CLEANER AIR FOR LONDON

Reducing air pollution from your building – a series of manuals for operators, designers & developers

Manual B – Minimising air pollution from new developments

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Reducing air pollution from your building Manual B -Minimising air pollution from new developments

This series of guides to reduce air pollution from your building comprises

- **Manual A - for building operators**
- **Manual B - minimising air pollution from new developments**
- **5 key questions about air pollution and buildings - a 1 page guide**

SOME CONVENTIONS USED IN THIS DOCUMENT

Key information
is highlighted in an orange box.

Examples and Case Studies
are shown inside a light blue box.

External Resources and Clickable links to websites
are shown like this

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Introduction

Almost all buildings emit air pollution due to combustion in their heating, cooling or electricity generation systems. While there's a lot of attention paid to carbon (CO_2) emissions from buildings that accelarate global warming, up to now the toxic air pollution from buildings has received less attention. In fact buildings account for as much as half of some air pollutants emitted in London. Buildings tend to cause the background air pollution in cities – when this combines with the vehicle exhaust along roads it can create **hotspots** where air pollution concentrations both pose a threat to health and breach legal limits.

This is a significant problem for public health. In London about 4,000 premature deaths a year have been attributed to **Particulate Matter (PM)** pollution by the NHS. PM is a type of soot whose very fine particles get deep into people's lungs and pass into the blood, making all sorts of health problems worse. PM also causes cancer. Buildings also emit **Nitrogen Dioxide (NO_2),** usually in much larger amounts than PM. This is associated with increased hospital admissions and deaths from heart failure. Reducing air pollution from buildings not only improves people's health, but it also tends to save money as a key aspect of minimising air pollution is energy efficiency.

HOW TO MINIMISE AIR POLLUTION FROM BUILDINGS

The main regulations applying to air pollution from buildings can usually be complied with if two key actions are taken. First, the demand for onsite heat and electricity consumption in the building should be minimised. In other words, the building should be designed to be as energy efficient as possible, at least to the latest Part L standards and ideally better than these. This has the effect of reducing the demand for heat and electricity generation services that emit air pollution. Second, as far as possible use low polluting services to generate heat and - if required - power. These need not be exotic or expensive - conventional high efficiency or condensing gas boilers are the ideal solution in many cases, in particular the ultra low NO_x variants. But renewable options exist too, like heat pumps, solar hot water and solar PV/electric panels. All are supported by government incentives. This dual approach will also help your building approach or achieve standards like the zero carbon building or BREEAM. This document covers five main areas to help you design a low pollution building:

The central principles of reducing air pollution from buildings

1. Design the building to maximise energy efficiency.
2. Use low polluting systems to meet the remaining energy demand.

1. Legislation & regulations, which explains how the Building Regulations and local air pollution regulations interact
2. The key steps to designing in energy efficiency
3. Some simple methods that can be used to estimate heating and cooling demand after an energy efficient design has been agreed
4. Heat and energy services, how much they pollute and which to use
5. The main types of boiler and heating controls you should use to ensure the heat and energy services are used optimally and efficiently.

This information will help you ensure your building respects the local environment and public health and is low cost to occupy.

B1

Legal Requirements, Regulations & Standards

B1.1 INTRODUCTION

New buildings are the primary target of regulations to help minimise energy consumption and other environmental impacts, including air pollution. This is because the energy efficiency and environmental impact of new buildings is the largest opportunity to improve the overall impact of the UK buildings stock. Maximising the design energy efficiency of the building is the first step to minimising the air pollution emmissions from the buildings heating plant.

This section outlines

- Building regulations on energy efficiency and therefore emissions
- The national, regional and local regulations
- Air Quality regulations
- Regulations on Energy Performance of Buildings and EcoDesign
- The BREEAM and LEED voluntary standards and how BREEAM is required by many government programmes.

Reading recommendations are provided for reducing emissions from transport that may be required by your development.

