Scottish Government
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Building Standards Non-domestic Technical Handbook (extract)

Consultation proposals – Non-domestic Building Services Compliance Guide

July 2021

The Building Standards Technical Handbooks provide guidance on achieving the standards set in The Building (Scotland) Regulations 2004.

Further information on the Scottish building standards system can be found at: www.gov.scot/policies/building-standards/.

This document sets out proposed changes to the mandatory standards and supporting guidance issued in support of **section 6 'energy'** within the Building Standards **Domestic Technical Handbook**.

Where text is amended from the current, published 2015 edition of the handbook, this is shown by highlighting relevant passages in yellow.

The subject matter of these changes is set out in more detail within section 3 of the consultation document 'Scottish Building Regulations – Proposed Changes to Energy Standards and associated topics', published online at: https://consult.gov.scot/local-government-and-communities/building-regulations-energy-standards-review/.

Section 1: Introduction

1.1 Scope

This guide provides detailed guidance for the installation of fixed building services in new and existing non-domestic buildings in support of compliance with the energy efficiency requirements set out under standards 6.3 to 6.6 of the building regulations.

This edition covers the design, installation and commissioning of:

- conventional means of providing primary space heating, domestic hot water, mechanical ventilation, comfort cooling and interior lighting; and
- low carbon generation of heat, by heat pumps and combined heat and power systems.

The guide sets out recommended minimum energy efficiency standards for components of building services systems, including the use of controls. For systems installed in new buildings, the standards are minimum design limits (or back-stop values). For new or replacement systems and components installed in existing buildings, the standards represent appropriate provision for complying with building regulations.

It is important to note that standards higher than many of these recommended minimum standards will need to be achieved where:

- new buildings are to meet the target carbon dioxide emission rate (TER) or Target Primary Energy Rate (TPER) calculated under standard 6.1 using National Calculation Methodology (NCM) tools such as SBEM[1]
- systems (up to 45 kW heat output) are to comply with the Microgeneration Certification Scheme standards that enable building owners to receive payments under UK Government initiatives

The guide includes some supplementary information that identifies good practice design and installation standards that exceed the minimum standards in this guide. Microgeneration Certification Scheme standards[2] are one example of good practice standards.

A summary of recommended minimum energy efficiency standards is presented in Table 1 at the end of this section.

1.2 Innovative systems

It is also important to note that this guide covers a range of frequently occurring situations. It deals with the most commonly used fixed building services technologies. In doing so it neither endorses these methods and technologies nor excludes other more innovative technologies that may offer an alternative means of meeting the functional requirements of the building regulations.

Where the alternative technology has been the subject of a recognised testing procedure that assesses its energy performance, this may be used to indicate that the system is

1 https://www.uk-ncm.org.uk/
2 https://mcscertified.com/standards-tools-library/

adequately efficient. In the event that there is no recognised testing standard, suitable calculations or modelling methods should be used to show the carbon performance of the system.

1.3 Implemented European Directives

The design and installation of fixed building services products, such as boilers, circulators and heat pumps, shall at the appropriate time comply with all relevant requirements of EU Directives to December 2020, as currently implemented via UK legislation. See also Regulations: ecodesign of energy-consuming products - GOV.UK (www.gov.uk)

National building regulations continue to implement elements of The Energy Performance of Buildings Directive 2010/31/EU and its most recent 2018 amendment (for example by setting standards for new buildings and new building work).

For guidance on the most recent changes affecting new and existing non domestic buildings, see Section 6 Energy of the Non-Domestic Technical Handbook[3].

For guidance on other requirements relating to building certification and inspection of heating and air conditioning systems, see the BSD website[4].

1.4 Status of guide

The building regulations in Scotland are expressed in terms of functional standards. These standards are statements of functions the complete building must fulfil or allow. The standards are set out in building regulations and are intended to:

- secure the health, safety and welfare and convenience of persons in or about buildings;
- further the conservation of fuel and power; and
- further the achievement of sustainable development.

These functional requirements are often drafted in broad terms and so, from the standard alone, it may not always be immediately clear to a person carrying out work how to comply with the relevant requirements. Consequently, the Building Standards Division issues guidance in the form of Technical Handbooks and other published information, such as this document, which provide practical guidance on ways of complying with specific aspects of the building regulations in most common building situations.

The Technical Handbooks are intended to provide practical guidance, but they are not intended to be comprehensive. Consequently, they may contain references to other documents which will provide more detailed information and assistance on parts of the guidance. This guide is one of those documents. It provides more detailed information on the guidance contained in Section 6 Energy of the Non-domestic Technical Handbook about compliance with the energy efficiency requirements which apply when installing fixed building services in new and existing buildings.

3 Draft Guidance - Section 6 (Energy) Non-domestic
4 http://www.gov.scot/epc

If you follow the guidance in the Technical Handbooks and companion documents, such guidance may be relied on in any proceedings as tending to negative liability for an alleged contravention of the building regulations (refer to Section 0 of the Technical Handbooks for further explanation).

However, in each every case it is for the verifier (local authority) to determine whether work complies with the requirements of the building regulations. Where there is doubt, it is appropriate to check with the verifier before starting work to establish what is necessary for compliance with building regulations. In Scotland, all new buildings and much work to existing buildings will require the issue of a building warrant prior to any works commencing on site. Information on works which must comply with building regulations but for which a building warrant is not required are set out in schedule 3 to regulation 5 (refer to Section 0 of the Technical Handbooks).

1.5 How to use the guide

The guide is divided into the following sections:

Section 1: Introduction and summary of energy efficiency standards

Section 2: Gas, oil and biomass-fired boilers

Section 3: Heat pumps

Section 4: Gas and oil-fired warm air heaters

Section 5: Gas and oil-fired radiant heaters

Section 6: Combined heat and power and community heating

Section 7: Direct electric space heating

Section 8: Domestic hot water

Section 9: Comfort cooling

Section 10: Air distribution

Section 11: Pipework and ductwork insulation

Section 12: Interior lighting

Section 13: Heating and cooling system circulators and water pumps

Section 14 – Building Automation and Control Systems

Section 15 – Self-Regulating Devices

Supplementary information is shown in *blue italics* or as text in light blue tables. This may be further information to help in establishing the minimum energy efficiency provisions needed to comply with the building regulations or it may be guidance on best practice that goes beyond the recommended minimum standards.

Key terms are printed in italics and are defined at appropriate points throughout the guide.

1.6 Key terms for space heating and domestic hot water systems

The following general definitions are applicable to the sections that deal with space heating and hot water. Further definitions are included in later sections as appropriate.

Heat generator means a device for converting fuel or electricity into heat – e.g. a boiler or radiant heater.

Heat generator efficiency means the useful heat output divided by the energy input in the fuel (based on gross calorific value) or electricity delivered to the *heat generator*, as determined by the appropriate test methods for that type of *heat generator*.

Heat generator seasonal efficiency means the estimated seasonal heat output from the *heat generator* divided by the heat input. This will depend on the *heat generator efficiency* and the operating mode of the *heat generator* over the heating season. For example, in the case of boilers it is a 'weighted' average of the efficiencies of the boiler at 30% and 100% of the boiler output. For other technologies the *heat generator seasonal efficiency* may be the same as the *heat generator efficiency*.

Minimum controls package means a package of controls specific to each technology that represents the recommended minimum provision necessary to meet the building regulations energy efficiency requirements.

Additional measures means additional controls or other measures that go beyond the recommended *minimum controls package*.

Space heating system means the complete system that is installed to provide heating to the space. It includes the heating plant and the distribution system by which heating is delivered to zones.

Domestic hot water system means a local or central system for providing hot water for use by building occupants.

1.7 Work on existing systems

A requirement of building regulations is that work on existing buildings should be carried out in such a way that when the work is complete:

a. the work itself complies with the applicable requirements of building regulations
b. the parts of the building not affected by the work are no worse in relation to the requirements of regulations than before the work was started.

This means that when a system component like a boiler or a room thermostat is replaced, only the new component is expected to comply with the provisions in this guide (which in some cases may be lower than for new systems). When replacing a boiler, the boiler controls are considered to be part of the boiler installation and should therefore meet the standards set out in the relevant sections of this document.

It is not a general requirement to upgrade the rest of the existing system, but this guide does include some recommendations on minor upgrades for compliance with building regulations where they would be cost-effective and may be necessary to ensure efficient operation of the new component.

1.8 Replacement of primary heating appliances

When replacing an existing appliance, the seasonal efficiency of the new equipment should be as stated in the relevant fuel-based section of this guide, subject to any guidance identifying alternatives in exceptional circumstances.

If the replacement involves a change in fuels then the system should both:

a) not produce more CO_2 emissions per kWh of heat than the appliance being replaced
b) not use more primary energy per kWh of heat than the appliance being replaced.

For example:

Replacing an LPG boiler with emissions of 0.241 kg.CO_2/kWh and primary energy of 1.141 kWh_{PE}/m^2 /year at 70% efficiency with an oil-fired boiler with emissions of 0.298 kgCO_2/kWh and primary energy of 1.18 kWh_{PE}/m^2 /year at 90% efficiency.

CO_2 emissions –

- LPG boiler: 0.241/0.70 = 0.34 kgCO_2/kWh
- Oil boiler: 0.298/0.90 = 0.33 kgCO_2/kWh

Primary energy –

- LPG boiler: 1.141/0.70 = 1.63 kWhPE/m^2 /year
- Oil boiler: 1.18/0.90 = 1.31 kWh_{PE}/m^2 /year

In this instance, the oil boiler has both lower CO_2 emissions and primary energy than the LPG boiler being replaced, and therefore complies.

1.9 Sizing heating and hot water system

The specification of space heating systems should be based on an appropriate heat loss calculation for the building, based on **BS EN 12831-1** and CIBSE's *Design Guide A.* Systems should not be significantly oversized. In most circumstances this means that the heating appliance should not be sized for more than 120 per cent of the design heating load.

Where a wet heating system is being newly installed or fully replaced in an existing building, including both the heating appliance and the emitters, the system should be sized to allow the space heating system to operate effectively, and in a manner which meets the heating needs of the dwelling, at a flow temperature of 55°C or lower.

Where it is not feasible to install a space heating system which can operate at this temperature (for example, where there is insufficient space for larger radiators, or the existing distribution system is provided by higher temperature heat from a low carbon external heat network) the space heating system should be designed to the lowest design temperature possible which will still meet the heating needs of the building.

1.10 Summary of recommended minimum energy efficiency standards

Unless specified otherwise in this guide, it is recommended that, where relevant, building services are provided with controls that as a minimum correspond to Band C in BS EN 15232:2017 – 'Energy performance of buildings – impact of building automation, controls and building management'.

