Best Environmental Management Practice full content PDF
Best Environmental Management Practice

Managing and minimising energy use

In a nutshell

<table>
<tr><th>SUMMARY</th></tr>
<tr><td>It is best practice to implement energy management according to the principles of the 'plan, do, check, act' cycle in offices owned or managed by the public administration by:

collecting frequently or monitoring constantly energy use data; data can be collected at building level, per building area (e.g. lobby, offices, canteen/bar), per type of energy source (e.g. gas, electricity) and per end-use category (e.g. lighting, space heating);
analysing the data, setting targets, identifying benchmarks and using them for comparing actual energy use performance;
defining a strategy and action plan for the improvement of the energy performance of the office building.
</td></tr>
<tr><th>Target group</th></tr>
<tr><td>Public administrations having office-based operations</td></tr>
<tr><th>Applicability</th></tr>
<tr><td>This BEMP is broadly applicable to office buildings owned or managed by public administrations. However, actions that may arise from implementing this best practice may be more limited in rented buildings.</td></tr>
<tr><th>Environmental performance indicators</th></tr>
</table>

- Total annual energy use per unit of floor area[1], expressed as final energy (kWh/m^2/year).

If available, this can also be broken down into:

- space heating (kWh/m^2/year)
- space cooling (kWh/m^2/year)
- lighting (kWh/m^2/year)
- other electricity uses (kWh/m^2/year)

- Total annual energy use per full time equivalent (FTE) employee, expressed as final energy (kWh/FTE/year).

If available, this can also be broken down into:

- space heating (kWh/FTE/year)
- space cooling (kWh/FTE/year)
- lighting (kWh/FTE/year)
- other electricity uses (kWh/FTE/year)

- Total annual primary energy use per floor area or full time equivalent (FTE) employee (kWh/m^2/year, kWh/FTE/year)

- Total annual greenhouse gas emissions per floor area or full time equivalent (FTE) employee (kg CO2eq/FTE/year)

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N/A

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[1] Floor area can be calculated taking into account the useful surface area of the building, for example, the surface used in the energy performance certificates.

Description

Energy use (mainly for space heating and cooling) is a key environmental impact of office buildings. Concrete actions regarding improving energy efficiency and generating renewable energy in public buildings are covered under specific best practices of this section. These include retrofitting the building envelope, optimising heating, ventilation and air conditioning (HVAC) systems, installing on-site renewable energy generation and other technological solutions. Additionally, minimising energy use of buildings can also be achieved through monitoring, energy management and fostering of behavioural change, as described also in a specific BEMP (see Section 3.2.5). The present best practice focuses instead on the role of energy management itself, specifically for Public Administration offices.

Energy management, often together with carbon management, is an important element within environmental management. Energy management comprises a systematic approach to managing energy consumption including energy efficiency (reducing the amount of energy used) and renewable energy (switching to a low or zero carbon energy source). Good energy management should be integrated into wider management systems and have support at the top level of management and a dedicated staff resource. It must include a policy (action plan and regular reviews) and performance measurement. It must be embedded at all levels through internal and external communication plus staff training.

This BEMP explains how energy management can be implemented in practice and applies at the building level. It follows the principles of PDCA (Plan, Do, Check, Act) (IEMA, 2014) as per leading environmental management systems e.g. EMAS and ISO 14001. This is an iterative sequence which facilitates continuous improvement and allows those responsible to be proactive. This BEMP focuses on implementing parts of the PDCA cycle which are specific to energy management:

- Identify benchmarks
- Data collection and ongoing monitoring (in the “check” part of the cycle)
- Data analysis, target setting, establishing a strategy / action plan (in the “plan” part of the cycle)

Identify benchmarks

Benchmarks are useful for comparing actual energy use performance to standardised performance – whether that is best practice, good practice or typical performance.

PassivHaus is an example of one of the most ambitious energy performance standards on the market and represents a best practice benchmark – see Table 1. Energy performance for new buildings should certainly be equivalent to this. Passive House has been developed for cool temperate climates but should be applicable throughout Europe unless there are particularly extreme conditions. An example of office building complying with the PassiveHaus standard is the 4-storey, 8266 m2 Energon office in Ulm, Germany. It achieves 12 kWh per m^2 per year for heating and primary energy use of 67kWh/ m2 per year (EnOB, 2014).