B1.2 UK BUILDING REGULATIONS

UK Building Regulations set energy efficiency standards for all new buildings and for buildings that are being refurbished. They require that all new homes should be Zero Carbon by 2016 and all other buildings by 2019. Progress towards this target has been set in stages:

- 2010 building regulations required a 25% improvement in the carbon performance based upon the 2006 requirements
- In 2014, fabric energy efficiency requirements are expected to increase to give an additional improvement in carbon performace
- In 2016, new homes should emit net zero carbon
- In 2019 all new buildings should emit net zero carbon.

The exact means by which **Zero Carbon Buildings** should be achieved is still being considered. Broadly a mix of fabric energy efficiency, low-carbon heat and electricity generation and 'Allowable Solutions' should be combined so that all emissions from the building and the activities that take place within it must be carbon neutral over the course of a year. Any residual emissions can be offset using **Allowable Solutions,** though at present there is uncertainty about exactly what these will be and how much they will cost. Allowable Solutions compensate for residual emissions by delivering approved on-site, near-site or off-site carbon-saving projects.

Part L of Building Regulations specifies the main strategies to be used in maximising energy efficiency in a new building or in a building whose thermal elements are to be substantially upgraded. It also outlines targets for carbon emissions from the buildings through a **Target Emissions Rate** of CO_2.

Main strategies laid out in Part L

Part L requires conservation of fuel and power in buildings in three main ways: insulation, energy systems and buildings management and information. The legal requirements are that reasonable provision shall be made for:

(a) limiting heat gains and losses through thermal elements and other parts of the building fabric; and from pipes, ducts and vessels used for space heating, space cooling and hot water services;

(b) providing fixed building services which are energy-efficient, have effective controls, and are commissioned by testing and adjusting to ensure they use no more fuel and power than is reasonable in the circumstances;

(c) providing sufficient information to the owner about the building, the fixed building services and their maintenance requirements so that the building can be operated in such a manner as to use no more fuel and power than is reasonable in the circumstances.

In the remainder of this document, additional information is provided on how each of these provisions can be met.

Part L and the Approved Documents can all be found at www.planningportal.gov.uk

B1.3 THE LAW AND AIR POLLUTION FROM BUILDINGS

There are strong interactions between government policies on sustainable buildings, building energy efficiency and air quality. Most new social housing is required to meet Level 4 of the Code for Sustainable Homes (BREEAM for homes), which specifies high levels of insulations and the installation of an ultra-low NO_x boiler. These are available at no extra cost. The government's tightening of Part L aims to reduce dramatically the carbon emissions through using less fuel, with consequent improvements in NO_x and PM emissions. But they can also have a negative impact on air pollution if developers use biomass boilers or poorly planned Combined Heat and Power instead of fabric energy efficiency to achieve the Target Emissions Rate of CO_2. Use of biomass fuels is forbidden by many urban Supplementary Planning Documents (SPDs). More detailed information on planning and air quality is provided in the IES Air Quality and Planning Law briefing (reference to be found at right).

Pollution abatement

In Air Quality Management Areas heating system options can be increased by using abatement technologies that reduce the NO_x and PM emissions of what would otherwise be more polluting systems. For each fuel and burner there are several approaches to pollutant reduction both inside the boiler and by treating the boiler exhaust gases. In addition, flue and stack heights can be increased to reduce or prevent flue gases reaching the ground or surrounding buildings. This all requires careful planning as the concentration of air pollution at receptors where people might be exposed depend strongly on the shape of the building, the surrounding buildings and the terrain itself.

Transport emissions and Low Emission Strategies

As with direct building emissions, transport emissions must also be minimised. This is an extensive topic in its own right, but there are many tools and resources than can help, in particular the **Low Emission Strategies (LES)** website and toolkits. LES aims to help you plan transport so that demand for polluting transport is minimised and so you can help offset any emissions from your building through better transport options.

IES Air Quality & Planning Law (2013) is an excellent introduction to the the topic by two UCL legal experts.
www.ies-uk.org.uk/analysis/air_quality_and_planning_law

The **Low Emission Strategies** website contains advice, guidance and tools to help reduce transport emissions.
www.lowemissionstrategies.org

B1.4 LONDON'S SUPPLEMENTARY PLANNING GUIDANCE

The London Plan places several air quality requirements on new developments and these are elaborated in London's Sustainable Design and Construction SPG. Overall this is intended to encourage walking and cycling, high energy efficiency buildings and use of ultra-low NOx boilers or zero emission heating. The SPG covers the following main areas.

