CARBON TRUST

Air conditioning

Maximising comfort, minimising energy consumption

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Preface

Reducing energy 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 for lighting and demonstrates how simple actions can save energy, cut costs, improve conditions and increase profit margins.

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Introduction

Around 40% of commercial floor space is expected to be air-conditioned by 2020, compared with only 10% at the end of 1994.

The demand for air conditioning[1] in UK buildings is growing rapidly in response to more intensive building use, increased demands for comfort by occupants, business and market pressures and the expectation of a warmer climate. Around 40% of commercial floor space is expected to be air-conditioned by 2020, compared with only 10% at the end of 1994.

This continual growth in the use of air conditioning, along with a corresponding increase in electricity consumption and power station carbon dioxide emissions is at odds with the Government's energy goals. These include reducing emissions of carbon dioxide the main contributor to global warming – by some 60% by 2050. Energy efficiency measures are expected to deliver half of the necessary improvements.

Furthermore, a new EU directive, known as the Energy Performance of Buildings Directive (EPBD), came into force in January 2006 which is designed to increase investment in energy efficiency measures. This has influenced the recent UK building regulations amendments which deal specifically with ventilation and the conservation of fuel and power but provide challenging targets to meet in terms of overall energy performance of new and refurbished buildings.

Meeting the requirements of the new regulations is just one reason to examine the use of air conditioning. Keeping down energy costs, ensuring adequate comfort and considering the carbon footprint of a business are all factors to take into account.

Although demand for air conditioning is high, there are increasing opportunities to exploit 'free cooling' and for adopting simpler and more cost-effective technology. Building operators and those who are involved in purchasing should be aware of these opportunities and understand the options available to them before investing in air conditioning systems.

Who is this publication for?

This guide will help energy managers or facilities managers to:

- Understand the process that should be undertaken in the early stages of design when it may be possible to minimise or avoid the need for air conditioning
- Review the best choice of air conditioning systems and highlight opportunities for energy savings.

Did you know?

Comfort cooling is very expensive. In the UK, there are relatively few days per year where the temperature is very high (over 28°C). Using comfort cooling for just this short time can cost as much as a whole year's heating.

[1] The true definition of an 'air conditioning system' is one which has the ability to control temperature, humidity and air quality, yet the term is often applied to systems which only provide cooling. These cool air systems are more correctly referred to as 'comfort cooling'. This guide will use the general term 'air conditioning' to refer to both types of system.

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Energy consumption

The energy consumed by air conditioning systems in commercial buildings is expected to double from current levels by 2020. In a typical office, air conditioning can account for over 30% of annual electricity consumption.

Recent years have seen a shift in energy consumption patterns in the UK. In the past, energy consumption was significantly greater in winter due to heating demand. However, the summer demand has been growing dramatically which is primarily due to the increased use of air conditioning. As air conditioning uses electricity, which is responsible for higher CO_2 emissions than the equivalent amount of fossil fuel energy, its impact on the carbon footprint of a building can be significant.

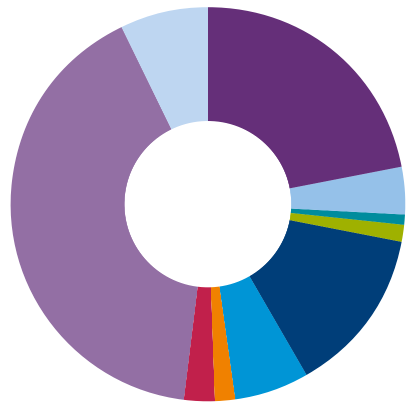
Changes in climate will affect energy use in buildings. Average annual temperatures in the UK are predicted to increase by a few degrees over this century particularly in the south-east of England. Naturally ventilated buildings are likely to overheat more frequently in extreme conditions and air conditioning systems may fail more regularly. It is probable that full air conditioning will be demanded in more buildings to control summer temperatures and humidity, leading to an increase in energy usage.

It is imperative that designs for future buildings and major refurbishments account for a changing climate to ensure that buildings can provide comfortable and healthy internal environments over their lifetime, whilst minimising energy use and greenhouse gas emissions.

Did you know?

The energy costs and associated CO_2 emissions of a typical air-conditioned building are 30% higher than a naturally ventilated building. It is also more likely to have increased capital and maintenance costs.

Figure 1 Air conditioning energy use by UK sector



- Commercial office 22%
- Communication and transport 4%
- Further and higher education <1%
- Government estate 1%
- Hospitality 1%
- Leisure 6%
- Other government <2%
- Other service sector 2%
- Retail 41%
- Warehouses 7%

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Air conditioning energy use

There are a number of important factors that determine the energy use of an air conditioning system:

- The design, layout and operation of the building – this affects how the external environment impacts on internal temperatures and humidity
- The required indoor temperature and air quality – cooler temperatures, greater precision and more refined air quality all consume more energy
- The heat generated internally by lighting, equipment and people – all of these have an impact on how much cooling a building requires
- The design and efficiency of the air conditioning plant – this provides cooling and moisture control exactly where it is needed in the building
- The operating times of the air conditioning equipment and ability of the controls – these limit operation to exactly when it is needed
- The amount of fresh air provided per person.

Reducing the air conditioning load allows alternative ways of cooling to be considered that are simpler and less energy intensive. This can reduce energy consumption whilst providing cost savings and maintaining a healthy and comfortable environment for staff.

Building performance

The performance of buildings with full air conditioning depends critically on three things:

1. Good design
2. Suitable commissioning
3. Effective maintenance and management.

Unfortunately, this is not often achieved in practice. Many buildings with complex service systems are awkward to operate and they underperform in terms of occupant satisfaction and operating costs. Some of the best performing buildings are those with simpler, passive or free cooling systems. Such buildings are also easier to operate and maintain, which in turn reduces costs and breakdowns.

Did you know?

Energy efficient buildings need not cost any more to build than a conventional building. In fact, building fabric and services design can be integrated effectively to even reduce capital costs. For example, the cost of adding external shading can be offset by minimising or avoiding air conditioning plant.

Technology overview

The components of an air conditioning system, as well as the way they are set up and controlled, have a big impact on energy use and the levels of comfort provided for occupants. By examining the existing system, it should be possible to highlight areas for potential energy saving opportunities.

The primary mechanism central to all mechanical cooling systems is the refrigeration cycle, in which heat is moved from one place to another. Systems that include the refrigeration cycle may be called a 'chiller' or 'refrigeration machine'. In smaller systems, it may be called an 'air conditioner'.

In essence, a refrigeration machine operates in the same way as a domestic refrigerator, where heat is absorbed from inside the cabinet and rejected outside, but on a larger scale. This takes place either directly via an air-cooled pipe coil or via an intermediate 'condenser' water circuit at a remote cooling tower (see *Figure 3*).

The cold fluid can be either refrigerant or chilled water. Where chilled water is provided, pumps are needed to move it around the building to where cooling takes place.

The cooling generated has to be transferred into the air in the room where cooling is required. The heat transfer often takes place in a 'pipe coil', which consists of rows of parallel pipes through which the cold fluid passes. Metal fins at right angles to the pipes aid the heat transfer from the air, which is usually blown over the coil by a fan. This fan can either be next to the coil or at a more remote point of a ductwork system.

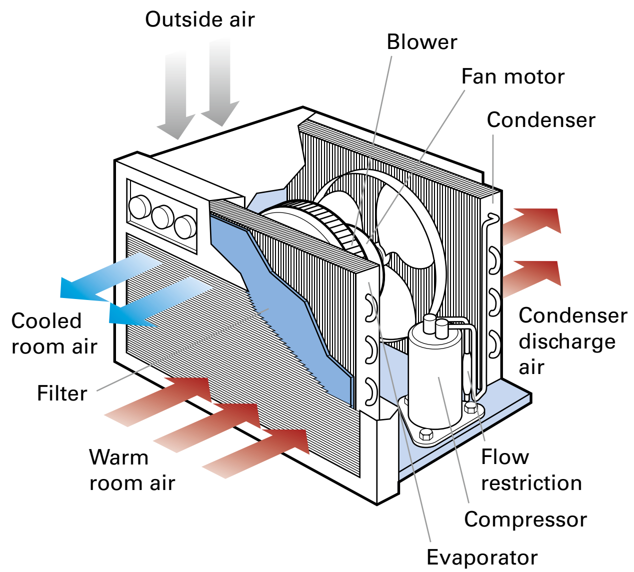
The air that has passed over the coil then mixes with the air in the room, cooling it down and achieving the required temperature. The amount of cooling given to the space can be varied by changing either the temperature difference between the incoming air and the room, or by changing the volume of air entering the room, or both.

