control. It refers to other parts of this document for further guidance.

Produce your own action plan with these headings, showing specific actions and projects, each with target completion dates. The plan should be consulted frequently and reviewed annually.



MEASURES TO ACHIEVE ENERGY SAVINGS

4.1 Initial measures

In most industrial buildings it is possible to make some savings by using the existing building and equipment as efficiently as possible. No financial investment is needed; instead, a check on how the building is being used may reveal areas where equipment can be turned off when it is not needed, or where the level of service can be reduced without affecting the comfort of staff.

Some opportunities may be easy to identify and implement, such as altering thermostats or timeclocks. Others, such as turning lights off when rooms are not being used, may require the cooperation of staff. Motivating staff to help is therefore important, although a long term task. The list below indicates the type of items to check in an initial assessment of 'good housekeeping' opportunities. An exercise to review energy purchasing tariffs (see section 2.4) should be carried out at the same time.

Checklist of Initial Energy Saving Measures

Lighting

- Ensure that someone is responsible for switching off in each room or area when not in use.
- Make the best use of daylight by keeping windows and roof lights clean and by using working areas near windows where possible; encourage staff to turn off lights when daylight is good.
- Investigate existing lighting controls to see if the hours of use of artificial lighting can be reduced.
- Install 'task' lighting where this means that background artificial lighting levels or hours of use can be reduced.
- Avoid excessive lighting levels and hours of use in corridors. Where fluorescent lighting is used, it may be possible to reduce the number of tubes in luminaires.

Ventilation

- Ensure that loading bay doors are kept closed.
- Ensure the main ventilation plant and toilet extractor fans and are switched off outside occupancy hours.
- Check that windows are not being opened to avoid overheating during winter.
- Ensure kitchen fans are switched off when no cooking is taking place.

Air conditioning

- Set temperature controls for cooling to 24°C or higher - lower settings require more cooling energy and may be 'fighting' the heating.
- Make sure that refrigeration plant such as chilled water systems do not run unnecessarily.
- Ensure that fans and pumps do not run when not required.

Controls

- Ensure all controls are labelled to indicate their function and, if appropriate, their new reduced settings.
- Establish responsibilities for control setting, review and adjustment.

Building fabric

- Ensure all insulation and draught proofing is in a state of good repair.

Space and water heating

- Consider fuel switching (if your boiler can operate using more than one fuel).
- Check that time switches are set to the minimum period and ensure that room thermostats and radiator controls are on minimum settings commensurate with comfort conditions.
- Ensure that only occupied areas are heated, and that heating is off or reduced in non-working hours.
- If you have a building energy management system (BEMS), check that it is operating correctly and ensure that operators are trained to use it effectively.
- Reduce temperature of stored domestic hot water by turning down the thermostat to a minimum of 60°C, but no lower because of the risk of Legionella.
- Make sure that pumps are running only when required.

4.2 Maintenance

Regular maintenance is a prerequisite to controlling energy costs and is also essential for maintaining a healthy environment in buildings. A maintenance programme should include:

- Replace filters at the manufacturer's recommended intervals and keep heat exchanger surfaces, grilles and vents clean in order to allow unobstructed flow of air.
- Check plant operation and controls regularly.
- Ensure that all motorised valves and dampers fully open and close without sticking.
- Check that thermostats and humidistats are accurate.
- Check calibration of controls.
- Service the boiler plant and check combustion efficiency regularly.
- Look for water and steam leaks and carry out repairs where necessary.
- Ensure steam traps are free from dirt and scale.
- Clean windows to maximise daylighting.
- Replace 38mm diameter fluorescent tubes in switch start fittings with 26mm diameter high efficiency triphosphor tubes as the former expire (see diagram on page 10).
- Clean lamps and luminaires regularly and replace at the manufacturer's recommended intervals.

4.3 Longer term measures

There will almost certainly be items of equipment or insulation which could be replaced with more efficient alternatives. The main areas for savings, starting with the most cost effective, are:

- Control systems
- Lighting and office equipment
- Heating, steam and air conditioning plant
- Building fabric.

Care is required in deciding which measures to implement and the most effective way of carrying them through. In the first instance, measures should be undertaken which have as many of the following features as possible:

- Worthwhile energy and cost savings
- Low capital cost
- Short period to repay initial cost
- Little technical knowledge required
- Little or no extra maintenance
- Little or no disruption to normal operations.

Further information is given in references listed in section 9 - note particularly:

EEO Fuel Efficiency Booklets:
1 Energy audits for buildings
8 The economic thickness of insulation for hot pipes
10 Controls
12 Lighting

EEO Energy Consumption Guide 18 - Energy efficiency in industrial buildings and sites

EEO Good Practice Guides:
61 Design manual. Energy efficiency in advance factory units
62 Occupiers manual. Energy efficiency in advance factory units

THERMIE Maxibrochure. Energy Efficient Lighting in Industrial Buildings (1993).

Assessing costs of measures

The cost effectiveness of an energy efficiency investment can be expressed as the initial cost divided by the monthly or annual cost savings - the simple payback period.

More sophisticated appraisal techniques for comparing different investments, such as 'discounted cash flow' methods, are sometimes used in larger organisations and for major investments. If these are needed, advice should be sought from those who use these methods.

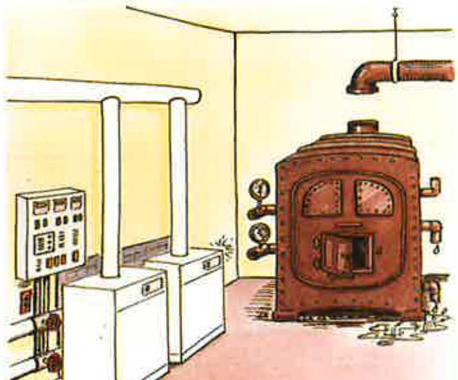
If energy-saving initiatives are taken during refurbishment or when moving to another site, capital cost is often substantially reduced and interference with normal working practices is kept to a minimum.

For measures included during replacement or refurbishment, the initial cost (for calculating the payback period) is only the over-cost: for example, the extra cost of a high efficiency 'condensing' boiler compared with a conventional boiler. This reduces payback periods and increases cost-effectiveness.

In some cases, energy efficiency measures can reduce overall capital costs, such as providing natural ventilation which avoids the need for air conditioning.

Where shortage of funds and/or lack of expertise is holding up promising measures, it may be worth considering contract energy management as described in section 2.10.

Measures can be split into those which require limited attention such as insulation, and those which require management time to ensure that they continue to be effective, such as building energy management



Modern efficient plant can achieve dramatic savings compared to old plant systems. For the latter, manageability is as important as the potential for energy savings, and should be a prime consideration in the design.

LIGHTING

Lighting is usually the largest or second largest energy cost in an industrial building, and good savings can be achieved by ensuring that lighting equipment and its controls and management are of a high standard.

The energy used for lighting depends upon the energy consumption of the lamps and the hours of use. The most efficient systems are well designed, and have efficient lamps and fittings which provide the required level of illuminance (without over-lighting). They have controls which enable the lights to be switched off when they are not required, whether because a space is not being used or because there is sufficient daylight.

Some types of lamps, in order of increasing efficiency, are:

- 'Domestic' tungsten bulbs - very inefficient; should usually be replaced
- High pressure mercury (MBF) - used for internal industrial lighting and exterior lighting
- Tungsten spotlights - used for display lighting; even the most efficient lamps are much less efficient than fluorescent lamps
- Compact fluorescent lamps - efficient replacements for tungsten bulbs, although not as efficient as modern tubular fluorescent lamps
- Fluorescent tubes - widely used in production and administration areas
- Metal halide and sodium discharge lamps - vary in efficiency depending on type (most are more efficient than fluorescent tubes). Well suited to lighting large areas with high ceilings and for floodlighting
- Low pressure sodium discharge - used for exterior lighting and security lighting.

Tungsten bulbs typically have a life of about 1,000 hours, while fluorescent and discharge lamps typically last for 8,000 hours or more. Removing tungsten bulbs therefore gives substantial savings in maintenance costs in addition to energy savings.

Luminaires, left to right: recessed mirrored reflector with louvres, batten fittings, opal, and prismatic diffusers.

Photographs supplied by Philips and Fitzgerald.