Table 1: Recommended minimum energy efficiency standards for building services	
Gas, oil and biomass-fired boilers: **New buildings**	**Seasonal efficiency** **(gross calorific value)**

Table 1: Recommended minimum energy efficiency standards for building services		
Natural gas	Single boiler ≤ 2 MW output	93%
	Single boiler > 2 MW output	88%
	Multiple-boiler system	88% for any individual boiler 93% for overall multi-boiler system
	Single boiler ≤ 2 MW output	93%
	Single boiler > 2 MW output	88%
	Multiple-boiler system	88% for any individual boiler 93% for overall multi-boiler system
Oil	Single boiler system	93%
	Multiple-boiler system	88% for any individual boiler 93% for overall multi-boiler system
Biomass – independent, automatic, pellet/ woodchip		75%
Biomass - independent gravity-fed boilers < 20.5 kW		65%
Gas, oil and biomass-fired boilers: Existing buildings		**Seasonal efficiency (gross calorific value)**
Natural gas	Single boiler system ≤ 400 kW output	91%
	Single boiler 401 kW to 2 MW	88%
	Single boiler system ≤ 2 MW output	84%
	Multiple-boiler system	84% for any individual boiler 91% for overall multi-boiler system
LPG		As new buildings
Oil		As new buildings
Biomass – independent, automatic, pellet/ woodchip		75%
Biomass - independent gravity-fed boilers < 20.5 kW		65%
Heat pump type		**Minimum COP (BS EN 14511-2)**
All types (except air-to-air with output ≤ 12 kW, absorption and gas-engine) for space heating		2.5
All types (except absorption and gas-engine) for domestic hot water heating		2.0
Absorption		0.5
Gas-engine		1.0

<table>
<tr><th colspan="5">Table 1: Recommended minimum energy efficiency standards for building services</th></tr>
<tr><th colspan="3">Gas and oil-fired warm air systems</th><th colspan="2">Heat generator seasonal efficiency (net calorific value)</th></tr>
<tr><td colspan="3">Gas-fired forced convection</td><td colspan="2">91%</td></tr>
<tr><td colspan="3">Direct gas-fired forced convection</td><td colspan="2">100%</td></tr>
<tr><td colspan="3">Oil-fired forced convection</td><td colspan="2">91%</td></tr>
<tr><th colspan="3" rowspan="2">Radiant heaters</th><th colspan="2">Heat generator seasonal efficiency</th></tr>
<tr><th>Thermal</th><th>Radiant</th></tr>
<tr><td colspan="3">Luminous radiant heater (unflued)</td><td>86%</td><td>55%</td></tr>
<tr><td colspan="3">Non-luminous radiant heater (unflued)</td><td>86%</td><td>55%</td></tr>
<tr><td colspan="3">Non-luminous radiant heater (flued)</td><td>86%</td><td>55%</td></tr>
<tr><td colspan="3">Multi-burner radiant heater</td><td>91%</td><td>N/A</td></tr>
<tr><th colspan="3">CHP</th><th>CHPQA quality index</th><th>Power efficiency</th></tr>
<tr><td colspan="3">All types</td><td>105</td><td>20%</td></tr>
<tr><th colspan="3">Electric (primary) heating</th><th colspan="2">Seasonal efficiency</th></tr>
<tr><td colspan="3">Boiler and warm air</td><td colspan="2">N/A</td></tr>
<tr><th>DHW system type</th><th colspan="2">Fuel type</th><th colspan="2">Heat generator seasonal efficiency (gross)</th></tr>
<tr><td rowspan="4">Direct-fired circulator</td><td colspan="2">Natural gas > 30 kW output</td><td colspan="2">91%</td></tr>
<tr><td colspan="2">Natural gas ≤ 30 kW output</td><td colspan="2">91%</td></tr>
<tr><td colspan="2">LPG > 30 kW output</td><td colspan="2">92%</td></tr>
<tr><td colspan="2">Oil</td><td colspan="2">91%</td></tr>
<tr><td rowspan="3">Indirect-fired circulator*</td><td colspan="2">Natural gas</td><td colspan="2">91% (boiler efficiency)</td></tr>
<tr><td colspan="2">LPG</td><td colspan="2">91% (boiler efficiency)</td></tr>
<tr><td colspan="2">Oil</td><td colspan="2">91% (boiler efficiency)</td></tr>
<tr><td>Electrically-heated</td><td colspan="2"></td><td colspan="2">assumed 100% thermally efficient</td></tr>
<tr><td colspan="5">*See Table 17 for method of calculating efficiency for primary return temperatures > or ≤ 55°C.</td></tr>
<tr><th colspan="3">Comfort cooling systems</th><th colspan="2">Cooling unit SEER</th></tr>
<tr><td colspan="2">Packaged air conditioners</td><td>Single duct type</td><td colspan="2">3.0</td></tr>
</table>

Table 1: Recommended minimum energy efficiency standards for building services

	Other types	3.0
Split and multi-split air conditioners > 12 kW		5.0
Split and multi-split air conditioners ≤ 12 kW		5.0
Variable refrigerant flow/volume systems[2]		5.0
Water-to-water chillers < 400 kW		5.0
Water-to-water chillers 400 - 1500 kW		6.0
Water-to-water chillers ≥ 1500 kW		6.5
Vapour compression cycle chillers, air-cooled < 400 kW		4.0
Vapour compression cycle chillers, air-cooled ≥ 400 kW		4.5
Absorption cycle chillers[3]		EER 0.7
Gas-engine-driven variable refrigerant flow		1.6

Air distribution systems	**SFP (W/(l/s))** [1,2]	
	New buildings	**Existing buildings**
Central balanced mechanical ventilation system with heating and cooling	2.0	2.6
Central balanced mechanical ventilation system with heating only	1.9	2.2
All other central balanced mechanical ventilation systems	1.5	2.0
Zonal supply system where fan is remote from zone, such as ceiling void or roof mounted units	1.1	1.4
Zonal extract system where fan is remote from zone	0.5	0.5
Zonal supply and extract ventilation units, such as ceiling void or roof units serving single room or zone with heating and heat recovery	2.3	2.3
Local balanced supply and extract ventilation system such as wall/ roof units serving single area with heat recovery	2.0	2.0
Local supply or extract ventilation units such as window/ wall/ roof units serving single area (e.g. toilet extract)	0.3	0.4
Other local ventilation supply or extract units	0.5	0.5

Table 1: Recommended minimum energy efficiency standards for building services		
Fan assisted terminal Variable Air Volume	0.5	0.5
Fan coil unit (rating weighted average) [3 4]	0.3	0.3
Kitchen extract, fan remote from zone with grease filter	1.0	1.0
Heat exchanger type	**Dry heat recovery efficiency**	
Plate heat exchanger	50%	
Heat pipes	60%	
Thermal wheel	65%	
Run around coil	45%	
Internal lighting	**Effective lighting efficacy**	
General lighting (minimum efficacy)	95 luminaire lumens per circuit-watt	
Display lighting (minimum efficacy)	22 lamp lumens per circuit-watt	
Lighting system (LENI calculation)	≤ lighting energy limit (kWh/m^2/year) specified in Table 28	
Building Automation and Control Systems	**Minimum provision**	
Installed systems	BS EN 15232 Class A Rated type system	

Section 2: Gas, oil and biomass-fired boilers

2.1 Introduction

This section provides guidance on specifying gas, oil and biomass-fired space heating systems for new and existing buildings to meet relevant energy efficiency requirements in building regulations.

The guidance applies to wet central heating systems using commercial boilers fired by:

- natural gas
- liquid petroleum gas (LPG)
- oil, and
- biomass.

The guidance in this section does not cover:

- steam boilers (as these are used primarily for processes rather than provision of space heating), or
- electric boilers (for which see Section 7).

2.2 Key terms

The terminology used to describe efficiencies for boiler systems is detailed below. In this section the *heat generator* is a boiler.

Biomass means all material of biological origin, excluding material embedded in geological formations and transformed to fossil fuel.

Boiler efficiency means the energy delivered by the water as it leaves the boiler (or boilers in multi-boiler installations) to supply the heat emitters, divided by the energy (based on gross calorific value) in the fuel delivered to the boiler, expressed as a percentage. It is an expression of the boiler's performance and excludes energy used by boiler auxiliary controls, pumps, boiler room ventilation fans, mechanical flue extraction fans and fan dilution systems. The *boiler efficiency* is measured according to the standards that are used to demonstrate compliance with the Boiler Efficiency Directive[5].

Effective boiler seasonal efficiency is the *boiler seasonal efficiency* (as calculated by Equation 2 below for individual boilers, or by Equation 3.1 for multiple boilers).

Economiser means a device, including a secondary heat exchanger fitted on or near to a boiler, which provides additional heat transfer capacity. For the purposes of this guide, any boiler which will be supplied with an *economiser* should have the *economiser* fitted when the *boiler efficiency* is tested according to the standards that are used to demonstrate compliance with the Boiler Efficiency Directive. The effect of this on the *boiler efficiency* at 30% and 100% of the boiler output may be taken into account in the values used for the

5 Council Directive 92/42/EEC (the Boiler Efficiency Directive) relates to the efficiency requirements for new hot water boilers fired with liquid or gaseous fuels. The associated UK legislation is the Boiler (Efficiency) Regulations 1993 (SI 1993/3083), amended by the Boiler (Efficiency) (Amendment) Regulations 1994 (SI 1994/3083).

calculation of the *boiler seasonal efficiency* using Equations 2 or 3.1 or the three-step method and Equations 3.2 and 3.3, as appropriate.

Condensing boiler means a boiler that offers a higher energy efficiency by recovering heat from the flue gases. This is achieved by increasing the heat exchanger surface area, which recovers extra sensible heat whenever the boiler fires. The boiler becomes even more efficient when system water temperatures are low because the larger heat exchanger area promotes condensation, allowing much of the latent heat to be recaptured. Standing losses (when the boiler is not firing) are low and part load performance is very good. In multiple-boiler systems, condensing boilers can be used as the lead boiler.

Standard boiler means, in the context of this document, a non-condensing boiler.

Zone control means independent control of rooms or areas within buildings that need to be heated to different temperatures at different times. Where several rooms or areas of a building behave in a similar manner, they can be grouped together as a 'zone' and put on the same circuit and controller.

Sequence control enables two or more heating boilers to be switched on or off in sequence when the heating load changes. This maximises the efficiency of the boilers, so reducing fuel consumption, and reduces wear and tear on the boilers.

Direct acting weather compensation is a type of control that enables a *heat generator* to work at its optimum efficiency. The control allows the boiler to vary its operating flow temperature to suit the external temperature conditions and the temperatures inside the building. Weather compensation relies on communication between an external sensor and one inside the boiler. The boiler's water flow temperature is varied accordingly, so that energy is not wasted by the boiler turning on and off.

Weather compensation via a mixing valve is similar to *direct acting weather compensation* except that the outside temperature is used to control the temperature of water supplied to the heat emitters by mixing the boiler flow and return rather than by altering the boiler temperature.

Optimum start is a control system or algorithm which starts plant operation at the latest time possible to achieve specified conditions at the start of the occupancy period.

Optimiser is a control system employing an *optimum start* algorithm.

Optimum stop is a control system or algorithm which stops plant operation at the earliest possible time such that internal conditions will not deteriorate beyond preset limits by the end of the occupancy period.

Two-stage burner control is a type of control that offers two distinct boiler firing rates.

Multi-stage burner control is a type of control that offers more than two distinct firing rates, but without continuous adjustment between firing rates.

Modulating burner control is a type of control that provides a continuously variable firing rate, which is altered to match the boiler load over the whole turndown ratio.

Decentralisation means the replacement of centralised boiler plant and its associated distribution pipework with several smaller, more accurately sized boiler plants, installed within or adjacent to the buildings or systems they serve. This eliminates long pipe runs between buildings or through unheated areas, so reducing heat losses.

Building management system (BMS) means a building wide network which allows communication with and control of items of HVAC plant (and other building systems) from a single control centre, which may be local or remote. More advanced ('full') *building management systems* offer a wide range of functions, including *sequential control*, *zone control*, *weather compensation*, frost protection and night set-back, as well as monitoring and targeting. See also section 14 on Building Automation and Control Systems.

2.3 Determining boiler seasonal efficiency

Single-boiler systems and multiple-boiler systems with identical boilers

For boilers the relevant *heat generator seasonal efficiency* is the *boiler seasonal efficiency*. The *boiler seasonal efficiency* is a 'weighted' average of the efficiencies of the boiler at 15%, 30% and 100% of the boiler output (the efficiency at 15% being taken to be the same as that at 30%). This is usually quoted by the boiler manufacturer. Note that the efficiencies based on net calorific value should be converted to efficiencies based on gross calorific value using the appropriate conversion factor in SAP 10 Table E4.

The *boiler efficiencies*, measured at 100% load and at 30% load, are used in Equation 2 to calculate the *boiler seasonal efficiency*. The weighting factors in Equation 2 reflect typical seasonal operating conditions for a boiler.

$$\text{Boiler seasonal efficiency} = 0.81\eta_{30\%} + 0.19\,\eta_{100\%}$$ **Equation 2**[6]

where:

$\eta_{30\%}$ is the gross boiler efficiency measured at 30% load

$\eta_{100\%}$ is the gross boiler efficiency measured at 100% load

Equation 2 applies to:

- single-boiler systems where the boiler output is ≤ 400 kW and the boiler will operate on a low temperature system
- multiple-boiler systems where all individual boilers have identical efficiencies and where the output of each boiler is ≤ 400 kW operating on low temperature systems.

For boilers with an output > 400 kW, the manufacturer's declared efficiencies should be used.