Air quality assessments needed for many developments

Detailed air quality assessments must be conducted for any building in an AQMA, that is likely to cause or worsen an exceedence of the Limit Values, or expose sensitive individuals to higher pollution or that involves biofuels or CHP.

Air Quality Neutral Requirement

To prevent further deterioration of London's air quality, benchmark maximum emissions per square metre of floor area have been set for different land use classes, both for the building's emissions and related transport. If these are exceeded the developer must offset the emissions through another local activity.

Combustion, especially Combined Heat & Power and biofuels

The SPG sets standards for emissions of NO_x and PM from combustion, CHP and biomass in new buildings. These require use of ultra-low NO_x boilers where feasible and appropriate abatement for the technology in use, and set maximum emissions levels for different combustion technologies, depending on whether they are in an AQMA or an area where Limit Values are already exceeded.

London's Sustainable Design and Construction SPG
may be obtained from the GLA website:
www.london.gov.uk

B1.5 EPCS AND DECS SHOW BUILDING ENERGY PERFORMANCE

The UK law enacting the **Energy Performance of Buildings Directive** requires buildings to have a current Energy Performance Certificate (EPC) when built, sold or rented out. Public buildings larger than 500m^2 must be certified annually on the basis of actual energy performance and the resulting Display Energy Certificate (DEC) must be displayed. The rating achieved in these certificates will be strongly influenced by heating system choice and performance, so keeping a regular maintenance schedule for energy systems is important. The Directive also includes a requirement for the analysis of high efficiency alternative systems for new buildings occupied by public authorities, which are now in force.

The **Eco-Design Directive** sets the minimum energy performance standards of a wide range of products to be sold/used in Europe, and in coming years it will require that many energy-consuming devices used in buildings are more efficient, including boilers, computers, televisions, transformers, industrial fans and industrial furnaces. Other energy-related products (ERPs) that have an impact on energy consumption such as windows, insulation material, shower heads, taps etc., will also be required to be improved by the regulations.

UK.GOV contains more information on EPCs
www.gov.uk/energy-performance-certificate-commercial-property/overview

B1.6 BREEAM & LEED

The Building Research Establishment's Environmental Assessment Methodology (BREEAM) and Leadership in Energy and Environmental Design (LEED) are the two main certification schemes used to improve sustainability within commercial building design and operation. Whilst currently this is voluntary, the public sector demands their use and there is growing demand within commercial sectors to improve Corporate Social Responsibility (CSR), attract funding, and provide genuine evidence of sustainability within an organisation. Different building types have tailored assessment schemes, such as in the healthcare, industrial, offices, retail and higher education sectors; and both now have 'in-use' assessment schemes for certification of existing buildings.

The assessment schemes are credit based assessment systems covering all aspects of a building's operation. Choice of HVAC system and distribution services, together with levels of control and management can significantly influence the score and ratings achieved. The 'in-use' schemes are self-assessment based, followed by certification from an independent auditor.

BREEAM information is available from

www.breeam.org

LEED information is available from:

www.usgbc.org

BREEAM & CSH Level 4 & above require air quality measures

Under the "Pol 2" code in BREEAM and the Code for Sustainable Homes points are given for installation of Low-NO_x and Ultra-Low NO_x boilers. These systems are available at all scales and studies by DCLG and Cyril Sweet show they are available at no extra cost (examples are provided at the end of this chapter).

Fabric Energy Efficiency & Zero Emission Energy are the most cost-effective approaches to building energy strategy

Evidence also suggests that the most cost-effective way for developers to implement both energy and air quality efficiency is through fabric energy efficiency, use of solar hot water, heat pumps and other zero-emission energy sources such as Mechanical Ventilation Heat Recovery, then finally making up the remaining heat demand using Ultra Low-NO_x gas boilers. This has lower capital cost than CHP.