There are three generic types of air conditioning system, each with many variations:

- Centralised air systems, where all the heating and cooling is carried out in a central plant room and conveyed to the rooms by ductwork
- Partially centralised air/water systems, where centrally cooled or heated air is further heated or cooled at entry to the rooms
- Local systems, where all operations are performed locally.

Each of these is discussed in the following sections.

Figure 2 ***Components of an air conditioning unit***



This diagram shows the major components of an air conditioning unit in a packaged system. Most air conditioning systems have these components; however, they will be arranged differently in every application. Packaged systems are discussed further on page 9.

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Centralised air systems

These systems typically supply cooling from large central chillers that generate chilled water. This water is then pumped around the building through pipes to wherever cooling is required.

Centralised systems are often based around a packaged air handling unit (AHU), which typically contains heating and cooling coils, a humidifier, filter and fan to move the air. The incoming air is drawn into the AHU and passed over the coils to heat or cool the air as required. This 'conditioned' air is then supplied by ductwork to the rooms within the building. The equipment is normally located in central plant rooms but may be roof-mounted (see *Figure 3*).

The chillers (the refrigeration equipment) provide chilled water for the cooling coil(s) within the AHU. The chiller may be water cooled (with a cooling tower) or cooled by outside air. Hot water for the heating coils is provided by boilers, which may be located in another plant room. Heating and cooling can be distributed to the occupied spaces via air ducts, or through pipes that provide heated and cooled water to terminal units in each room.

When outside air is cooler than the internal temperature, fresh air can be introduced and chilling is not required. In the UK, temperatures are often below 19°C, so exploit this 'free cooling' to minimise the need for refrigeration.

Types of centralised air systems

Constant volume (CV) single zone systems are simple, relatively low cost and easy to commission, but cannot provide adequate control for areas or 'zones' with different/simultaneous heating or cooling needs. Several separate systems may be required to serve different zones, increasing capital costs and plant space.

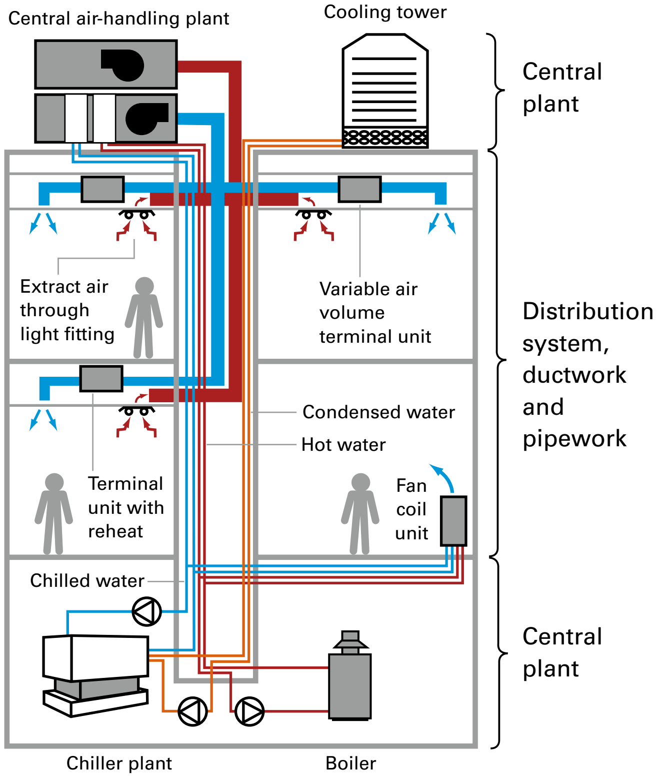
Variable air volume (VAV) systems address the problem of zones with different requirements by varying the quantity of air (and hence the amount of cooling) supplied to each space.

VAV systems can be particularly energy efficient as they are able to operate the main supply and extract fans at reduced speeds. This can yield significant energy savings from reduced fan power and a reduction in the costs associated with heating and cooling air.

VAV systems are primarily for buildings with a year-round cooling demand. They can be smaller than the equivalent multi-zone system because their design does not provide full cooling simultaneously in all zones. This complexity makes them an expensive solution which requires careful commissioning.

Displacement ventilation systems provide cool air from a central plant and supply it at low velocity to ventilation terminals. The supply temperature is slightly cooler than the room temperature and so the air rises to ceiling level by natural convection as it picks up heat from occupants and equipment. The warm air is then removed. Displacement systems are energy efficient and give good indoor air quality and thermal comfort.

Figure 3 A centralised air system



Further information

For more information, order [Heating, ventilation and airconditioning (CTV046)] from the Carbon Trust

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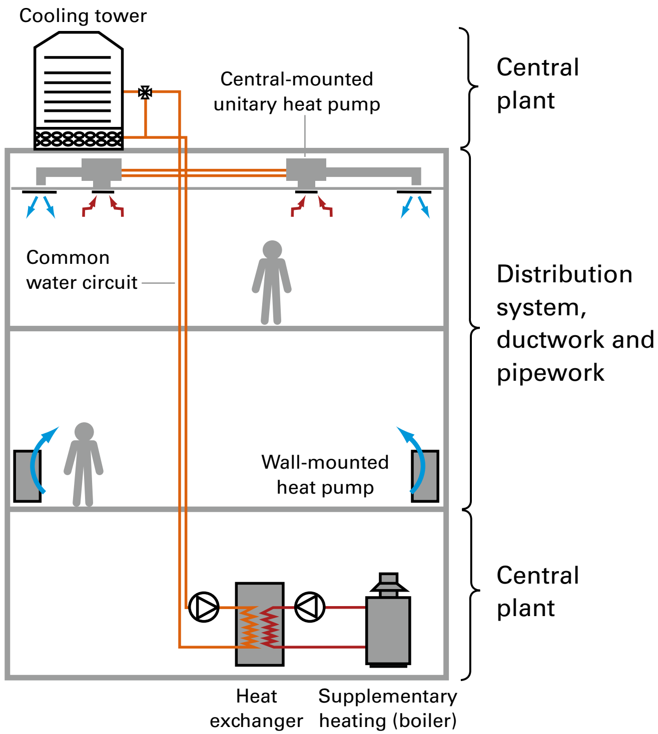
Partially centralised systems

A central AHU provides the common factor in partially centralised systems although further conditioning in the room may be locally controlled. These systems can supply a high level of localised control making them flexible to individual user's needs. If controlled correctly, this results in energy savings by ensuring that heating and cooling only operate where required.

Figure 4 A partially centralised air system



Types of partially centralised air systems

Some systems give extra control to existing **centralised air systems.** The air from the central supply is further heated or cooled to room requirements by additional heating or cooling coils (known as batteries). In constant volume systems, this increases controllability and the ductwork can be configured to serve rooms with quite different requirements. Heating and cooling coils can be located either within ceiling voids (partially centralised system) or in the plant room (fully centralised system).

Four-pipe fan-coil units typically comprise a fan, heating coil, cooling coil and air filter, all housed in a metal casing. Fan-coil systems can satisfy the individual heating and cooling requirements of multi-zone buildings and enable good building flexibility. They are only partially centralised since fresh air is usually ducted to each unit from central plant along with piped heating and chilled water.

Fan coils provide good environmental control and air movement yet require a lot of maintenance, as they are in essence, mini air handling units. Providing only minimum fresh air from the central AHU means that a much lower volume of air is ducted around the building compared to the equivalent multi-zone system.

Chilled ceilings and beams consist of ceiling-mounted panels of pipes that are cooled by chilled water. They transfer their cooling effect to the space by radiation or natural convection without using fans to encourage air movement, hence these systems are referred to as 'static cooling systems'. Since they use water as the main medium for the distribution of cooling around the building, they make considerable savings in fan energy.