Multiple-boiler systems with non-identical boilers replacing existing systems

Where more than one boiler is installed on the same heating system and the efficiencies of the boilers are not all identical, Equation 3.1 should be used to calculate the overall *boiler seasonal efficiency.* All boilers should be included in the calculation, even when some are identical. The *boiler seasonal efficiency* for multiple-boiler systems with non-identical boilers is:

[6] This equation assumes that the efficiency at 15% load is the same as at 30% (and the equation has been simplified accordingly).

$$\eta_{OSBE} = \frac{\Sigma(\eta_{BSE} \times R)}{\Sigma R} \qquad \textbf{Equation 3.1}$$

where:

η_{OSBE} is the gross overall *boiler seasonal efficiency*, being an average weighted by boiler output of the individual seasonal boiler efficiencies

η_{BSE} is the gross *boiler seasonal efficiency* of each individual boiler calculated using Equation 2

R is the rated output in kW of each individual boiler (at 80/60°C).

Multiple-boiler systems in new buildings

In the case of multiple boilers in new buildings, the more accurate three-step method described below should be used to calculate the overall seasonal boiler efficiency. These steps can readily be programmed into a spreadsheet to automate the calculation.

Step 1 - Determine the load on each boiler for each of the three system part-load conditions of 15%, 30% and 100%. For example, if the total system output is made up of three equally sized boilers, at 15% of system output the lead boiler will be operating at 45% of its rated output, with the other two boilers switched off.

Step 2 - Determine the efficiency of each boiler for the above operating conditions. In the above example, the efficiency of the boiler operating at 45% can be determined by linear interpolation between its efficiencies at 30% and 100% of rated output. Where it is necessary to determine the efficiency of an individual boiler at 15% of rated output, this should be taken as the same as the efficiency at 30% of rated output. (Note that the efficiency at 15% of rated output will only be needed if a single boiler meets the full design output)

Step 3 - Calculate the overall operating efficiency at each of the system part load conditions using:

$$\eta_p = Q_p / \Sigma(q_{b,p}/\eta_{b,p}) \qquad \textbf{Equation 3.2}$$

where:

η_p is the system efficiency at part load condition p, i.e. 15%, 30% and 100% of system rated output

Q_p is the system heat output at part load condition p

$q_{b,p}$ is the individual boiler heat output at system part load condition p

$\eta_{b,p}$ is the individual boiler efficiency at system part load condition p.

Step 4 - Calculate the overall *boiler seasonal efficiency* as the weighted average of the efficiencies at the three load conditions using:

$$\eta_{OSBE} = 0.36\eta_{15\%} + 0.45\eta_{30\%} + 0.19\eta_{100\%} \qquad \textbf{Equation 3.3}$$

Table 2 is a worksheet for following through these calculations (using manufacturer data for boiler efficiency at 100% and 30% output). Table 3 shows a completed example calculation using this worksheet, for the case where a system with a rated output of 625 kW is served by three boilers, each rated at 250 kW. The first two boilers are *condensing boilers*, while the third is a *standard boiler*. Because the installation is oversized (750 kW compared to 625 kW), at full system output the final boiler is only operating at 50% output (125/250).

The notes at the foot of the table illustrate how the various values are calculated.

Table 2: Worksheet for calculating the overall boiler seasonal efficiency of a multiple-boiler system using the alternative three-step method

Boiler No.	Rating (kW)	Boiler % efficiency at boiler outputs of		Boiler % output at system outputs of			Boiler % efficiency at system outputs of		
		100%	30%	15%	30%	100%	15%	30%	100%
1									
2									
3									
System efficiency at part load									
Weighting factor							0.36	0.45	0.19
Overall seasonal boiler efficiency									

Table 3: Example calculation of the overall boiler seasonal efficiency of a multiple-boiler system in a new building

Boiler No.	Rating (kW)	Boiler % efficiency at boiler outputs of		Boiler % output at system outputs of			Boiler % efficiency at system outputs of		
		100%	30%	15%	30%	100%	15%	30%	100%
1	250	90%	86%	38%	75%	100%	89.6%[1]	87.4%	86%
2	250	90%	86%	nf [4]	nf	100%	nf	nf	86%
3	250	85%	82%	nf	nf	50%	nf	nf	84.1%
System efficiency at part load							89.6%	87.4%	85.6%[2]
Weighting factor							0.36	0.45	0.19
Overall seasonal boiler efficiency							**87.9%**[3]		

Notes:

1. Calculated by linear interpolation: $\eta_{b,p} = \eta_{30\%} - (\eta_{30\%} - \eta_{100\%}) \times \frac{(q_{b,p} - 30\%)}{(100\% - 30\%)}$

$$\eta_{1,15\%} = \eta_{30\%} - (\eta_{30\%} - \eta_{100\%}) \times \frac{(38\% - 30\%)}{(100\% - 30\%)}$$

2. Calculated by dividing the thermal output of the system (625 kW) by the rate of fuel consumption, which is given by the sum of the boiler outputs divided by their individual operating efficiency, i.e

$$\frac{625}{\frac{250 \times 100\%}{86.0\%} + \frac{250 \times 100\%}{86.0\%} + \frac{250 \times 50\%}{84.1\%}}$$

3. Calculated as the weighted average, i.e.

$$(89.6\% \times 0.36) + (87.4\% \times 0.45) + (85.6\% \times 0.19) = 87.9\%$$

4. nf = not firing

2.4 Boilers in new buildings

Background

New buildings should be provided with high efficiency condensing or non-condensing boilers that meet the recommended minimum standards for *heat generator seasonal efficiency* in this guide.

Commercial heating systems are inherently more complicated than domestic systems with a wider range of temperatures and heat emitters. The selection of condensing or non-condensing boilers will be determined by application and physical constraints.

> *Note: Water quality can have a major impact on system efficiency. It is important that designers take appropriate measures to ensure that the system water is of good quality*.

Condensing boilers will meet projected efficiencies only when they operate with a system return temperature between 30°C and 40°C for 80% of the annual operating hours. With a return temperature of 55°C and above, *condensing boilers* will not produce condensate and will have similar efficiencies to non-condensing high efficiency boilers. Some systems are suitable for *weather compensation*, which allows return temperatures to fall into the condensing range for some periods of the heating season, and they may be best served by a mixture of condensing and non-condensing boilers.

The efficiency value that should be entered into approved NCM tools to calculate the emissions and primary energy rates is the *heat generator seasonal efficiency*.

Recommended minimum standards

To meet relevant energy efficiency requirements in the building regulations when installing boiler plant in new buildings:

a. where a single boiler is used to meet the heat demand, its *boiler seasonal efficiency* (gross calorific value) calculated using Equation 2 should be not less than the value in Table 4

b. for multiple-boiler systems, the *boiler seasonal efficiency* of each boiler should be not less than 82% (gross calorific value), as calculated using Equation 2; and the overall *boiler seasonal efficiency* of the multiple-boiler system, as defined by the three-step method and calculated using Equations 3.2 and 3.3, should be not less than the value in Table 4

c. the relevant minimum controls package in Table 5 should be adopted.

Table 4: Recommended minimum heat generator seasonal efficiency for boiler systems in new buildings

Fuel type	System	Boiler seasonal efficiency (gross calorific value)
Natural gas	Single boiler ≤ 2 MW output	93%
	Single boiler > 2 MW output	88%
	Multiple-boiler system	88% for any individual boiler 93% for overall multi-boiler system
LPG	Single boiler ≤ 2 MW output	93%
	Single boiler > 2 MW output	88%
	Multiple-boiler system	88% for any individual boiler 93% for overall multi-boiler system
Oil	Single boiler system	93%
	Multiple-boiler system	88% for any individual boiler 93% for overall multi-boiler system

Table 5: Recommended minimum controls package for new boilers and multiple-boiler systems

Boiler plant output	Package	Minimum controls
< 100 kW	A	Self-regulating devices fitted at a room or zone level (see Section 15) Timing and temperature demand control, which should be zone specific where the building floor area is greater than 150 m². Weather compensation except where a constant temperature supply is required.
100 kW to 500 kW	B	Controls package A above, plus • Optimum start/stop control with either night set-back or frost protection outside occupied periods. • Two-stage high/low firing facility in boiler <u>or</u> multiple boilers with sequence control to provide efficient part-load performance. Note: The heat loss from non-firing boiler modules should be limited by design or application. For boilers that do not have

		low standing losses, it may be necessary to install isolation valves or dampers.
> 500 kW individual boilers	C	Controls package A and controls package B. For gas-fired boilers and multi-stage oil-fired boilers, fully modulating burner controls.

2.5 Boilers in existing buildings

Background

Boiler efficiencies have improved markedly over recent years. A modern boiler meeting the minimum requirements of the Boiler Efficiency Directive has a *boiler seasonal efficiency* of approximately 78.5% (based on gross calorific value). This guidance recognises that in many cases using *condensing boiler* technology in existing buildings would be either technically impractical (due to flueing constraints) or economically unviable. For this reason non-condensing boilers may be used provided that they meet the recommended minimum efficiency standards given in this section.

To meet relevant energy efficiency requirements in the building regulations when installing boiler plant in existing buildings:

a. the *boiler seasonal efficiency* of each boiler (in a single-boiler system or a multiple-boiler system with identical boilers) calculated using Equation 2 should be not less than the value in Table 6

b. for multiple-boiler systems using non-identical boilers, the overall *boiler seasonal efficiency* calculated using Equation 3.1 should be not less than the value in Table 6

c. the *controls package* in Table 7 should be adopted – i.e. *zone control*, demand control and time control

Table 6: Recommended minimum boiler seasonal efficiency for boiler systems in existing buildings

Gas, LPG and oil-fired boilers		Seasonal efficiency (gross calorific value)
Natural gas	Single boiler system ≤ 400 kW output	91%
	Single boiler 401 kW to 2 MW	88%
	Single boiler system ≤ 2 MW output	84%
	Multiple-boiler system	84% for any individual boiler 91% for overall multi-boiler system
LPG		As new buildings
Oil		As new buildings

Table 7: Recommended minimum controls package for replacement boilers in existing buildings	
Minimum controls package	**Suitable controls**
a. Room/Zone control	Self-regulating devices fitted at a room or zone level as far as is practicable (see Section 15)
b. Demand control	Room thermostat which controls through a diverter valve with constant boiler flow water temperature. This method of control is not suitable for condensing boilers.
c. Time control	Independent time controls.

2.6 Biomass boilers

Background

The method in Section 2.4 for calculating the seasonal efficiency of single and multiple boilers fired by gas, LPG and oil is not appropriate for biomass boilers.

For biomass boilers, requirements and test methods are covered by EN 12809:2001+ A1:2004 – 'Residential independent boilers fired by solid fuel. Nominal heat output up to 50 kW. Requirements and test methods'.

Recommended minimum standards

To meet relevant energy efficiency requirements in the Building Regulations:

a. the efficiency of biomass boilers at their nominal load should be at least:

   i. 65% for independent gravity-fed boilers < 20.5 kW

   ii. 75% for independent automatic pellet/ woodchip boilers

b. controls as for gas, LPG and oil boilers in Table 5 should be provided, where technically feasible.

Section 3: Heat pumps

3.1 Introduction

This section gives guidance on specifying heat pumps to provide space heating and domestic hot water in new and existing buildings to meet relevant energy efficiency requirements in the Building Regulations. The heat pumps covered in this section take heat energy from a low temperature source and upgrade it to a higher temperature at which it can be usefully employed for heating.

For guidance on reverse cycle heat pumps that also provide cooling, see Section 9 of this guide.

3.2 Key terms

Coefficient of performance (COP) is a measure of the efficiency of a heat pump at specified source and sink temperatures, measured using the procedures in BS EN 14511-2:

Heating COP = heat output / power input **Equation 4**

% COP (*COP* x 100) is the *heat generator efficiency.*

Seasonal coefficient of performance (SCOP) is the overall *coefficient of performance* of the unit for the designated heating season. It makes general assumptions about the amount of auxiliary heating needed to top up the space and water heating available from the heat pump.

SCOP is measured in accordance with the procedures in BS EN 14825:2013 – 'Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling. Testing and rating at part load conditions and calculation of seasonal performance'.

The National Calculation Methodology for calculating carbon dioxide emission rates from buildings uses *SCOP*.

3.3 Heat pumps in new and existing buildings

Heat pumps in new and existing buildings should:

a. have a *COP* which is not less than the value in Table 10; or

b. if air-to-air heat pumps with an output less than or equal to 12 kW, have at least a *SCOP* 'D' rating for the median temperature range in EN 14825; and

c. feature as a minimum the *controls package* in Table 11.