Figure 4.1 Typical relative energy consumption

lamp type	typical energy consumption relative to tungsten bulbs for similar levels of lighting (%)
tungsten filament bulb	100
tungsten halogen spotlight	70
compact fluorescent with electronic ballast	18
metal halide (MBI)	15
high pressure sodium	11
low pressure sodium	7
Fluorescent tubes:	
(1) choke & starter control gear with 38mm diameter tubes	18
(2) as 1), but 26mm diameter high efficiency triphosphor tubes	16.5
(3) as 2), but with electronic ballast	13

Typical levels of energy consumption of different types of lamp, expressed as a percentage relative to tungsten lamps, are given in figure 4.1.

These figures give an indication of the typical savings which may be made by replacing lamps with more efficient alternatives. For example, replacing an old inefficient tubular fluorescent system (1) with a modern efficient system (3) would reduce energy consumption by a factor of 13/18, a reduction of about 30%.

As well as lamps, light fittings (luminaires) contain a number of other elements, including:

- Diffusers or louvres - these are designed to give a good distribution of light without glare. Luminaires with prismatic and especially opal diffusers are less efficient than those with reflectors.

Compact fluorescent lamps

- Control gear - fluorescent and other discharge lamps need control gear to strike up and maintain light output. Old fluorescent luminaires have chokes and starters; modern electronic controls (ballasts) are more efficient.

In large warehouses where some areas are used less frequently than others, it should be possible to control the lighting in each area independently. Switches should be labelled. Lighting controls should be used to ensure that, as far as possible, lights are off when they are not needed.

Lighting controls include:

- Manual control - it should be possible to control all lights manually, whatever automatic controls are also used.
- Time controls - allow any group of lights to be switched on or off automatically at set times of the day.
- Presence detectors - automatically switch lights on when somebody enters a space, and off again after the space is vacated.
- Daylight detectors - allow groups of lights to be switched off or on according to the level of daylight. Some lights can also be dimmed as daylight levels alter.

LIGHTING MEASURES

- Use sodium discharge lamps and metal halide lamps for areas with high ceilings and for outside areas such as car parks.
- Replace tungsten lamps with compact fluorescent lamps or, better, with tubular fluorescent lamps.
- Replace tungsten spotlights with low voltage tungsten halogen lamps.
- Replace existing control gear in fluorescent fittings with electronic, high frequency ballasts.
- Replace diffusers in tubular fluorescent fittings with reflectors and reduce the number of tubes if possible.
- If light fittings are over 15 years old, replace with new efficient fittings and consider installing new lighting controls.
- Replace fluorescent fittings in high-bay warehouses with high pressure sodium lamps.
- Improve lighting controls, including:
  - local manual switching, such as pull cords on lights, so that all staff have control over their local lighting where practicable
  - time controls or daylight detection controls for external lighting
  - presence detection control for areas that are not in continuous use such as aisles (for example where stock is required only intermittently), corridors and stairs (excluding emergency lighting), and toilets.

HEATING SYSTEMS

The cost of providing heat for space heating or hot water depends on the cost of the fuel used, the efficiency of conversion of fuel to heat, and the extent of the distribution losses in supplying the heat when and where it is needed.

Radiant heaters are often the most efficient form of space heating in factories and warehouses. Their advantages over other forms of heating include:

- Rapid response to changes in temperature
- Lower air temperatures are needed for the same comfort level
- Simple to control different areas independently; areas which are not occupied need not be heated
- Low maintenance requirements
- Low capital costs.

The use of radiant heating should be considered with care in areas with high bay racking or girder cranes.

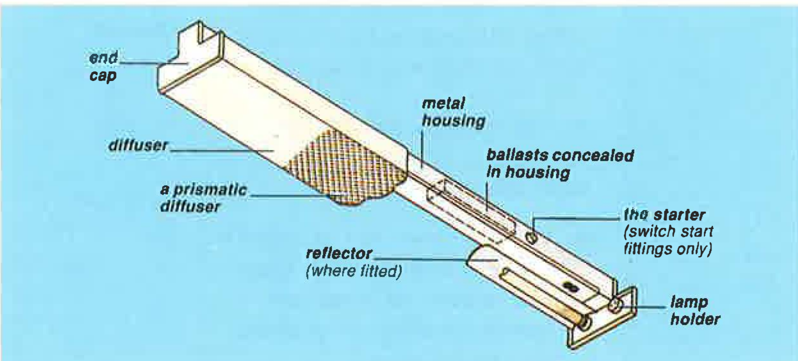
The most common type of radiant heater used in factories and warehouses is the gas-fired overhead radiant tube heater.

For further information on radiant heaters see:

EEO Good Practice Guides 61 & 62 - Energy efficiency in advance factory units.

EEO Fuel Efficiency Booklet 3 - Economic use of fired space heaters for industry and commerce.

Old boilers may convert less than 50% of the energy content of the fuel into heat in the heating system, compared with the most efficient gas condensing boilers which achieve



The parts of a fluorescent light fitting seasonal efficiencies of over 90%. Condensing boilers ought to be considered whenever boilers are replaced.

Where possible, large boilers should not be operated to meet small loads, as the efficiency will be very low. This may occur in summer if the requirement for process heat is low. Heat should only be supplied to a space or process or to produce hot water where and when it is needed.

On older sites, extensive mains may once have fed a wide range of processes but now supply primarily space heating and domestic hot water only. On these sites summer efficiencies may fall to 10% or less. Steam systems have particularly low efficiencies.

Where a building is used for storage, it is often more efficient to use dehumidifiers and allow the temperature to fall, rather than to heat. Dehumidification is achieved by specialised packaged plant.

Many buildings have warm air heating systems that are often inadequate or inappropriate. Air heating systems are most effective in buildings which are well sealed and insulated. Buildings with high bay racking can be heated effectively by high velocity air systems.

Whatever system you have effective heating controls are essential. Types of control include:

- Simple time control: a time switch that turns heating on and off at a fixed time each day
- Optimum start control: switches the heating on so that the building reaches the desired temperature just in time for occupation
- Weather compensation: varies the heating according to the outside temperature
- Thermostat: keeps the temperature in a space to a required level. Radiant heaters are often controlled by a 'black bulb' thermostat.

HEATING MEASURES

- Install radiant gas heating to replace existing systems.
- Upgrade heating controls to include a seven day programmable timer, optimum start control and weather compensation as a minimum.
- Where small volumes of domestic hot water are required a long way from the main heating plant, consider installing local instantaneous water heaters.
- Install spray taps where possible.
- Insulate hot water tanks and boilers, and all pipework, valves and flanges which do not provide useful heat to occupied spaces.
- Review the position of thermostats; ensure they are away from doors or draughts.
- Install thermal syphons or punkah fans in high bay buildings to return warm air from high ceiling to floor level.
- Replace an old boiler installation with one that provides a minimum seasonal efficiency of at least 80%, preferably including at least one condensing boiler. Specify multiple boilers with a sequence controller rather than one large boiler in installations over 100kW, with the most efficient boiler leading the firing sequence.
- Ensure that boilers can only run when there is a heat demand. Unnecessary firing is known as "dry-cycling" and is often remedied by correctly wiring the boiler thermostat into the control system. In multi-boiler installations, wide band thermostats often overcome dry-cycling.
- Where the requirement for process heat is low, consider decentralising the major plant.
- Separate the heating system into zones so that areas of the building with different heating requirements can be controlled separately.
- Where warm air systems are used consider linking loading bay door opening to heating controls so that heating is turned off when doors are opened.

STEAM SYSTEMS

At sites where there is a large process requirement for steam, it is common for the space heating and domestic hot water requirements to be met by the central steam plant. However, steam is an inherently inefficient heating medium owing to the high distribution heat losses.

Blowdown is a necessary operation for boiler plant in order to maintain correct water conditions. The need for it should be reduced by treating the boiler feedwater wherever possible.

Leakages from faulty valves, pipework flanges and joints are an obvious source of heat loss. Such leakages are easily detected and should not be allowed to continue, since the wastage through even a small leak is significant.

Steam traps can waste steam or fail to keep the steam plant clear of water if they are not kept clean.

STEAM PLANT MEASURES

- Minimise boiler blow down and recover heat. Waste heat recovery from a continuous blowdown system is generally more manageable than from an intermittent system.
- Consider generating steam locally if it is not required throughout the site.
- Ensure insulation is of optimum thickness and repair any which is damaged or waterlogged.
- Maximise the return of condensate to the boiler plant.

For further information see:

EEO Fuel Efficiency Booklet 2 - Steam

EEO Fuel Efficiency Booklet 8 - Economic thickness of insulation for hot pipes

EEO Good Practice Guide 30 - Energy efficient operation of industrial boiler plant.