Table 1: Passive House Institute criteria for non-residential buildings (PassivHaus Institut, 2013, p.1)

Heating	**Cooling**	**Primary energy**
Specific space heating demand ? 15 kWh/(m^2 / year) *or alternatively:* heating load ? 10 W/ m^2	Specific useful cooling demand) ? 15 kWh/(m^2 / year)	Total specific primary energy demand) ? 120 kWh/(m^2 / year)

Schlenger (2009) analysed energy use for typical office buildings categorised into three climate zones – and then modelled energy use if the buildings were to be optimised. Colder climates did not necessarily have larger energy use, as warmer climates use cooling energy. The energy performance of the optimised buildings were:

- Oslo - 47.8 kWh/ m2/year (of which 13.6 kWh/ m2/year heating)
- Brussels - 33.3 kWh/ m2/year (of which 19.3 kWh/ m2/year heating)

- Madrid – 50.8 kWh/ m2/year (of which 43.5 kWh/ m2/year heating)

The UK Energy Efficiency Best Practice Program (2000) showed best practice total values ranging between 112 and 348 kWh/ m2/year and carbon emissions from 8.3 – 36.6 CO_2eq / m2/year depending on office type (Wade et al, 2003, p.7-8).

Current average energy intensity for offices in the UK, Czech Republic, France, Finland and Belgium is in the range 200 - 320 kWh/ m2 (Economidou, M., 2011, p53).

Data collection and monitoring

Energy consumption data should be collected at building level and ideally also by building area, particularly if the building envelope has different characteristics in different zones (such as a lobby which has more air changes, or two wings built in different decades). The data should be collected by fuel type and also if possible by end use category, such as heating, catering, lighting and equipment. This should all be set up within the building management system (BMS) where available and / or possible to implement. A summary of information that could be collected is shown in Table 2:

Table 2: Types of energy, what they are used for and how they are measured

Type	**How measure**	**Used for**
Gas	Use meter readings	Boiler or other heating Domestic hot water Catering
Oil	Use gauge / tank dip or use heat submeter	Boiler or other heating Domestic hot water Catering
Coal	Measure level or use heat submeter	Boiler or other heating Domestic hot water Catering
Biomass	Measure level, use heat submeter or record delivery figures	Boiler or other heating Domestic hot water Catering
LPG	Use delivery figures or submeter	Boiler or other heating Domestic hot water Catering

Type	How measure	Used for
Electricity	Use meter readings	Lighting IT equipment Ventilation Air conditioning Heating system pumps Catering
Purchased hot water and heat	Use heat meter readings	Heating Domestic hot water

The data collected above is expressed in terms of final energy. It is important to analyse the data and develop indicators not only for final energy but also in terms of primary energy. To do so, primary energy factors should be applied to all fuels and energy carriers (Pout, 2011). Primary energy more accurately reflects resources used. This is important when comparing the effects of a fuel switch, as the same amount of final energy for different energy carriers can correspond to very different amounts of upstream energy needed to generate them. Final energy can be more helpful for analysing the elements within the building occupants' control.

Measuring energy use continuously using automatic meter readings (AMR), ideally as part of a building management system / building energy management system, is usually the best possible option. However, functioning of the meters and sensors must be regularly checked. Energy use can be monitored half-hourly, particularly where this is dependent on external temperature and weather such as heating and cooling. This is less important where energy use is automated e.g. for ventilation which is set to a constant level during office hours. For unmetered commodities (often liquid / solid fuels), delivery notes, stock-level records and period opening and closing values can be used. Use of invoices should be avoided in case they are based on supplier estimates. All units will need to be converted into a common unit (e.g. kWh) if other units have been used e.g. for gas / LPG.

As well as the data on energy, data on other variables will need to be gathered, such as floorspace and occupancy i.e. full time equivalent staff.

Data analysis

Data must be analysed in order to detect inefficiencies and establish priorities for action. Space heating and space cooling energy use needs to be normalised for weather variations in order to allow meaningful comparison e.g. with benchmarks, targets or previous years. Regression analysis and cumulative sum of deviation (cusum) can quickly help energy managers spot wastage.