Table 10: Minimum COP for heat pumps in new and existing buildings

Heat pump type	**Minimum COP (at rating conditions in BS EN 14511-2)**
All types (except air-to-air with output ≤ 12 kW, absorption and gas-engine) for space heating	2.5
All types (except absorption and gas-engine) for domestic hot water heating	2.0
Absorption	0.5
Gas-engine	1.0

Note: It is recommended that heat pumps below should be designed and installed in accordance with the technical standards given in the Microgeneration Certification Scheme's Microgeneration Installation Standard: MIS 3005, subject to the limitations on scope as outlined in this Standard.

For non-residential buildings, the heat pump system can be sized to meet either the full heating and hot water demand or part of it. Economically viable installations provide at least 50% of the heating and hot water demand for the building.

Table 11: Recommended minimum controls package for heat pump systems in new and existing buildings

Heat source/sink	**Technology**		**Minimum controls package**
All types	All technologies	A	On/off zone control. If the unit serves a single zone, and for buildings with a floor area of 150 m² or less, the minimum requirement is achieved by default. Time control. Where appropriate and technically feasible, weather compensation.
Air-to-air	Single package Split system Multi-split system Variable refrigerant flow system	B	**Controls package A above plus:** Heat pump unit controls for: • control of room air temperature (if not provided externally) • control of outdoor fan operation • defrost control of external airside heat exchanger • control for secondary heating (if fitted). External room thermostat (if not provided in the heat pump unit) to regulate the space temperature and interlocked with the heat pump unit operation.
Water-to-air	Single package	D	**Controls package A above plus**:

Table 11: Recommended minimum controls package for heat pump systems in new and existing buildings			
Ground-to-air	energy transfer systems (matching heating/cooling demand in buildings)		Heat pump unit controls for: • control of room air temperature (if not provided externally) • control of outdoor fan operation for cooling tower or dry cooler (energy transfer systems) • control for secondary heating (if fitted) on air to air systems • control of external water pump operation. External room thermostat (if not provided in the heat pump unit) to regulate the space temperature and interlocked with the heat pump unit operation.
Air-to-water Water-to-water Ground-to-water	Single package Split package	E	**Controls package A above plus:** Heat pump unit controls for: • control of water pump operation (internal and external as appropriate) • control of water temperature for the distribution system • control of outdoor fan operation for air to water units • defrost control of external airside heat exchanger for air to water systems. External room thermostat (if not provided in the heat pump unit) to regulate the space temperature and interlocked with the heat pump unit operation.
Gas-engine-driven heat pumps are currently available only as variable refrigerant flow warm air systems	Multi-split Variable refrigerant flow	F	**Controls package A above plus:** Heat pump unit controls for: • control of room air temperature (if not provided externally) • control of outdoor fan operation • defrost control of external airside heat exchanger • control for secondary heating (if fitted). External room thermostat (if not provided in the heat pump unit) to regulate the space temperature and interlocked with the heat pump unit operation.

In addition to the general guidance for zoning and controls in Section 5, any outdoor fans, including those in cooling towers or dry coolers, should be controlled.

3.6 Supplementary information

Heat source/sink	Technology	Comments
Air-to-air	• Single package	Units may be ducted on one or other of the supply and return air sides or ducted on both sides. Ducting needs to be designed to take into account the maximum specific fan power allowable (see Section 10 of this guide) and to maintain the minimum allowable coefficient of performance.
	• Split • Multi-split • Variable refrigerant flow • Gas engine-driven	A split system will comprise a single outdoor unit and a single indoor unit as a package. Multi-split and VRF systems will comprise a single outdoor unit and two or more indoor units as a package. Several packages may be used to satisfy the requirements of the building. In order for efficiencies to be maintained, all connecting pipework should be installed in accordance with manufacturers' recommendations (diameter, length, insulation and riser height). Any ducting should be designed to take into account the maximum specific fan power allowable and to maintain the minimum allowable coefficient of performance.
Water-to-air **Ground-to-air**	• Single package • Energy transfer	Energy transfer systems generally consist of multiple water-source heat pumps connected in parallel to a common closed water loop. They are installed to offset the simultaneous heating and cooling demand in a building due to the different loads present on the aspects of the building. Water circulation pumps for the closed loop should be taken into consideration along with the fan power required for the cooling tower or dry cooler or energy for water pumps for the ground loop if this method is utilised for heat injection and rejection. Any ducting should be designed to take into account the maximum specific fan power allowable and to maintain the minimum allowable coefficient of performance.
Air-to-water **Water-to-ground** **Water-to-water**	• Single package • Split package	Water circulation pumps for the delivery of heated water to the building along with the energy of water pumps used for the heat source (water or ground) should be considered in the calculation. Any ducting should be designed to take into account the maximum specific fan power allowable and to maintain the minimum allowable coefficient of performance.
Additional guidance on design criteria for heating systems with integrated heat pumps is given in BS EN 15450:2007 – 'Heating systems in buildings. Design of heat pump heating systems'.		

Section 4: Gas and oil-fired warm air heaters

4.1 Introduction

This section gives guidance on specifying gas and oil-fired warm air heaters for space heating in new and existing buildings to meet relevant energy efficiency requirements in the Building Regulations. The guidance also covers indirect gas or oil-fired heat exchangers (as used in large ducted systems for office blocks, etc.) to provide heating and fresh or conditioned air. Warm air central heating systems are not within the scope of this section but are covered in the relevant heat generator section and Section 10 - Air distribution.

4.2 Key terms

Heat generator seasonal efficiency of air heaters, since they operate under the same conditions at all times, is equivalent to their measured steady state thermal efficiency (net calorific value), which can be obtained from the heater manufacturer's data and converted to efficiency (gross calorific value) using the conversion factors in SAP 2012 Table E4.

- For indirect-fired heaters, data values for heat output and net heat input are measured using the efficiency test methods described in EN 1020, EN 621 or EN 13824 as appropriate.
- For direct-fired heaters, the efficiency should be calculated using the method described in EN 525.

The calculation of the thermal efficiency (net) should:

- take account of the heater and the exhaust chimney within the building envelope
- exclude fans.

4.3 Warm air heaters in new and existing buildings

Warm air systems in new and existing buildings should have:

a. a *heat generator seasonal efficiency* which is no worse than in Table 16

b. a *controls package* featuring, as a minimum, time control, space temperature control, and, where appropriate for buildings with a floor area greater than 150 m^2, *zone control*.

Table 12: Recommended minimum heat generator seasonal efficiency

Warm air heater type	Heat generator seasonal efficiency (net calorific value)	Product standard
Gas-fired forced convection to assist transportation of combustion air and/or combustion products	91%	BS EN 621 (unfanned) BS EN 1020 (fanned)
Direct gas-fired forced convection	100%	BS EN 525
Oil-fired forced convection	91%	BS EN 13842

Note: For Direct gas-fired forced convection air heaters, 100% of the net heat input is delivered to the space. Specific ventilation requirements as defined in EN 525 should be met.

Section 5: Gas and oil-fired radiant heaters

5.1 Introduction

This section gives guidance on specifying radiant heaters for space heating in new and existing buildings to meet relevant energy efficiency requirements in the Building Regulations.

5.2 Key terms

Radiant heater seasonal efficiency (*heat generator seasonal efficiency*) is equivalent to thermal efficiency (net calorific value).

For flued appliances, the manufacturer of the radiant heater should declare a thermal efficiency measured to the test standards BS EN 117082[7] or BS EN 13842[8] as applicable.

The calculation of the thermal efficiency (net calorific value) should:

a. take account of the radiant heater and associated flue pipe/ tailpipe within the building envelope

b. exclude fans.

5.4 Radiant heaters

Radiant heaters in new and existing buildings should have:

a. an *effective heat generator seasonal efficiency* not worse than in Table 13

b. a *controls package* consisting of, as a minimum, time control and space temperature control with black bulb sensors.

Table 13: Recommended minimum performance standards for radiant heaters

Appliance type	Heat generator seasonal efficiency	
	Thermal	Radiant
Luminous radiant heater – unflued	86%	55%
Non-luminous radiant heater – unflued	86%	55%
Non-luminous radiant heater – flued	86%	55%
Multi-burner radiant heater	91%	N/A

7 BS EN 17082:2019 - Domestic and non-domestic gas-fired forced convection air heaters for space heating not exceeding a net heat input of 300 kW

8 BS EN 13842:2004 – 'Oil-fired convection air heaters – stationary and transportable for space heating'.

Section 6: Combined heat & power and community heating

6.1 Introduction

This section gives guidance on specifying *combined heat and power (CHP)* systems for space heating, hot water and chilled water (via absorption chillers) in new and existing buildings to meet relevant energy efficiency requirements in the Building Regulations. Guidance on the design of community heating systems can be found in Section 6 of the Domestic Building Services Compliance Guide for Scotland.

The guidance in this section covers CHP systems with a total power capacity less than 5 MWe used in commercial applications. The CHP units may or may not supply community heating.

CHP units are normally used in conjunction with boilers. The majority of the annual heat demand is usually provided by the CHP plant, while the boilers are used to meet peak demand and in periods when the CHP unit is not operating (for example at night or when undergoing maintenance). CHP units may on a relatively small scale supply single buildings, or on a larger scale supply a number of buildings through a community heating system. The most common fuel is natural gas, which can be used in spark-ignition gas engines, micro-turbines, or gas turbines in open cycle or combined cycle.

6.3 Key terms

Combined heat and power (CHP) means the simultaneous generation of heat and power in a single process. The power output is usually electricity, but may include mechanical power. Heat outputs can include steam, hot water or hot air for process heating, space heating or absorption cooling.

Combined heat and power quality assurance (CHPQA) is a scheme under which registration and certification of CHP systems is carried out according to defined quality criteria. Further information about the CHPQA programme is available at https://www.gov.uk/guidance/combined-heat-power-quality-assurance-programme.

CHPQA quality index is an indicator of the energy efficiency and environmental performance of a CHP scheme relative to generation of the same amounts of heat and power by alternative means.

Power efficiency is the total annual power output divided by the total annual fuel input of a CHP unit.

6.4 CHP in new and existing buildings

CHP plant in new and existing buildings should have:

- a minimum *CHPQA Quality Index* (QI) of 105 and *power efficiency* greater than 20%, both under annual operation
- a control system that, as a minimum, ensures that the *CHP* unit operates as the lead heat generator

- metering to measure hours run, electricity generated and fuel supplied to the *CHP* unit.

The CHP plant should be sized to supply not less than 45% of the annual total heating demand (i.e. space heating, domestic hot water heating and process heating) unless there are overriding practical or economic constraints.

Note: due to the introduction of monthly factors for grid electricity, advice on the calculation of the emissions from a CHP system are removed from this document. Advice on the revised calculation process will be provided on finalisation of the revisions to SBEM for 2022.

6.5 Supplementary information

Community heating systems may include other low and zero carbon sources of energy such as biomass heating. Emission factors should be determined based on the particular details of the scheme, but should take account of the annual average performance of the whole system – that is, of the distribution circuits and all the heat generating plant, including any CHP and any waste heat recovery or heat dumping. The calculation of the building carbon dioxide emission rate should be carried out by a suitably qualified person, who should explain how the emission factors were derived.

The design of the community heating connection and the heating control system of the building should take account of the requirements of the community heating organisation with respect to maintaining low return temperatures at part-load and limiting the maximum flow rate to be supplied by the community heating system to the agreed level. A heat meter should be installed to measure the heat energy supplied and to monitor the maximum heat demand, the maximum community heating flow rate and the return temperatures into the community heating network.

Section 7: Direct electric space heating

7.1 Introduction

This section gives guidance on specifying direct electric heaters for space heating in new and existing buildings. It addresses the relevant electric heater types and the minimum provision of controls.

The guidance given in this section covers the following types of electric heating systems, which may be used to provide primary or secondary space heating:

- electric boilers
- electric warm air systems
- electric panel heaters
- electric storage systems, including integrated storage/ direct systems
- electric fan heaters and fan convector heaters
- electric radiant heaters, including quartz and ceramic types.

The guidance does not cover electric heat pumps (see section 3) or portable electric heating devices (outwith the scope of building regulations).

7.2 Electric space heating in new and existing buildings

It is assumed that electric heating devices convert electricity to heat within a building with an efficiency of 100%. A *minimum heat generator seasonal efficiency* is therefore not specified.