COMBINED HEAT AND POWER (CHP)

With CHP, electricity is generated on site and the 'waste' heat is available for space and process heating requirements. A demand for hot water or process steam for at least 4,500 hrs per annum is usually required for CHP to be cost-effective.

For further information see:

EEO Good Practice Guide 1 - Guidance notes for the implementation of small scale combined heat and power

EEO Good Practice Guide 3 - Introduction to small-scale CHP

EEO Good Practice Guide 43 - Introduction to large- scale combined heat and power.

BUILDING FABRIC

Simple roof insulation and draught proofing are usually cost effective at any time, but other fabric measures are most cost effective when they form part of general maintenance or refurbishment.

BUILDING FABRIC MEASURES

- Insulate roof voids
- Install false ceilings where suitable.
- Install fast acting doors.
- Install strip curtains between areas that have different temperatures and ventilation requirements.
- Seal any sources of air leakage through the fabric.
- Install cavity wall insulation or internal or external insulation.
- Reduce excessive glazing areas by replacing the glass with insulated wall panels.
- If windows are being replaced, fit multiple glazing, preferably with low emissivity glass which reduces heat loss in winter.
- Insulate loading bay doors.

MECHANICAL VENTILATION AND AIR CONDITIONING

Most ventilation relies on leakage through gaps in the building fabric. Simple extract systems increase ventilation rates by removing air. Simple supply systems which deliver tempered fresh air are more efficient and do not create draughts. The most cost effective are balanced ventilation systems, where the tempered supply air balances the extracted air. These often incorporate recirculation and heat recovery. However, they are not effective in leaky buildings.

In buildings with dirty processes or where fumes are produced, local extraction systems should be used to remove the pollution at source.

Air conditioning may be required for 'comfort cooling' of occupants, or to maintain specific conditions imposed by process or equipment. Air conditioning inevitably leads to higher energy use than natural ventilation alone. In air conditioned buildings, pumps and fans typically consume at least half, and often more, of the total energy used for air conditioning.

Cooling systems should be controlled and insulated in the same way as heating systems. The savings will be proportionally higher as cooling is considerably more expensive to produce than heat.

MECHANICAL VENTILATION AND AIR CONDITIONING MEASURES

- Install variable speed controls on fans and pumps; these allow motor speeds to be controlled according to the demand instead of running at full power continuously.
- Explore the opportunities for heat recovery from any source of warm exhaust air but bear in mind the increase in fan power that will be required.
- Minimise the conditioned volume (for example, build a room to house equipment or processes) to minimise the size of air conditioning plant.
- Ensure that air conditioning systems make use of outside air for 'free cooling' whenever possible.
- If humidifiers are being specified or replaced use ultrasonic humidification (but ensure that precautions are taken to avoid Legionella).
- Install local extract systems to deal with fumes or dust rather than a full building ventilation system.

BUILDING ENERGY MANAGEMENT SYSTEMS (BEMS)

BEMS are computer-based systems which automatically monitor and control building services such as heating, air conditioning, lighting etc. They can also provide M&T data. They are most cost-effective in large buildings with complex services.

Caution: A BEMS should be considered as an aid to management and not a substitute for it, and it is important that someone manages it to ensure that it operates effectively.

5

ENERGY USE IN FACTORIES AND WAREHOUSES

5.1 Why analyse building energy use?

Assessing the energy performance of a building allows you to:

1. Compare performance with standards to suggest the potential for energy saving in the building.
2. Compare with other buildings in an estate or group of buildings to help identify which should be investigated first.
3. Compare with performance in previous years to monitor progress and to assess the effect of any changes or energy saving measures.
4. Consider the energy use in more depth to help understand where energy is used and wasted, and hence where savings are most likely to be made.

A general understanding of what electricity and fuels are used for in different types of building helps to concentrate attention on priority areas, especially where the use of one of the fuels is particularly high.

5.2 Types of factory/warehouse building and their energy use patterns

Factories and warehouses come in all shapes and sizes, but for clarity four common types have been defined. Characteristics of each type are given below, together with a pie chart showing the breakdown of typical annual energy costs. Note that the consumptions of energy for different purposes in any one building may be significantly different from the typical breakdowns given here.

Type 1. General manufacturing

- Internal height typically 8m to accommodate tall equipment, gantry cranes and local storage racking
- Lighting typically by high pressure sodium, mercury halide or fluorescent fittings. Rooflights may be present, but these are often dirty or obstructed, giving little effective daylight.
- Mezzanine areas in places
- Two shift operation
- Warm air, radiant or steam heating to 16°C
- Ridge ventilation or mechanical ventilation to areas of high process heat gain
- Space heating consumption can be highly variable depending on the heat output and ventilation needs of the process.

This type of building often also accommodates industries such as plastics, large scale printing, heavy engineering and food.

Type 2. Factory - Office

- Modern office like space with little differentiation between production, office and storage areas
- Clear internal height 4m often with lower suspended ceilings in office parts
- Lighting typically by fluorescent tube
- Flexitime operation with typically 10 occupied hours and 2 cleaning hours per day
- Perimeter windows, often double glazed
- Ducted warm air heating to internal spaces, with radiators at the perimeter, typically to 20°C
- Some local mechanical ventilation or air conditioning (Note that any significant air conditioning will in general increase energy consumption. See EEO Energy Consumption Guide 19 and Good Practice Guide 71).

Figure 5.1 General manufacturing
Typical energy cost breakdown

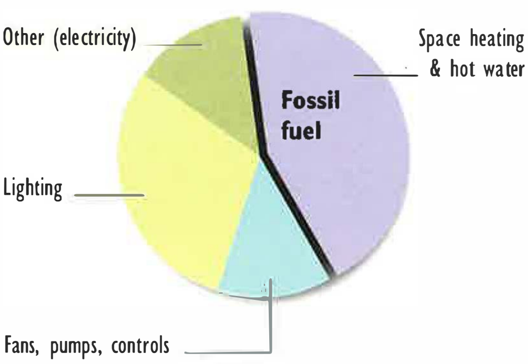
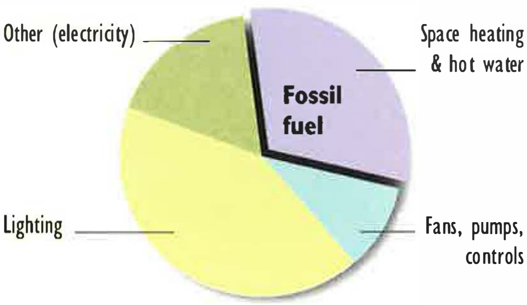


Figure 5.2 Factory - Office
Typical energy cost breakdown



Type 3. Light manufacturing

- Industrial unit of typically 5m clear internal height, with areas for office, storage and dispatch
- Largely naturally ventilated with occasional local mechanical extraction
- Warm air or radiant heater units, and 1.5 shift operation with heating to 16-18⁰C
- Lighting generally by fluorescent tube or low-bay high pressure sodium fittings
- Average 10% of roof area is rooflights.

This type of building may also be used for light engineering and electronic equipment assembly.

Type 4. Storage and distribution

- Warehousing with typically 7.5m clear internal height, and with pallet racking
- Natural ventilation and warm air heating to 16⁰C for single shift operation during the day
- Lighting generally by high pressure sodium high bay fittings
- Average 10% of roof area is rooflights
- Excludes refrigerated warehousing.

Typical annual energy costs for the four types of building are given in figure 5.5. The fossil fuel is assumed to be gas and the graph is representative of fairly small sites. Costs exclude process energy use.

Improved buildings tend to use 20% to 30% less energy than the equivalent typical building, mostly achieved by good management and simple measures. Still lower energy consumption is achievable in new buildings and major refurbishments.

EEO Energy Consumption Guide 18 gives 'typical', 'improved' and 'new' energy consumption values in kWh/m² for different areas of energy use such as lights, heating and hot water, fans, pumps and controls.

If you are able to determine the energy consumption of any of the different areas, by sub-metering for example, you can compare them with values given in Energy Consumption Guide 18. This will indicate the potential for savings in a specific area.