Climate correction

Energy use is normalised for weather using degree days to eliminate fluctuations caused by external weather changes. This allows energy figures to be meaningfully compared year to year and changes to reflect the results from actual actions taken rather than external factors such as a milder or cooler winter (International Energy Agency, 2014, Annex C).

Heating degree days are a measure of how much and for how long external air temperature fell below a certain base temperature (which should correspond to the average temperature at which the building is kept during the heating period). Number of heating degree days is directly proportional to amount of heating energy needed in order to maintain the building internal temperature. The figures vary depending on the base temperature – the external temperature above which the heating is switched on. This is always a few degrees lower than the thermostat setting for internal temperature. Eurostat (2010) defined a common European baseline figure of 15°C, based on a target internal air temperature of 18°C, with 3°C due to internal heat gain and effects of insulation. Heating degree days for local weather stations worldwide can be downloaded from various websites e.g. BiZee Degree Days (2014).

Annual reporting of heating energy used should include both actual and weather normalised figures in order to compare performance fairly from year to year (or other time period). This can be done as follows:

Annual total heating energy used/annual total degree day figure x degree days 20 year average

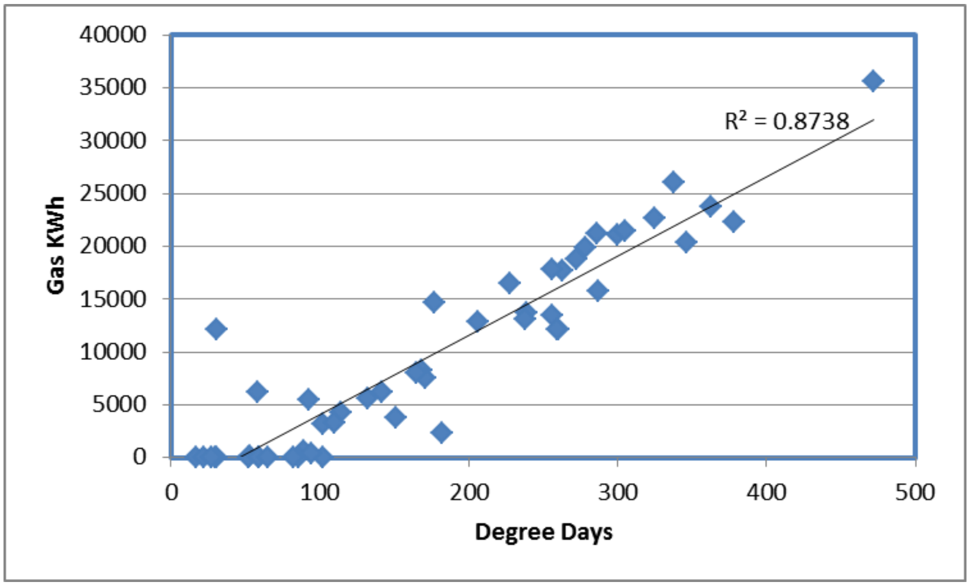
Conversely, cooling degree days measure how much and for how long external air temperature rose above a certain base temperature (which should correspond to the average temperature at which the building is kept during the cooling season). Number of cooling degree days therefore reflect the amount of cooling energy required to keep the building cool during warm weather in buildings which use cooling. The same methodologies can be applied as for heating degree days.

Tools for analysis over time

Analysis is then carried out to show differences over time e.g. a comparison with the same month in previous year. This allows the person responsible for energy management to ensure energy use is minimised and anomalies dealt with. It contributes to the “check” part of the plan-do-check-act cycle.

Regression analysis is a methodology where the energy used is plotted against degree days in order to detect anomalies. This can be done for any time period as long as the degree days for each point are for the same time period as the energy use. The example in Figure 1 shows daily gas use (kWh) plotted against degree days for a month during the heating season.

Figure 1 – Daily gas use plotted against degree days (Ransom, 2014)



The R^2 value describes the level of correlation between the two sets of data. The nearer to 1 the R^2 value is, the better the correlation, showing that control of the heating system is good, with proportional increases in heating use with colder weather. In the example shown in Figure 2, the building has a relatively good fit, improving further when the two outliers are removed (R^2 increases from 0.87 to 0.92). The particular outliers in this example were due to a temporary need to supply heating to a neighbouring building.

