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Briefing Paper

# Energy management and building controls

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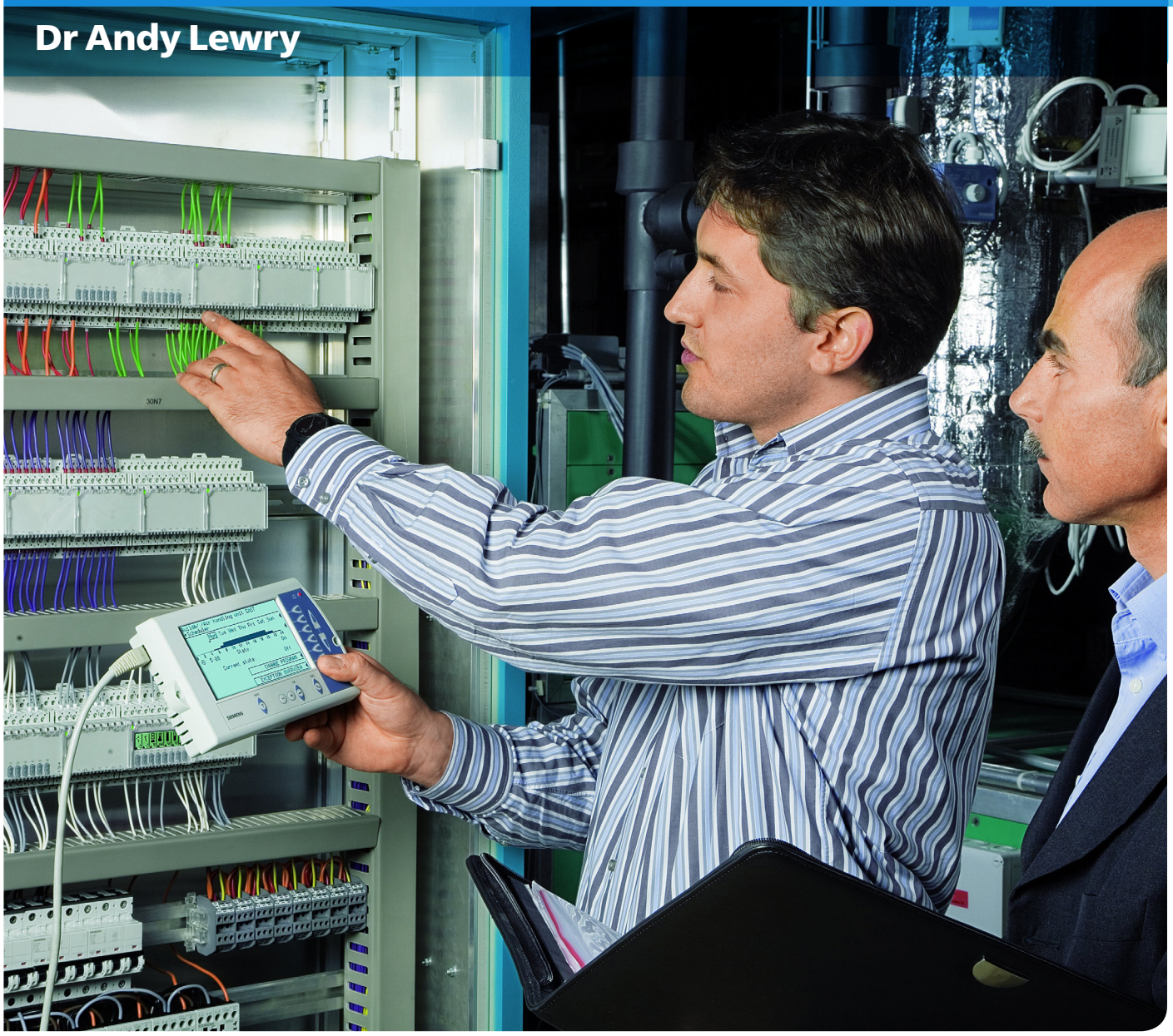

## Introduction

The control of energy in non-domestic buildings is generally poor, despite the availability of a range of tried and tested systems incorporating both established and innovative technologies. Although the installation of HVAC zone controls, optimising controllers (for Wet Heating Systems) and lighting controls is encouraged by the building codes, their requirements are basic. As a result, specifications are often limited to the minimum requirements, and superior technologies, such as pre-programmed packaged Building Energy Management Systems (BEMS) and Demand Control Ventilation (DCV), are ignored.

