CTV032 Technology Overview

Building controls

Realising savings through the use of controls

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Contents

Reducing energy use makes perfect business sense; it saves money, enhances corporate reputation and helps everyone in the fight against climate change.

The Carbon Trust provides simple, effective advice to help businesses take action to reduce carbon emissions, and the simplest way to do this is to use energy more efficiently.

This technology overview introduces the main energy saving opportunities relating to building controls and demonstrates how simple actions save energy, cut costs and increase comfort for building occupants.

Introduction

Poor control of heating, ventilation, cooling and lighting is responsible for excessive energy consumption in many buildings. Having better control over working areas helps to produce a consistently comfortable environment for building occupants.

There is a range of different systems used to provide services to buildings throughout the UK and in most of these, the effective use of controls can provide substantial savings. This overview explores some of the main types of building controls and demonstrates the best energy saving opportunities available. It will also help in:

- Assessing the potential for energy savings in a building and indicating key areas for improvement
- Providing background knowledge and practical tips on using building controls as cost effectively as possible.

Significant energy savings can be achieved by most organisations in the UK by simply installing controls where they are not currently present and ensuring that they are set, operated and maintained correctly.

Who is this publication for?

This overview is aimed at managers who are responsible for improving the quality of the internal environment, focusing on reducing energy consumption through the use of effective building controls.

Building controls can be a complex and diverse topic area. The following pages introduce some generic energy saving tips and provide some specific advice under four key subject areas:

- Controlling by time, staff presence or conditions
- Specification and installation of controls
- Correct commissioning and operation
- Use of a Building Energy Management System (BMS or BEMS).

There are many opportunities that can be incorporated into an energy saving action plan. Remember: the more measures that are implemented, the more savings that can be achieved.

fact:

In premises with well-controlled systems, heating bills can be 15-35% lower than in poorly-controlled buildings.

Principles of good building control

Well-controlled building services provide the right conditions at the appropriate time.

Controls manage the operation of all types of building services, such as:

- Heating and hot water
- Ventilation (through the use of fans and ductwork)
- Cooling and air conditioning
- Lighting
- Windows and shading devices.

As well as the features and capabilities of the system itself, there are a number of basic factors that are within the control of those who operate it. These include where the hardware is located, how controls are set and when/how often they are checked. Getting this right can have a major impact on the performance of building services.

Why use building controls?

Good control is essential within a building to optimise levels of service, comfort and safety in an energy efficient manner. When installed correctly and when working properly, building controls have a range of benefits. They can:

- Minimise running costs, energy consumption and pollution associated with energy use
- Improve comfort for building users
- Prevent the unwanted or out-of-hours operation of equipment
- Limit excessive wear and tear on building systems and plant
- Minimise maintenance, repair and replacement costs
- Reduce the need for cooling by minimising the heat gains associated with the use of equipment such as lighting, fans and motors.

Three main types of control are featured in this overview:

Controlling by time – time controls vary in complexity from simple 24-hour on/off timers, to sophisticated seven-day timers, which allow for control to be set for individual days of the week. Upgrading existing time controls to enable services to be switched on and off to better match daily and weekly requirements can result in substantial savings.

Controlling by occupancy – building services can be altered to accommodate changing staff working times. For instance, intermittently occupied spaces will often have lights left on unnecessarily. These are areas that could be better served using controls that switch lights off when no one is around. Occupancy controls are generally used for quick response services like lighting and individual ventilation fans. They are rarely appropriate for slower response services like heating and cooling across a whole building.

Controlling by condition – building services can be controlled by environmental conditions such as temperature (for heating, cooling and ventilation systems), day-lighting (for lighting and shading systems), humidity (for ventilation systems and air conditioning systems), and even carbon dioxide levels (for ventilation systems).

Combining controls

These three types of control can be brought together in various combinations. For example, a restaurant may use daylight control to switch external lights on when darkness falls, a timer to switch these off at 1am when all customers and staff have gone home, and then incorporate occupancy sensing for security purposes to switch the lights back on if an intruder is detected. This integration of controls can fine-tune building services to provide optimum conditions and yield substantial cost savings.

In larger buildings with interacting services, controls are sometimes brought together in a Building Energy Management System (BMS or BEMS). This is discussed further on page 16.

facts:

– It is estimated that up to 90% of heating, ventilation and air conditioning building control systems are inadequate in some way, costing industry and commerce over £500 million per year in additional energy costs.

– Inadequate or incorrect application of a boiler control can easily add 15-30% to fuel consumption compared to a well-controlled system.

Basic control terminology

In its simplest form, a control system consists of three basic elements: a **sensor**, a **controller** and a **controlled device**. The sensor measures a variable, such as temperature, and transmits its value to the controller. The controller uses this value to compute an output signal, which is transmitted to the controlled device. When the signal is transmitted, the controlled device changes the output of the load.

In Figures 1 and 2, the controller is attempting to maintain room temperature at a set point. A low room temperature results in increased output from the heater, which then raises the room temperature. This increase is detected by the sensor and transmitted to the controller, which alters its output accordingly to reduce the difference between the set point and the measured value of the controlled variable.

Open and closed loop control

An **open loop** is a control system that does not respond to its own actions, such as a heating system controlled only by an on/off timer. Such a system will continue to heat the space until the timer switches it off again. This type of basic control can result in poor use of services, higher energy costs and an uncomfortable internal environment.

Closed loop control allows the control to receive feedback, such as the heating system demonstrated in Figure 2. Switching the heating on or off in response to temperature can prevent the space overheating and improve comfort conditions. Unless used with an on/off timer, however, these can also be wasteful if heating is on when it is not needed.