B2

Energy Efficient Design

B2.1 INTRODUCTION

Studies have found that designing for and maximising efficiency within a building is the most cost-effective way to reduce energy consumption. This minimises energy demand, thus reducing air pollution and minimising carbon emissions. In general, these studies also indicate that the majority of energy efficiency measures require lower capital and operational expenditure than installing overblown or unnecessary heating provision, even if this is considered 'renewable' or 'low carbon'. This is because highly efficient building envelopes reduce the need for heating and cooling systems. Good and intelligent designed buildings can significantly reduce, or even avoid, the need for heating and cooling and reduce the need for ventilation. The main factors to consider are:

- Energy efficient design goals, building orientation & built form
- Understanding heating & cooling demand in the proposed development
- Passive heating & ventilation strategies and building fabric
- Energy distribution, motors, pumps, drives & fans
- Human factors
- Building information modelling
- Metering, modelling, targeting, building management

Design in energy effiency before your heating systems – this will improve the accuracy of the specification

There are often interactions between materials that are not fully understood or accounted for within the design process; this in turn complicates the quantification of benefits of heating system options. The best way to avoid this is by planning in all other energy efficiency measures to be undertaken before the heating system. This will improve the accuracy of the heating system choice and sizing, and any business case development.

B2.2 MAKE ENERGY EFFICIENT DESIGN A GOAL

It is essential to set a primary goal for the design team of minimising energy demand. Without this there is significant risk of failure to implement best solutions, for solutions to be at odds with each other, and for value engineering to cut back on energy efficiency as it is not seen as integral to overall delivery. Good design optimises site layout to maximise shading, solar gains, daylight and shelter from prevailing winds. Different building shapes match different functions e.g. compact buildings minimise heat loss and are suitable for a care home or hospital, while a rectangular building with south facing facade allows passive solar heating, day-lighting and natural ventilation, more suited to offices where most energy is used in lighting.

The process should include an estimated energy balance to understand where energy is being consumed and opportunities for reducing primary demand more effectively before deciding on Heating, Ventilation and Air Conditioning (HVAC) systems. Many energy problems can be traced to a conflict between building services, e.g. heat loss from piping installed next to refrigerators. An energy-efficient design strategy should avoid such conflicts.

Key considerations for the design strategy:

- Question the need for full air conditioning – only specify this if the internal environment needs to be closely controlled for temperature or humidity for reasons such as H&S.
- Reduce the need for mechanical ventilation by using zoning to separate out areas requiring higher temperatures, and areas of high heat gain.
- Enhance window design to prevent poor usability – also consider window interlocks, which switch heating off once windows are opened.
- Use stack-assisted ventilation – be careful with specification of this (use modelling) to ensure you are not creating extra warm areas on upper floors, or significant draughts at lower levels.
- Consider storing heat in the fabric during the day and removing it at night.
- Consider the use of 'free cooling' which uses the cooling capacity of ambient air to directly cool the space. Often referred to as 'night-cooling' in the UK during summer.
- Finally, reduce internal heat gains, for example by sourcing IT provision into a separate, sealed area, and introducing thin client technology (i.e. not having local CPUs).

CIBSE Guide F **Energy Efficiency in Buildings** includes an Energy Design Checklist and detailed information on energy-efficiency building design. www.cibseknowledgeportal.co.uk

B2.3 PASSIVE, HEATING & VENTILATION STRATEGIES

The design strategy should make use of heating, lighting and ventilation both from occupants and internal equipment and the local climate and environment. There are two ways to do this - **natural ventilation** and **heat recovery**. Natural ventilation is a design approach where the air flows through openings of a room or building, preferably from opposite sides, provides the majority of fresh air and temperature management. It also uses rising hot air to suck in cooler air through windows or vents from a lower level or through atria, which is known as **stack-assisted ventilation**. This can be supplemented by **air handling units (AHUs)** which comprise blowers, filters, heating and cooling elements.