Electric space heating systems in new and existing buildings should meet the minimum standards for:

a. controls for electric boilers in Table 14
b. controls for electric heating systems other than boilers in Table 15.

Table 14: Recommended minimum standards for control of electric boiler systems	
Type of control	**Standard**
Boiler temperature control	Boiler fitted with a flow temperature control and capable of modulating the power input to the primary water depending on space heating conditions.
Zoning	For buildings with a total usable floor area greater than 150 m^2, at least two space heating zones with independent time and temperature controls using either: • multiple heating zone programmers; or • a single multi-channel programmer.
Temperature control of space heating	Separate temperature control of zones within the building using either: • room thermostats or programmable room thermostats in all zones; or • a room thermostat or programmable room thermostat in the main zone and individual radiator controls such as thermostatic radiator valves (TRVs) on all radiators in the other zones; or • a combination of (i) and (ii) above.
Time control of space and water heating	Provide using: • a full programmer with separate time control for each circuit; or • separate timers for each circuit; or • programmable room thermostats for the heating circuits, with separate time control for all the circuits.

Note: An acceptable alternative to the above controls is any boiler management control system that meets the specified zoning, timing and temperature requirements.

Table 15: Recommended minimum standards for control of primary and secondary electric heating systems other than electric boilers

Type of system	Type of control	Standard
Warm air	Time and temperature control, either integral to the heater or external	A time switch/ programmer and room thermostat or a programmable room thermostat.
	Zone control	For buildings with a total usable floor area greater than 150 m^2, at least two space heating circuits, with independent timing and temperature controls using either: • multiple heating zone programmers; or • a single multi-channel programmer.
Radiant heaters	Zone or occupancy control	Connection to a passive infra-red detector. Self-regulating temperature controls.
Panel/ skirting heaters	Local time and temperature control	Time control provided by: • a programmable time switch integrated into the appliance; or • a separate time switch. Individual temperature control provided by: • integral thermostats; or • separate room thermostats.
Storage heaters	Charge control	Automatic control of input charge (based on an ability to detect the internal temperature and adjust the charging of the heater accordingly).
	Temperature control	Manual controls for adjusting the rate of heat release from the appliance, such as adjustable damper or some other thermostatically-controlled means.
Fan/ fan convector heaters	Local fan control	A switch integrated into the appliance or a separate remote switch.
	Individual temperature control	Integral switches or separate remote switching.

Section 8: Domestic hot water

8.1 Introduction

This section gives guidance on specifying domestic hot water (DHW) systems for new and existing buildings to meet relevant energy efficiency requirements in the Building Regulations. Domestic hot water systems are referred to as hot water service systems in SBEM.

The guidance in this section covers the conventional direct and indirect gas-fired, oil-fired and electrically-heated domestic hot water systems shown in Table 16.

Table 16: Types of hot water system	
Direct-fired circulator: gas and LPG	A system in which the water is supplied to the draw-off points from a hot water vessel in which water is heated by combustion gases from a primary energy source. The unit has no storage volume as water is stored in a supplementary storage vessel.
Direct-fired storage: gas, LPG and oil	A system in which the water is supplied to the draw-off points from an integral hot water vessel in which water is heated by combustion gases from a primary energy source.
Direct-fired continuous flow: gas and LPG	A system in which the water is supplied to the draw-off points from a device in which water is heated by combustion gases from a primary energy source that heat the cold water as it flows through the water heater. The water heater is situated close to the draw-off points. The unit has no storage volume as water is instantaneously heated as it flows through the device.
Indirect-fired circulator: natural gas, LPG and oil	A system in which the water is supplied to the draw-off points from a device in which water is heated by means of an element, through which the heating medium is circulated in such a manner that it does not mix with the hot water supply. In practice the heat source is likely to be a boiler dedicated to the supply of domestic hot water.
Instantaneous electrically-heated	A system in which the water is supplied to the draw-off points from a device in which the cold water is heated by an electric element or elements as it flows through the water heater. The water heater is situated close to the draw-off points. The unit has no storage volume as water is instantaneously heated as it flows through the device.
Point of use electrically-heated	A system in which the water is supplied to the draw-off points from a device in which water is heated by an electric element or elements immersed in the stored water. The water heater is situated close to the draw-off points and should have a storage capacity no greater than 100 litres.
Local electrically-heated	A system in which the water is supplied to the draw-off points from a device in which water is heated by an electric element or elements immersed in the stored water. The water heater is situated in the locality of the draw-off points and should have a storage capacity of between 100 and 300 litres. Bulk heating of the water heater should be with off-peak electricity.
Centralised electrically-heated	A system in which the water is supplied to the draw-off points from a device in which water is heated by an electric element or elements immersed in the stored water. The water heater is situated centrally with a distribution system to supply water to the draw off-points and should have a capacity greater than 300 litres. Bulk heating of the water heater should be with off-peak electricity.

The recommended minimum standards set out in this section apply only to dedicated water heaters. Central heating boilers which provide space heating and domestic hot water should meet the minimum standards in Section 2; and heat pumps which provide domestic hot water should meet the minim standards in Section 3.

The guidance in this section applies to back-up gas and electric systems used with solar thermal hot water systems, but not to solar thermal systems themselves. For solar systems with a cylinder capacity of less than 440 litres or collector surface area less than 20 m^2 metres, consult the Domestic Building Services Compliance Guide for Scotland or, for larger systems, the CIBSE Solar heating design and installation guide[9].

> ***Note:*** *Water quality can have a major impact on system efficiency. It is important that designers take appropriate measures to ensure that the system water is of good quality.*
>
> *As well as the building regulations, other regulations apply to the provision of domestic hot water. Energy-saving measures should not compromise the safety of people or the ability of the system to achieve approved regimes for the control of legionella.*

8.3 Domestic hot water systems in new and existing buildings

Domestic hot water systems should be sized for the anticipated domestic hot water demand of the building, based on BS EN 12831-3. Systems should not be significantly oversized.

Primary hot water circuits for domestic hot water or heating should have fully pumped circulation where this is compatible with the heat generator.

The thermal efficiency is defined for each system type in Table 17. Thermal efficiency should include the heat generator and any integral storage vessel, but exclude the following, where present.

- Secondary pipework.
- Fans and pumps.
- Diverter valves, solenoids, actuators.
- Supplementary storage vessels.

Domestic hot water systems in new and existing buildings should meet the recommended minimum standards for:

a. heat losses from DHW storage vessels in Table 18, or maintenance consumption values in EN 89.

b. controls in Tables 19 and 20.

Table 17: Minimum thermal efficiencies for Domestic Hot Water systems in new and existing buildings

DHW system type	Fuel type	Heat generator seasonal efficiency (gross)	Product standard
Direct-fired circulator	Natural gas > 30 kW output	91%	BS EN 15502-2; or BS EN 89; or BS EN 26 as appropriate
	Natural gas ≤ 30 kW output	91%	
	LPG > 30 kW output	92%	
	Oil	91%	

[9] http://www.cibse.org

Table 17: Minimum thermal efficiencies for Domestic Hot Water systems in new and existing buildings			
Indirect-fired circulator	Natural gas	91% (boiler efficiency)	• Calculate using Equations 2, 3.1, or 3.2 and 3.3 (as appropriate) in Section 2. • Use Equation 2 to calculate boiler seasonal efficiency if primary return temperature ≤ 55°C. • Use boiler full load efficiency (1.0$\eta_{100\%}$) at 80/60°C flow/return temperatures if primary return temperature > 55°C. • If *boiler seasonal efficiency* values are obtained as net values the factors in SAP 10 Table E4 should be used to convert to gross values.
	LPG	91% (boiler efficiency)	
	Oil	91% (boiler efficiency)	
Electrically-heated		assumed 100% thermally efficient	

Notes:

1. For hot water systems in new buildings, standing losses are calculated in the approved NCM tool.
2. Where efficiency data is not readily available, efficiencies can be calculated using manufacturers' recovery rates and the following equations:

Gross thermal efficiency = heater output / gross input **Equation 8**

Heater output = recovery rate of heater in litres/second x x specific heat capacity of water x temperature rise of water **Equation 9**

Table 18: Recommended maximum heat losses from DHW storage vessels			
Nominal volume (litres)	**Heat loss** (kWh/24h)	**Nominal volume** (litres)	**Heat loss** (kWh/24h)
200	2.1	900	4.5
300	2.6	1,000	4.7
400	3.1	1,100	4.8
500	3.5	1,200	4.9
600	3.8	1,300	5.0
700	4.1	1,500	5.1
800	4.3	2,000	5.2

Notes

1. For guidance on maximum heat losses from DHW storage vessels with a storage volume less than 200 litres, see BS EN 15450.
2. The heat loss from electrically-heated cylinders (volume V litres) should not exceed $1.28 \times (0.2+0.051V^{2/3})$ if point-of-use or $1.28 \times (0.051V^{2/3})$ if local.

Table 19: Recommended minimum controls package for gas and oil-fired domestic hot water systems

System type	Controls package
Direct-fired circulator; Direct-fired storage; or Indirect-fired	• Time control independent of space heating circuits. • Electronic temperature control. • Automatic thermostat control to shut off the burner/primary heat supply when the desired temperature of the hot water has been reached. • High limit thermostat to shut off primary flow if system temperature too high.
Direct-fired continuous flow	Controls as above, plus: • A flow sensor to control the rate of flow through the heat exchanger. This should control outlet temperatures and, if the sensor detects insufficient flow, shut off the burner/heat input.

Table 20: Recommended minimum controls package for electrically-heated domestic hot water systems

System Type	Point-of-use	Local	Central-ised	Instant-aneous
Automatic thermostat control to interrupt the electrical supply when the desired storage temperature has been reached.	Yes	Yes	Yes	x
High limit thermostat (thermal cut-out) to interrupt the energy supply if the system temperature gets too high.	Yes	Yes	Yes	x
Manual reset in the event of an over-temperature trip.	Yes	Yes	Yes	x
7-day time clock (or BMS interface) to ensure bulk heating of water using off-peak electricity. Facility to boost the temperature using on-peak electricity (ideally by means of an immersion heater fitted to heat the top 30% of the cylinder).	x	Yes	Yes	x
High limit thermostat (thermal cut-out) to interrupt the energy supply if the outlet temperature gets too high. (Note: Outlet temperature is controlled by rate of flow through the unit, which on basic units would be by the outlet tap or fitting).	x	x	x	Yes
Flow/ pressure sensor that only allows electrical input should sufficient flow through the unit be achieved.	x	x	x	Yes

8.5 Supplementary information on electric water heaters

Point-of-use

Relevant standard is BS EN 60335-2-21.

Instantaneous

Relevant standard is BS EN 60335-2-35.

Local

For vented systems, relevant standard is BS EN 60335-2-21, for unvented systems, relevant standard is BS EN 12897.

Centralised

Relevant standard is BS 853-1.

Bulk heating of the water should utilise off-peak electricity where possible.

When using off-peak electricity a ‘boost heater’ should be fitted to allow ‘on-peak’ heating. The ‘boost heater’ should heat the top 30% of the cylinder and be rated to approximately 30% of the main off-peak heater battery. The kW load will depend on the recovery time required.

The heater battery should either be of removable core or rod element construction. Removable core construction allows elements to be changed without removing the heater from the vessel or draining the system. For removable core construction, the maximum element watts density should not exceed 3 W/cm^2 for copper tubes or 2.5 W/cm^2 for stainless steel tubes. For rod element construction, elements should be of nickel alloy 825 sheath, be U-bent and have a maximum watts density of 10 W/cm^2. Temperature control should be by means of ‘on/off’ control of the heater battery utilising stage ramping for loadings above 30 kW. Thermostatic control is an ideal solution.

The control sensor should be mounted in the cylinder at an angle of approximately 45° to the heater and at a level just above the heating bundle. The over-temperature sensor (high limit) should be mounted in the top 30% of the cylinder directly above the heater bundle. A manual reset should be required in the event of an over-temperature trip.

For loadings greater than 6 kW, temperature sensors should not be fitted to the heater bundle. This is to prevent thermostat and contactor cycling which will lead to premature failure of the equipment and poor temperature control.

Section 9: Comfort cooling

9.1 Introduction

This section gives guidance on specifying comfort cooling for new and existing buildings to meet relevant energy efficiency requirements in the Building Regulations.