The author of this report has previously published a guide – *Understanding the choices for building controls* [2] – that provides simple explanations of various types of controls, what they can do, and where and why they can and should be used – the pros and cons, and how to achieve an effective solution in practice.

## BS EN 15232

Energy performance control systems can improve the energy performance of non-domestic buildings through the use of advanced control functions, e.g. adaptive cooling set points; and ventilation related to the number of occupants. The performance of these and simpler controls can be assessed by BS EN 15232 [1], which has a series of classes representing different levels of control of the energy performance – see Figure 1.

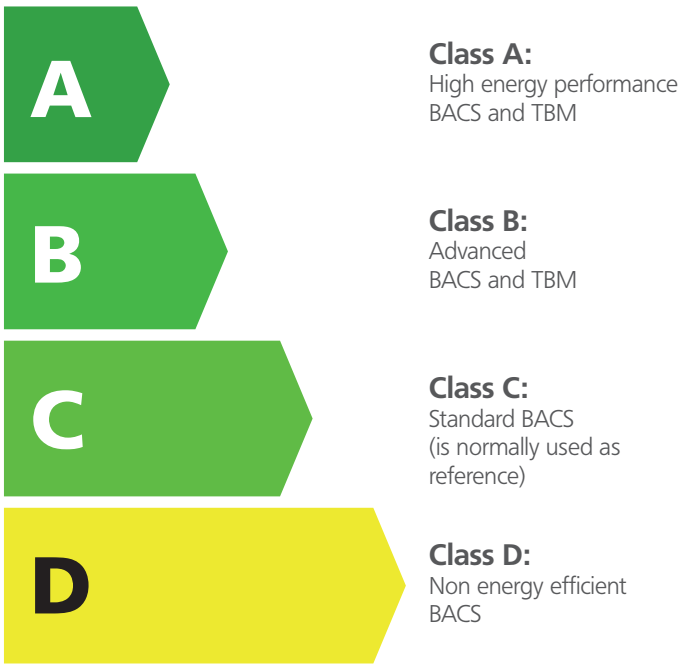


**Figure 1: Energy performance classes**

Note: What the Standard terms Building Automation and Controls Systems (BACS) and Technical Building Management Systems (TBM) are known as Building Management System (BMS) and Building Energy Management System (BEMS) respectively in the UK.

## What do the classes A-D mean?

### Class D

**Class D** are non-energy efficient controls, whilst **C** are considered as standard and are used as the reference point in EN 15232; B are advanced and **A** high energy performance.

### Class C

**Class C** are required by Part L of the building regulations and are Environment Zone Controls. These are typically used to control the environmental conditions (i.e. temperature, ventilation rate, etc.) in individual zones (i.e. rooms or areas) within a building and the supply of services to them.

### Class B

**Class B** are pre-programmed Building Energy Management systems (BEMs). They come with programs set up to keep environmental conditions within defined limits while taking account of occupation schedules, occupation status and/or level of activity in a zone of a building, external environmental conditions, and the specific operating requirements of the zone. These systems are stand-alone products using a fixed set of functions. They are normally expandable, so the size of the building is not a limiting factor. If installed with sensors, fan speed inverters and dampers, they can perform functions such as Demand Control Ventilation (DCV) functions and realise significant savings. DCV is the control of ventilation rate to maintain the required level of indoor air quality while avoiding unnecessary ventilation.

BEMs can also control other building systems, e.g. lighting, shading, etc., which increases the potential for energy savings.

However, they are only suited to small installations, as fixed control functions are limited in their ability to control efficiently the complexity of many HVAC systems and make the best use of extra services, such as renewable technologies.

### Class A

**Class A** are programmable BEMs and have greater functionality than Class B. As the title says, these are fully programmable and offer greater flexibility. They can perform a wide range of control strategies in addition to demand control ventilation (DCV); for example, using free cooling in order to reduce the chiller load may require ventilation rates to be increased, i.e. the BEMs considers the whole building energy picture. Ease of programming and recent reductions in cost have expanded applications into the market previously served by local pre-programmed controllers (e.g. small plant rooms), so these programmable BEMS can be applied to all applications regardless of size.