Figure 1 *The basic components of a simple control loop for heating*

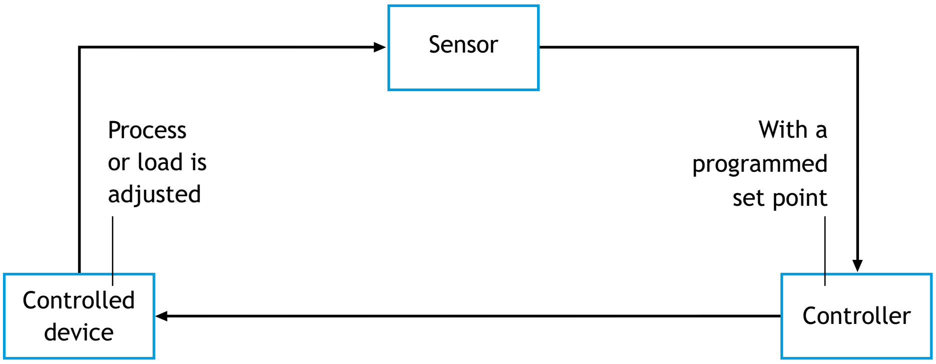
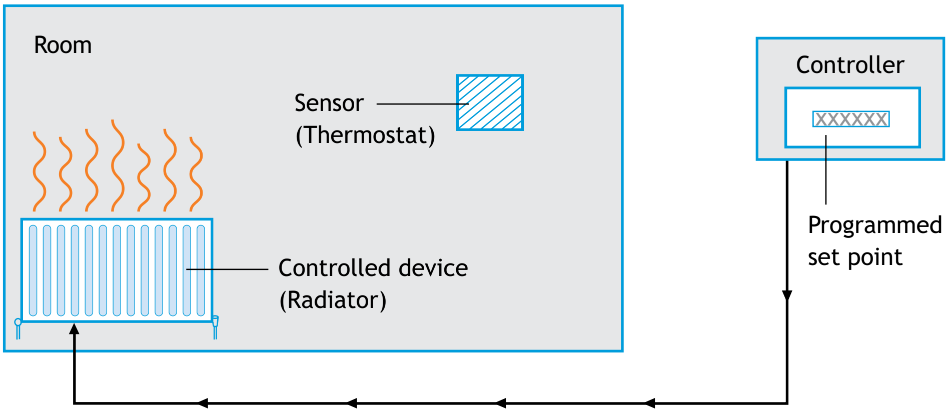


Figure 2 *Simple loop as applied to heating a room*



Most successful control strategies have an open loop element dictating whether the closed loop system should be enabled. For example:

- Setting the thermostat to only operate within occupied hours, using a timer
- Linking occupancy controls to timers to delay switch-off for a certain period after no movement is detected
- Combining daylight sensors with occupancy sensors on external security lights so that they do not come on unless it is dark.

Examples of more sophisticated closed loop control include:

Proportional control – this alters how the service responds in proportion to the needs of the space. For example, proportional control of a heating system will ensure a greater response when the internal temperature is well below the cut-off point. The response will reduce as the internal space moves towards the cut-off point, which in turn reduces the likelihood of the heating system overshooting control temperatures. Benefits include reduced energy consumption and costs, and fewer temperature fluctuations during the day, therefore improving comfort.

Proportional plus integral plus derivative (PID) control – proportional control can result in a system taking an excessively long time to reach the set point as response is reduced to prevent the system overshooting this. PID controllers ensure faster response times and minimal overshoot, but they are often only relevant in situations requiring close control of rapidly altering variables, for instance in some manufacturing or research activities.

> The cost benefits of controls should not be underestimated. Fitting a full set of controls to an older heating system which previously had none can save over 15% on energy bills.

Load control

Where a system has a fluctuating heating demand, it may be efficient to install load controls to the boilers. These are commonly used to control the loading of multiple boilers in order to reduce the need to fire all of them at times of low demand. Load control can also be applied to ventilation and cooling systems but these are less common. The main benefit of load control is that the system can run at the lower load most of the time but adapt when the requirement peaks.

Fixed priority strategy – this is the best strategy for installations that include CHP (Combined Heat and Power) or a condensing boiler. It will identify a priority for each heating load, allowing the system to drop the least important loads at times of higher demand than supply. For instance, this may mean that hot water provision takes priority over space heating (even if the thermostat is calling for heat) until the water requirements have been met.

Rotate strategy – this is the most common strategy for multiple boiler installations of similar output and efficiency, as it allows boilers to be rotated to match heating demand. Regular rotation of boilers extends their working life and ensures all are equally used.

Control algorithms

Complex control strategies will usually have a control algorithm that dictates how and in what circumstances the controls will operate. For example, in a typical air conditioning system, the following logic could be used, based on outside air temperature:

If outside air temperature is less than 10°C – system dampers allow minimum fresh air into the building. Heating is provided if the re-circulated air temperature drops below the heating threshold.

If outside air temperature is from 11-22°C – heating supply is reduced. As the building reaches a desirable temperature, the system dampers open to maximise free cooling using outside air. The system then only provides any additional cooling required.

If outside air temperature is more than 24°C – external air temperature is warmer than exhaust air. Dampers reset to minimum fresh air. The system then only needs to cool the minimum amount of warm fresh air.

Opportunities for energy saving

Controlling by time

Using timers to control building services can have a significant impact on energy used and on savings achieved.

Time switches

Time switches are simple controls that switch services on and off in response to programmed time settings. They are most appropriate for heating, ventilation and cooling systems but can also be used for lighting. There are a variety of time switches available – two common ones are:

24-hour timers – a simple 24-hour timer switches systems on and off at various set times. It can be beneficial for systems operating on a regular daily schedule, such as heating or lighting which come on and off at the same times each day. 24-hour timers are limited, so if there are varying patterns throughout, say, a week, consider more sophisticated controls, such as a seven-day timer.

Seven-day timers – these devices allow for the on/off function to be programmed to cover each day of the week. They are appropriate when requirements vary from day to day or throughout a week. A simple and common application would be for businesses which do not operate at the weekend and therefore have significantly reduced need for lighting and heating. These are relatively cheap and will often pay for themselves within a few months. Sophisticated time switches permit different settings for each day and control switching times to the nearest 10 minutes. It is best to fit these with a battery back-up to prevent the time programme being affected by short power cuts.

Automatic switch-off – in infrequently used spaces such as storerooms, controls can provide automated delayed switch-off times set at a pre-determined period. Switch on can be executed either by a manual switch or by automatic controls.

top tip:

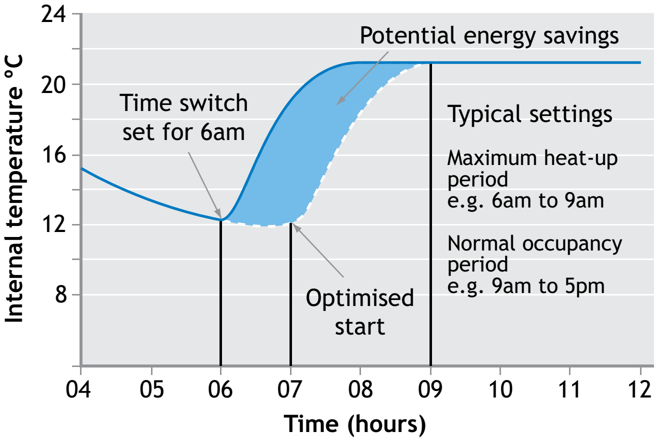
If time controls are used on heating or hot water services, it is important to ensure that they have adequate, but not excessive preheat times. This is so that a building reaches the right temperature and is equipped with sufficient hot water in time for when building occupants arrive – and not before.