The guidance covers the specification of refrigeration plant efficiency in terms of the *seasonal energy efficiency ratio (SEER)*, which is the value used by SBEM to calculate the carbon dioxide emission rate for a new building. SBEM allocates standard correction factors[10] to the performance of cooling plant to account for the use of the different systems for distributing cooling to the spaces. Evaporative cooling and desiccant cooling systems are not within the scope of this guidance.

9.2 Key terms

Cooling plant means that part of a cooling system that produces the supply of cooling medium. It does not include means of distributing the cooling medium or the delivery of the cooling into the relevant zone. It may consist, for example, of a single chiller or a series of chillers.

Cooling system means the complete system that is installed to provide the comfort cooling to the space. It includes the cooling plant and the system by which the cooling medium effects cooling in the relevant zone and the associated controls. This will in some cases be a complete packaged air conditioner.

Energy efficiency ratio (EER) for chillers is the cooling energy delivered into the cooling system divided by the energy input to the chiller, as determined by BS EN 14511[11].

In the case of packaged air conditioners, the *EER* is the energy removed from air within the conditioned space divided by the effective energy input to the unit, as determined by BS EN 14511 or other appropriate standard procedure. The test conditions for determining *EER* are those specified in BS EN 14511.

Part load energy efficiency ratio is the cooling energy delivered into the cooling system divided by the energy input to the cooling plant. Part load performance for individual chillers is determined assuming chilled water provision at 7 °C out and 12 °C in (at 100% load), under the following conditions:

Percentage part load	25%	50%	75%	100%
Air-cooled chillers ambient air temperature (°C)	20	25	30	35
Water-cooled chillers entering cooling water temperature (°C)	18	22	26	30

Seasonal energy efficiency ratio (SEER) is the total amount of cooling energy provided divided by the total energy input to a single cooling unit, summed over the year.

10 The SBEM Technical Manual is available for download from https://www.uk-ncm.org.uk/

11 BS EN 14511-2: 2011 – '*Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling. Test conditions*'.

European seasonal energy efficiency ratio (ESEER) is the *SEER* of a cooling unit as determined under the Eurovent Certification scheme.

Plant seasonal energy efficiency ratio (PSEER) is the total amount of cooling energy provided divided by the total energy input to the cooling plant (which may comprise more than one cooling unit), summed over the year.

9.3 Comfort cooling in new and existing buildings

For comfort cooling systems in new and existing buildings:

a. the *seasonal energy efficiency ratio (SEER)* of each cooling unit of the cooling plant should be no worse than recommended in Table 21

b. controls should comply with BS EN 15232:2012[12] Band C and be no worse than recommended in Table 22.

The specification of space cooling systems should be based on an appropriate heat gain calculation for the building, based on CIBSE's *Design Guide A*. Systems should not be significantly oversized. In most circumstances this means that the cooling appliance should not be sized for more than 120% of the design cooling load.

Table 21: Recommended minimum seasonal energy efficiency ratio (SEER)[1] for comfort cooling

Type		**Cooling unit SEER**
Packaged air conditioners	Single duct type	3.0
	Other types	3.0
Split and multi-split air conditioners > 12 kW		5.0
Split and multi-split air conditioners ≤ 12 kW		5.0
Variable refrigerant flow/volume systems[2]		5.0
Water-to-water chillers < 400 kW		5.0
Water-to-water chillers 400 - 1500 kW		6.0
Water-to-water chillers ≥ 1500 kW		6.5
Vapour compression cycle chillers, air-cooled < 400 kW		4.0
Vapour compression cycle chillers, air-cooled ≥ 400 kW		4.5
Absorption cycle chillers[3]		EER 0.7
Gas-engine-driven variable refrigerant flow		1.6

Notes:

1. Seasonal Space Cooling Energy Efficiency as defined by Eco design Commission Regulation No 206/2012 Annex II, at average rating conditions where applicable.

[12] BS EN 15232:2012 – 'Energy performance of buildings. Impact of building automation, controls and building management'.

2. For VRV/VRF systems, SEER is for the full system including indoor units.
3. For absorption chillers an EER (energy efficiency ratio) has been used instead. This should be determined according to BS EN 14511.

Table 22: Recommended minimum controls for comfort cooling in new and existing buildings	
Element	**Controls**
Cooling system	• The systems should be subdivided into separate control zones for areas of the building for which solar exposure, pattern of use, or type of use are significantly different: • For each control zone and for each terminal unit, it should be possible to control both timing and temperature independent of other control zones. • If both heating and cooling are provided in the same zone, controls should prevent them operating simultaneously.
Cooling plant	• Multiple cooling units should be provided with controls that ensure the combined plant operates in its most efficient modes. • Central plant should operate only when the zone systems require it. The default condition should be off.

9.4 Calculating the seasonal energy efficiency ratio for SBEM

The value of the *SEER* to be used in the SBEM tool can be calculated in a number of ways according to the availability of information and the application.

In general, where an industry approved test procedure for obtaining performance measurements of cooling units at partial load conditions exists, and the cooling load profile of the proposed building is known, the *SEER* of the cooling unit is given by:

$$SEER = a(EER_{100\%}) + b(EER_{75\%}) + c(EER_{50\%}) + d(EER_{25\%}) \quad \textbf{Equation 10}$$

where:

- EER_x is the EER measured at the load conditions of 100%, 75%, 50% and 25% at the operating conditions detailed under the *part load energy efficiency ratio* in Section 9.3
- a, b, c, and d, are the load profile weighting factors relevant to the proposed application. The load profile weighting factors can be taken from either of the following.
  - i. The table below, where appropriate.
  - ii. From detailed simulation or prediction of the load profile of the building. The calculation should include the desired indoor condition as well as the ambient loads the system will work in.

Standard cooling load factors for office accommodation			
a	**b**	**c**	**d**
0.03	0.33	0.41	0.23

These weighting factors are the same as those used for the determination of the *European Seasonal Energy Efficiency Ratio (ESEER)*. Most manufacturers publish *ESEER* figures and these can be verified by reference to the Eurovent Certification website at www.euorvent-certification.com. The *ESEER* value is then used as the *SEER* in the SBEM calculation.

Cooling units with no part load performance data

For cooling units that have no part load data, the *SEER* is the full load *EER*.

Unknown load profiles

For applications where the load profile under which the cooling plant operates is not known but there is some data on chiller part load *EER*, then:

a. for chillers where the full and half load (50%) *EERs* are known, the *SEER* is the average of the *EERs*, i.e. the 100% and 50% are equally weighted

b. for chillers with four points of part load *EER*, the *SEER* is calculated using Equation 10 with each *EER* weighted equally, i.e. a, b, c and d each equal to 0.25

c. if the chiller used does not have data for four steps of load, then the weights are apportioned appropriately.

Multiple-chiller systems

For plants with multiple-chillers, a *plant seasonal energy efficiency ratio (PSEER)* value may be calculated based on the sum of the energy consumptions of all the operating chillers. In this case care must be taken to include all the factors that can influence the combined performance of the multiple-chiller installation. These will include the:

- degree of oversizing of the total installed capacity
- sizes of individual chillers
- EERs of individual chillers at actual operating conditions
- control mode used: e.g. parallel, sequential, dedicated low-load unit
- load profile of the proposed building
- building location (as this determines ambient conditions).

When these are known it may be possible to calculate a *PSEER* which matches the proposed installation more closely than by applying the simplifications described earlier. This *PSEER* value is then used as the *SEER* in the SBEM calculation.

Systems with free cooling or heat recovery

Systems that have the ability to use free cooling or heat recovery can achieve a greater *SEER* than more conventional systems. In these cases the *SEER* must be derived for the specific application under consideration. For variable refrigerant flow (VRF) systems any calculations must include indoor and outdoor conditions, the power input from controls, and indoor units.

Absorption chillers and district cooling

Absorption chillers may be used in conjunction with on-site CHP or a community or district heating system. The carbon dioxide emissions are calculated in the same way as when using CHP for heating. The control system should ensure as far as possible that heat from boilers is not used to supply the absorption chiller. The minimum full load *EER* of the absorption chillers should be no worse than 0.7.

Where a district cooling scheme exists, lower carbon dioxide emissions may result if the cooling is produced centrally from CHP/ absorption chillers, heat pumps or high efficiency vapour compression chillers. The district cooling company will provide information on the carbon dioxide content of the cooling energy supplied, and this figure can then be used to calculate the carbon dioxide emission rate for the building.

9.6 Supplementary information

BS EN 15243 – 'Ventilation for buildings. Calculation of room temperatures and of load and energy for buildings with room conditioning systems' provides additional guidance on calculating the seasonal efficiency of cold generators and chillers in air conditioning systems. The guidance does not need to be followed to meet relevant energy efficiency requirements in the building regulations.

Section 10: Air distribution

10.1 Introduction

This section gives guidance on specifying air distribution systems for new and existing buildings to meet relevant energy efficiency requirements in the building regulations.

The guidance applies to the following types of air distribution system:

- central air conditioning systems
- central mechanical ventilation systems with heating, cooling or heat recovery
- all central systems not covered by the above two types
- zonal supply systems where the fan is remote from the zone, such as ceiling void or roof-mounted units
- zonal extract systems where the fan is remote from the zone
- local supply and extract ventilation units such as window, wall or roof units serving a single area (e.g. toilet extract)
- other local ventilation units, e.g. fan coil units and fan assisted terminal VAV units
- kitchen extract, fan remote from zone with grease filter.

Gas and oil-fired air heaters installed within the area to be heated are not within the scope of this section.

10.2 Key terms

Air conditioning system means a combination of components required to provide a form of air treatment in which temperature is controlled or can be lowered, possibly in combination with the control of ventilation, humidity and air cleanliness.

Ventilation system means a combination of components required to provide air treatment in which temperature, ventilation and air cleanliness are controlled.

Central system means a supply and extract system which serves the whole or major zones of the building.

Local unit means an unducted ventilation unit serving a single area.

Zonal system means a system which serves a group of rooms forming part of a building, i.e. a zone where ducting is required.

Demand control is a type of control where the ventilation rate is controlled by air quality, moisture, occupancy or some other indicator of the need for ventilation.

Specific fan power (SFP) of an air distribution system means the sum of the design circuit-watts of the system fans that supply air and exhaust it back outdoors, including losses through switchgear and controls such as inverters (i.e. the total circuit-watts for the supply and extract fans), divided by the design air flow rate through that system.

External system pressure drop means the total system pressure drop excluding the pressure drop across the air handling unit (AHU).

10.3 Air distribution systems in new and existing buildings

Air distribution systems in new and existing buildings should meet the following recommended minimum standards:

a. Air handling systems should be capable of achieving a *specific fan power* at 25% of design flow rate no greater than that achieved at 100% design flow rate.

b. In order to aid commissioning and to provide flexibility for future changes of use, appropriate provision would be to equip with variable speed drives those fans that are rated at more than 1100 W and which form part of the environmental control systems, including smoke control fans used for control of overheating. The provision is not applicable to smoke control fans and similar ventilation systems only used in abnormal circumstances.

c. In order to limit air leakage, ventilation ductwork should be made and assembled so as to be reasonably airtight. Ways of meeting this requirement would be to comply with the specifications given in:

   i. B&ES DW144[13]. Membership of the B&ES specialist ductwork group or the Association of Ductwork Contractors and Allied Services is one way of demonstrating suitable qualifications; or

   ii. British Standards such as BS EN 1507, BS EN 12237 and BS EN 13403.

d. In order to limit air leakage, air handling units should be made and assembled so as to be reasonably airtight. Ways of meeting this requirement would be to comply with Class L2 air leakage given in BS EN 1886:2007[14].

e. The specific fan power of air distribution systems at the design air flow rate should be no worse than in Table 23 for new and existing buildings. Specific fan power is a function of the system resistance that the fan has to overcome to provide the required flow rate. BS EN 13779[40] Table A8 provides guidance on system pressure drop. To minimise specific fan power it is recommended that the 'low range' is used as a design target.

   For balanced supply and extract systems, the maximum SFP now includes an allowance for heat recovery and return filter in relevant systems. Where an air distribution system includes further additional components listed in Table 23, the allowed specific fan powers may be increased by the amounts shown to account for additional resistance.

f. A minimum controls package should be provided in new and existing buildings as in Table 24.