Room-based reversible heat pumps are individual units which can be floor standing or concealed in the ceiling void, linked together by a piped water circuit that runs around the building. Each unit operates independently and is able to heat or cool the air in the immediate area. This is achieved by means of a small heat pump in the unit, which takes heat from the water circuit and uses it to heat the room. To cool the room, the heat pump works in reverse to remove heat from the space and transfer it to the water circuit. This type of system is often referred to by the trade name 'Versatemp'.

The key benefit of this system is its ability to save energy by transferring heat from an area where it is not needed to an area where it is, via the piped water circuit. It is most beneficial in zones which have different heating and cooling periods to each other.

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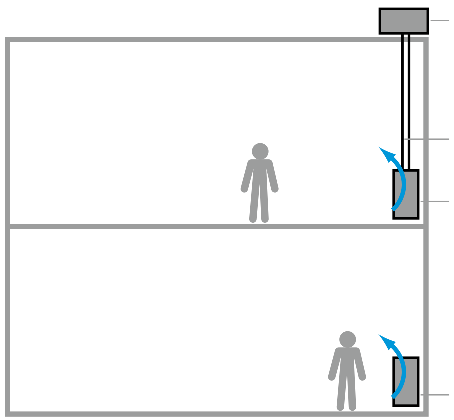
Local systems

Local systems are not linked to any centralised plant and only provide cooling in the immediate space where they are placed. They are commonly used to serve a single zone or small proportion of a building (see diagram below). They may or may not provide ventilation depending on their level of sophistication. Local systems are often used to provide 'comfort cooling' and can be useful where some areas require cooling for a different period from the rest of the building. For example, using them can allow the main centralised system to be turned off outside working hours.

Figure 5 A localised system



Types of local systems

Packaged and split systems provide a convenient way to air condition small buildings or specific areas within a building. Typical applications include shops, restaurants and office areas. Packaged air conditioners have all their components in a single box, which can be installed, ready-tested. 'Split systems' separate the room units, with their fan and heating/cooling coils, from the compressor and condensing units. The latter's noisy components can then be placed outside the building. The room units can be mounted in the wall, in an enclosure, or in the ceiling.

Variable refrigerant flow systems (VRF) are essentially sophisticated split systems. The difference is their ability to provide heating or cooling on an individual basis. This is particularly useful in applications such as office blocks, hotels and large retail stores etc, which may need cooling in some areas and heating in others.

VRF systems can be very flexible and energy efficient when used as a heat pump, that is, for heating and cooling. Where air conditioning is necessary, using VRF for heating and cooling incurs a marginal extra cost but could save the cost of a separate boiler plant.

Did you know?

All air conditioning systems require specialist service engineers for repairs and maintenance. They must be installed to a high standard to ensure good performance and reliability, and simple occupant controls should be provided to avoid wasting energy and money.

Low-energy cooling

Once established, low-energy solutions can keep a building cool for no additional capital outlay.

There are a number of strategies and technologies that have the potential to reduce energy consumption and costs associated with the use of air conditioning. Many of these are tried and tested, but application will depend on the individual circumstances presented in a building, as well as the requirements of occupants.

Reduce unnecessary heat gains

Before installing cooling equipment, always identify where the excess heat is coming from. Sunlight, equipment, lighting and refrigeration are often main causes. As a general rule, the more energy efficient equipment is, the less heat it produces. So installing low-energy lighting and keeping equipment operating at peak efficiency reduces cooling costs.

Night cooling

Night cooling is an established technique where cool night air is passed through the building to remove heat that has accumulated during the day. When the building fabric has cooled, it will absorb more heat, meaning lower internal temperatures the following day.

Generally, an exposed ceiling slab is required to provide sufficient storage of cooling energy. The movement of cool night air may be natural or fan-assisted. This free cooling of the building reduces energy consumption otherwise used by mechanical cooling and ventilation, leading to cost savings.

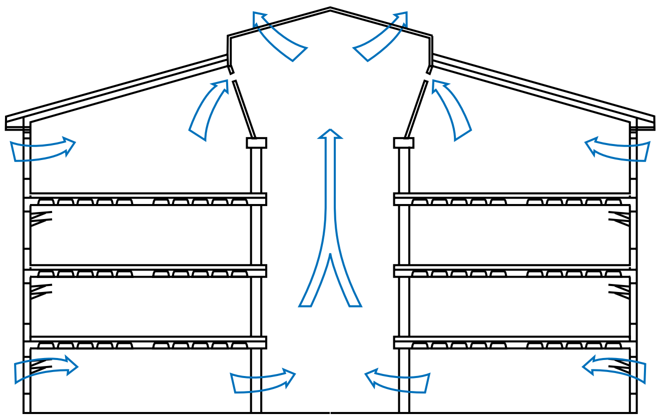
Natural ventilation and free cooling

As simple as it sounds, natural ventilation and free cooling relies on natural airflow between openings on opposite sides of a room or building – or rising warm air being replaced with cooler air sucked in through windows or vents. This technique relies on moving air through a building under the natural forces caused by outside wind pressure and the buoyancy effects of temperature differences. The most effective air paths are simple and generous.

It may be possible to use windows and doors to provide good levels of natural ventilation, allowing mechanical ventilation to be switched off or turned down to save money. When opening vents, doors and windows, always consider security implications.

Stack ventilation and wind scoops can also be utilised – these are more sophisticated natural ventilation techniques, often integrated with a simple yet effective structural design. They generally have to be designed into new buildings but are often well worth the effort in terms of cost savings and comfort for occupants. See *Figure 6* (below) for an illustration on how this can work.

Figure 6 ***Detail of stack-induced crossflow ventilation***



Mixed mode

Some buildings use what is known as a 'mixed mode' system; a combination of both natural and mechanical systems. Natural ventilation and cooling are used where possible, with mechanical systems being used only when absolutely necessary. There are various advantages of such a system:

- The building becomes more adaptable to a wide range of requirements
- The occupants have more control over their environment
- Businesses can cut down on energy spend and carbon emissions.

There are several variations/combinations of mixed mode systems. Ultimately, they offer the security of improved environmental conditions by using mechanical ventilation/cooling when needed without having to operate fans and chillers throughout the year.

Chillers with free cooling coils

There are now chillers available which incorporate a 'free cooling' coil. These operate when the outside air temperature drops below the temperature of the water returning from the system. At this point, the compressor in the chiller stops and free cooling begins. With the changeable UK weather, particularly in cooler regions, this option could have significant payback.

Free cooling in tower-based systems

There are several approaches that are based on cooling towers. These systems can shut the chillers down and allow the towers to supply chilled water providing free cooling during the cooler months of the year. The popularity of systems like chilled beams/ceilings that use higher chilled water temperatures has significantly increased the period when free cooling is available each year. Often a bespoke solution is called for which can lead to increased design costs and higher operational risks than standard systems. See the box below for safety considerations with bespoke systems.

Top tip

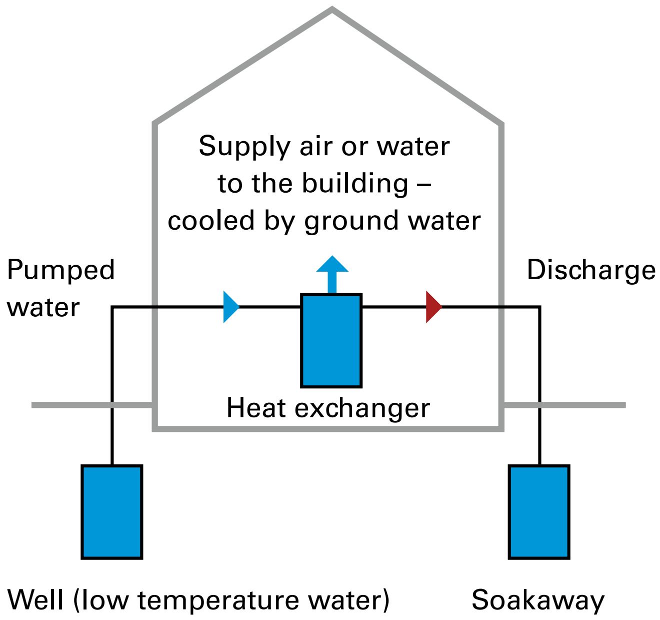
When installing air conditioning systems, make sure you ask about design and operational risk, particularly regarding Legionnaires' disease. For most systems, this will not be an issue but always pay particular attention when commissioning a bespoke solution and ensure the system is regularly maintained. If in doubt, consult an expert.