An R^2 value over 0.75 represents a reasonable correlation and over 0.9 represents a good correlation (Bizee Degree Days, 2014).

Where there is a wide scatter above the line, this could signal energy wastage e.g. too much heating in warm weather. Good performance for the building will be shown by the lower points under the line of best fit. However if there is an anomaly far below the line, this could signal, for example, a broken boiler on a cold day. A gradual drift of all points above the historic line of best fit would indicate more persistent changes which have not been addressed e.g. ineffective building energy management system settings or broken equipment.

If the best fit line meets the y-axis, it can indicate the building base load. In the example above, the line of best fit meets the x-axis. This indicates that the building is possibly benefitting from internal heat gain (e.g. due to good insulation). This will not affect the R^2 analysis.

A regression line can also be used to compare expected and actual energy use from a historical best practice line. Once a degree day figure has been obtained for a certain period, expected energy use can be read off from the y-axis and compared to the actual energy use for that period and wastage calculated.

Regression analysis is a useful tool; however it can be misleading due to assumptions around base temperatures, i.e. if the building is heated or cooled at temperatures which are (very) different from the chosen base temperatures.

A “cusum” (cumulative sum) chart shows trends in deviation from the best fit line (or any target). Cusum charts show the running total of deviation and can be used for energy consumption overall or for individual metering points. A cusum chart can be drawn by entering the monthly deviances from the expected energy use into a spreadsheet, then making these cumulative and plotting on a graph. Expected energy consumption can be read off a historic best-fit line such as Figure 2?1 using the degree days derived for the month.

An example of the resulting cusum graph is shown in Figure 2?2. A horizontal cusum line reflects expected performance.
(with a downward section indicating less energy use
t expected.

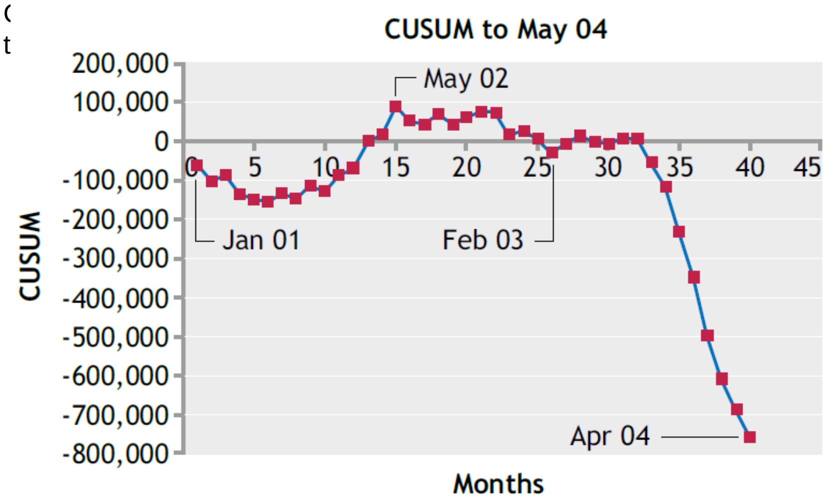


Figure 2: Sample cusum chart (Carbon Trust, 2012, p.18)

In the example, a sustained downward trend was due to replacement of an old boiler and controls.

The methodologies described above for analysing energy use can be performed as frequently as desired subject to availability of data and staff resources, however it is recommended they be carried out monthly as a minimum. A wider review can be done annually.

Target setting

Targets are a quantified goal to be reached within a specified timeframe. They are different to benchmarks which comprise a point of reference which could be typical, good practice or best practice and may be set by third parties. Benchmarks can also be theoretical such as 50% of a measured figure (Bosteels et al, 2010).

Whilst it is interesting to consider office energy use benchmarks and use these for aspirational wider corporate targets (e.g. 95% CO_2eq reduction by 2020 based on reaching best performance by then), there should be targets set at the office building level based on a bottom up approach. This means they should reflect proven achievable performance e.g. best achieved performance to date. This will be limited to constraints of the current building envelope, HVAC systems, and occupancy requirements.