Heat recovery systems pass heat from ventilated air into the incoming fresh air to pre-heat it, and in some circumstances it can exchange cooling. As only low grade heat that is recovered, it usually cannot be used as a primary heat provision mechanism. Waste heat can be recovered from boilers and hot exhaust gases from furnaces, kilns etc, compressors and refridgerators, and electricity generators. This can used for many purposes including:

- Pre-heating combustion air for boilers, ovens, furnaces, etc
- Pre-heating fresh air used for ventilation
- Hot water generation, including pre-heating boiler feed water
- Space heating & drying

It can also help reduce conflicts between heating and cooling requirements.

The Carbon Trust offers detailed information on heat recovery carbontrust.com/resources/guides/energy-efficiency/heat-recovery

B2.4 BUILDING FABRIC

Building Regulations set out maximum rates of heat loss **(u-values)** for building materials and levels of air-tightness, but if possible aim to exceed these to minimise heat loss. If the building will experience a lot of solar gain, consider solar film or integral blinds to reduce the **winter** cooling load.

B2.5 HEAT & COOLING DISTRIBUTION

Plant room requirements should be considered at an early stage to minise heat lost in the heat and cooling transportation systems. The following points should be taken into consideration:

- Significant energy savings can be achieved through careful sizing, routing and detailing of ductwork and pipework to reduce unnecessary pressure drops.
- Ensure that all pipes, ducts, vessels, valves, couplings and refrigerant pipework are adequately insulated
- Use hot water to transport heat, rather than hot air - this is more efficient
- Identify opportunities to decentralise heating, cooling and hot water provision to small local plants
- Consider the use of two-way and install variable frequency drives on heating and hot water coils
- Consider the use of de-stratification fans in buildings with high ceilings. These can reduce energy use by 20% by blowing warm air down to ground level where it is needed

Specifying VSDs, soft starts and high-efficiency pumps can reduce energy consumption by up to 60% where there are variable conditions of operation. The additional capital costs also tend to be fairly low.

Design in easy to use system controls for occupants

Ensure that control's user interfaces encourage good use of systems by the occupants and that occupants have enough control to feel comfortable. Equally important is to ensure that simple user guidance is produced to explain the control interfaces and systems to promote good use.

B2.6 BUILDING INFORMATION MODELLING

There is a growing movement away from value engineering to holistic Building Information Modeling (BIM). BIM allows any aspect of a design's performance to be simulated and assessed before it is built – helping to understand design more completely

B2.7 METERING, MODELLING, TARGETING & BUILDING MANAGEMENT:

Metering, monitoring and targeting (MM&T), is the management information system that supports energy management. It is an on-going cyclical process from data collection to taking action, via data analysis and communicating the resulting insights. MM&T gives you:

- Timely, relevant information on energy use and the ability to investigate the energy performance of buildings and processes
- The ability to take action to rectify exceptions in performance and to improve energy performance over time
- Energy reports to support accountability for energy use
- The ability to verify savings made following project implementation.

B3

UNDERSTAND YOUR HEAT REQUIREMENT

B3.1 INTRODUCTION

To minimise wasted energy, fuel and pollution emissions it is essential to correctly determine the size of the required heating system using one of several methods, from crude rules of thumb to complex building energy models. There are five factors that determine the energy load on a heating system:

1. The design, layout and operation of the building
2. The required indoor temperatures and air quality
3. The heat generated internally by lighting, equipment and people
4. The type, design and efficiency of the heating plant
5. Building usage patterns

With increasing levels of insulation, airtightness and internal gain of buildings, the heat balance can involve many interactions and determining the heat balance can be complex. There are many Building Energy Modelling (BEM) software packages available to estimate the dynamic response and performance of buildings and help to assess and compare the effects of different design options. This helps design teams make properly informed value judgements about the costs and benefits of different design strategies and options. To comply with Part L and the EPBD the sBEM software package must be used. CIBSE's AM11 guidance explains how to get an outline understanding of your likely heating requirements.

CIBSE AM11 Building Energy & Environmental Modelling (1998) provides useful background information but is somewhat out of date.

Use the Simple Sizing Calculation to scope out initial options

This can check against conceptual boiler size and plant space requirements, and to determine initial options for heating system choice. It can also be used to give an early indication of running consumption and costs for the heating plant.