However, the BEMs is only as good as the person who writes the code; as a result the programmer or systems house needs to have a full knowledge of the system and the hardware/software protocols.

## The benefits of building control

Building controls, whether stand-alone units or full Building Energy Management systems (BEMS), are designed to provide a comfortable climate for building occupants while ensuring this is delivered with the lowest possible energy consumption. Energy is 40% of the life costs and 50% of the running costs of a building. Managing these costs effectively requires controls.

## Potential savings

BS EN 15232:2012 relates these classes of energy management controls – A to D – to a range of building types; it provides efficiency factors which can converted into potential savings.

Table 1 shows these efficiency factors but they are difficult to put into context. The reference point in Table 1 is Class C, which was introduced into the UK building regulations (November 2013) through amendments to Approved Document Part L [3, 4] and the production of a new Non-Domestic Building Services Compliance (NDBSC) Guide [5].

**For savings to be estimated for an existing building or system, its current controls need to be rated against the classification system in BS EN 15232.**

Most of the building stock in the UK currently has controls at a level D or worse. Using Class D as the reference point, the indicative savings for various types of building have been calculated and are shown in Table 2.

Looking at the office buildings line, we can see that fitting Class C controls could realise 34% savings, while an additional 13% can be achieved through Class B controls. Pre-programmable BEMs would satisfy the Class B criteria, but, in order to achieve Class A of the standard and realise the final 7% of energy savings, fully programmable BEMs would be required.

This indicates that approximately 54% energy savings can be achieved by fitting BS EN 15232 Class A controls (a programmable BEMs).

**Table 1: Overall BACS efficiency factors $f_{BACS,th}$ – Non-residential buildings taken from Table 5 of BS EN15232**

| Non-residential building types | Overall BACS efficiency factors $f_{BACS,th}$ | | | |
|---|---|---|---|---|
| | D | C (Reference) | B | A |
| | Non energy efficient | Standard | Advanced | High energy performance |
| **Offices** | **151** | **100** | **80** | **70*** |
| Lecture halls | 124 | 100 | 75 | 50 |
| Education buildings (schools) | 120 | 100 | 88 | 80 |
| Hospitals | 131 | 100 | 91 | 86 |
| Hotels | 131 | 100 | 85 | 68 |
| Restaurants | 123 | 100 | 77 | 68 |
| Wholesale and retail trade service buildings | 156 | 100 | 73 | 60 |
| Other types:<br>– sport facilities<br>– storage<br>– industrial buildings<br>– etc. | | 100 | | |

* These values depend on the heating / cooling demand for ventilation.

**Table 2: Indicative savings for increasing the class of building controls from Class D of BS EN 15232**

| Non-residential building types | % savings from D | | | |
|---|---|---|---|---|
| | D | C (Reference) | B | A |
| | Non energy efficient | Standard | Advanced | High energy performance |
| **Offices** | **0** | **34** | **47** | **54*** |
| Lecture halls | 0 | 19 | 40 | 60 |
| Education buildings (schools) | 0 | 17 | 27 | 33 |
| Hospitals | 0 | 24 | 30 | 34 |
| Hotels | 0 | 24 | 35 | 48 |
| Restaurants | 0. | 19 | 37 | 45 |
| Wholesale and retail trade service buildings | 0 | 36 | 53 | 62 |
| Other types:<br>– sport facilities<br>– storage<br>– industrial buildings<br>– etc. | | N/A | | |

* These values depend on the heating / cooling demand for ventilation.

## Which class of controls?

When choosing a class of control **you need to consider:**

### What else can the controls do?

Controls can be used to manage heating systems, cooling systems, air conditioning systems, lighting systems and blinds – as well as fire and security systems and lifts. They can also be used to directly collect and display data from meters. Energy data can then be displayed on the BEMS; having good quality data about actual energy consumption is the key to achieving an energy efficient building.

### What type of control do I need?

Demand-based control is the most energy efficient; turning things off when not needed or, if this cannot be done, then at least turning them down.

## Which technologies should I use?

There is a range of technologies available (see Table 3) but you need to consider what functionality is required of the control systems. **The first step is to consider which services need to be controlled and what level of control is required – a servicing strategy**.