Figure 5.3 Lighting manufacturing
Typical energy cost breakdown

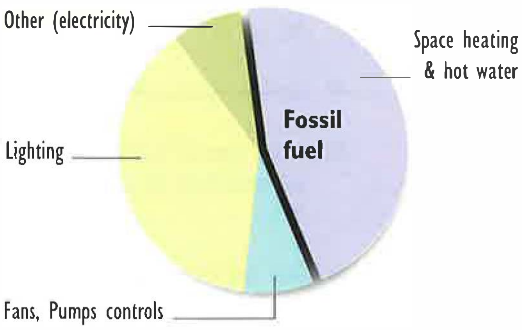


Figure 5.4 Storage and distribution
Typical energy cost breakdown

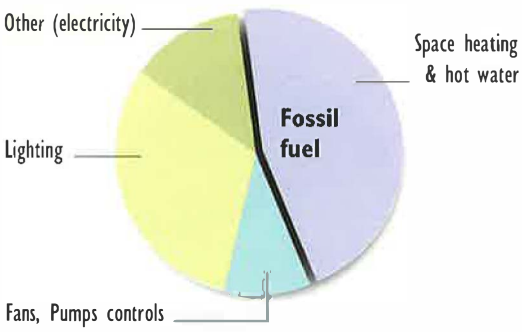
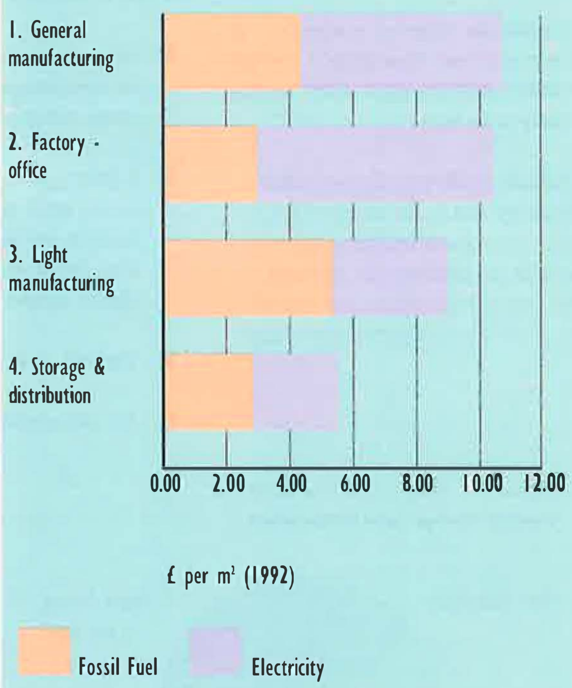


Figure 5.5 Typical annual energy cost of factories and warehouses



COMPARING WITH ACCEPTED STANDARDS - PERFORMANCE INDICES

6.1 Why use performance indices?

Performance indices give a measure of the energy use of a building which can be compared with the yardsticks. They can indicate the potential for improvements and can be used to show progress over time. They can also allow comparisons to be made between buildings in a group or estate.

6.2 Calculating the performance indices of a building and comparing to yardsticks

Two separate indices are calculated for the building, one for electricity and the other for fossil fuels. The separate indices should not be added together, because of the different cost and environmental impact of fossil fuels and electricity.
The performance indices are obtained by dividing the annual building energy use by the floor area of the building. Yardstick values for the different building types are given in figures 6.2 and 6.3, with electricity consumption and fossil fuel energy consumption shown separately.

The procedure is:

1. Enter the building's annual energy use (excluding any process energy use) for each fuel into column 1 of figure 6.1.
2. Multiply each fuel by the conversion factor in column 2 to get common units of energy (kWh is used for electricity and now for gas - conversion units are given in Appendix 2).
3. Enter the gross floor area of the building in column 4.
4. Divide the energy use of each fuel by the floor area to get energy use per unit area (kWh/m^2) in column 5.
5. Add the fossil fuel figures together to get a fossil fuel index - the electricity figure can be used directly.
6. Compare the indices with yardsticks for the building type in figure 6.2 to give an energy performance assessment.

Note: this does not take account of the effect of weather on heating energy use (see section 6.4).

Alternatively, energy performance indices can be calculated based on building volume. The same calculation procedure is used, except building volume is inserted into column 4 of figure 6.1 instead of floor area.

The volume yardsticks in figure 6.2 are based on these representative building heights :

Building type	Clear internal height
General manufacturing	8m
Factory office	4m
Light manufacturing	5m
Storage and distribution	7.5m

Floor area information.
The measure of floor area used to standardise energy consumption is gross area. Gross area is the total building area measured inside external walls. Building volumes can also be used to standardise energy consumption. It is important to consider the likely accuracy of area or volume information, and where necessary check measurements.

Annual energy consumption of your building.
This is most conveniently obtained from past bills but take care that the figures collected represent a full year and are not "estimated" by the utility. It may be helpful to look at more than one year's bills providing that there have been no significant changes to the building or its use in that time. The numbers you require are the energy units consumed, not the money value. Include all fuels: solid fuel, bottled fuel, natural gas, oil and electricity.

Figure 6.1 Energy Performance Index Calculation

		Column 1 Annual Billed Units			Column 2 kWh* Conversion	Column 3 Annual kWh	Column 4 Gross floor area (m^2) divide by	Column 5 Annual kWh/m^2
Gas			kWh	x	1.0			
Oil type			litres	x				
Other Fossil fuel								
Total of fossil fuel								
Electricity			kWh	x	1.0			

Note * for kWh conversion factors see Appendix 2

There may be exceptional reasons to explain a low or high consumption. For example, a building's energy consumption may be affected by the industrial process taking place. Heat from the process may contribute to the space heating; alternatively, ventilation of noxious fumes or dust may lead to an increase in the requirement for heating.

Figure 6.2 Energy Consumption Yardsticks

Performance Assessment

	Low consumption / Less than	Medium Consumption / Between	High consumption / Greater than
	Yardsticks	Yardsticks	
Floor area basis	in kWh/m^2	in kWh/m^2	
Type 1. General manufacturing			
Fossil fuels	225	325	
Electricity	65	85	
Type 2. Factory - office			
Fossil fuels	150	225	
Electricity	72	100	
Type 3. Light manufacturing			
Fossil fuels	175	300	
Electricity	43	70	
Type 4. Storage and distribution			
Fossil fuels	135	185	
Electricity	29	43	
Building volume basis	in kWh/m^3	in kWh/m^3	
Type 1. General manufacturing			
Fossil fuels	28	41	
Electricity	8	11	
Type 2. Factory - office			
Fossil fuels	38	56	
Electricity	18	25	
Type 3. Light manufacturing			
Fossil fuels	35	60	
Electricity	9	14	
Type 4. Storage and distribution			
Fossil fuels	18	25	
Electricity	4	6	

Even a building with a low consumption may have opportunities for cost-effective improvement.

The indices show which fuel requires the most attention. The description of typical energy use patterns in section 5 may help to ascertain which use of energy is most likely to offer potential for savings. Section 4 then shows possible energy saving measures for each energy use. The next step is to select and progress suitable measures.

6.3 Overall yardsticks

Overall yardsticks based on carbon dioxide (CO_2) emissions or the cost of energy per m^2 of floor area can be used to provide a single performance index. These can be used to prepare league tables which compare groups of buildings or to assess buildings which have fuel supply arrangements which do not fit into the yardstick categories. This may occur, for example, in buildings with electric heating and buildings which use combined heat and power (CHP).

Appendix 1 shows how to apply simple factors for CO_2 emissions or energy cost for each fuel type to calculate an overall performance index.

6.4 Refining the performance indices

If there is more information available, you may wish to improve the accuracy of your performance indices as described in Appendix 1.

- If your building has unusual occupancy, or experiences unusual weather or exposure you may want to know their likely effect.
- You can compare your building performance with the 'Normalised Performance Indicator' used in previous editions of these guides.
- You may wish to take account of the effect of weather when comparing buildings in different parts of the country.

A CLOSER LOOK AT ENERGY CONSUMPTION

7.1 Introduction

Often a fuller understanding of energy use in a building may be useful, for example after the initial measures have been undertaken, if there is a problem, if the building has poor performance or if it has unexpected energy bills. This section outlines techniques which you may find useful.

7.2 Monthly energy use

You can ask your supplier for monthly fuel data, or take monthly meter readings yourself.

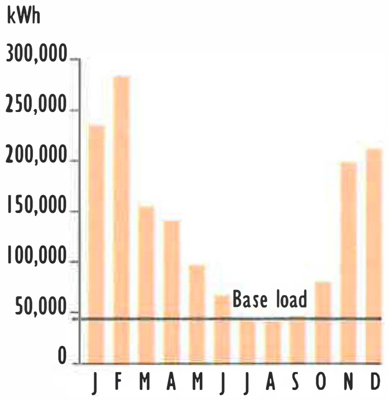
Larger sites have monthly energy bills. By looking at how these vary with the seasons some valuable insights can be obtained. Produce a monthly consumptions bar chart plot for each energy source over a year.