Optimum time controls

An optimum start controller learns how quickly the building reaches the desired temperature and brings the heating on at just the right time to achieve the correct temperature as people arrive. Installing these controls typically results in heating switching on later on mild days, as shorter warm-up times are required.

Optimisers can provide a 10% efficiency improvement, even compared with a well-set seven-day time switch – see the diagram below. Savings are greatest in well-insulated buildings.

Figure 3 *Time switch compared with optimum time control – savings achieved*



Most optimisers vary the heating start time on the basis of both internal space and external temperature readings. Generally, they are also self-adaptive in that they 'learn' the way that the building responds to the outside temperature and heating plant. Simpler versions only take internal space temperature into account and are therefore less accurate.

In addition, optimum stop control is used to switch the heating off as early as possible without compromising comfort conditions. Other features such as day economy and frost protection can also be specified.

Ensure that actual building occupancy times are programmed in. Preheat information is not required as this will be learnt during operation.

Daytime optimisation

Daytime optimisation will switch heating off during a building occupancy period if the temperature is not predicted to fall significantly. For example, an optimised heating system would switch off, say, an hour before the end of the working day. The space will not feel overly cool while people are still in the building. Several internal sensors may be required, as a single sensor could give a reading inconsistent with the temperature elsewhere in the building.

Work-week and post holiday starts

If heating is switched off over holidays or weekends, an extended preheat period may be required for the first day back at work. This is because the internal temperature may drop below normal overnight temperatures and the building fabric (especially the walls) will have lost any residual heat from the previous occupied period. An optimiser would account for this, and if it is operating correctly, there should be no need for an extended preheat.

The current **Building Regulations** call for optimum start controls to be fitted to all boiler plant rated at over 50kW. Boiler ratings are usually displayed on the front of the boiler.

Boost or advance controls

Sometimes known as advance controls, boost controls are used almost exclusively in heating systems and are invaluable in providing additional service without the need to override existing time controls.

In normal heating and hot water circuits, the boost control will switch the hot water circuit on for a limited time period (usually one hour) outside its normal time control settings, allowing for the provision of additional hot water or space heating.

In electric storage heaters, boost controls allow a faster release of heat. The amount of heat stored in the heaters is fixed once the charge is complete, so the boost increases the speed at which this heat is released into a room. Once the heat is released, the unit will not warm up again until the timer switches it back on (usually overnight). Always return any adjusted controls to original settings before the unit charges again.

Advance controls allow a heating system to be switched on without overriding existing time settings. They will switch heating on immediately, but the heating system will then revert to the preset time, allowing the unit to automatically switch off again at the next scheduled switch-off time.

> Ensure time controls take account of unoccupied periods so that heating is not operating to occupancy levels when there is no one in the building.

Override facilities

Override facilities are present on most timer-based controls. Their use should be discouraged wherever possible to prevent services from being permanently left on. Ensure settings are reviewed every month or so to check that they are correct, and that short-term changes are always reversed when no longer required.

Questions to ask

- What time do staff generally arrive, and what time do they tend to leave?
- When do the cleaners come in, and when are they finished?
- What is the weekly pattern – is the building shut at weekends, or is there scheduled down-time?
- Do people leave the services (lights, heating etc) on when they leave the building?
- Are there different areas of the workspace which need services at different times or in different patterns, for example, toilets, meeting rooms, work areas?
- Would the workspace benefit from investing in optimum time control, or are simpler controls sufficient?
- Are there unusual occupancy patterns which need enhanced control, such as boost control or override facilities?

Controlling by occupancy

Occupancy sensors can help to ensure that building services only operate when there is somebody present.

These types of controls are mainly used in lighting systems, though they can also be used for fast-response extract fan systems in bathroom areas. Heating and cooling systems tend to be too slow in their response to be effectively controlled by occupancy sensors.

Occupancy control can:

- Prevent unwanted operation or control systems out-of-hours
- Improve personal safety (for example, provision of security lighting in car parking areas) and help meet health and safety requirements (for example, extract air provision in bathrooms)
- Extend the life of services and reduce maintenance, repair and replacement costs.

There are four types of sensing technology available and these can be adjusted to increase or reduce sensitivity to suit a particular application:

Passive infrared (PIR) sensors are the cheapest and most common sensors and can only 'see' in an unobstructed, direct line of sight. They work by splitting their field of vision into segments and responding to infrared radiation (such as body heat) being detected in a new area. PIR sensors are appropriate in areas with little or no obstructions, such as in small offices and conference rooms. Figure 4 shows how these cover an area.

Ultrasonic sensors emit and receive high frequency sound waves. Any changes in the pattern of sound waves received by the sensor triggers a response, for example, lights being switched on. These devices can pick up smaller degrees of motion and can detect movement outside their line of sight, but can be more expensive than PIR sensors.

Ultrasonic sensors as shown in Figure 5, are suitable in larger areas such as open plan offices, conference rooms, bathrooms and unusually shaped spaces. However, their sensitivity can lead to 'false' readings from heating, ventilation and cooling-related air currents, and some obstructions can interfere with their accuracy. Take care that sensors' fields do not overlap.

***Figure 4** Infrared sensor pattern*

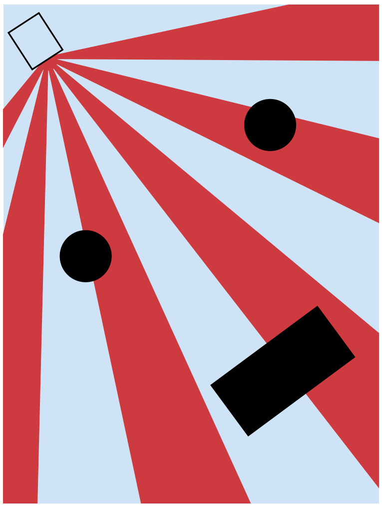
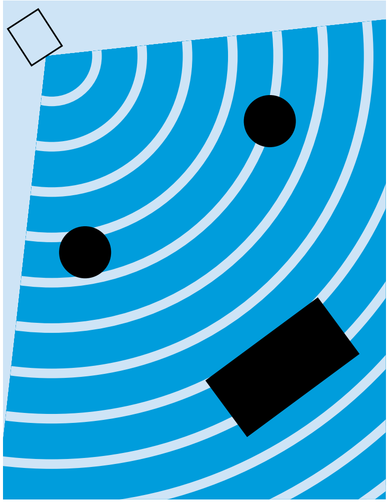


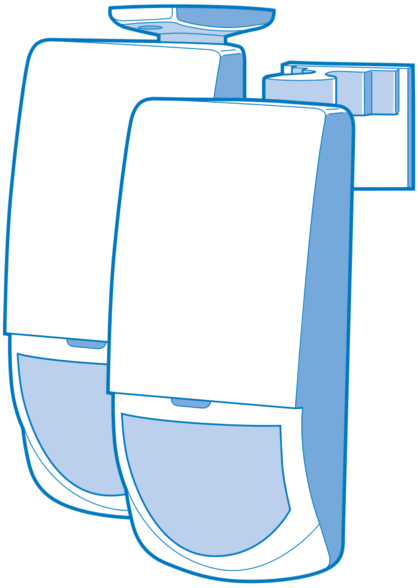
***Figure 5** Ultrasonic sensor pattern*



Microwave sensors generate and receive microwaves and operate by sensing changes in reflective frequency. Microwave sensors are very sensitive and can provide good directional and spatial coverage. They are commonly used for automatic door control.