[13] Ductwork Specification DW/144 – 'Specifications for sheet metal ductwork. Low, medium and high pressure/velocity air systems' (Appendix M revision 2002), HVCA, 1998.

[14] BS EN 1886:2007 – 'Ventilation for buildings. Air handling units. Mechanical performance'.

Table 23: Maximum specific fan powers in air distribution systems in new and existing buildings		
System type	SFP (W/(l/s)) [1 2]	
	New buildings	Existing buildings
Central balanced mechanical ventilation system with heating and cooling	2.0	2.6
Central balanced mechanical ventilation system with heating only	1.9	2.2
All other central balanced mechanical ventilation systems	1.5	2.0
Zonal supply system where fan is remote from zone, such as ceiling void or roof mounted units	1.1	1.4
Zonal extract system where fan is remote from zone	0.5	0.5
Zonal supply and extract ventilation units, such as ceiling void or roof units serving single room or zone with heating and heat recovery	2.3	2.3
Local balanced supply and extract ventilation system such as wall/ roof units serving single area with heat recovery	2.0	2.0
Local supply or extract ventilation units such as window/ wall/ roof units serving single area (e.g. toilet extract)	0.3	0.4
Other local ventilation supply or extract units	0.5	0.5
Fan assisted terminal Variable Air Volume	0.5	0.5
Fan coil unit (rating weighted average) [3 4]	0.3	0.3
Kitchen extract, fan remote from zone with grease filter	1.0	1.0

Notes:

1. For balanced supply and extract systems, the maximum SFP includes an allowance for heat recovery and return filter.
2. Where any of the following components are included in the installation, the maximum SFP may be increased.
   - High-efficiency particulate air (HEPA) filter: add 1.0 W/(l.s).
   - Humidifier/dehumidifier: add 0.1 W(l.s).
   - Active chilled beams: add 0.3 W/(l.s).

   For example, a central balanced mechanical ventilation system with heating and cooling, HEPA filter and humidifier, installed in a new building - SFP = 2.0 + 1.0 + 0.1 = 3.1 W/(l.s)

3. The rating weighted average is calculated by the following formula:

$$\frac{P_{mains,1} \times SFP_1 + P_{mains,2} \times SFP_2 + P_{mains,3} \times SFP_3 + \ldots}{P_{mains,1} + P_{mains,2} + P_{mains,3} + \ldots}$$

where P_{mains} is useful power supplied from the mains in W.

Table 24: Recommended minimum controls for air distribution systems in new and existing buildings from BS EN 15232

System type		Controls package
Central mechanical ventilation with heating, cooling or heat recovery	Air flow control at room level	Time control
	Air flow control at air handler level	On/off time control
	Heat exchanger defrosting control	Defrost control so that during cold periods ice does not form on the heat exchanger
	Heat exchanger overheating control	Overheating control so that when the system is cooling and heat recovery is undesirable, the heat exchanger is stopped, modulated or bypassed
	Supply temperature control	Variable set point with outdoor temperature compensation
Central mechanical ventilation with heating or heat recovery	Air flow control at room level	Time control
	Air flow control at air handler level	On/off time control
	Heat exchanger defrosting control	Defrost control so that during cold periods ice does not form on the heat exchanger
	Heat exchanger overheating control	Overheating control so that when the system is cooling and heat recovery is undesirable, the heat exchanger is stopped, modulated or bypassed
	Supply temperature control	Demand control.
Zonal / Local	Air flow control at room level	On/off

10.4 Heat recovery in air distribution systems in new and existing buildings

Air supply and extract ventilation systems including heating or cooling should be fitted with a heat recovery system where this is technically feasible. The application of a heat recovery system is described in 6.5 of BS EN 13053:2006+A1:2011[15]. The methods for testing air-to-air heat recovery devices are given in BS EN 308:1997[16].

The minimum dry heat recovery efficiency with reference to the mass flow ratio 1:1 should be no less than that recommended in Table 38.

Table 25: Recommended minimum dry heat recovery efficiency for heat exchangers in new and existing buildings

Heat exchanger type	Dry heat recovery efficiency (%)
Plate heat exchanger	50
Heat pipes	60
Thermal wheel	65
Run around coil	45

10.5 Calculating the specific fan power for SBEM

SBEM assumes a value of *SFP* for the fan coil system, so this figure should not be added to the *SFP* for the fan coil units when entering the data into SBEM.

HEPA filtration is recognised as an option in SBEM. The pressure drop can be specified or SBEM will assume a default value from the NCM activity database.

15 BS EN 13053:2006+A1:2011 – 'Ventilation for buildings. Air handling units. Rating and performance for units, components and sections'.

16 BS EN 308:1997 – 'Heat exchangers. Test procedures for establishing the performance of air to air and flue gases heat recovery devices'.

Section 11: Pipework and ductwork insulation

11.1 Introduction

This section gives guidance on insulating pipework and ducting serving space heating, hot water and cooling systems in new and existing buildings to meet relevant energy efficiency requirements in the building regulations.

The insulation of pipework and ducting is essential to minimise heating system heat losses and cooling system heat gains. For cooling systems, it is also important to ensure that the risk of condensation is adequately controlled.

The guidance in this section covers insulation for the following types of pipework and ductwork serving space heating, domestic hot water and cooling systems:

- pipework: direct hot water, low, medium and high temperature heating, and cooled
- ductwork: heated, cooled and dual-purpose heated and cooled.

11.2 Insulation of pipes and ducts in new and existing buildings

To optimise the effectiveness of the supply of heat or cooling, hot water pipework and warm or cold air ductwork should be insulated in all areas inside and outside the building.

Insulation of pipes and ducts serving heating and cooling systems should meet the following recommended minimum standards.

Direct hot water and heating pipework

Pipework serving space heating and hot water systems should be insulated in all areas outside of the heated building envelope. In addition, pipes should be insulated in all voids within the building envelope and within spaces which will normally be heated, if there is a possibility that those spaces might be maintained at temperatures different to those maintained in other zones. The guiding principles are that control should be maximised and that heat loss from uninsulated pipes should only be permitted where the heat can be demonstrated as ‘always useful’.

Insulation should be designed so that the permissible heat losses in **BS 5422** for hot water services in non-domestic buildings are not exceeded. For low temperature systems, the heat losses shown in Table 26 for different pipe sizes and temperatures should not be exceeded. Insulation thickness should be calculated in accordance with BS EN ISO 12241.

Table 26: Minimum pipework insulation thicknesses for hot water services and space heating applications in low temperature hot water systems

Nominal internal pipe diameter (mm)	Minimum insulation thickness (mm) for low temperature hot water systems
≤ 15	15
≤ 32	20
≤ 80	25
≤ 100	30

Notes:

1. Thicknesses apply for low-emissivity faced insulation with a thermal conductivity of 0.025 W/(m.K) or better. Otherwise consult BS 5422.
2. Insulation thicknesses designed to achieve permissible heat losses from BS 5422 for heating systems ≤ 95 °C

Heating and cooling ductwork

Ducting should be insulated along its whole length in order to provide the necessary means of limiting heat gains or heat losses.

The heat losses or gains per unit area should not exceed the values in Table 27. Where ducting may be used for both heating and cooling, the limits for chilled ducting should be adopted since these are more onerous (heat gains are shown as negative values).

As with pipework, additional insulation may be required to provide adequate condensation control, as detailed in TIMSA guidance.

Table 27: Recommended maximum heat losses and gains for ducts delivering air for heating and/or cooling

	Heating duct	Cooling / dual-purpose duct
Heat transfer (W/m²)	16.34	-6.45
Indicative insulation thickness (mm)	21	36

Notes:

Insulation thicknesses should be calculated according to BS EN ISO 12241 using the following standardised assumptions:

- Horizontal duct at 35 °C, with 600 mm vertical sidewall in still air at 15 °C
- Horizontal duct at 13 °C, with 600 mm vertical sidewall in still air at 25 °C

Thicknesses apply for low-emissivity faced insulation with a thermal conductivity of 0.025 W/(m.K) or better. Otherwise consult BS 5422.

Section 12: Lighting

12.1 Introduction

This section provides guidance on specifying lighting for new and existing non-domestic buildings to meet relevant energy efficiency requirements in the building regulations. There are two alternative approaches, applicable both to systems in new buildings and to replacement systems in existing buildings.

The guidance in this section applies to the following types of lighting:

- general interior lighting
- display lighting.

12.2 Key terms

Office area means a space that involves predominantly desk-based tasks – e.g. a classroom, seminar or conference room.

Daylit space means any space:

a. within 6 m of a window wall, provided that the glazing area is at least 20% of the internal area of the window wall

b. below rooflights, provided that the glazing area is at least 10% of the floor area.

The normal light transmittance of the glazing should be at least 70%; if the light transmittance is below 70%, the glazing area should be increased proportionately for the space to be defined as daylit.

Space classification for control purposes[17]:

- ***Owned space*** means a space such as a small room for one or two people who control the lighting – e.g. a cellular office or consulting room.
- ***Shared space*** means a multi-occupied area – e.g. an open-plan office or factory production area.
- ***Temporarily owned space*** means a space where people are expected to operate the lighting controls while they are there – e.g. a hotel room or meeting room.
- ***Occasionally visited space*** means a space where people generally stay for a relatively short period of time when they visit the space – e.g. a storeroom or toilet.
- ***Unowned space*** means a space where individual users require lighting but are not expected to operate the lighting controls – e.g. a corridor or atrium.
- ***Managed space*** means a space where lighting is under the control of a responsible person – e.g. a hotel lounge, restaurant or shop.

Local manual switching means that the distance on plan from any local switch to the luminaire it controls should generally be not more than 6 m, or twice the height of the light

[17] These definitions are given in more detail in BRE Information Paper IP6/96 – 'People and lighting controls' and BRE Digest 498 – 'Selecting lighting controls'.

fitting above the floor if this is greater. Where the space is a daylit space served by side windows, the perimeter row of lighting should in general be separately switched.

Photoelectric control is a type of control which switches or dims lighting in response to the amount of incoming daylight.

Presence detection is a type of control which switches the lighting on when someone enters a space, and switches it off, or dims it down, after the space becomes unoccupied.

Absence detection is a type of control which switches the lighting off, or dims it down, after the space becomes unoccupied, but where switching on is done manually.

Lamp lumens means the sum of the average initial (100 hour) lumen output of all the lamps in the luminaire.

Circuit-watt is the power consumed in lighting circuits by lamps and, where applicable, their associated control gear (including transformers and drivers) and power factor correction equipment.

Lamp lumens per circuit-watt is the total *lamp lumens* summed for all luminaires in the relevant areas of the building, divided by the total circuit-watts for all the luminaires.

LOR is the light output ratio of the luminaire, which means the ratio of the total light output of the luminaire under stated practical conditions to that of the lamp or lamps contained in the luminaire under reference conditions.

Luminaire lumens per circuit-watt is the (*lamp lumens* x *LOR*) summed for all luminaires in the relevant areas of the building, divided by the total *circuit-watts* for all the luminaires.

LENI (Lighting Energy Numerical Indicator) is a measure of the performance of lighting in terms of energy per square metre per year (kWh/m^2/year), based on BS EN 15193:2007 – ‘Energy performance of buildings. Energy requirements for lighting’.

12.3 Lighting in new and existing buildings

Lighting should be designed to achieve lighting levels appropriate to the activity in the space, based on the CIBSE’s *SLL Lighting Handbook* or an equivalent design guide. Spaces should be within the recommended illuminance range and should not be over-illuminated.

General Lighting - efficacy

General lighting should have an average luminaire efficacy of 95 luminaire lumens per circuit-watt or demonstrate an equivalent efficacy using the Lighting Energy Numeric Indicator (LENI) method (see section 12.4).

Display Lighting - efficacy

Display lighting should have an average luminaire efficacy of 80 luminaire lumens per circuit-watt.

Lighting controls

Lighting controls in new and existing buildings should follow the guidance in BRE Digest 498 – ‘Selecting lighting controls’.

Display lighting, where provided, should be controlled on dedicated circuits that can be switched off at times when it is not needed for the purpose for which it is provided.

Lighting metering

The lighting should be metered to record its energy consumption in accordance with the minimum standards in Table 43.