Targets should be set for energy intensity per m^2 and per employee. Sometimes an increase in intensity will be necessary if more employees begin working in a building. Equally, if a building expansion is planned, this could affect energy intensity per employee. Identifying best performance to date varies by use, so targets should be calculated that apply to individual monitored streams, which can be consolidated to form an overarching target in kWh/m^2/year and kWh/employee/year.

Heating targets can be set using cusum by identifying those points on low-gradient sections of the cusum chart (y axis is kWh used, x axis is month) and plotting these on a chart showing monthly kWh used against degree days for the month (making sure all seasons are covered, ideally over the course of several years). Then a best fit line can be created as mentioned above, which indicates kWh/degree day based on best previous performance.

This figure can be multiplied by 20-year average degree days for the region or country, giving a prediction of energy use based on best previous performance. The percentage improvement can be calculated based on current energy usage. A date can then be set for achieving this improvement and will depend on estimated length of time for actions to be implemented e.g. changing BMS settings or behaviour change. For each intervening year / month, figures should be calculated reflecting these expectations to ensure progressive improvement is being achieved. Targets should be updated regularly as better performance is achieved.

Establishing a strategy

An energy strategy outlines how energy is managed in a building or portfolio of buildings and actions that will be taken to reduce energy use. This involves:

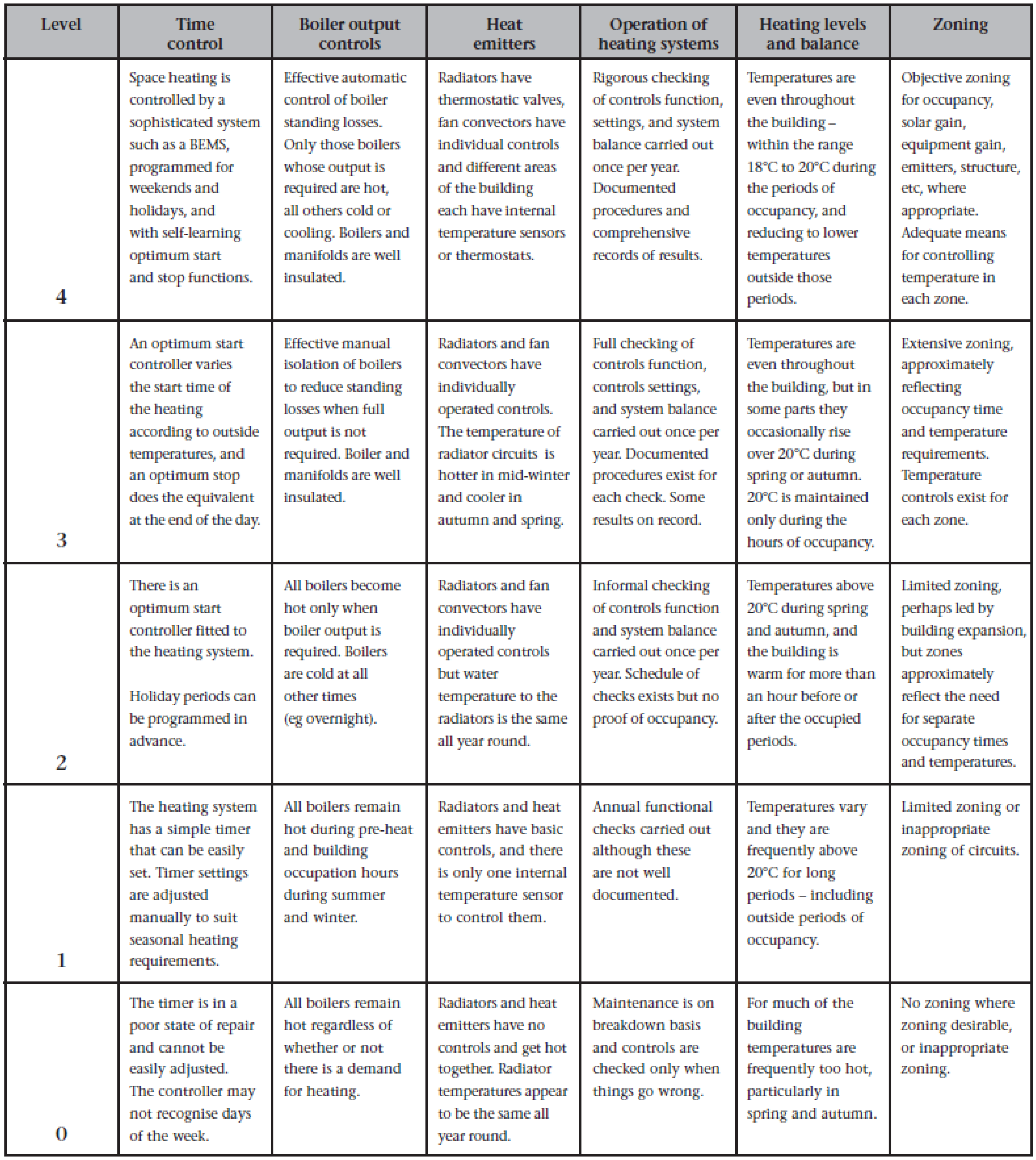
- Carrying out an initial energy audit

- Carrying out an audit of the current situation, including the building systems (HVAC), building envelope characteristics and any energy management systems already in place.

Once the energy management strategy starts to be implemented, ensuing tasks will help locate and implement energy saving projects. The strategy should include who is responsible for energy management, how regulatory compliance will be ensured, what investments will be made in energy saving equipment or renewables and how procurement will be managed taking energy efficiency implications into account (Carbon Trust, 2011).

Identification of energy saving projects is key to the strategy as mentioned above. This will involve prioritisation in terms of management activities and physical upgrades. BRECSU (2001) produced a guide which includes matrices for scoring progress on three levels including overall energy management, awareness and information and technical matrices covering space heating, lighting, boilers and building fabric. The detailed matrix is reproduced in Table 3. The levels 0 – 4 reflect scores, with 4 being the best.

Table 3: scoring matrix for space heating (BRECSU, 2001, p15)



Level	Time control	Boiler output controls	Heat emitters	Operation of heating systems	Heating levels and balance	Zoning