Audio sensors contain a microphone that picks up sound. They are fairly inexpensive, are unaffected by obstructions and do not rely on movement to be activated. Their main problem is that they cannot differentiate between internal and external noise and will interpret, for example, a ringing phone as a sign of occupation. Therefore, areas with no other sound interruptions (such as telephones or alarms) are the only suitable areas for this type of sensor.

__Figure 6__ Combined PIR and microwave sensor



Combined or hybrid sensors

Greater accuracy and improved response can be obtained by combining some of the above technologies into one sensor. It is possible to purchase combined PIR and microwave or PIR and ultrasonic controls. However, this can increase purchase costs making them less viable for smaller spaces.

It is also possible to purchase hybrid occupancy/condition sensors, for example, PIR sensors with daylight detection to ensure lights only come on if it is dark and movement is detected. These controls are useful for intermittently occupied areas such as meeting rooms, storerooms and bathrooms.

User interactive control systems

These provide individual, local control of building systems, particularly lighting levels and shading devices. Control is usually provided to the user though an electronic system, for example, through PCs or telephones.

The main benefits in using interactive control systems for lighting and shading are:

- The user feels in control of their environment
- Telephone and PC-based systems can enable individual desk control
- Considerable energy savings are achievable with unpredictable occupancy levels.

Occupant information and training

The way occupants use controls depends on their understanding of how they work and whether they believe the controls help to enhance their environment. Controls which dictate to occupants are likely to be overridden or bypassed which negates any savings.

To reduce the possibility of this occurring, it is important that staff understand how controls function in their work area, so that they have full control of their environment. A basic action is to label controls with the preferred settings, so users can return them to their correct settings if they have been adjusted.

Questions to ask

- Where are workers located at different times of the day? Consider meeting rooms, individual offices, toilets and canteen areas, for example
- Are services needed at all times for each of these spaces, or could control be provided that allows them to be turned off or down when they are not needed?
- Does the floor arrangement (say, plant in a factory or furniture in an open-plan office) suggest opportunities for turning off services, such as banks of lights? If not, could the workspace be altered and/or controls be introduced, to achieve savings?
- Where could occupancy sensors be sited? Will these be practical for staff and the kind of work they do?
- Could staff take responsibility for their own conditions? What training would they need?

DID YOU KNOW?

Whilst heating and cooling for individual work spaces is possible, it can be expensive to operate, install and maintain. This is due to the increased likelihood of heating and cooling working against each other in adjacent spaces and the need for individual mixing of hot and cold air at each workstation.

CASE STUDY

The Environmental Building, BRE

Staff have full control of the space temperature, ventilation, shading and lighting in their office bay through a user interactive control system. Each person attends a training session on how to use the controls and is also given a mouse mat that features a synopsis of the training session, reminding them how to control their local environment.

Image courtesy of BRE.

Controlling by condition

Energy savings and improved occupant comfort can be achieved through monitoring and adjusting building services in response to internal conditions.

The conditions that are usually controlled are:

- Temperature – used to control heating, cooling and ventilation
- Daylight levels – used to control lighting
- Humidity – used mainly to control air conditioning
- Carbon dioxide levels – used mainly to control ventilation.

Control by temperature

Room thermostats positioned in an appropriate location can provide overall temperature control of an area so that it reflects the activity taking place in the space. Thermostatic controls should not be used as on/off switches. Turning to maximum does not speed up the heating process; it just results in an overheated space. See the box below for further information.

MYTH – Turning the heating or cooling temperature setting to maximum or minimum speeds up system response times, allowing the space to get to the right temperature more quickly.

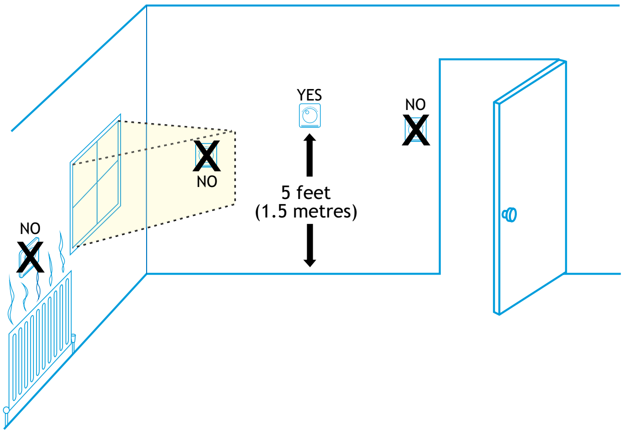
REALITY – Temperatures change at the same rate but then overshoot, causing the space to be too cold or too hot. If controls are not coordinated, the temperatures could vary enough for both heating and cooling to be operating at the same time, creating uncomfortable conditions and wasting energy.

REMEDY – Set thermostats correctly, based on the desired temperature and educate staff to dispel this myth. As a last resort, protect thermostats to prevent tampering, where possible.

In a radiator-based heating system, **thermostatic radiator valves** (TRVs) give greater control. A TRV is a simple control valve with an air temperature sensor, used to control the heat output from a radiator by adjusting water flow. Correctly fitted and operated, TRVs can provide efficient control. In a large room with several radiators and a variety of activities and heat gains, control of individual radiators can provide the correct level of localised heating. Fit these controls in the right place for maximum benefit.

Thermostats and sensors should not be influenced by draughts or heat sources such as sunlight, radiators or office equipment. These factors create a false local temperature and may result in heating systems over or under-heating a building. Ideally, thermostats should be placed in a north facing room, approximately halfway up the wall if possible. This helps to provide a more representative temperature.

Figure 7 *Correct thermostat placement*



Compensation controls

Reducing temperatures in heating systems during milder weather can reduce costs and improve occupant comfort. This is done with the installation of weather compensation controls which measure the external temperature and adjust the circulating temperature accordingly.