Consider using local renewable resources

Some renewable energy options are outlined below. The suitability of each of these is heavily reliant on the physical conditions of the proposed site.

Ground water cooling essentially consists of two wells drilled into the ground, where water is pumped from one well to the other via a heat exchanger to provide useful cooling. Only certain sites have suitable ground water sources at convenient depths so careful investigation is required.

Figure 7 Ground water cooling



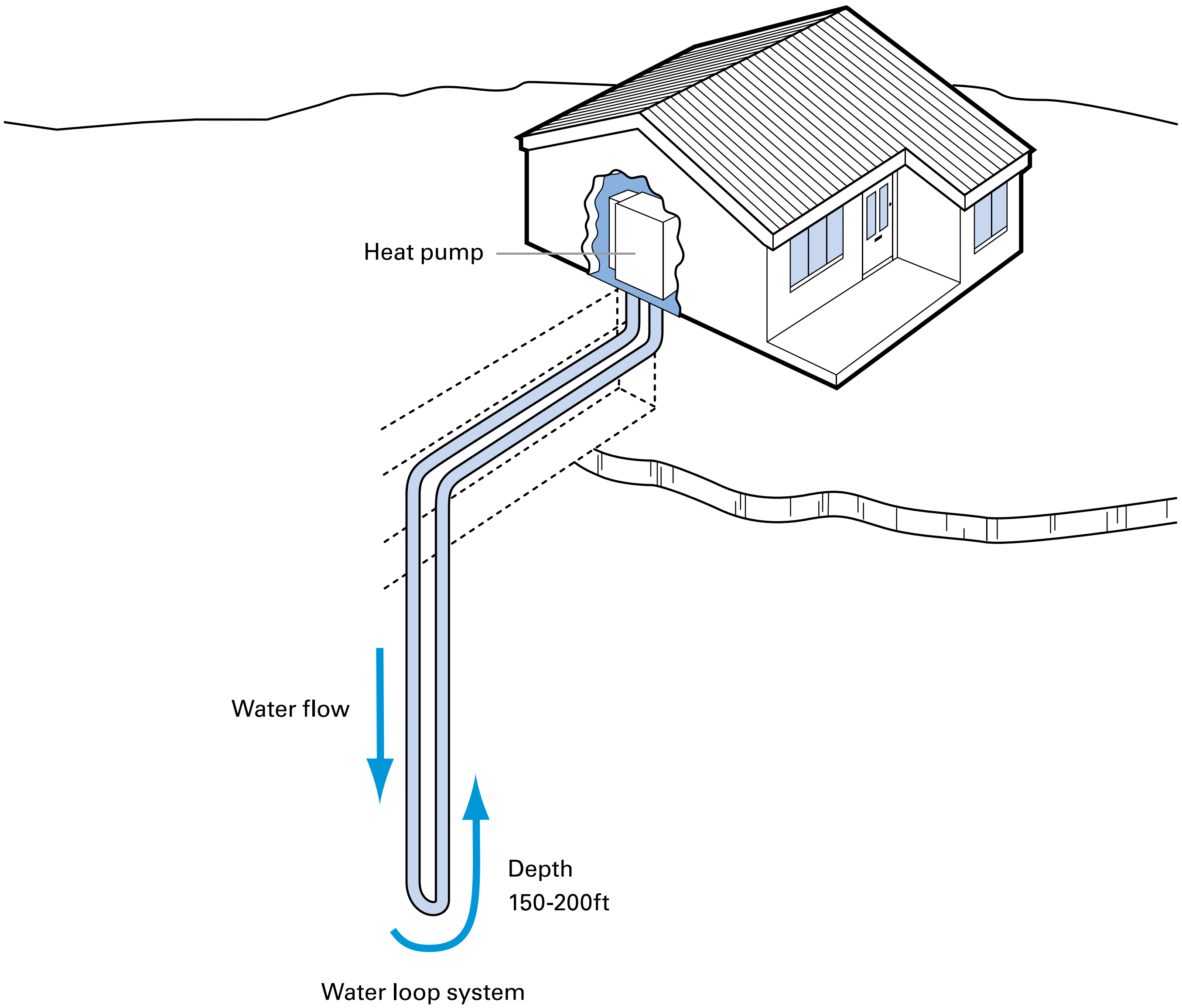
Ground coupling using air utilises the natural storage of the earth to cool air passed through underground pipes. The cooled air can be used directly, or for buildings that demand strict internal conditions, it can be used to pre-cool the air in a conventional system. Heat transfer depends upon soil type, moisture content and ground water movement and only some sites are suitable.

Ground source heat pumps use the ground for cooling or heating via a reversible heat pump. They consist of a continuous loop of pipe filled with a water/antifreeze mix, buried in the ground and connected to the heat pump. In winter, the same system can be operated to transfer heat from the ground to the building, typically via a low temperature heating system such as underfloor heating. This system is best suited to a site with appropriate space and soil type for digging a trench or borehole to accommodate the loop of pipe.

Did you know?

The energy consumed by cooling systems can be reduced significantly by using chilled water or refrigerant instead of air as the medium to transport cooling around the building.

Figure 8 Ground source heat pumps



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Delivery considerations

The way that cooling is delivered to occupied spaces can have a significant impact on the effectiveness of the various low-energy cooling options. Systems that can operate with higher chilled water temperatures (for example, chilled beams) or supply air (for example, displacement ventilation systems) are far more likely to make low-energy cooling solutions viable.

Many of the 'passive' and 'free cooling' technologies which offer reductions in refrigeration load can cause an increase in fan or pump power requirements. A balance must be struck between this additional fan or pump power and reduced refrigeration loads.

Myth

Leaving air conditioning on overnight reduces energy costs as the system stays at the required temperature.

Reality
The result is much higher energy consumption than necessary.

Remedy
An office building only needs a fraction of overnight energy to reach adequate temperatures for the start of the day. Air conditioning may not be needed at all at this time if 'night cooling' is used.

Myth

Turning air conditioning thermostats as low as they can go cools the building more quickly.

Reality
The temperature drops at the same rate but then overshoots, using more energy than necessary and making it uncomfortable for occupants. If controls are not coordinated, the temperature could even go low enough for the heating system to be switched on. Both systems then operate at the same time.

Remedy
Set thermostats correctly and educate staff to dispel this myth. As a last resort, protect thermostats to prevent tampering, where possible.

Did you know?

The energy consumed by cooling systems can be reduced significantly by using chilled water or refrigerant instead of air as the medium to transport cooling around the building.

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Existing buildings

A building working at optimum performance will provide a safe, comfortable working environment whilst delivering maximum productivity. However, even when new, few buildings achieve this level of performance. This is often due to poorly specified systems that have not been set up to work correctly.

The key to understanding an existing building is to:

- Appreciate how the building has been designed to work in its environment
- Identify the current status of the building and assess its performance
- Ensure that the building and its systems are well documented in a language and format that is easy for managers to understand
- Identify and address problem areas.

Optimising internal conditions in the work place can result in improvements in productivity and other substantial returns. For example, hospitals may experience improved patient recovery and hotels often report increases in guest satisfaction.

Review building operation

Ask the following questions to troubleshoot problems in an air conditioning system. These may highlight a need to review building controls and services, or possible replacement of plant and equipment.

Has energy consumption been increasing?
This may be a sign that building and air conditioning plant are not operating as efficiently as originally intended, or that air conditioning components and control settings need to be reviewed.

Are maintenance costs increasing and is plant and equipment regularly failing through wear?
This can be identified from maintenance log books and records. Ensure that a comprehensive preventative maintenance plan is in operation and consider investing in new, more efficient plant.

Was the system set up properly in the first place?
This may only be discovered as a result of other operational problems such as overheating or overcooling. Compare settings with the original design figures specified in the operating and maintenance manuals.

Are there increasing complaints from building occupants about being too hot, cold, draughty?
A significant number of grievances should trigger an in-depth investigation of the system to fully understand any problems. The solution may be a combination of the points described on this page.