B3.2 RULES OF THUMB

At the concept stage, simple ‘rule of thumb’ sizing calculations are often sufficient to determine approximate plant requirements and sizes. Rules of thumb can be useful to calculate approximate values, set outline targets and rapidly compare different options.

The rule of thumb usually needs to be adjusted according to the plant efficiency to correctly size the heating plant. Boiler seasonal efficiency values should be used rather than manufacturers quoted instantaneous efficiencies, as this takes into account the actual operation of the boiler or its practical use, measured at full and part load. It is a weighted average of a defined number of hours of full and part load operation which represents a full year of operation. Note that the boiler efficiency is also affected by the heating system type.

CIBSE Guides A and B and Carbon Trust CTV046 list recommended heating temperatures for particular buildings, external design temperatures, activities, and processes. **Guide B** gives details of the calculation of system loads.

Rule of Thumb	Heating Load (W/m^2 GIA)
Educational Buildings	87
Industrial Buildings	80
Offices	70
Residential Buildings	60
Retail Buildings	100
Example: a 1000m^2 office block can be expected to have a 70kW heat load, based on 1000m^2 x 70.	
Source: BSRIA Rules of Thumb (2011) for heating loads.	

Typical Seasonal Efficiencies	Seasonal efficiency %
Condensing boilers	
Under floor or warm water system	90 or greater
Standard radiators with weather compensation	87
Standard fixed temperature emitters	85
Non-condensing boilers	
Modern high efficiency	82
Modern boiler closely matched to demand	80
Typical existing oversized boiler	45 – 70
Example: the 1000m^2 office from the previous example would require a boiler delivering 80.5kW of heat using standard radiators given that 70kW x (100 ÷ 87) = 80.5kW Source CIBSE	

B3.3 HOW TO PERFORM A SIMPLE SIZING CALCULATION

This calculation works by determining the high-level heat losses in your building, and then working out the level of heating that would be required to achieve the building's desired temperature. We start with Q_T the total heat demand

$$Q_T = Q_F + Q_V \text{ (in Watts)}$$

where Q_F is fabric heat loss and Q_V is the ventilation and infiltration heat loss. The Watt (W) is a unit of power, the **rate** at which energy is generated or consumed. 1000W = 1kW.

$$Q_F = U \times A \times \Delta T \text{ (in Watts)}$$

where U is the u-value for each surface material (W/m^{2}°C)

A is the surface area of each building component (m^2)

ΔT is the difference between desired internal and external temperatures

and $Q_V = ⅓ \times N \times V \times \Delta T$ (Watts)

where N = number of air changes hourly (see CIBSE Guide A Rules Of Thumb)

V = volume of building (m^3).

To calculate the annual energy load:

$$E_{annual\ load} = [[Q_T \div (T_i - T_o)] \times DD \times 24] \div 1000 \text{ (kWh)}$$

where

T_i is the internal design temperature

T_O is the outside design temperature

DD is the Degree Days for your region

As before, actual energy load is dependent on efficiency of system

$$E_{total} = [[Q_T \div (T_i - T_o)] \times DD \times 24 \div \eta)] \div 1000 \text{ (kWh)}$$

where η is the system seasonal efficiency.

Total annual consumption can then be calculated as:

$$E_{annual} = E_{total} \times \text{heating hours in year}$$

Degree Days are fully explained, along with data for your region, at **www.degreedays.net**

B4

Fuel Choice, Pollution & Abatement

B4.1 HEATING SYSTEM ABATEMENT TECHNOLOGIES

The heating system and fuel you choose will be the main determining factor of how much air pollution your building will emit (see table at right). Some systems, such as solar collectors for hot water or air source heat pumps, both minimise air pollution and carbon emissions and are eligible for various subsidies. Most types of gas boiler come in “ultra low NO_x” variants that can minimise toxic air pollution at little or no extra cost. Biomass boilers, emit comparatively large amounts of toxic air pollution per kWh of heat generated, (see right) and so are unsuitable for many London locations and are forbidden in many boroughs.