For more information on compensators and other controls. See the *Heating control* technology guide (CTG002), available from the Carbon Trust.

Controlling by daylight level

Light sensors or 'photocells' are most commonly used to control artificial lighting when there is sufficient natural daylight. As daylight hours vary throughout the year, sensors help to provide closer control and can achieve substantial savings. Where high-frequency fluorescent lighting is installed, these controls can dim the light output when daylight is adequate. Photocell controls are also useful for external lighting and can often pay back their costs in less than a year.

Photocell control can be combined with occupancy control systems to reduce light output when day-lighting levels are adequate, and switch lighting off when the space is unoccupied.

Figure 8 *Occupancy control and daylight sensing technology can provide substantial savings*

Control by humidity

Humidity control is specific to certain applications and is achieved through 'humidistat' control of heating, ventilation or cooling services. The main areas where humidity control may be required are listed below.

Swimming pools – humidistat control can be effectively used in pool hall areas to maintain appropriate levels of humidity and prevent condensation forming. This type of control can be used to reduce pool hall costs by switching on ventilation only when required.

Fabric protection – some buildings, particularly older structures, can be affected by damp which often leads to a deterioration in the building fabric. Conditions can be improved in the affected areas using dehumidifiers controlled by humidistats.

Museums and galleries – stored artefacts can also deteriorate if they are not kept under optimum conditions. Dehumidifiers controlled by humidistats are often used to ensure adequate conditions for storage.

Manufacturing processes – the method for controlling humidity in manufacturing processes is usually dictated by the process requirements. Humidity control is used for some specific applications, including meeting health and safety requirements and providing a better quality of product or improved output.

fact:

Making use of daylight can reduce lighting costs by 19% in a typical office. In conjunction with staff action, the use of automatic controls can ensure these savings are achieved.

Control by carbon dioxide levels

Ventilation speeds can be regulated to meet requirements based on the levels of carbon dioxide in the air, which can be used to measure air quality. In buildings with variable occupancy patterns, an increase in the number of people occupying a space will lead to higher concentrations of carbon dioxide. Connecting carbon dioxide sensors to variable speed ventilation fans results in airflow dropping when there is less demand for fresh air. Lowering ventilation rates saves energy in two ways: first by reducing the ventilation fan speed; second through lowering heating/cooling requirements as less heated (or cooled) air is lost and therefore less needs to be replaced.

Variable control

Fans, motors and pumps rarely need to operate at full speed all of the time. Variable control can help to reduce costs by enabling the output speed of this equipment to match requirements at different times of the day, or at different stages of a process. This reduction in speed saves energy and there are corresponding heating and cooling cost savings too. More information can be found in the *Motors and drives* technology overview (CTV016).

Control by zoning

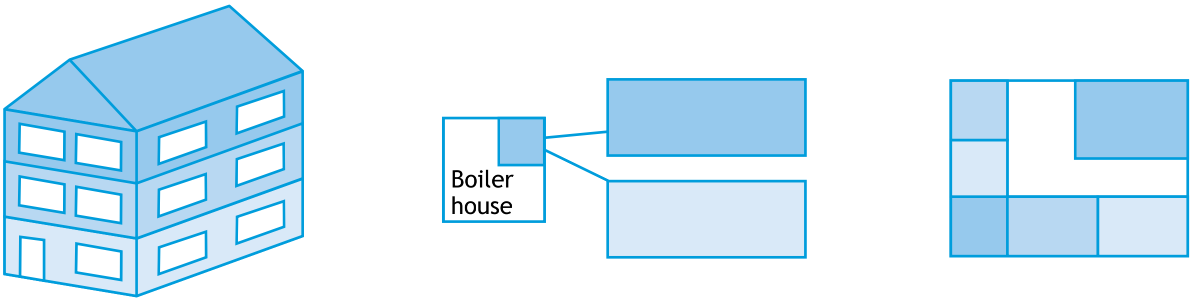
Some areas in large buildings require different levels of heating, lighting, cooling and ventilation. A solution to this is to create 'zones' in the building where separate time, temperature and occupancy controls are installed for individual areas. Zoned areas will provide closer, more efficient control. This can improve local conditions and save on costs.

Zoning should be considered when there are:

- Different occupancy patterns
- Different temperature requirements
- Different activities taking place
- A number of floors (particularly where top floors are poorly insulated).

Although zoning can involve a capital investment, costs can be recouped over time through energy savings. However, the most obvious improvement is increased staff comfort and productivity as local temperatures are able to be better controlled by the occupants.

Figure 9 *Efficient control through zoning*



Multi-storey buildings can be zoned floor by floor

Multiple buildings served by the same boiler house can be zoned separately

Multi-tenanted buildings provide an ideal opportunity to zone on the basis of tenants requirements

For more information on variable speed drives see the technology guide on *Motors and drives* (CTV016), available from the Carbon Trust (details can be found inside the back cover).

Interlocking controls

An interlocking control switches off building services when triggered and can be used to minimise the risk of two systems operating in competition. It is also possible to install interlocking controls to prevent heating or cooling systems operating if any external doors or windows in the controlled space are open. Simple interlock controls are relatively cheap to install and can be effective in achieving energy savings.

top tip:

Select and set automatic controls carefully. Where control systems are obtrusive, counter-productive or set poorly, staff will be tempted to tamper with them. Usually, the best way to minimise these problems is to ensure that building services are delivered satisfactorily, and to train staff in using the control system effectively.

> Enhanced Capital Allowances are available for certain heating control zoning technology on the Energy Technology list. Contact the Carbon Trust for more information.

Questions to ask

- Do workers complain about their space being too hot or too cold? Is it too dim, or is there any excessive glare?
- What conditions need to be controlled? Look at temperature, light, humidity, fresh air, pollution, carbon dioxide levels
- What factors affect the conditions? These might include heat gains or losses, changing light coming in from windows, varying staff occupancy through the working day
- What can be changed without having to invest in controls? For example, fix damp or gaps in the building fabric, train staff to use the blinds appropriately or investigate current functioning of ventilation systems to ensure optimum performance?
- What extra controls need to be installed to make savings and improve the workspace?
- Are there any health and safety regulations that need to be considered, especially regarding the provision of fresh air and light?

Figure 10 *Consider the effects of daylight when designing lighting in an open-plan office*

Building Energy Management Systems

Many of the controls and functions described within this guide can be integrated into a single Building Energy Management System (BEMS or BMS). A BEMS offers closer control and monitoring of building services performance, including heating, cooling, ventilation and lighting, showing data on a computer screen in real time. This allows settings to be changed quickly and easily. This is particularly relevant for larger buildings with an energy bill in excess of £10,000, and is likely to offer an appropriate and cost-effective solution.