The billing periods should be checked. If they are not regular, some months will appear unrealistically low and others unrealistically high. If this is the case the average daily consumption for each month can be plotted to give more accuracy.

Fossil fuel consumption, used mainly for heating, should reduce greatly in summer - to zero if it is not being used for other services such as hot water or catering.

Electricity consumption should decrease in summer in a building which is not air conditioned, because of lower lighting loads. In an air conditioned building, peaks in spring and autumn may indicate simultaneous heating and cooling.

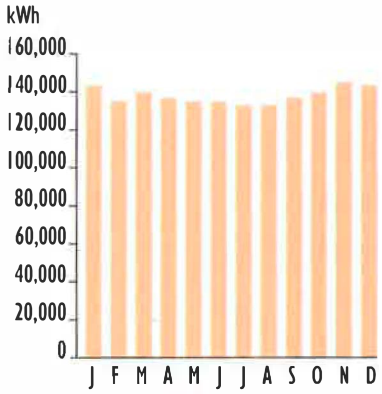
Example monthly fossil fuel use



The figure above shows the monthly fossil energy consumption of a fairly efficient building which has a central boiler system for heating and hot water - the summer usage is much lower than winter usage and is at a fairly steady 'base load' level which suggests that the heating is off, though it is useful to confirm this by checking that heating pumps are off, and that pipework used solely for heating is cold.

This graph shows a base load, which helps to identify the hot water load and system losses, and the heating load which depends on the weather.

Example monthly electricity use

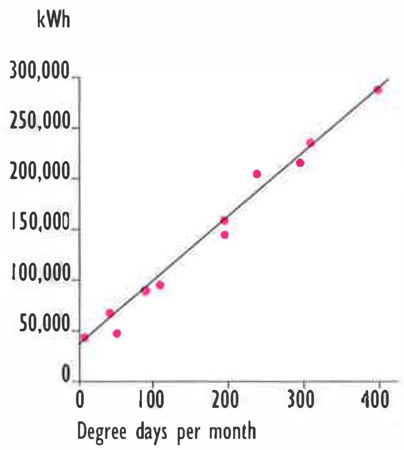


The figure above shows monthly electricity consumption for a non air conditioned building. The small increase in winter may be due to increased lighting or some electric heating.

7.3 Relating heating use to weather

A fuel that is mainly used for heating should be used more in colder weather. The coldness of the weather can be expressed by a measure known as degree days. This shows by how much and for how long the outside temperature is below a control temperature (usually 15.5°C) Drawing a graph of fossil fuel consumption against the degree days for each month in the year shows how energy consuption is related to weather. Monthly figures for degree days for different areas of the country are published in the EEO's free bimonthly magazine 'Energy Management' (section 9.4).

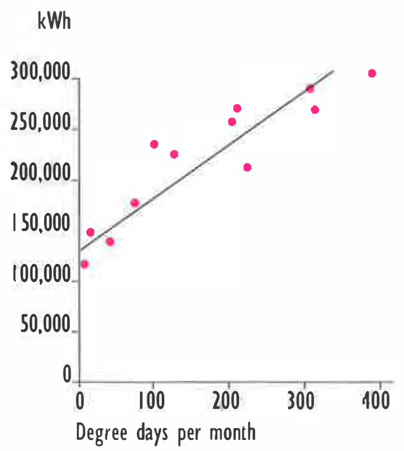
Example monthly heating energy use in a well controlled building



The building represented above has a well controlled heating system shown by the close fit of the straight line. As the weather gets colder the energy used goes up proportionally. For this building the energy consumption falls to a small value in summer when only hot water is being provided.

A building with better insulation would have a less steep slope because energy consumption in winter would be lower.

Example monthly heating energy use in a poorly controlled building



The figure above has a large scatter of points indicating a building with poor control. The energy use in the summer months remains higher than in the previous figure, indicating that there is a process load, that the heating is being used unnecessarily or that the boiler and hot water systems have high losses which lead to excessive waste.

For further information see:
EEO Fuel Efficiency Booklet 7. Degree Days

7.4 Adjusting energy use for weather

Once you know how weather conditions affect energy use, it is possible to allow for varying conditions. For example, it is possible to take account of the weather when comparing a building energy performance from year to year. Such comparisons show with greater accuracy the effect of any energy saving measures.

In order to adjust for weather it is necessary to know how much of the fossil energy is used for heating and how much is a steady base load. The base load can be estimated by looking at the monthly consumption of fossil energy as shown in section 7.2 or the graphs of fossil fuel against degree days as shown in section 7.3, and the rest is the energy used for space heating which varies with weather conditions.

7.5 Comparing energy use with standards

More detailed information on energy use in industrial buildings is available from the EEO. It is possible to meter or estimate energy usage for a particular service such as heating or lighting and compare against published levels. This helps to ask more detailed questions and so identify more precisely where savings are most likely to be achieved.

For further information see:

EEO Energy Consumption Guide 18 - Energy effieciency in industrial buildings and sites

CIBSE Applications Manual 5 Energy Audits and Surveys.

CASE STUDIES

This section gives examples of buildings where energy saving measures have been implemented.

The use of the Performance Index calculation is also demonstrated, both for assessing how energy efficient a building is, and as a means of evaluating the improvement in energy performance resulting from the implementation of energy saving measures.

8.1 GEC Alsthom Large Machines Ltd, Rugby

GEC Alsthom Large Machines Ltd is an engineering company specialising in the design and manufacture of large bespoke electric motors and generators. The majority of the buildings on its site at Rugby are used for manufacturing and storage facilities.

The company undertook a series of energy saving measures between 1987 and 1992 as part of a site and company rationalisation. These measures are described below. The investment for these measures was funded entirely from the Company's own profits and the system design, project management, employee training and installation of the new equipment has been resourced from within the company to ensure the minimum of disruption to production.

Heating systems

Space heating and hot water was previously produced via a steam district heating main from a central coal fired boiler installation, which also served process needs.
The works are now heated by high efficiency direct fired gas radiant tube heaters controlled via "blackbulb" thermostats and the offices are heated by a wet radiator system connected to gas fired modular boilers. Steam drives for pumps and compressors have been replaced by electric motors. Local steam generators provide process steam.

Domestic hot water is now produced locally, either by electric point of use water heaters or by gas hot water boilers. This has produced dramatic savings by eliminating losses from long pipe runs and inefficient operation of boilers at part load in the summer. Decentralisation has improved the efficiency and effectiveness of the heating plant. Coupled with good controls, incorporating an energy management system (EMS), flexibility and better comfort for staff have resulted.

All these changes provide more flexible control at the point of use without the former high standing losses in the boiler plant and pipework distribution system.

Roof Improvement

The roof had to be replaced owing to water leakage. Insulation (plastic sheeting with 60mm glass fibre/plasterboard) was included when fitting the new roof. The capital cost attributed to the measure is the differential cost of insulation over a straight replacement.

Fast Acting Doors

Fast acting doors were installed to alleviate the problems of severe draughts from open vehicle access doors. These are activated manually by the fork lift driver at a push-button located to be operable without dismounting. The doors rise and fall in only two seconds to ensure that the minimum warm air is lost. The doors remain open for 10 seconds to allow passage of the vehicle.

Air Lobby

An extension was built on to one of the buildings to give an air lobby between two automatic roller doors. This easy-

to-use facility successfully reduces the high rate of cold air infiltration previously experienced in the building by allowing vehicles of up to 9m in length to be admitted without the chilling effect of a large air change.

Lighting

In the offices and canteens, old fluorescent lighting was replaced with high frequency units which give a reduction in electricity use of 30%. In manufacturing areas most of the fluorescent and mercury vapour (MBFU) lamps were replaced with high pressure sodium (SON) lamps. External lighting was rationalised between 1988 and 1991 with a variety of sodium lighting.

Electrical Load Shedding

The works has a potential electrical demand of 7 MW but the EMS is programmed to monitor demand levels at 8 locations to report when a set level of 4 MW is being approached. The system can shed loads automatically but GEC at present rely on manual isolation of strategic loads to maintain an acceptable demand.

Cost Savings

The combined effect of the measures achieved annual cost savings of about £600,000 per annum, for a capital cost of about £1.6 million, giving a simple payback period of about 2.5 years.