Has building function/layout changed since original design?
This could mean re-setting control zones, time and temperature settings and air flows. For example, conversion of a standard open plan office into a 24-hour call centre might double occupation levels and require an increase in air conditioning operating time.

Are controls fine-tuned to suit current building operation?
Controls are often set only once at installation before occupancy or work habits have been identified. The result is a system that does not meet the current needs of staff. To avoid this, walk around the unoccupied building outside core business hours and check whether the air conditioning plant is in operation. Also examine energy usage data from meter readings. This will help identify if there is unnecessary energy consumption which can then be easily resolved by resetting time controls to suit hours of occupation.

Are heat gains from internal equipment and lighting lower than expected in the original design?
This can result in air conditioning running inefficiently at low load. Compare current operation with the original design figures specified in the operating and maintenance (O&M) manuals. Review the arrangement for the chiller(s) and supplied air volumes and determine if these can be revised.

Has occupancy changed significantly since design?
This can result in either over- or under-provision of fresh air. Under-provision may lead to occupant complaints and over-provision will result in additional heating/cooling costs. Compare operation with the original design figures specified in the O&M manuals or in the building logbook if available. The solution may be as simple as resetting the main air handling unit to regulate the amount of fresh air entering the system.

Problems should be investigated and resolved promptly. In all of the above areas, commissioning activities such as resetting controls and/or re-balancing air flows could make a significant difference to building performance and reduced operational costs.

Conduct a building health check

If necessary, ask a qualified technician to investigate and provide a building health check. This will provide recommendations for:

- Restoring the optimal operation of building systems
- Saving energy
- Improving comfort conditions
- Achieving cost savings.

Keep a log book

Many existing buildings have either inadequate or missing O&M manuals and commissioning records. It is important that this information is readily available on-site or summarised in the form of a log book. Preparation and use of a comprehensive but easily understood log book will help develop a better appreciation of the building and system design resulting in improved building management. Ongoing use of the log book will provide a means of recording building performance, enabling building occupiers to understand and operate the building in an energy efficient manner.

Adapt carefully

Many interior environments are designed to be easily adaptable for changing business needs, occupant requirements or a different use of the space. It is often during these changes that system controls and operation go awry; for example, control zones and times are incorrect for the new occupational hours in a reconfigured area of a building.

Moreover, building changes can introduce new structures that might interfere with efficient use of building services. For example, office partitions may prevent good air distribution or natural cross-ventilation and cause temperature sensors to become separated from the zones they control.

Top tip

Building managers should continue to seek opportunities for improving existing buildings whilst ensuring that the installation of energy saving technologies does not work against the building's original design. Always seek specialist help where required.

Opportunities for energy saving

Simple actions on existing systems can save energy and costs.

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Building fabric

Improve the building fabric

Well-maintained buildings with good insulation save on heating and cooling costs. If there are any gaps in the fabric, heated or cooled air can escape which wastes energy and money. It therefore makes sense to improve the building fabric prior to improving or replacing an existing cooling system. In particular, gaps or holes in walls, windows, doors and skylights should be repaired as soon as they become apparent.

Redirect heat from the sun

Overheating due to high levels of glazing is a growing problem in buildings. Consider fixed or moveable external shading for windows, or replacing window panes with special heat-reflective glass to prevent heat build-up. Alternatively, internal blinds can be angled to redirect useful light on to the ceiling whilst cutting out much of the sun's heat. This will allow more daylight into the space, whilst minimising glare.

Basic control

Set appropriate internal temperatures

Most people feel comfortable in a temperature range of between 18–26°C, provided the temperature is in line with outdoor conditions. It is common sense that staff and visitors will be dressed for the weather conditions, so when it is hot outside, they will be wearing cooler clothing. Make sure this is factored in when setting air conditioning. It is recommended that the temperature set point for cooling in, for example, an office is ideally no more than 3°C below the external temperature. So, with an outside temperature of 27°C, the cooling set point should be set at 24°C.

Observe staff behaviour. If people are bringing in warmer clothing to wear whilst working, this may be a sign that the air conditioning is set too high. Set internal temperatures appropriately and encourage staff to dress in a way that suits the setting. If uniforms are provided, make sure they are suitable for their purpose, considering extreme temperatures if necessary.

If possible, also ensure workspaces are shielded from draughts and direct sunlight to help improve the comfort of the entire work area. These are no-cost solutions that save money and help maintain comfort.

Did you know?

Energy efficiency measures such as turning air conditioning equipment down or off can increase the lifespan of equipment and reduce maintenance and replacement costs.

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Train staff to use controls

Staff should receive guidance on recommended operating temperatures and on how to set heating or cooling units correctly. 'Louvres' (movable slats to guide the cool or heated air) are a feature on most air conditioning units and staff should be trained to operate these to maintain a comfortable temperature. Display instructions on individual units and ensure that remote controls have accessible and obvious storage spaces. Provide instructions for systems that provide cooling to separate function rooms or areas, such as meeting rooms off an open plan office.

Do not let heating and cooling operate at the same time

Most air-conditioned areas need not be cooler than 24°C (unless for a specific process requirement). Similarly, the maximum temperature recommended for heating is 19°C (the temperature in an area can be comfortably above 19°C but a system should not be providing heat when it is over 19°C).

It is common to find heating and cooling operating at the same time which wastes large amounts of energy and money. A good solution is to set a gap, say between 19-24°C, to create a comfortable 'dead band' where no heating or cooling is operating. This will help to keep occupants happy and increase cost savings. Unless this is implemented, both systems may operate simultaneously and waste energy and money.

Maintenance

Maintain plant

Ensure cooling plant are regularly maintained to avoid operating at reduced levels of efficiency. Check for refrigerant charge and leakage. Replace insulation on refrigerant pipework as poor condition will affect the temperature of the refrigerant flowing through the system and thus consume more energy in maintaining the required temperature. Pay specific attention to pipework located outside a building.

Check condensers

Condensers are usually located on the outside of buildings and eject heat that has been removed from inside. Always ensure condensing and evaporating devices are clean, well maintained and free from any obstructions.

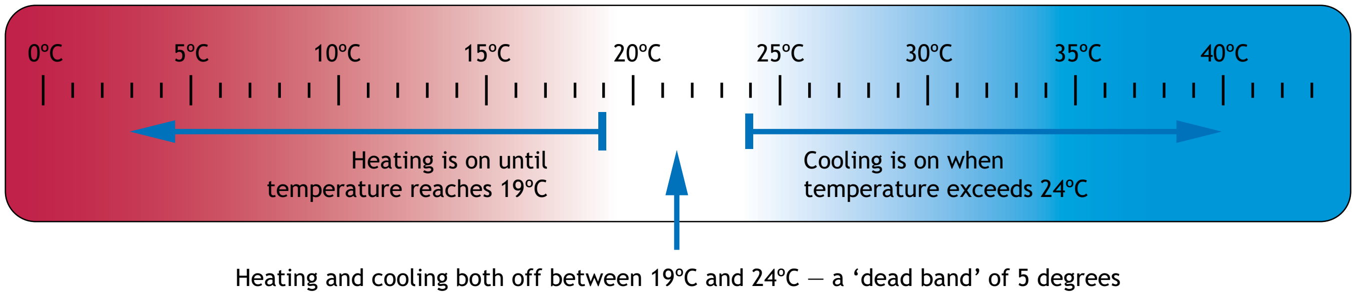
Keep it clean

Filters in ventilation systems should be regularly checked to ensure they are not blocked. Blocked filters lead to reduced airflow and increased operating costs. Consider fitting gauges to indicate when replacement of filters is required.

Do spot checks

Air conditioning plant may well be wasting energy for some time before it fails completely. Do not wait for equipment failure or rely on the maintenance company to identify problem areas – preventive maintenance makes better business sense.

Figure 9 Diagram of 'dead band' control recommended temperatures



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Efficient maintenance contracts

Day-to-day maintenance of equipment and control settings can have a significant impact on energy consumption, yet few maintenance contracts explicitly include energy efficient operation of systems as a requirement. As a result, the plant is often run constantly and at maximum settings that waste energy. Consider using a performance-based contract where the maintenance contractor and staff are obliged to operate building systems efficiently to minimise energy consumption whilst providing an optimum internal environment.