For example, Demand control adapts the standard assumptions on occupancy and follows actual occupancy patterns. Although building services may be sized to allow for peak loads and occupancy levels, in normal operation these conditions rarely occur.

## How do the controls work?

Typical occupancy patterns are provided in BS EN 15232 for a range of non-domestic building types; it defines classes of energy efficient controls where each class has a certain degree of control – the level of control increases with the change in class.

Figure 2 shows, what is considered, the standard operational characteristics of buildings – where there is a small difference between heating and cooling temperature set point. The operation of all HVAC systems starts two hours before occupancy and finishes three hours after occupied period is ended. This control set up is not considered to be energy efficient as there is no need to maintain comfort conditions for three hours after occupancy.

This is typical of control packages defined under the building codes that do not optimise the energy performance of the building.

Figure 3 shows how a high energy performance controls systems improves the energy performance by advanced control functions, e.g. using adaptive cooling set points and ventilation (Variable Air Volume) related to the number of occupants. A programmable BEMS would normally be required to achieve this and realise the Class A potential savings shown in Table 2.

**Table 3: The range of building control technologies**

| Control | Uses and applications |
|---|---|
| Building management system (BMS) | – A BMS is a computer-based system which integrates building functions, i.e. heating, ventilation and air conditioning (HVAC), fire, security, power systems and lighting.<br>– Available in pre-programmed or programmable formats.<br>– Systems are available for all types of businesses and sizes of buildings. |
| Building energy management system (BEMS) | – BEMS control and monitor plant such as lighting and HVAC in order to specifically address energy use.<br>– BEMS does not integrate all control systems as a BMS does, i.e. control of security and fire protection systems is not normally included. |
| Demand control or zone control | – Demand control enables the HVAC system to operate until the demand is satisfied, e.g. cooling, hot water, radiators and air handling.<br>– Demand control can be linked to $CO_2$ sensors or footfall sensors.<br>– Allows the building to be separated into zones in which services are supplied and controlled as required. |
| Sequencing | – Sequencing can be a stand-alone control or via the BMS/BEMS.<br>– Controlling the number of boilers required to meet the current heating load of the building. |
| Weather compensation | – Controlling the indoor temperature of the building independently of increases or decrease in outdoor temperature.<br>– Enables energy savings to be achieved by reducing the heating system's operating (flow) temperature. |
| Boiler load optimisation | – Stand-alone control which prevents boilers from dry cycling and reduces energy costs.<br>– Boiler optimisation can be programmed as part of the BEMS and some have a standard strategy package to do this. |
| Optimum start/ stop | – A time schedule should be set up to control plant and equipment to fit in with the occupancy of times of a building. This time schedule will also be used to provide optimum start (and stop) of the HVAC plant to ensure comfort conditions are achieved for the start and finish of occupancy. |
| Occupancy controls | – Mainly used in lighting systems, though they can also be used for fast-response extract fan systems in bathroom areas.<br>– There are typically four types of sensors: passive infrared (PIR) sensors, ultrasonic sensors, microwave sensors and audio sensors. |
| Variable controls | – Controlling the speed of drives and fans when full speed is not required will deliver cost savings. |
| Interlock controls | – Prevents unnecessary energy use and plant operation.<br>– For example, if doors or windows are opened, sensors detect this and the interlock controls prevent the boiler(s) or air conditioning from operating. |