8.2 Strategy One Ltd, Nelson

Strategy One, part of the Strategy Group, offers a range of packaging services to the food and confectionery industry. The factory at Nelson was built in 1987 and is leased from a landlord. It consists of two factory workspaces, together with office accommodation and a stores area. The site is classed as light manufacturing.

Two particular factors prompted Strategy One to install energy saving measures. Firstly, space heating running costs were high, a result of controls that were easily tampered with. Secondly, there was a high temperature gradient between floor and roof, while it was necessary to maintain a more uniform temperature during both summer and winter to ensure that clients' perishable products were not damaged. Measures were implemented during spring 1990 to rectify this situation.

Destratification Fans

Fans were installed to reduce temperature stratification during the heating season (this is common in areas using warm air space heaters). The fans prevent heat collecting near the roof and causing excessive heat loss, and reduce the entry of cold outside air through doorways as a result of warm air rising.

The circulation of air in summer months has also improved the comfort of the occupants and helped to stabilise temperatures, thus reducing the risk of damage to the confectionery products.

Heating Controls

Five space heating zone controllers were installed in the Works Manager's office for adjustment only by authorised staff, with accurate temperature sensors in the factory and office workspace.

Strip Curtains

A new stores area was built in 1988, attached to the factory. The stores area, although supplied with a unit heater, is seldom heated other than for frost protection. There is therefore a significant difference in temperature between the production area and the stores. Strip curtains were installed to reduce heat loss and ingress of cooler air to the main factory areas, while allowing forklift trucks to move freely.

Assessment of energy and cost savings

The combined cost savings resulting from the measures described above are £1,464 for a total capital cost of £6,539. The initial investment will therefore be recovered after about 4.5 years. The fossil fuel performance index has improved from 'medium' to 'low' consumption.

There have been no adverse comments to the measures undertaken, and staff appreciate the circulation of air by the destratification fans during the summer months.

The management has recorded the energy consumption in the months since the new controls and fans were installed and are aware of the success the measures have achieved.

More detailed monitoring of energy consumption on a monthly basis would, however, enable management to respond to any decline in energy performance, should it occur.

Improvement in fossil fuel performance index

Treated floor area (m²) 2258	1989/90	1990/91
Fossil fuel consumption (kWh)	418,458	305,858
Fossil fuel performance index (kWh/m²)	185	135
Fossil fuel performance assessment	Medium consumption	Low consumption

Capital cost, savings and payback periods

Date	Measure	Annual cost saving (£)	Capital cost (£)	Payback time (yrs)
May 1990	Destratification fans	559	1,850	3.3
May 1990	Time/Temperature controllers	832	3,480	4.2
Jan 1991	Strip doors	73	1,209	16.6
Overall		**1,464**	**6,539**	**4.5**

8.3 Romford Brewery Co Ltd

Background

The Romford Brewery Company has been making beer for over 200 years at its present site. The largest structure on the site is the brewing and fermentation building.

Energy Survey

An energy survey in 1989 drew attention to the excessive use of electricity for lighting which cost about £35,000 per year. A lighting audit was undertaken which identified the potential for substantial savings.

The audit showed that most of the luminaires were 38mm diameter fluorescent tubes, with chokes and starters. Some lamps and luminaires were in poor condition or had failed, and needed replacement. These included some that required scaffold to reach them. Other luminaires were completely obscured by plant. Many lamps were left on when spaces were unoccupied. Maintenance was not planned and lamps replaced only after receiving a complaint.

Action Plan

Responding to the findings of the audit, the following six-point action plan was implemented:

- Reduce the number of luminaires
- Use more energy efficient luminaires
- Use more energy efficient lamps
- Renew all faulty or deteriorated luminaires
- Fit automatic control systems
- Initiate a planned maintenance schedule.

Light Fittings

All existing luminaires that were not fulfilling a requirement were removed or repositioned.

All 38mm diameter fluorescent tubes were replaced by 26mm diameter tubes. These slimmer lights produce the same output as the larger lights, but consume about 9% less electricity. Most tungsten lamps were replaced by compact fluorescent lamps which reduce maintenance and electricity costs by about 80%. All high pressure mercury discharge lamps were replaced by fluorescent fittings or high pressure sodium lamps.

Choke and starter gear were replaced by electronic ballasts in all existing fluorescent luminaires. All new fluorescent fittings were specified with low energy high frequency electronic ballasts.

Lighting Controls

Daylight-linked controls were installed to allow lighting levels to be adjusted according to the level of daylight. This requires high frequency electronic ballasts to be fitted in luminaires. Occupational sensor controls were fitted to detect movement of personnel in an area and switch lighting on and off as appropriate.

In areas which are infrequently occupied, manual push-button switches with an in-built timing facility, which can be adjusted to set the lighting period, were installed. Manual on/off switches were installed to provide local control in working areas which are occupied for long periods.

Maintenance Schedule

Efficient lighting performance requires luminaires to be cleaned and kept in working order, and lamps to be replaced at the end of their useful life, usually before failure occurs. A planned maintenance schedule has therefore been implemented, with fluorescent and sodium lamps being replaced after 8000 hours use and all luminaires being cleaned every six months.

Energy-Related Cost Savings

Total annual cost savings are £35,000 (£22,700 on electricity and £12,400 on maintenance) and the total installation cost was £75,000, giving a payback period of a little over two years.

For further information see:

EEO Good Practice Case Study 159: Romford Brewery Co Ltd

Cost savings from the new lighting system

	Installed load (kW)	Annual electricity consumption (kWh)	Electricity cost @ 5p/kWh (£)
Original system	164	984,000	34,400
New system	81	334,500	11,700
Savings	83	649,500	22,700

9

ADVICE AND HELP

9.1 The Energy Efficiency Office

The Energy Efficiency Office (EEO) is part of the Department of the Environment.

The EEO currently aims to achieve environmental and economic benefits by promoting cost effective energy efficiency measures in the industrial, commercial, domestic and public sectors of the economy by:

- Raising awareness
- Identifying and overcoming barriers to action
- Providing financial incentives where appropriate
- Regulation where necessary
- Providing technical advice.

9.2 Best Practice Programme

The EEO's Best Practice programme gathers and disseminates authoritative information on cost effective energy saving measures. The Best Practice programme for buildings is managed on behalf of the EEO by the Building Research Energy Conservation Support Unit (BRECSU) and for industry by the Energy Technology Support Unit (ETSU).

A range of publications is available under the Best Practice programme, normally free of charge. Relevant titles for factories and warehouses are listed here.

Energy Consumption Guides give data on the way in which energy is currently used in specific building types and for industrial processes, enabling organisations to compare their current energy usage with others in their sector or occupying similar building types.

Available from BRECSU

18 Energy Efficiency in Industrial Buildings and Sites

19 Energy Efficiency in Offices. A Technical Guide For Owners and Single Tenants.

Good Practice Guides give advice on how to implement energy saving measures. Titles available relating to factories and warehouses are as follows:

Available from BRECSU

61 Design Manual. Energy Efficiency in Advance Factory Units

62 Occupiers Manual. Energy Efficiency in Advance Factory Units

71 Selecting Air Conditioning Systems

84 Managing And Motivating Staff To Save Energy.

Available from ETSU

1 Guidance notes for the implementation of small scale combined heat and power

2 Electric Motor and Drive Systems

3 Introduction to small-scale CHP

13 Heat Recovery From High Temperature Waste Gas

14 Retrofitting AC Variable Speed Drives

18 Reducing Energy Costs by Steam Metering

30 Energy Efficient Operation of Industrial Boiler Plant

43 Large Scale Combined Heat and Power

General Information Leaflets and Reports also give advice on how to implement energy saving measures. General Information Leaflets relating to factories and warehouses are as follows:

Available from BRECSU

1 The success of condensing boilers in non domestic buildings. A user study

Information on energy management is contained in these General Information Reports:

12 Organisational aspects of energy management

13 Reviewing energy management

14 Energy management of buildings including a review of some case studies.

Good Practice Case Studies provide examples of proven techniques which are already enabling the better energy users to be more energy efficient. Series available relating to factories and warehouses are as follows:

Available from BRECSU

Energy efficiency in advance factory units case studies series

Energy efficiency in mixed use business space case studies series

Energy efficient lighting in factories case studies series

Energy efficient lighting in warehouses case studies series

Energy efficiency in refurbishment of industrial buildings case studies series.

Available from ETSU

Many titles available relating to efficient use of process energy.