Top tip

Heat exchangers and cooling towers must be kept clean and water treatment processes carefully maintained. This saves energy and prevents health problems such as Legionella.

Upgrading existing plant

Sub-meter the system

Chillers can account for up to a third of electrical consumption in a building. Installing sub-metering and collecting energy data enables inefficient areas to be identified, investigated and eliminated. By gaining an understanding of the energy used by air conditioning components, performance targets can be set and monitored regularly. Sub-metering and the corresponding monitoring and targeting can save up to 5% of the energy consumed by the equipment that is being metered. Therefore, sub-metering can be a good investment if the costs of its installation are less than 5% of the yearly energy used by the air conditioning system.

Review zoning arrangements

Many air conditioning systems are set up in 'zones' to provide different levels of cooling to specific areas within a building. Whenever building use changes, these zones should be reviewed to ensure that they are still delivering required conditions without wasting energy. In addition, a yearly review of zoning arrangements should be carried out to ensure that systems are operating to peak efficiency.

Replace old, inefficient plant

Advances in technology mean that more efficient, modern equipment is available to replace older, inefficient components in air conditioning systems. This includes pumps, motors and fans, and payback on these can be relatively quick. Investigate all components in relation to the equipment, application, hours of use and the life cost. Spending time considering the options will help make the most energy efficient purchase.

Fit variable speed drives (VSDs)

Fans and pumps do not always need to operate at full speed all of the time. VSDs can help to reduce costs by enabling the output speed of the motors to match requirements at different times of the day. This reduction in speed saves energy and there are corresponding cooling cost savings too. More information can be found in the Carbon Trust's technology guide to Variable speed drives (CTG070).

Did you know?

Energy consumption can increase by up to 30% if regular maintenance is not undertaken. Cleaning fans, filters and air ducts can improve efficiency by up to 60%.

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Retrofit and system changes

Cooling control measures

In the UK, cooling is generally only required for parts of the year. However, the refrigeration plant used to provide the cooling is often found operating unnecessarily or inefficiently to supply such small loads. There are significant energy savings in upgrading refrigeration systems and controls, or installing smaller plant to serve such loads. To maximise performance and reduce energy consumption:

- Review refrigeration controls and ensure they are coordinated with the rest of the building's plant and equipment
- Review the sequencing of chillers (and boilers) and check they are operating at maximum efficiency
- Check that free cooling is maximised in winter and switch off chillers where possible

If there is a continuous small cooling load for 24 hours a day, consider installing a separate small chiller so that main chillers can be switched off outside occupancy hours.

Reduce fan energy

Fans used to move cool air around a building consume a major part of the energy used by conventional centralised air conditioning and comfort cooling systems. The amount of energy used by the chiller is generally much lower than the fan energy in air-conditioned buildings in the UK.

Fan energy can be reduced by:

- Asking for systems to be designed to a low 'specific fan power'. This means reducing the resistance to airflow through the ductwork, which in turn means making the ducts as large and as short as possible, with smoothed rather than sharp bends
- Using efficient fans and motors
- Installing fan speed control. This reduces the airflow at part load or part occupancy
- Improving the ventilation effectiveness; for example, using ventilation to deal with specific areas of heat load rather than by conditioning the whole space.

Review the suitability of the locations of any zone control sensors. For example, make sure that they are not in a location exposed to sunlight and heat.

Building Energy Management Systems

Businesses with an energy bill of more than £10,000 a year could benefit from installing a Building Energy Management System (BEMS or BMS). This would be particularly beneficial for businesses considering investing in a control upgrade. A BEMS is a computer-based system which can control any building service – including air conditioning. Intelligent controllers or 'outstations' monitor conditions throughout the building and determine the operation of plant such as chillers, pumps and fans in response to changing conditions such as time, temperature and air quality.

To make the most of a BEMS, ensure that it is well maintained and that staff are trained to operate it properly. Used correctly, BEMS can reduce total energy costs by 10% and increase comfort so they are well worth considering.

Integrating the measures

An energy survey or health check should highlight areas that require action. These can be prioritised in line with investment policy or as part of a general upgrade or major refurbishment. This may vary from simply resetting control points to complete new heating, ventilation and air conditioning systems. It is essential that the proposed changes are co-ordinated to avoid conflict between one measure and another.

Did you know?

Option appraisal. Before making a change to an existing system, it is important to consider all the available options, particularly where new investment is involved. An option appraisal compares different possible solutions to a particular problem in order to determine the best option.

The appraisal includes capital and operating costs and environmental impact, as well as practical issues like plant location, weight and access and the flexibility to cope with changes in building use and occupancy.

Top tip

Don't be afraid to ask! If you think your system is not operating correctly, or if staff members complain about problem areas in your building, act on it immediately. Always contact your maintenance technician with any concerns.

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Specifying new systems

When specifying new air conditioning systems, it pays to buy the most efficient equipment possible. Day-to-day running costs may quickly outweigh any additional installation costs and so installing a more efficient system will ultimately be less expensive to run.

Always:

- Select the most appropriate cooling system for your requirements
- Prioritise energy efficiency in the design and installation stages from the very beginning
- Implement and maintain good system controls
- Carry out effective commissioning of the system
- Develop a maintenance plan to ensure that the system continues to run efficiently, once installed (this may be through a maintenance contractor)
- Provide suitable training for all system users.

Is air conditioning required?

The choice of a passive or a mechanical cooling approach can be determined by answering a series of relatively straightforward questions about a building and its internal environment:

Is close control of humidity required?

For most people, humidity is acceptable within the range of 40–70% relative humidity (RH). If humidity is too low then problems can occur, such as static electricity (below 40% RH) and health problems associated with the drying of the respiratory tract (below 30% RH). However, as most buildings in the UK sit within the 40%–70% range, they do not often require the additional expense of humidification plant accompanied by excessive energy costs. Unless humidification is required for a process, question whether it is really necessary.

Does the building need to be sealed against noise and pollution?

Noise and pollution can be caused by a number of factors and it can be a nuisance for a building's occupants. It is often possible to provide ventilation from the back or to the side of a building where air quality may be better. Remember that people prefer to open windows for fresh air, so sealing the building should be avoided unless absolutely necessary.

Top tip

If new or refurbished buildings are over specified and complex, they may put themselves beyond the competence of the building management team to achieve high standards of performance. Even if controls are set up and commissioned correctly, they may be overridden in an attempt to improve occupant comfort. Always ensure users fully understand the best way to use controls.