4	Space heating is controlled by a sophisticated system such as a BEMS, programmed for weekends and holidays, and with self-learning optimum start and stop functions.	Effective automatic control of boiler standing losses. Only those boilers whose output is required are hot, all others cold or cooling. Boilers and manifolds are well insulated.	Radiators have thermostatic valves, fan convectors have individual controls and different areas of the building each have internal temperature sensors or thermostats.	Rigorous checking of controls function, settings, and system balance carried out once per year. Documented procedures and comprehensive records of results.	Temperatures are even throughout the building – within the range 18°C to 20°C during the periods of occupancy, and reducing to lower temperatures outside those periods.	Objective zoning for occupancy, solar gain, equipment gain, emitters, structure, etc, where appropriate. Adequate means for controlling temperature in each zone.
3	An optimum start controller varies the start time of the heating according to outside temperatures, and an optimum stop does the equivalent at the end of the day.	Effective manual isolation of boilers to reduce standing losses when full output is not required. Boiler and manifolds are well insulated.	Radiators and fan convectors have individually operated controls. The temperature of radiator circuits is hotter in mid-winter and cooler in autumn and spring.	Full checking of controls function, controls settings, and system balance carried out once per year. Documented procedures exist for each check. Some results on record.	Temperatures are even throughout the building, but in some parts they occasionally rise over 20°C during spring or autumn. 20°C is maintained only during the hours of occupancy.	Extensive zoning, approximately reflecting occupancy time and temperature requirements. Temperature controls exist for each zone.
2	There is an optimum start controller fitted to the heating system. Holiday periods can be programmed in advance.	All boilers become hot only when boiler output is required. Boilers are cold at all other times (eg overnight).	Radiators and fan convectors have individually operated controls but water temperature to the radiators is the same all year round.	Informal checking of controls function and system balance carried out once per year. Schedule of checks exists but no proof of occupancy.	Temperatures above 20°C during spring and autumn, and the building is warm for more than an hour before or after the occupied periods.	Limited zoning, perhaps led by building expansion, but zones approximately reflect the need for separate occupancy times and temperatures.
1	The heating system has a simple timer that can be easily set. Timer settings are adjusted manually to suit seasonal heating requirements.	All boilers remain hot during pre-heat and building occupation hours during summer and winter.	Radiators and heat emitters have basic controls, and there is only one internal temperature sensor to control them.	Annual functional checks carried out although these are not well documented.	Temperatures vary and they are frequently above 20°C for long periods – including outside periods of occupancy.	Limited zoning or inappropriate zoning of circuits.
0	The timer is in a poor state of repair and cannot be easily adjusted. The controller may not recognise days of the week.	All boilers remain hot regardless of whether or not there is a demand for heating.	Radiators and heat emitters have no controls and get hot together. Radiator temperatures appear to be the same all year round.	Maintenance is on breakdown basis and controls are checked only when things go wrong.	For much of the building temperatures are frequently too hot, particularly in spring and autumn.	No zoning where zoning desirable, or inappropriate zoning.