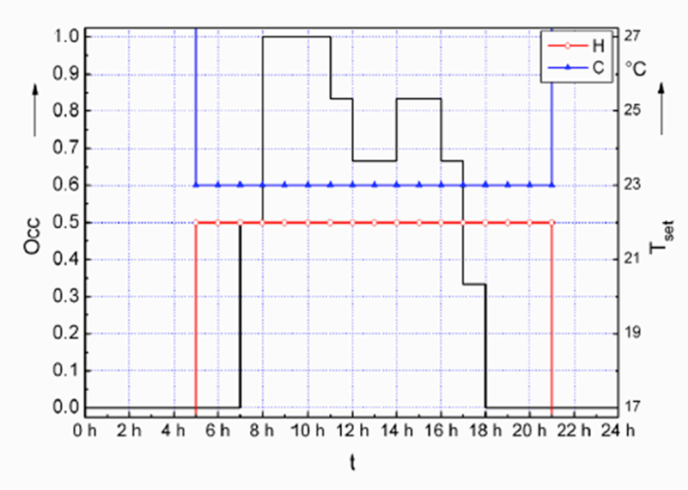


**Figure 2: Class C – Standard operational characteristics of buildings**
Note: H – heating; C – cooling

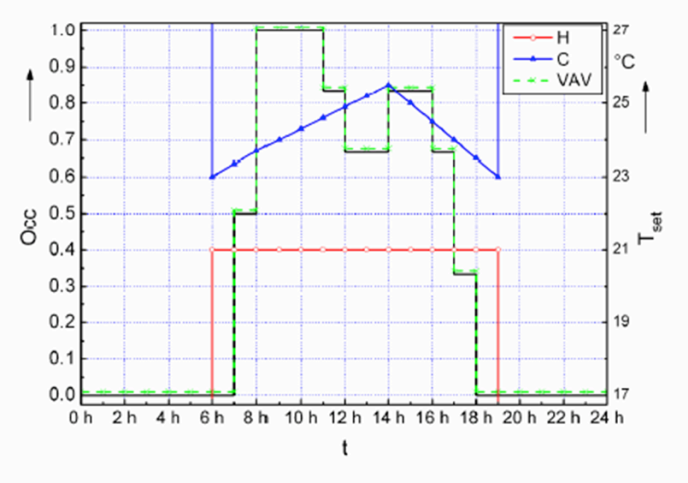


**Figure 3: Class A – High energy performance controls systems**
Note: H – heating; C – cooling; VAV – Variable Air Volume.

## Servicing strategies

When establishing your Servicing and Controls Strategy, the first point is to **determine your business's objectives over the next 3 to 5 years**. This will be driven by issues such as:

- Is your business expanding in size?
- Will more space be required?
- What is the plan with your business's estate?
- How long is left on the lease?
- Does your business have the skill set or expertise to manage and control the building controls?
- Is senior management committed to reducing energy costs and/or carbon emissions?

Next **you need to understand what existing controls** you have in your building(s) and across your estate. An asset log of your plant should exist; if not, it is recommended that one is created, maintained and updated. An audit may be required to highlight areas where controls are lacking and enable you to identify areas where controls are urgently required.

## Good practice and specifications

This would generally be a Class B control which can be programmed to maintain environmental conditions within pre-set limits in a manner that reflects occupation schedules, occupation status and/or level of activity in the zone, whilst also taking account of environmental conditions, and the specific operating requirements of the zone.

Use the Building Environment Zone Controls criteria in the UK Energy Technology List (ETL) [6], plus the summer/winter change-over functionality and a requirement for 365 day programming, as defined in BS EN 15500 [7]. This will cover the Heating, Ventilation and Air Conditioning (HVAC) requirements of Class B, but extra requirements will have to be added when other types of equipment are controlled:

### What extra requirements will I need to consider?

Extra requirements will have to be added when other types of equipment are controlled, for example: Lighting control; Automatic monitoring and targeting equipment; Commercial refrigeration equipment system controls and Air compressor master controllers.

### How do I control lighting?

Lighting controls are technology specific; and are products that are specifically designed to switch electric lighting on or off, and/or to dim its output. In addition to the functionality covered by the building environment zone controls described above, lighting controls cover presence detection and daylight detection – with and without dimming[8].

### How do I specify lighting controls?

Again use the UK Energy Technology List (ETL) – https://www.gov.uk/guidance/energy-technology-list criteria – when specifying lighting controls, heating management controllers and Variable Speed Drives (VSDs). These should be added to the Class B control requirements where appropriate.

Please remember that, if you specify a class under BS EN 15232, **the whole of the building** must have that level of control to be compliant with the standard.

**The use of this standard and the estimation of savings on a case-by-case basis is an expert's job.** If required, the European Building Automation and Controls Association (eu.bac) has a certification scheme based on BS EN 15232. The purpose of this scheme is to ensure that a system's extensive features and functionality, in terms of energy-saving measures, are installed and used to their full potential over the lifetime of the system.