BEMS basics

A BEMS is a computer-based system which provides the facility to control any building service. Intelligent controllers, or 'outstations' monitor conditions throughout the building and determine the operation of boilers, pumps, fans, motors and lighting in response to changing conditions such as time, temperature and light levels.

A system can begin with a single controller. As other controllers are added, these can be linked using a simple communication network, and a PC can be connected to this network to observe their performance and adjust settings. With recent advances in technology, access to various networks at remote geographic locations can be achieved through the use of modems, IT networks and the internet. Many systems now make use of computer interfaces and so, many aspects of their operation are intuitive to users who are familiar with web-based software.

Advantages of a BEMS

The main advantage of a BEMS installation is the ease with which users can review the performance of controls and conveniently make adjustments.

Other advantages include:

- Close control of environmental conditions, providing more comfort for building occupants
- Energy saving control functions which will reduce energy bills
- Ability to log and archive data for energy management purposes
- Provision of rapid information on plant status
- Automatic generation of alarms to warn appropriate personnel of equipment failure or condition changes
- Identification of both planned and reactive maintenance requirements (for example, systems can record the number of hours that motors have run, or identify filters on air supply systems which have become blocked)
- Ease of expansion.

fact:

Used correctly, a BEMS can reduce total energy costs by 10% and increase comfort.

Components of BEMS

BEMS consist of:

- Hardware, such as sensors, actuators and controllers
- Software, including programs set up to deliver the control strategy
- A network or networks, as well as interfaces with other systems, such as the operator's PC, fire alarms and security systems.

Sensors

These provide information to the BEMS on their surroundings. There are three principal types:

Digital inputs – to show, for example, whether a boiler is on or off, or if a pump is running or stopped. These can monitor the condition of any device which has two possible states.

Analogue inputs – these provide information of variables such as temperature, humidity, light levels etc, which have values associated with them.

Pulse inputs – these act as counters, usually providing information on consumption through interfaces with meters and similar devices.

Actuators

These are the action element of the system and fall into two categories:

Digital outputs – control devices with two states, for example, to switch equipment on or off.

Analogue outputs – adjust devices to a specific position, for example, valve/damper control, variable speed drives and dimmers for lighting.

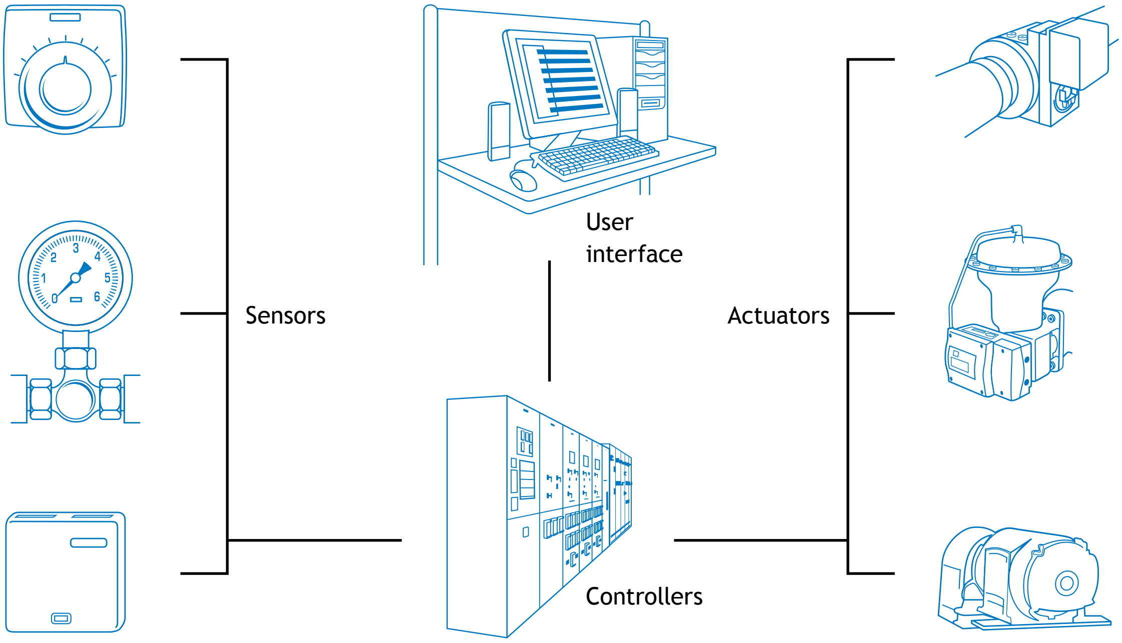
Controllers

The basic building blocks of a BEMS are the controllers (or outstations). The capacity of a BEMS can be increased by adding additional controllers to the network. These include:

- Internal clocks and microprocessors which contain the control and network communication software, but are capable of operating as a stand-alone device
- Integral power supplies
- Interfaces to sensors and actuators – collectively known as 'points'.

Most standard controllers are capable of operating independently of the BEMS network and, as such, are quite similar to other stand-alone controllers in terms of complexity and hardware requirements. The operation of these controllers can be simplified by connecting them to the BEMS network which can also enhance their capabilities. In addition, it also provides an opportunity to make information on their performance widely available.

Figure 11 *Basic BEMS arrangement*



BEMS and energy efficiency

Most of the energy efficiency opportunities available through BEMS can be achieved by adhering to five simple key principles:

- Only supply building services where there is a demand
- React to external temperatures and light levels (where appropriate) by adjusting internal settings
- Never operate heating and cooling in the same place at the same time
- Control separate zones with different needs independently
- Provide necessary heating or cooling with minimal boiler or chiller capacity.

A BEMS is only as good as the people who use it. Therefore, it is essential that any staff who will be operating and maintaining the system are trained appropriately. All reputable BEMS suppliers encourage training as it is in their interest that the system works well. If installing a new BEMS, involve key staff at the beginning of the project, ensure that they are aware of what the system can do and how to keep it performing efficiently.

> A BEMS is only as good as the people who use it.

! Safety first

The BEMS should never be programmed to override any basic safety or security considerations.

Routine operation

All staff with access to the BEMS should develop experience in managing the building using it on a routine basis. Most BEMS have alarms set and staff should know what to do when these alarms sound.

Maintenance requirements

To optimise internal conditions and make ongoing savings, BEMS need to be regularly maintained. Review BEMS at least every month and check that settings match building use. When inspecting the system, focus on the points set out below.

General – check the integrity of any cabling and connections and any cabinets or panels in the installation.