Fuel Efficiency Booklets are working manuals which provide detailed technical guidance on specific areas of energy use in buildings and industry. Relevant booklets are:

Available from BRECSU

1 Energy audits for buildings

2 Steam

3 Economic use of fired space heaters for industry and commerce

7 Degree days

8 The economic thickness of insulation for hot pipes

9 Economic use of electricity in buildings

10 Controls and energy savings

12 Energy management and good lighting practices

14 Economic use of oil-fired boiler plant

15 Economic use of gas-fired boiler plant

16 Economic thickness of insulation for existing industrial buildings

17 Economic use of coal-fired boiler plant

In addition, a wide range of events is organised to promote the results of the Best Practice Programme. This includes seminars, workshops and site visits targeted at different sectors and professionals.

Details of publications and events can be obtained from:

BRECSU (for buildings)
Building Research Establishment
Garston
Watford WD2 7JR
Tel. 0923 664258
Fax. 0923 664097

ETSU (for industrial projects)
Harwell
Didcot
Oxon OX11 ORA
Tel. 0235 436747
Fax. 0235 432923.

9.3 Other publications available from BRECSU

Energy Efficient Lighting in Industrial Buildings (1993). A THERMIE Maxibrochure.

9.4 Free Publications From the EEO

The Introduction to Energy Efficiency series. There are 13 Guides in this series, of which this is one:

Catering establishments
Entertainment buildings
Factories and warehouses
Further and higher education
Health care buildings
Hotels
Museums, galleries, libraries and churches
Offices
Post Offices, banks, building societies and agencies
Prisons, emergency buildings and courts
Schools
Shops and stores
Sports and recreation centres

Choosing an Energy Efficiency Consultant (EMAS 2)

Practical Energy Saving Guide for Smaller Businesses (ACBE 1)

The above are all available from:
Department of the Environment
Blackhorse Rd
London SE99 6TT
Tel: 081 691 9000

The 'Energy Management' journal. Published bi-monthly and available from the EEO.
Tel: 071 276 6200.

9.5 Other EEO Programmes

Making a Corporate Commitment Campaign

The 'Making a Corporate Commitment' campaign seeks board level commitment to energy efficiency. It encourages directors to sign a Declaration of Commitment to responsible energy management, prepare a business plan for energy efficiency and ensure that it becomes an item that is considered regularly by their main board.
Publications:

Chairman's Checklist
Executive Action Plan
Energy, Environment and Profits - Six case studies on corporate commitment to energy efficiency.

Further information is available from the Campaign Offices on 071 276 4613.

Energy Management Assistance Scheme

The Energy Management Assistance Scheme may provide support for small and medium sized businesses (up to 500 employees) to employ an energy consultant. This aims to upgrade the expertise in energy efficiency among smaller companies, and tackle the capital priority barrier through financial support.

Further information can be obtained on 071 276 3787.

9.6 Sources of Free Advice and Information

Regional Energy Efficiency Officers

11 Regional Energy Efficiency Officers (REEOs) around the UK can provide copies of all the EEO's literature and give specific advice on:

- opportunities for better energy efficiency in your organisation
- technologies and management techniques you should be thinking about
- appropriate sources of specialist advice and assistance in the private sector
- EEO programmes
- regional energy managers' groups.

REEO Northern Region
Wellbar House
Gallowgate
Newcastle Upon Tyne NE1 4TD
Tel: 091 201 3343

REEO Yorkshire and Humberside
City House
New Station Street
Leeds LS1 4JD
Tel: 0532 836 376

REEO North West
Sunley Tower
Piccadilly Plaza
Manchester M1 4BA
Tel: 061 838 5335

REEO East Midlands
Cranbrook House
Cranbrook Street
Nottingham
Nottinghamshire NG1 1EY
Tel: 0602 350 602

REEO West Midlands
Five Ways Tower
Frederick Road
Birmingham B15 1SJ
Tel: 021 626 2222

REEO Eastern
Heron House
49-53 Goldington Road
Bedford MK40 3LL
Tel: 0234 276 194

REEO South West
Tollgate House
Houlton Street
Bristol BS2 9DJ
Tel: 0272 878 665

REEO South East
Charles House
Room 565
375 Kensington High St
London W14 8QH
Tel: 071 605 9160

REEO Scotland
New St Andrews House
Edinburgh
Scotland EH1 3TG
Tel: 031 244 1200

REEO Wales
Cathays Park
Cardiff
Wales CF1 1NQ
Tel: 0222 823 126

REEO Northern Ireland
Dept of Economic Development
Netherleigh House
Massey Avenue
Belfast
N Ireland BT4 2JT
Tel: 0232 529900.

9.7 Other Programmes

Energy Design Advice Scheme

The Energy Design Advice Scheme is a Department of Trade and Industry discretionary initiative aimed at improving the energy and environmental performance of the building stock by making low energy building design expertise more accessible for the energy efficient design and refurbishment of buildings. The scheme offers support, via a number of Regional Centres, to design teams or clients in the energy aspects of design of new buildings or refurbishment projects over 500m^2 gross area.

Further information can be obtained from the following Regional Centres:

For Scotland
Tel: 031 228 4414

For South East England
Tel: 071 916 3891

For Northern England
Tel: 0742 721 140

For Northern Ireland
Tel: 0232 364 090

EU Programmes

Several EU programmes aimed at demonstrating energy efficiency measures and encouraging energy efficiency R&D. Details change periodically. For further information contact BRECSU for buildings and ETSU for industry.

9.8 Other Publications

Chartered Institution of Building Services Engineers (CIBSE):

CIBSE Applications Manual, AM 5:1991, Energy Audits and Surveys

CIBSE Applications Manual, AM 6:1991, Contract Energy Management

CIBSE Applications Manual, AM3, Condensing Boilers

CIBSE Applications Manual, AM8, Private and Standby Generation of Electricity

CIBSE Code for Interior Lighting (1984)

CIBSE Lighting Guide 1(LG1)(1989). The Industrial Environment.

Available from:

CIBSE, 222 Balham High Rd,
Balham,
London SW12 9BS.
Tel: 081 675 5211
Fax: 081 675 5449.

Heating and Ventilating Contractors Association (HVCA):

Standard Specification for Maintenance of Building Services. Volumes 1 - 5. 1990 - 1992.

Available from:

HVCA Publications, Old Mansion House, Earmont Bridge, Cumbria, CA10 2BX
Tel: 0768 64771.

Building Research Establishment (BRE):

BREEAM/New Industrial Units, Version 5/93
An environmental assessment for new industrial, warehousing and non-food retail units.

Available from:

BRE Bookshop, Building Research Establishment, Garston, Watford WD2 7JR.
Tel: 0923 664444,
Fax: 0923 664400

9.9 Other Useful Addresses

Energy Systems Trade Association Ltd (ESTA)
PO Box 16, Stroud, Gloucestershire
GL6 9YB
Tel: 0453 886776
Fax: 0453 885226

Major Energy Users' Council
10 Audley Road
London W5 3ET
Tel: 081 997 2561 1/3854
Fax: 081 566 7073.

APPENDIX 1

Development of Building Performance Indices (PI)

Introduction

This section outlines how to calculate environmental and cost indices for the energy used in your building. It describes the effect of weather, building occupancy, exposure and process energy on the performance of a building, with a method to allow for the first three of these if required.

Adjustments of the PI for these factors produces a 'Normalised Performance Index' (NPI) which is compatible with earlier versions of this guide. For many purposes, the effect of these factors on performance indices is small enough to be ignored.

Overall performance indices

Overall performance indices provide a single measure of building performance, and can be expressed in terms of carbon dioxide (CO_2) emissions or energy cost. Overall energy indices are useful for comparing a stock of buildings or for assessing the performance of buildings with electric heating or combined heat and power (CHP). However, separate fossil fuel and electricity performance indices are more useful to assist in deciding a course of action.

To calculate overall performance indices you need the annual energy use indices as obtained in figure 6.1 and conversion factors for each of the fuels - some of which are given in figures A1.1 and A1.2. The calculation procedure is to enter the kWh/m² figure in Column 1, and multiply by the relevant conversion factors in column 2 to get either the kg of CO_2 per m² or the cost per m² in column 3.

The conversion factors shown are broadly representative of the current fuels used in industrial buildings, and can be used if a consistent set of factors is required. CO_2 factors, particularly for electricity, may vary from this data. Cost factors will also vary over time and as a function of use. Energy unit costs in larger buildings tend to be cheaper than for smaller supplies. You may wish to use your own costs from your own bills instead of those given here.