## What are the key issues?

There are **ten** key issues to address:

### Specification breaking – procurement routes and 'value engineering'

This is normally a cost-cutting exercise with the temptation to cut capital costs. Stand-alone controls are cheap, in the order of £250 installed, but several will be required. Pre-programmed BEMS have an installed price of around £1000. But to fully realise the potential savings from energy efficiency, you probably need a programmable BEMS which costs in the range of £3,500 and £5,000 installed.

### Occupancy patterns – schedules and density

As we have seen above, knowledge of how the building is used improves the estimation of potential savings and, following installation, allows commissioning of the controls to fully realise the potential energy savings.

### Future proofing – flexibility and upgrades

Technology soon becomes dated and to ensure that your system does not become redundant it needs to be programmable. A programmable system is likely to be flexible enough to take into account changes in usage and can be upgraded to benefit from technological and software advances.

### Links to monitoring and targeting (M&T) – optimisation systems

Energy management relies on the old adage 'if you cannot measure it, you cannot manage it'. This means that the control system (i.e. the BEMS) needs to be linked to the metering, so that all the monitoring and targeting M&T functions can be carried out in the same place, thus allowing management to be instantaneous.

### Verification/certification

To justify business cases it is increasingly important for the performance of new assets, including control systems, to be verified. A fully integrated system can allow collection and analysis of this data, thus allowing this step to be simple and relatively painless.

### Commissioning – initial set-up and an on-going process

It is essential to understand your business and building(s) when producing a Servicing and Controls Strategy. The next step is to ensure that the controls are installed and commissioned to achieve this strategy. However, it is an unending process to resolve operating problems, improve comfort, optimise energy use and identify retrofits for existing buildings and central plant facilities.

### Training

Training is only as current as the last person trained, so, like commissioning, should be an on-going process to ensure that Facilities staff, the Facilities Management (FM) contractor (if you have one) and other users know how to optimise the use of the system. If knowledge is lost, the temptation is to use default systems which leads to inefficiencies and defeats the object of having a customisable programmable system.

### Maintenance requirements – planned upgrades

This runs alongside ongoing commissioning, requiring the hardware to be monitored and upgraded where appropriate. This is especially true of sensors where the system will still run if they are damaged or have drifted due to old age, but not at optimal performance. The likely result is far higher running costs.

### Management reporting

For energy management to be effective, the data has to be presented in a concise manner and in a form appropriate to the audience. What is required for management of the system will be far more detailed than that required for the financial department to reconcile the bills on a monthly basis. Board reports need to be concise and to highlight any issues.

### Additional functionality – critical services/alarms

When managing services you need to ensure that they are delivering the right amount at the right time. Modern systems can be set up to alert key staff by email when services fail to switch off when expected, use more energy than expected or when communications go down. This minimises risk to the business in terms of uncontrolled usage and possible damage to the asset.

## The process

1. Understand what controls you already have
2. Determine your business needs
3. Determine the functionality required of the controls
4. Select an appropriate servicing strategy
5. Match these against a class of BS EN 15232
6. Ensure the chosen class has the required functionality
7. Produce a comprehensive specification
8. Ensure the "10" key issues are addressed
9. Engage an expert(s) at the stage where internal capabilities are exceeded; this is not something you can learn as you go along.

## Next steps

Once you have addressed all the questions and issues above, you are now ready to implement the strategy. It is a good idea to get expert help at this stage, although, due to the complex nature of this technology area and its application, you may choose to engage this earlier.

If you have a Facilities Management (FM) provider, Mechanical and Electrical (M&E) contractor or BMS/BEMS service provider, they will be able to help you understand what you have and what is possible within your estate. Use their experience and knowledge to your advantage. Alternatively, if you do not have such partnerships or service providers, consultants can provide a valuable service by carrying out an in-depth Energy/Building audit.

Understanding of the standard and its application are more complex and an expert consultant may be needed.

## References


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## Summary

This technical briefing note informs readers of the benefits of the European standard BS EN15232:2012 [1] and helps them to navigate through the standard. It highlights the points to consider when deciding which controls would best suit a company's needs, and includes a guide to best practice.



## Acknowledgements

The author would like to thank ESTA, the Energy Services and Technology Association, the UK's leading Energy energy Management management industry association (www.esta.org.uk), for both their contribution to the production of this publication and for organising an industry steering group.

A special thank-you to Julian Kay of Danlers Ltd. for his input and advice.


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