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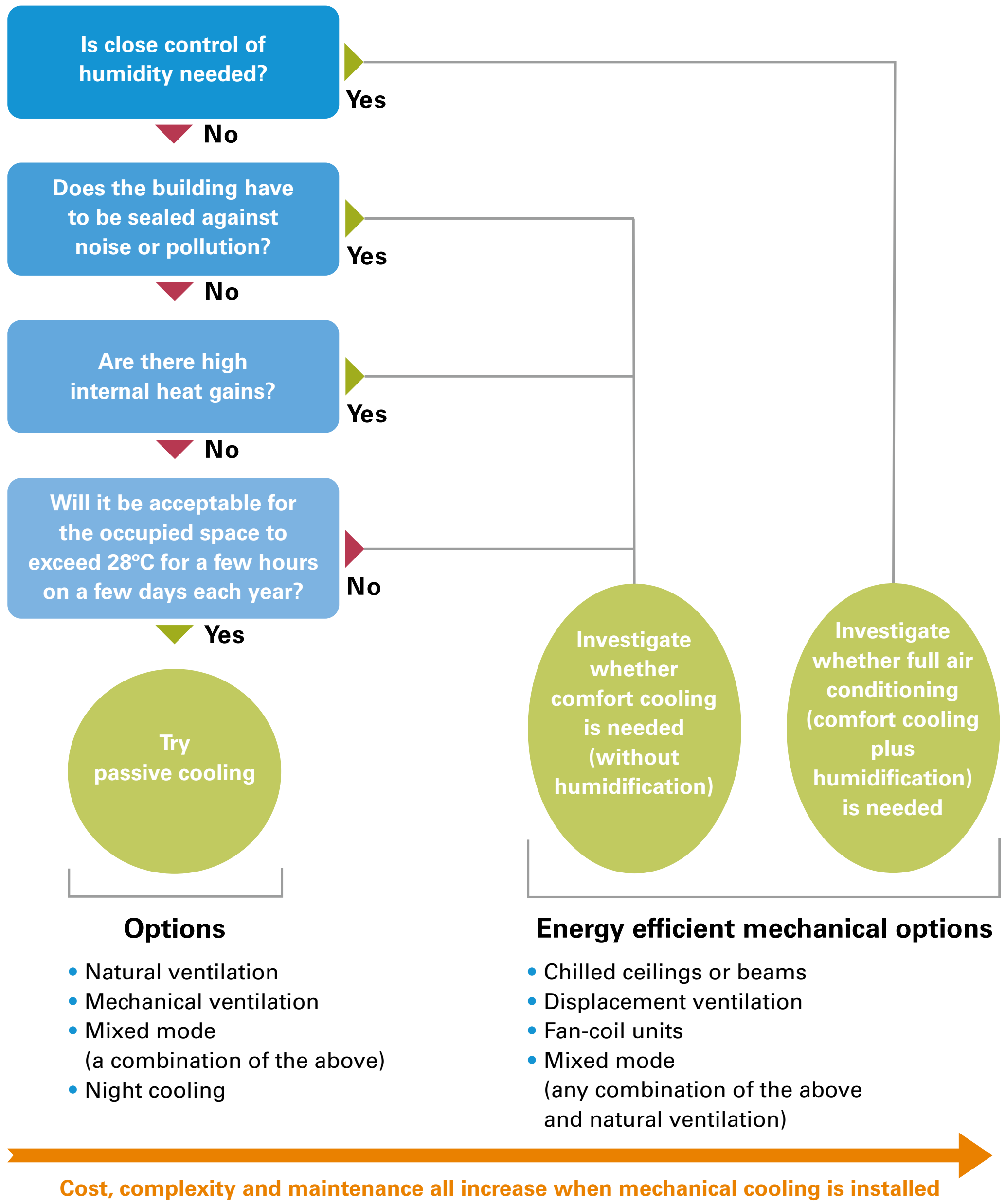
Are there high internal heat gains?

Internal heat gains are caused by building occupants, sunshine, lighting, computers and other electrical equipment. Strategies to reduce heat gains can reduce the need for cooling and make natural ventilation a viable option. For example, replacing an inefficient tungsten lighting system with a more efficient system can significantly reduce the heat in the lit space. See the Carbon Trust's technology overview to Lighting (CTV049) for more details.

Is there a need for limiting internal temperatures?

Temperature fluctuations may occur in a number of buildings but as the UK's climate is generally moderate, excessive temperatures are relatively uncommon. Consider whether it would be acceptable for the occupied space to exceed 28°C for a few days each year. If so, then a low-energy, naturally ventilated solution may be a viable option.

The flow chart opposite presents a summary of these questions and indicates whether comfort cooling or full air conditioning may be required.



Consider the options

Careful specification of a new air conditioning system will help ensure that it meets the building's requirements while being both efficient and cost effective.

Most air conditioning systems are made up of separate pieces of equipment, working together to deliver a comfortable internal environment. When new air conditioning is proposed, the efficiency of each component should be examined – not only in isolation but also in relation to how it will work with the other components that make up the whole system.

Manufacturers are a valuable resource when considering equipment requirements. Many have a selection of appropriate systems and often have software which can provide an analysis of running costs. This can cover aspects such as the choice of heat pump and the impact that controls can have. It may also be worthwhile considering leasing possibilities and maintenance agreements when calculating the lifetime costs of the system.

Consider the level of expertise or competence required to look after and operate the equipment as this could influence your purchasing decision.

Developing a brief for a new system

When specifying a new air conditioning system, a comprehensive brief should be developed that describes both the user and the client requirements, including foreseeable changes.

The activities within the building will dictate:

- The amount of individual control required
- Whether temperature and humidity need to be controlled to a tight tolerance
- The level of internal heat gain from office equipment, lighting, etc.
- The amount of ventilation air that needs to be provided (usually derived from current and potential occupancy density)
- Zoning requirements and flexibility in spatial changes
- The proposed use of the building and its opening hours, occupancy patterns etc.

As a general rule, it is important that the brief stipulates how ventilation and cooling systems should:

- Be easily maintained
- Provide the required internal conditions
- Operate with minimal detriment to the external environment
- Have a reasonable operating cost.

Comparisons between different options should be on the basis of the whole life cost and not just on simple payback of initial capital costs. Whole life costs (or life-cycle costs) take account of estimations of the annual recurring costs for energy, maintenance, replacement and repair, as well as capital costs and interest charges.

Did you know?

Building occupants generally have an increased tolerance to higher temperatures when they are able to take some personal action to make themselves more comfortable, such as opening windows. Of course, take care that windows are not opened when air conditioning or heating is on.

Energy-Efficiency Financing

Investing in energy efficient equipment makes sound business and environmental sense, especially with the easy, affordable and flexible Energy Efficiency Financing scheme brought to you by Carbon Trust Implementation and Siemens Financial Services. To find out more visit www.energyefficiencyfinancing.co.uk

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Tender evaluation

During the tender evaluation, it is advisable to assess the proposed systems together with the answers given by tendering companies.

Is it as simple as possible?
When considering the schemes, assess whether the complexity of a system is appropriate to the user's requirements – the best maxim is to 'keep it as simple as possible'. Ensure that operators can understand how the system should be controlled for an energy efficient performance.

Is zoning considered?
Ensure the scheme has taken into account areas requiring different environmental conditions and those with different occupancy periods.

Has maintenance been considered?
Ensure that there is adequate space and access to carry out regular maintenance of plant, cleaning of ventilation air paths, etc.

Does it represent best value?
Assess the whole life costs of the equipment and determine which gives best value for money, taking into account the available budget for the project.

Commissioning

To ensure that a building operates correctly and meets the design requirements, the specification needs to include a commitment to properly documented and independently- verified commissioning and testing. The objective is to set up and test the equipment and controls to make sure that they work together as designed. Results from this process should be included in the Operations and Maintenance (O&M) manuals and log book to show how the building services were handed over in terms of equipment and control settings. A requirement for the building to be revisited for 'system fine-tuning' at a different time of year should also be included. For example, if the system was set up in winter, it should be checked for satisfactory operation in the summer months.

Maintenance
Maintenance is key to running an efficient and problem-free system. Determine whether maintenance work is to be contracted out or provided by in-house staff.

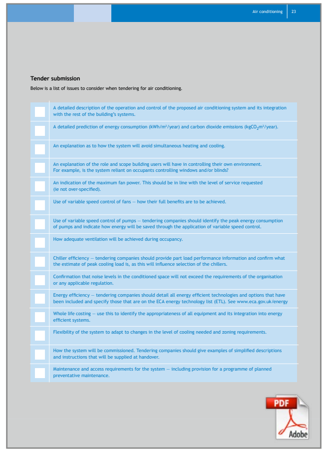
Users
Include reference to the importance of users in any specification and make it a requirement for suppliers to provide all users and facilities managers with information, training and guidance on how to operate building services effectively.

Handover
Handover is a very important stage in the process. It is unwise to accept a new system until all the commissioning and testing has been completed satisfactorily. When a new system is handed over, it should be accompanied by a Health and Safety file including the O&M manuals together with the building log book required by the Building Regulations.

Writing a tender?

Download our handy list of issues to ask any bidders to cover.

Download


Tender submission

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Next steps

There are many easy low and no-cost options to help save money and improve operation of the air conditioning system within your building.

Step 1. Understand your energy use

Look at the air conditioning system components and check the condition and operation of all pieces of equipment. Monitor the energy consumption of the building over, say, one month to obtain a base figure against which energy efficiency improvements can be measured.

Step 2. Identify your opportunities

Compile an energy checklist. Walk round the building and complete the checklist at different times of day (including after hours) to identify where energy savings can be made. Compare different buildings to determine how they are performing in relation to each other.

You can build a walk-round checklist based on the information on page 28 and on page 14. For a complete guide to conducting an energy walk round), contact the Carbon Trust and request a copy of Assessing the energy use in your building (CTL172).