Overall yardsticks for CO_2 emissions or energy costs can also be calculated, by inserting yardstick energy consumptions (given in figure 6.2) into column 1. These can be compared with the actual index for your building to give an overall assessment. CO_2 and cost yardsticks calculated on the basis that the fossil fuel is gas are presented in figure A1.3.

Effect of weather on energy use

Weather changes from year to year for a given site cause variations in fossil/heating energy use of typically ±5% from the average values or ±10% in more extreme years.

Weather differences across the country cause variation in heating requirements of typically ±10% from average values and ±20% in more extreme areas.

The effect on electricity use will be small unless electricity is used for space heating, or in air conditioned buildings where the cooling energy will be higher during a warm summer.

Exposure

If a building is very exposed (on an exposed hill for example), heating energy increases by 5-10% and likewise a completely protected building may use 5-10% less. In many cases steps will have been taken on exposed buildings to improve draught sealing which will offset the increase. Electricity use is largely unaffected except in electrically heated buildings.

Process Energy

There is considerable variability and no simple relationship between building and process energy. An industrial process can either reduce or increase the requirement for building energy. For example:

- Heat output from 'clean' processes can lower space heating requirements.
- 'Dirty' processes require ventilation which often adds to building electrical requirements and heating loads.
- Excessive process heat requires ventilation and cooling.

Figure A1.1
CO_2 Performance Index Calculation

	Column 1 Annual energy use kWh/m²	Column 2 CO_2 conversion* factors kg/kWh	Column 3 Annual CO_2 emissions kg/m²
Gas		x 0.20	
Oil		x 0.29	
Coal		x 0.32	
Electricity		x 0.70	
Total CO_2 emissions per m²			

*typical 1993 emission factors

Figure A1.2
Cost Performance Index Calculation

	Column 1 Annual energy use kWh/m²	Column 2 Cost conversion factors £/kWh	Column 3 Annual cost £/m²
Gas		x 0.014	
Oil		x 0.012	
Coal		x 0.009	
Electricity		x 0.071	
Total energy cost per m²			

*typical 1992 prices

Figure A1.3 Carbon dioxide and cost yardsticks

CO_2 Performance Assessment

	Low Emissions Less than	Medium Emissions Between	High Emissions Greater than
Building Type	Yardsticks in kg CO_2/m^2	Yardsticks in kg CO_2/m^2	
1. General manufacturing	91	125	
2. Factory - office	80	115	
3. Light manufacturing	65	110	
4. Storage & distribution	47	67	

Cost Performance Assessment

	Low Cost Less than	Medium Cost Between	High Cost Greater than
Building Type	Yardsticks in £/m²	Yardsticks in £/m²	
1. General manufacturing	7.80	10.60	
2. Factory - office	7.20	10.30	
3. Light manufacturing	5.50	9.20	
4. Storage & distribution	4.00	5.60	

CO_2 and cost yardsticks are based on factors given in figures A1.1 & A1.2

- Some processes require better lighting over large areas than others: the need varies with industry and process.
- Some processes have special and energy demanding air quality requirements.

Hours that the building is occupied (occupancy)

Occupancy affects buildings' energy use in different ways for different systems. Heating energy in a naturally ventilated heavy building varies very little with occupancy - say 5%. If a building has a light weight structure or is mechanically ventilated or air conditioned, the heating energy may increase in more direct proportion to the occupied hours, giving 20% variation or more from the typical occupancy.

Electricity consumption of a badly controlled building will be almost independent of the occupancy, owing to lights and services left on from early morning to last thing at night. But for a well controlled building, both lights and plant may operate in direct proportion to occupancy.

Normalised performance indices

It is possible to adjust (normalise) performance indices for weather, exposure and extended occupancy, but care is needed as incorrectly applied adjustments, or adjustments that are too simplistic, may introduce larger errors than the typical variations discussed above. For example, the effect of extended hours of use on energy consumption can easily be exaggerated, making the building performance seem better than is really the case.

Note also that while a normalised performance index is a better measure of a building's efficiency than an unnormalised index, the latter shows the building's actual performance. So a building with a low normalised performance index, but a high performance index before adjustment, is efficient, but since it is still a high user of energy, it may well offer good opportunities for cost effective energy saving.
The worksheet in figure A1.4 can be used to obtain performance indices which are normalised to standard conditions of weather, exposure and occupancy. This is useful if:

- You require normalised performance indices for compatibility with previous work
- Any of the factors cause significant errors (see above sub sections to evaluate this).

A normalised performance index based on overall CO_2 emissions or energy cost is obtained by using figure A1.1 or A1.2 and inserting the normalised performance indices for each fuel into Column 1. If more than one fuel is used for heating, calculate a separate normalised performance index for each fuel first and then use this procedure.

Performance indices - summary

- Simple performance indices are for initial energy assessments. Separate performance indices are calculated, one for fossil fuels and one for electricity use, and no adjustments are made.
- Overall performance indices, based on carbon dioxide (CO_2) or cost, are normally used when the energy supply arrangement is not typical or when a number of buildings are to be compared. Also, you may want to know the cost or the CO_2 performance for a single building.
- Normalised performance indices are used when more sensitive comparisons are required and the effect of factors such as weather and occupancy become significant and must be adjusted. But if you choose to normalise, be aware of introducing errors.

Figure A1.4 Normalised Performance Indices calculation

	Fossil fuel: Gas	Fossil fuel: Oil	Fossil fuel: Other		Total of Fossil Fuels	Electricity
Total energy consumption (kWh)				(A)		
Space heating energy (kWh)				*(B)		
Non space heating energy (kWh)				A-B = (C)		
Find the degree days for the energy data year				*(D)		
Weather correction factor = 2462 ÷ D =				(E)		
Obtain the exposure factor below				*(F)		
Obtain occupancy factor from below				*(G)		
Annual heating energy use for standard conditions				BxExFxG = (H)		
Obtain occupancy factor from below				*(G)		
Annual non-heating energy use = C x G =				(L)		
Normalised energy use = H + L =				kWh (M)		
Find floor area				m² (N)		
Find the Normalised Performance Indices = M ÷ N =				kWh/m² (P)		

*Notes:
(B) Estimation of weather-dependent heating energy use is discussed in section 7.
(D) For degree day information, see Fuel Efficiency Booklet 7 - Degree Days
Monthly degree day figures are published in 'Energy Management' (see section 9.4)
(F) Exposure factors from figure A1.5
(G) Occupancy factors from figure A1.6

Figure A1.5 Exposure factor

	Factor
Sheltered. The building is in a built-up area with other buildings of similar or greater height surrounding it. This would apply to most city centre locations.	1.1
Normal. The building is on level ground in urban or rural surroundings. It would be usual to have some trees or adjacent buildings.	1.0
Exposed. Coastal and hilly sites with little or no adjacent screening.	0.9

Figure A1.6 Occupancy Factors

	Single shift, 5 day week	Single shift, 7 day week	Double shift, 5 day week	Double shift, 7 day week	Continuous working
General manufacturing	1.30	1.08	1.00	0.94	0.94
Factory - office	1.00	0.83	0.77	0.72	0.72
Light manufacturing	1.30	1.08	1.00	0.94	0.94
Storage & distribution	1.00	0.83	0.77	0.72	0.72

Single shift corresponds to an occupancy of about 10 hours per day.
Double shift corresponds to an occupancy of at least 15 hours per day.

APPENDIX 2

Energy Conversion Factors

The unit of energy used in this guide is the kilowatt - hour (kWh). One kilowatt - hour is consumed by a typical one bar electrical fire in one hour. For fuels which are metered in other units, multiply the metered value by the relevant conversion factor from the following table to obtain the value in kWh.

Figure A2.1 Conversion to kWh

	kWh conversion
Light Fuel Oil	11.2 kWh/litre
Medium Fuel Oil	11.3 kWh/litre
Heavy Fuel Oil	11.4 kWh/litre
Gas Oil (35 second)	10.8 kWh/litre
Kerosene - burning oil 22 second	10.4 kWh/litre
Electricity	[Metered directly in kWh]
Natural gas	29.31 kWh/therm
Liquid Petroleum Gas (LPG) (Propane)	6.96 kWh/litre
Coal (washed shingles)	7,900 kWh/tonne
Coal (washed smalls)	7,800 kWh/tonne

BEST PRACTICE PROGRAMME

Energy Efficiency Office

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