Environmental benefits

The main environmental benefits to energy management in offices, specifically strategy, measurement and implementation of performance improvements at a building level are reductions in:

- energy use and, especially, use of non-renewable fossil fuels; and consequently
- greenhouse gas emissions.

Of particular relevance to public offices, there is the secondary benefit of dissemination of good practice that can lead other organisations to also reduce their energy consumption. Information can be shared retrospectively including lessons learned and wider strategy (DECC, 2012). Energy use can be shared publicly in real time – for example see Carbon Culture.net (https://platform.carbonculture.net/landing/).

Side effects

There are no cross-media effects from the implementation of this BEMP. The increased energy use from the implementation of AMR and IT systems to control the energy use and/or the building operations are much lower than the likely energy savings.

Applicability

This best practice relates to public administration offices and is applicable across the whole of Europe. Though most of the principles are widely applicable, this best practice is specific to office buildings and not other buildings that may be owned by public administrations but used for other uses. Indeed, aspects of energy management that apply specifically to other functions such as industrial process energy management have not been covered. This best practice has environmental and economic benefits whether the building is rented or owned even though actions may be more restricted in rented buildings.

Economics

Public administrations can save 20% of their energy costs by implementing energy management in their office buildings. Savings range from 5 – 25% with payback typically two years or less. Even with minimal capital expenditure, savings of 5 – 10% can be made. UK Carbon Trust research has identified that the investments required to save 15% of energy bills have an average Internal Rate of Return (IRR) of 48%, well above the minimum requirement set by businesses, which averages 11.5% (Carbon Trust, 2013, p.7).

Driving forces for implementation

Public Administrations are implementing energy management to help reduce energy costs and, if applicable, carbon taxes payable, comply with legislation, help ensure business continuity (security of supply), enhance reputation and contribute to comfort and wellbeing of the building's users. The implementation of energy management can also be dictated by environmental consciousness and/or the need to deliver carbon and resource savings to reach high-level political targets. When an effective energy management system is implemented specifically for Public Administration offices, it can play the additional role of leading by example. For example the energy policy, energy data, KPIs and actions can be made public.

Often implementing energy management has been part of a broader sustainability agenda, sometimes first considered under Agenda21. Bristol City Council has a Climate Change and Energy Security Framework, which aims to reduce carbon emissions by 40% by 2020 from a 2005 baseline. For DECC energy management was an important part of their own carbon management. As well as having a 10% central government carbon reduction target, they consider it crucial to lead by example (DECC, 2011). For the City of Frankfurt, internal energy management has its own department as an integral part of the broader management of municipal buildings. They have been keeping records of gas, oil, electricity, water use, etc. since 1990.

Reference organisations

Bristol City Council (UK)

In Bristol Council's Create Building effective energy management has halved energy and carbon intensity per building occupant. This is as a result of increased occupancy as well as updating settings, fitting insulation and introducing renewables.

Department of Energy and Climate Change, London (UK)

Whitehall Place has reduced energy use by around 60% between 2008 and 2012 thanks to proactive energy management, including fine-tuning building management system settings.

Stadt Frankfurt am Main (Germany)

Stadt Frankfurt am Main has a comprehensive metering and monitoring system for its buildings as well as a programme of thermal imaging reporting.

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