Sensors – test accuracy and review the suitability of their locations.

Actuators – examine control outputs and ensure that controlled devices are working over their full operating range.

Digital inputs – confirm that inputs are operational and working correctly. Calibrate or adjust switching devices if necessary.

Controllers – verify that break-up battery supplies are adequate and that controllers automatically restart following interruption to power supplies.

Record keeping – document key changes to the BEMS, including any alterations to set points and control strategies, software upgrades, additions to the network, any faults identified or maintenance performed.

Questions to ask

- Do you have a significant energy bill, and control over your premises, which would justify the outlay on a BEMS?
- Do you have the resources – in terms of staff time and expertise – to properly run and maintain the system?
- Would staff benefit from integrated controls? Would you save on your energy bill overall?
- What else could be done with the energy data the BEMS gives you? Might this be useful?

Specification and installation

Controls must be specified and installed correctly if the expected savings are to be realised.

It is important to match the type and complexity of control to the requirement of the building systems and the abilities of the individuals who will operate them. Over-specified or excessively complex control systems can be expensive to implement and maintain. Above all, they may not provide the desired control nor make the planned savings. In many instances, relatively simple stand-alone controls can be the most appropriate.

Where systems require more complex control, a Building Energy Management System (BEMS) is often preferable to allow the performance of plant to be monitored and settings to be changed quickly and easily.

Typical specifications for building systems – points to consider

Heating and hot water

- Basic systems should have time switch controls while more sophisticated systems benefit from optimisers
- The current building regulations call for optimum start controls to be fitted to all boiler plant rated at over 50kW
- Even on small systems, temperature control should be provided using room thermostats. Large buildings may use several thermostats, each one controlling a separate zone. In addition, thermostatic radiator valves (TRVs) for local control should be considered
- In new systems, incorporate weather compensation controls to comply with building regulations
- Hot water systems should be time and temperature-controlled, and capable of holding the water temperature to within 2.5°C of the set point temperature
- Time controls switch off boilers and any circulating pumps during periods when hot water is not needed.

Ventilation and cooling

- Ventilation and cooling systems should incorporate some form of time and temperature control. For larger sites, consider including optimum start and stop controls
- Depending on the type of cooling or ventilation system, temperature sensors may be room or duct-mounted. These sensors are usually used to control heating and/or cooling coils to regulate the supply temperature to the space
- With large systems, control must be designed so that the effect of control on one zone does not affect another zone or system, for example, simultaneous heating and cooling
- Minimum fresh air quantity is normally controlled via the supply, re-circulation and extract ductwork dampers in relation to air quality. In full fresh air systems the air volume can be controlled in relation to air quality via variable speed controls.

! Safety considerations

Always seek specialist help before investing in upgrading existing controls to ensure predicted savings are achievable.

Safety controls should override all other functions and can be applied to individual items of equipment, such as the high limit thermostat on a boiler, or to multiple plant items, such as the panic button in a boiler house to shut down all plant and fuel supplies.

System design, commissioning, operational and maintenance procedures must comply with all relevant safety legislation and codes.

Lighting

- Lighting controls can be manual or automatic, or a combination of automatic with a manual override
- Savings can be achieved with a manual switch combined with a presence-operated switch to turn lighting off. This is sometimes referred to as 'absence sensing'
- Time switching is simple and effective
- Manual lighting controls should be labelled clearly and organised in definable zones
- Occupancy sensing is especially valuable for infrequently used spaces
- Photoelectric control maximises energy from daylight by dimming and switching off lights
- Time switching can provide simple, effective control
- Investigate incorporating a lighting energy management system within a building management system.

When refurbishing or replacing controls, check eligibility for an interest-free loan from the Carbon Trust to cover the costs of purchasing and installing equipment. Also, as part of the Carbon Trust Enhanced Capital Allowances (ECA) scheme, an Energy Technology List has been produced. The list details all energy saving technologies and products that qualify for the ECA scheme and should be used as a guide when purchasing new controls.

For more information, see the loans and ECA boxes below.

Energy-Efficiency Loans

Small or medium-sized enterprises (SMEs) in England or Scotland and all businesses in Wales that have been trading for at least 12 months could borrow* from £5,000 to £100,000. Loans are unsecured, interest-free and repayable over a period of up to four years. There are no arrangement fees and applying is straightforward.

All businesses in Northern Ireland* that have been trading for at least 12 months may be eligible for an unsecured, interest-free loan of up to £200,000.

*Subject to eligibility. Regional variations apply.

Top tips for good sensor location

Outside air temperature sensors used for frost protection and weather compensation should be located on the north face of the building out of direct sunlight, away from sources of heat such as opening windows, vents, fans and flues.

External temperature sensors that are used for the control of building services should not be installed in a location that may leave them exposed to direct contact with the wind. This could lead to false readings from the sensors which may result in higher energy use and uncomfortable temperatures.

Room temperature sensors and thermostats should be located on a wall or column, around 1.5m above the finished floor level, away from heat sources and out of direct sunlight. For radiant heating, use a **black bulb sensor** placed in direct line of sight of the heat source but far enough away to prevent any non-radiant heat produced from affecting it.

Internal daylight sensors should be placed within the same line as the lights they control.

Internal light switches should be located in the room of the lights they control, or clearly labelled, where just outside the area. Switches should be no more than 8m away from the lights they are controlling.

Tax incentives

Enhanced Capital Allowances (ECAs) enable businesses to buy energy-efficient equipment using a 100% rate of tax allowance in the year of purchase. Businesses can claim this allowance on the investment value of energy efficient equipment, if it is on the Energy Technology List. The procedure for claiming an ECA is the same as for any other capital allowance. For further information please visit www.eca.gov.uk/energy or call the Carbon Trust on 0800 085 2005.

Commissioning and operation

In most situations, it is advisable to leave the commissioning of controls to a qualified technician.

Commissioning refers to the 'advancement of systems to a working order'. For each system it includes:

- Setting up and getting the system to work
- Regulation to achieve the specified performance
- The calibration, setting up and testing of the associated automatic control systems
- A record of the system settings and performance test results that have been accepted as satisfactory.

At the end of the commissioning process, an inspection report should be provided which indicates:

- Confirmation that the specified and approved provision of building services systems have been put in place
- A commissioning plan showing that every system has been inspected and commissioned in an appropriate sequence
- Results of tests that confirm the performance is in line with expectations.