Step 3. Prioritise your actions

Draw up an action plan detailing a schedule of improvements that need to be made and when, along with who will be responsible for them. Where funding is limited, focus on energy intensive areas or those that are performing badly first.

Step 4. Seek specialist help

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

Step 5. Make the changes and measure the savings

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

Step 6. Continue to manage the site's energy use

Enforce policies, systems and procedures to ensure that the building and air conditioning system 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 airconditioning (CTV046)

Building fabric (CTV014)

Motors and drives (CTV048)

Technology guides

Variable speed drives (CTG070)

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Glossary

Air handler
The component of heating and cooling systems that forces air through the ductwork of a building. Air handlers usually consist of a sheet metal box housing fans and other equipment such as heating and cooling coils.

Ambient temperature
The temperature of the outside air.

Batteries
(In air conditioning systems) Additional heating or cooling coils in a system.

Building Energy Management System (BMS or BEMS)
A computerised system based on a network of controllers offering closer control and monitoring of building services performance, including heating, ventilation, air conditioning and sometimes lighting. This is shown on a computer screen in real time and allows the performance of plant to be monitored and settings to be changed easily.

Chiller sequence control
A control or switching of two or more chillers in order to achieve the desired cooling temperature. This helps to maximise chiller efficiency.

Commissioning
The process of testing, checking or calibrating the function of any building services component.

Compressor
A device that moves refrigerant from an evaporator to a condenser and back to the evaporator again.

Condenser
A heat exchanger in which a gas, such as a refrigerant vapour, cools and then condenses to liquid form. In heating, ventilation and air conditioning (HVAC) systems, condensers are usually located on the outside of buildings and reject heat that has been removed from inside.

Condenser coil
A series or network of tubes filled with refrigerant, normally located outside the premises, that removes heat from the hot, gaseous refrigerant so that the refrigerant becomes liquid again.

Cooling capacity
A measure of the ability of a unit to remove heat from an enclosed space.

Dead band
This is established when heating and cooling controls are set to give a wide gap between the temperatures at which they cut in, to prevent heating and cooling operating at the same time.

DX coil
The direct expansion (DX) coil contains the refrigerant in a packaged air conditioner.

Ductwork
This distributes the air from air handlers to conditioned spaces. In many buildings, this is hidden behind suspended ceilings and within walls.

Evaporator
A heat exchanger in which a liquid refrigerant absorbs energy from its surroundings and vaporises, producing a cooling effect.

Interlocking controls
Controls that prevent two or more systems operating at the same time.

Louvres
Movable slats to guide cool or heated air. These are a feature on most air conditioning units.

Mixed mode systems
A combination of both natural and mechanical systems. The building uses natural ventilation, heating and cooling where possible, with mechanical systems being used only when required.

Night cooling
An established technique where cool night air is passed through the building to remove heat that has accumulated during the day. When the building fabric is cooled, it will absorb more heat the following day, meaning lower internal temperatures.

Packaged air-conditioners
A type of local air conditioning system with all its components in a single box which can be installed ready tested.

Passive heating, ventilation and cooling
The use of available natural energy such as heat from the sun and wind-assisted ventilation, in order to benefit a building and maintain optimum comfort temperature.

Refrigerant
The working fluid of the refrigeration system which absorbs heat in the evaporator and rejects it in the condenser.

Refrigerant leakage
Most types of refrigeration system are prone to some degree of refrigerant leakage. This can cause a loss of cooling performance, excessive energy consumption and damage to the environment.

Split air conditioning system
A local air conditioning system that separates the in-room unit, with fan and heating/cooling coils, from the compressor and condensing unit which can be placed outside the building.

Temperature controls
These ensure systems provide the correct required temperatures.

Terminal units
Devices at the end of a duct or pipework that transfer heating or cooling to the conditioned space. The most commonly found types include fan-coil units, induction units and convectors.

Time controls
These ensure systems only operate when and where the building is occupied.

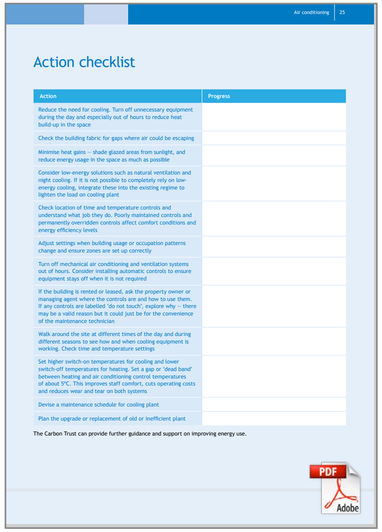
Variable speed drive
A device that controls the rotational speed of a piece of motor-driven equipment such as a fan or pump. In an HVAC system, this can help to reduce costs by enabling the output speed of fans to match requirements.

Water cooled condenser
A heat exchanger used to condense refrigerant vapour using cooling water.

Zoning
Allows a building to be separated into individual areas based on different requirements. Each zone may have separate time and temperature controls, allowing conditions in each area to be provided with heating or cooling appropriate to its individual needs and thus achieving energy savings.

Appendix

Action checklist


Air conditioning 25

Action checklist

Action	Progress
Reduce the need for cooling. Turn off unnecessary equipment during the day and especially out of hours to reduce heat build-up in the space	
Check the building fabric for gaps where air could be escaping	
Minimise heat gains – shade glazed areas from sunlight, and reduce energy usage in the space as much as possible	
Consider low-energy solutions such as natural ventilation and night cooling. If it is not possible to completely rely on low-energy cooling, integrate these into the existing regime to lighten the load on cooling plant	
Check location of time and temperature controls and understand what job they do. Poorly maintained controls and permanently overridden controls affect comfort conditions and energy efficiency levels	
Adjust settings when building usage or occupation patterns change and ensure zones are set up correctly	
Turn off mechanical air conditioning and ventilation systems out of hours. Consider installing automatic controls to ensure equipment stays off when it is not required	
If the building is rented or leased, ask the property owner or managing agent where the controls are and how to use them. If any controls are labelled 'do not touch', explore why – there may be a valid reason but it could just be for the convenience of the maintenance technician	
Walk around the site at different times of the day and during different seasons to see how and when cooling equipment is working. Check time and temperature settings	
Set higher switch-on temperatures for cooling and lower switch-off temperatures for heating. Set a gap or 'dead band' between heating and air conditioning control temperatures of about 5°C. This improves staff comfort, cuts operating costs and reduces wear and tear on both systems	
Devise a maintenance schedule for cooling plant	
Plan the upgrade or replacement of old or inefficient plant	

The Carbon Trust can provide further guidance and support on improving energy use.

PDF Adobe

Download

To start saving energy and reducing your costs now, download and print our air conditioning action checklist

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Further services from the Carbon Trust

The Carbon Trust advises businesses and public sector organisations on their opportunities in a sustainable, low carbon world. We offer a range of information, tools and services including:

Website – Visit us at www.carbontrust.co.uk for our full range of advice and services.

www.carbontrust.co.uk

Publications – We have a library of publications detailing energy saving techniques for a range of sectors and technologies.

www.carbontrust.co.uk/publications

Case Studies – Our case studies show that it's often easier and less expensive than you might think to bring about real change.

www.carbontrust.co.uk/casestudies

Carbon Trust Advisory – Delivers strategic and operational advice on sustainable business value to large organisations.

www.carbontrust.co.uk/advisory

Carbon Trust Certification – Delivers certification and verification services to companies and runs the Carbon Trust Standard and Carbon Reduction Label.

www.carbontrust.co.uk/certification

Carbon Trust Implementation – Delivers services to business in support of implementation of energy efficient equipment and energy efficiency financing.

www.carbontrust.co.uk/implementation

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The Carbon Trust is a not-for-profit company with the mission to accelerate the move to a low carbon economy. We provide specialist support to business and the public sector to help cut carbon emissions, save energy and commercialise low carbon technologies. By stimulating low carbon action we contribute to key UK goals of lower carbon emissions, the development of low carbon businesses, increased energy security and associated jobs.

We help to cut carbon emissions now by:

- providing specialist advice and finance to help organisations cut carbon
- setting standards for carbon reduction.

We reduce potential future carbon emissions by:

- opening markets for low carbon technologies
- leading industry collaborations to commercialise technologies
- investing in early-stage low carbon companies.

www.carbontrust.com

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