Table 28: Recommended minimum standards for metering of general and display lighting in new and existing buildings	
	Metering solution
Metering for general or display lighting	Either: • kWh meters on dedicated lighting circuits in the electrical distribution; or • local power meter coupled to or integrated in the lighting controllers of a lighting or building management system; or • a lighting management system that can calculate the consumed energy and make this information available to a building management system or in an exportable file format. (This could involve logging the hours run and the dimming level, and relating this to the installed load).

12.4 Lighting Energy Numerical Indicator (LENI)

An alternative to complying via a minimum efficacy level in Section 12.3 is to follow the Lighting Energy Numerical Indicator (*LENI*) method.

The *LENI* method calculates the performance of lighting in terms of energy per square metre per year. The approach described below must be followed in calculating the *LENI* for a lighting scheme. The *LENI* should not exceed the lighting energy limit specified in Table 44 for a given illuminance and hours run.

Design the lighting

The first step to energy efficient lighting is to design the lighting installation in a way that meets all of the users' needs for the space under consideration. Recommendations for appropriate illuminance values and other lighting requirements may be found in BS EN 12464-1:2011 – 'Light and lighting - Lighting of work places - Indoor work places' [18] and in the Society of Light and Lighting (SLL) Code for Lighting. The SLL Handbook provides practical advice on how to design lighting for a number of different applications[19].

Step 1 - Determine the lighting energy limit – from Table 29.

If display lighting is used, then the lighting energy limit may be increased by the value given for normal display lighting for the area of the room where display lighting is used.

Step 2 - Calculate the parasitic energy use (E_p)

If the parasitic energy use is unknown, an allowance of 0.3 W/m2 should be made for any control system. If no lighting control system is used, then Ep = 0.

[18] BS EN 12464-1:2011 – 'Light and lighting. Lighting of work places. Indoor work places'.
[19] For further information, see www.sll.org.uk and www.thelia.org.uk

Step 3 - Determine the total power of lighting (P_l)

This is the total power in watts consumed by the luminaires within a space.

Step 4 - Determine the occupancy factor (F_o)

If no automatic control is used, then $F_o = 1$. If controls turn off the lights within 20 minutes of the room being empty, then $F_o = 0.8$.

Step 5 - Determine the factor for daylight (F_d)

If no daylight-linked dimming system is used, then Fd = 1. If the electric lighting dims in response to daylight being available, then in areas with adequate daylight Fd = 0.8. This may be taken as all areas within 6 m of a window wall or in areas where 10% or more of the roof is translucent or made up of rooflights.

Step 6 - Determine the constant illuminance factor (F_c)

Systems that control the lighting in this way have $F_c = 0.9$, and those that do not have $F_c = 1$.

Step 7 - Determine the daytime energy use (E_d)

The day time energy use is: $$E_d = \frac{P_l \times F_o \times F_d \times F_c \times T_d}{1000}$$

Step 8 - Determine the night time energy use (E_n)

The night time energy use is: $$E_n = \frac{P_l \times F_o \times F_c \times T_n}{1000}$$

Step 9 - Calculate total energy (kWh) per square metre per year (LENI)

The total energy per square metre per year is the sum of the daytime, night- time and parasitic energy uses per year divided by the area (A), as set out in the formula below:

$$LENI = \frac{E_p + E_d + E_n}{A}$$

Table 29: Recommended maximum LENI (kWh per square metre per year) in new and existing buildings

Hours			Illuminance (lux)								Display Lighting	
Total	Day	Night	50	100	150	200	300	500	750	1000	Normal	Shop Window
1000	821	179										
1500	1277	223										
2000	1726	274										
2500	2164	336										
3000	2585	415										
3700	3133	567										
4400	3621	779										
5400	4184	1216										
6400	4547	1853										
8760	4380	4380										

Note: the values in highlighted cells require to be updated to provide an equivalent energy efficiency as cited in Section 12.4.

Section 13: Heating and cooling system circulators and water pumps

13.1 Introduction

Heating and cooling water in HVAC systems of non-domestic buildings can circulate for extensive periods and be responsible for considerable energy use.

This section provides guidance on specifying:

- heating system glandless circulators, both standalone and integrated in products
- heating and cooling system water pumps

to limit their energy consumption and meet relevant energy efficiency requirements in the Building Regulations. The guidance covers circulators and water pumps when used in closed systems.

13.2 Key terms

Heating system glandless circulator means a pump used to circulate hot water in closed circuit heating systems. The glandless (or wet rotor) circulator is a centrifugal pump with an integral motor and no mechanical seal. It can have an integrated motor drive unit for variable speed operation.

Water pump (also known as 'dry rotor' or 'direct coupled' pump) means a centrifugal pump driven by an electric motor and generally having mechanical seals. Common pump types include in-line, end suction and vertical multi-stage. The first two are usually single-stage pumps having single-entry volute. By design they can all be used as circulators for all HVAC applications depending on configuration and duty.

13.3 Glandless circulators and water pumps in new and existing buildings

Heating system glandless circulators and heating and cooling system water pumps in new and existing buildings should meet the following recommended minimum standards

- Variable speed glandless circulators should be used on variable volume systems.
- If a water pump is used on a closed loop circuit and the motor is rated at more than 750 W, then it should be fitted with or controlled by an appropriate variable speed controller on any variable volume system. On water pump booster sets with an open loop circuit, the static head should be checked before an appropriate variable speed controller is used.

13.4 Supplementary information

Further information and guidance is available from www.bpma.org.uk where a list of approved glandless circulators and water pumps can be found

Section 14 – Building Automation and Control Systems.

14.1 Introduction

This section provides guidance on the provision of Building Automation and Control Systems (BACS) in new and existing buildings to meet relevant energy efficiency requirements in the building regulations.

14.2 Key terms

Building Automation and Control System means a system comprising all products, software and engineering services that can support energy efficient, economical and safe operation of fixed building services/technical building systems through automatic controls and by facilitating the manual management of those building systems.

Technical Building Systems means any of the following systems: Space heating; Space cooling; Ventilation; Domestic hot water; Lighting; Building Automation and Control Systems; and On-site electricity generation.

14.3 Building Automation and Control Systems

If a new building has a space heating or air-conditioning system with an effective rated output of greater than to 290 kW, a Building Automation and Control System should be installed.

If an existing building has a space heating or air-conditioning system with an effective rated output greater than 290kW, a Building Automation and Control System being replaced or installed should provide the functions set out below.

The above provisions also apply to buildings containing heating and air-conditioning systems which are combined with ventilation systems.

Note: in situations where neither of the above situations occur, consideration should be given to providing centralised switches to allow the facilities manager to switch off appliances when they are not needed. Where appropriate, these should be automated (with manual override) so that energy savings are maximised. Consideration should be given to the power requirements of essential (e.g. life safety) systems.

Determining the effective rated output

The effective rated output is the combined output of the equipment in the building which is provided for heating or cooling the internal space in normal operation, for the comfort of occupants.

For air-conditioning systems, the effective rated output should include the combined maximum output of both of the following, as specified by the manufacturer.

- Air-conditioning systems
- Air-conditioning systems combined with or as part of a ventilation system.

For heating systems, the effective rated output should include the combined maximum output of all the following, as specified by the manufacturer.

- Primary space heating systems.
- Space heating systems combined with or as part of a ventilation system.
- Secondary space heating systems.

Assessment of effective rated output does not include any of the following.

- Heating or cooling equipment only intended for emergency or occasional backup use.
- Heating equipment for frost protection.
- Heating for domestic hot water.
- Heating or cooling for industrial processes.

If the building is heated through a district heat network or community heating system, the effective rated output should be based on the capacity of the equipment installed in the building, making reasonable assumptions for the operation of the district heat network or community heating system, including flow temperatures.

The requirements are based on the final installed capacity of the heating or air-conditioning system. When estimating the effective rated output at design stage, designers should make allowances for the final installed capacity, including potential oversizing and equipment substitution.

Installed system - functions

Where a Building Automation and Control System is installed, it should comply with EN ISO 16484 and provide the following functions.

- Continuously monitor, log, analyse and allow for adjusting of energy use.
- Benchmark the building energy efficiency, detect losses in efficiency of technical building systems, and inform the person responsible for the facilities or building management about opportunities for energy efficiency improvement.
- Allow communication with connected technical building systems and other appliances inside the building and be interoperable with technical building systems across different types of proprietary technologies, devices and manufacturers.

Note: A BS EN 15232 Class A Rated type system would meet the above requirements.

Where a building automation and control system is installed, as well as meeting the requirements above, its control capabilities should be appropriate for the building, its expected usage, the expected technical knowledge of the building automation and control system user, and the building services specification. The system should be appropriately sized.

Section 15 – Self-Regulating Devices

15.1 Introduction

This section provides guidance on the provision of self-regulating devices, such as room and emitter thermostats, in new and existing buildings to meet relevant energy efficiency requirements in the building regulations.

15.2 Key terms

Self-regulating device means a device or system that automatically controls the output of heating and/or cooling emitters to independently control the temperature in each room or, (where justified, a heating zone) where heating and/or cooling is provided by a fixed building service.

15.3 Self-regulating devices

For heating and cooling systems in new buildings, each room or, where justified in accordance with guidance given below, heating zone should be provided with self-regulating devices for the separate control of heating in the room/zone.

Provision of self-regulating devices

Provision for self-regulating devices can be achieved by providing any of the following solutions:

- An individual networked heat emitter control for each emitter; or
- A thermostat in a room that the heating circuit serves, together with an individual self-regulating device for each heat emitter, such as a thermostatic radiator valve, on all heat emitters outside the room which contains the thermostat.

  Thermostatic radiator valves should not be located in the same room as the thermostat.
- An individual room/ heating zone thermostat or fan coil thermostat for each room/heating zone.
- Any other controls which provide the same function as a self-regulating device.

Existing Buildings

For work in existing buildings, when a heat generator, such as a boiler, is replaced, f not already present, self-regulating devices should be installed, where technically feasible and economically feasible, for the separate control of heating in each room served by the heating appliance.

Where it is not technically feasible or economically feasible to install self-regulating devices the requirement does not need to be met. Measures which are not technically feasible include, but are not limited to:

- Buildings with very low heat demand (e.g. <10 W/m2).
- Homes with buffer zones for heat absorption or dissipation with high thermal mass.

In normal circumstances, the installation of thermostatic radiator valves in wet central heating systems is likely to be economically feasible.

Option to provide control at zone level

Alternatively, where justified below, heating may be controlled for each heating zone rather than individual rooms where any of the following apply:

- in open-plan spaces in which heating demand and patterns of use are similar across the whole space, sub-zoning of temperature control might not be appropriate. In such cases, the space should be considered as a single heating zone
- where two adjacent rooms have a similar function and heating requirements (e.g. kitchen and utility room).

It might not be possible to equip some heating system types with self-regulating devices for the control of individual rooms. Such systems should only be used where controlling a whole heating zone can be justified.

Appendix A: Abbreviations

BER	Building (Carbon Dioxide) Emission Rate
BMS	Building Management System
BS	British Standard
BSD	Building Standards Division
CHP	Combined Heat And Power
CHPQA	Combined Heat And Power Quality Assurance
CO_2	Carbon Dioxide
COP	Coefficient Of Performance
DECC	Department For Energy And Climate Change
DHW	Domestic Hot Water
EEI	Energy Efficiency Index
EER	Energy Efficiency Ratio
EN	European Norm (Standard)
ESEER	European Seasonal Energy Efficiency Ratio
HEPA	High-Efficiency Particulate Absorption
HVAC	Heating Ventilation And Air Conditioning
LENI	Lighting Energy Numeric Indicator
LPG	Liquefied Petroleum Gas
MF	Maintenance Factor
NCM	National Calculation Methodology
PSEER	Plant Seasonal Energy Efficiency Ratio
QI	Quality Index
RHI	Renewable Heat Incentive
SAP	Standards Assessment Procedure
SBEM	Simplified Building Energy Model
SCOP	Seasonal Coefficient Of Performance
SG	Scottish Government
SEDBUK	Seasonal Efficiency Of Domestic Boilers In The UK
SEER	Seasonal Energy Efficiency Ratio
SFP	Specific Fan Power
SI	Statutory Instrument
SPEER	Seasonal Primary Energy Efficiency Ratio
SPF	Seasonal Performance Factor
TER	Target (Carbon Dioxide) Emission Rate
TRV	Thermostatic Radiator Valve
VAV	Variable Air Volume