Building log books

Building Regulations require that new buildings are handed over with a log book containing details of the building services and controls installed, their method of operation and maintenance, and other details that enable energy consumption to be monitored and controlled. The information should be provided in summary form, suitable for day-to-day use. Suggested contents are:

- A description of the whole building and its services
- A schedule of accommodation and services
- The location of plant, including schematics and details of the installed capacities
- Descriptions of the control strategies for the energy consuming services in the building
- A copy of the commissioning report and operating and maintenance instructions
- A schedule of meters and sub-meters and the measured air permeability of the building
- For systems serving areas greater than 200 m^2, a design assessment of carbon emissions.

Ongoing operation of controls

When new controls have been installed, ensure that the contractor or supplier clearly explains how to set and use the new system. Keep a record of control settings and display these near to the controls themselves so that they can be returned to their optimum settings if temporarily adjusted.

Carry out regular good housekeeping walk rounds to check that controls are working properly. Carry out these checks on controls:

- Check control set points are correct and have not been inaccurately adjusted
- Check all controls are clean and clear of obstructions
- Check controls are operating as expected.

It can be helpful to keep a record of results when carrying out control checks. This might include:

- Where the set point controls were found at
- The default set point at the time of commissioning
- The 'condition' of the space the device controls, such as the temperature
- Any comments or concerns raised by staff in these areas.

This will help to identify patterns of control use or misuse and should highlight any issues which may need to be addressed.

top tip:

Maintain controls: Energy consumption can increase by more than 50% if regular maintenance is not undertaken.

Action checklist

Date of inspection:	Check all areas within the building and make a note of items that need attention	
Action	**Checked**	**Comments**
Heating and hot water		
Check for complaints about comfort conditions and report any over/under heating issues		
Check that heating controls/room thermostats are correctly set		
Check timer clocks and settings on programmable heating controls and ensure they are correct		
Measure space and water temperatures, and document against a schedule of preferred conditions		
Lighting		
Check that lights are switched off if there is sufficient daylight		
Ensure that lights are switched off when rooms are unoccupied		
Check that external lighting is off during the day, that daylight sensors are in good condition and timers are correctly set		
Check that lighting time switches are correctly set		
Ventilation and air conditioning		
Ensure air conditioning is switched off when not required		
Check that cooling is switching on only when required to meet comfort conditions		
Check that ventilation fans are only on when required		
Ensure that heating and cooling are not operating at the same time		
Other equipment		
Ensure variable control of pumps, fans and motors is set and working correctly		
Ensure that vending machines are switched off when not required, using simple timer controls		

Contact the Carbon Trust for further guidance and support on improving energy use.

Glossary

Actuators	A device which is part of a building control system that responds to the sensors and adjusts conditions accordingly. See also controllers.
Analogue device	Gathers information of variables (for example, damper position, lighting level) that have a wide potential range of possible values.
Boiler sequence control	A control or switching of two or more heating boilers in order to achieve the desired heating temperature. This helps to maximise boiler efficiency.
Building Energy Management System (BEMS or BMS)	A computer-based system that provides the facility to control any or all building services.
Building log book	A document that contains a full description of a building and the services and systems within it.
Building services	Any electrical (such as lighting) or mechanical (such as heating) system in a building that has an influence on its environment or in providing controlled conditions for occupants.
Commissioning	The process of testing, checking or calibrating the function of any building services component, to advance it to a working order.
Compensator	A form of control for heating systems that automatically regulates the building temperature based on weather conditions.
Controllers	Devices that control building services components through actuators in response to sensors.
Daylight sensing	Controls that monitor levels of daylight and switch electric lights on and off, or variable control (dimming) in response to the measured daylight level.
Digital device	Gathers information of variables that have two possible conditions (for example, is a boiler on or off or is a pump running or stopped).
Interlocking controls	Controls that prevent two or more systems operating at the same time. An example of this would be a controller that would disable boiler operation following a fire alarm signal being activated.
Occupancy sensor	A device which detects whether people are present or absent from the space.
Optimum start (or an Optimiser)	A controller that adjusts the time the heating comes on to ensure that the set temperature is reached at the start of the programmed occupancy period.
Passive Infrared (PIR)	A sensor that detects and reacts to a change in the location of heat (infrared), often used to control electric lighting or security.
Photocell	A sensor that reacts to the levels of daylight it senses, often used to control electric lighting — see daylight sensing.
Sensors	Devices that provide data on their surroundings to a central control system. See also controllers and actuators.
Thermostat	A device that automatically controls the operation of heating or cooling equipment by responding to changes in space temperature.
Thermostatic radiator valve (TRV)	A device that alters the amount of hot water entering a radiator and so can allow finer control over the temperature of a space.
Variable speed control	Adjusts the speed of a fan, motor or pump to better match its speed to the load or demand. Reducing the speeds of these devices will also reduce their energy use.
Zoning	Allows different areas in a building with differing temperature, time or lighting requirements to be controlled separately with individual control systems.

Next steps

There are many easy low and no-cost options to help save money and improve the energy performance of a building through correct use of building controls:

Step 1. Understand your energy use

Look at your building and identify the major areas of energy consumption. Check the condition and operation of the controls and monitor the power consumption over one week to obtain a base figure against which energy improvements can be measured.

Step 2. Identify opportunities

Walk round and complete an action checklist at different times of day to identify where control-related savings can be made. The checklist given in this guide (on page 22) is a good starting point.

Step 3. Prioritise actions

Draw up an action plan detailing a schedule of improvements that need to be made and when, nominating the person who will be responsible for them.

Step 4. Seek specialist help

It may be possible to implement some control-related energy saving measures in-house but many will require specialist help. Discuss the more complex or expensive options with a qualified technician.

Step 5. Make the changes then measure the savings

Implement energy saving actions and measure against original consumption figures. This will assist future management decisions regarding energy priorities.

Step 6. Continue managing the business for energy efficiency

Enforce policies, systems and procedures to ensure that your organisation operates efficiently and that savings are maintained in the future.

Related publications

The following publications are available from the Carbon Trust:

Technology overviews
Heating, ventilation and air conditioning (CTV003)
Lighting (CTV021)

Technology guides
Air conditioning (CTG005)
Heating control (CTG002)

For further information...

call the Carbon Trust on 0800 085 2005

You'll find free advice on what your organisation can do to save energy and save money. Our team handles questions ranging from straightforward requests for information to in-depth technical queries about particular technologies and deals with all kinds of energy saving topics for people at all levels of experience.

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The Carbon Trust is a private company set up by Government in response to the threat of climate change, to accelerate the move to a low carbon economy.

The Carbon Trust works with UK business and the public sector to create practical business-focused solutions through its external work in five complementary areas: Insights, Solutions, Innovations, Enterprises and Investments. Together these help to explain, deliver, develop, create and finance low carbon enterprise.

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Making business sense
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