The pollution’s impact is also determined by the location and height of the exhaust or flue from the heating systems, and the abatement equipment interposed between the boiler and the flue. This section outlines the advantages of disadvantages of the main systems suitable for use in London and explains the circumstances in which it can most appropriately be applied.

Typical air pollutant emissions from different heating technologies

Technology	Local NO_x, mg/kWh	Local PM, mg/kWh	CO_2, g/kWh	Efficiency
Solar thermal	0	0	0	46%-74%
Heat pump (electric)	0	0	132g/kWh	290%-340%
Ultra low-NO_x gas boiler	< 40mg/kWh	< 1mg/kWh	185g/kWh	90%-94%
Oil fired boiler	< 120mg/kWh	16mg/kWh	245g/kWh	70%-87%
Proposed London CHP standard	< 300mg/kWh	To be announced	Not applicable	75%-85%
Biomass Boiler (RHI eligible)	< 530mg/kWh	< 107mg/kWh	0	Variable

Pollution abatement technologies

In AQMAs, heating system options can be increased by using abatement technologies that reduce the NO_x and PM emissions of what would otherwise be more polluting systems. For each fuel and burner type there are several approaches to pollutant reduction both inside the boiler (primary or internal abatement) and by treating the boiler’s exhaust gases (secondary or external abatement). In addition, flue and stack heights can be increased so as to reduce or eliminate the likelihood of flue gases reaching the ground or surrounding buildings.

Primary abatement methods

For each boiler technology there are often several ways to reduce emissions to the exhaust. Approaches based on loading and efficiency typically require that the burner or boiler is mainly operated at the loading at which it is most efficient – depending on the technology this can vary between 50% and 90% of maximum load, or can require the system to operate continuously. You must therefore scale the boiler chosen so that the typical demand is met at the optimum efficiency level. For example, meeting 100kW heat demand using a gas boiler that is most efficient at 90% load means that the boiler should ideally have maximum output of 110kW. Meeting it using an Internal Combustion CHP system that's most efficient at 50% load requires a 200kW rated system.

In gas boilers and CHP systems, combustion temperature approaches aim to reduce NOx pollution by ensuring that the fuel is burned completely, or reducing the amount of nitrogen from the air that is burnt in the combustion process. Such approaches include: lean burn, water injection, exhaust gas recirculation or low-NOx boiler designs that reduce the flame temperature. Ultra low-NO_x designs exist that reduce NO_x emissions to below BS Class 5 levels (see above).

Biomass boiler abatement tends to focus on minimising PM emissions – these are much greater from biomass than from fossil fuel. This often focusses on the quality of the fuel used, ensuring it is stored so it stays dry, and controlling the supply of air to the burner. Design of the overall system and correctly matching heat supply to demand is important. Biomass burners are often most polluting during start-up so heating systems should be designed to ensure continuous operation wherever possible.

Secondary abatement methods

Again, the choices of secondary abatement depend entirely on the choice of fuel and burner technology to be applied. For biomass boilers abatement is mainly mechanical or electrostatic, using filtration or centrifugal methods to remove particles from the air. For CHP and gas burners a variety of exhaust treatments are available, confusingly known by the similar acronyms SNCR, SCR and NSCR. Selective Non-Catalytic Reduction (SNCR) requires very high temperature (1,100°C) injection of ammonia or urea into the burner – this chemically converts NO_x to nitrogen gas.

This approach is popular in the UK, not least as it is considerably less expensive than SCR and NSCR. Selective Catalytic Reduction (SCR) also requires ammonia or urea and operates at a much lower 400°C. However, the catalysts are often expensive and can as much as double the price of the boiler system. Non-Selective Catalytic Reduction (NSCR) uses a fuel and a catalyst to convert the NO_x into nitrogen gas. In all three cases, reductions of 75%-90% in the exhaust emissions of NO_x are typically achieved.

The US EPA provides comprehensive information on abatement technologies: www.epa.gov

EPUK Guidance is available from the IAQM iaqm.co.uk/guidance

B4.2 SELECT THE CORRECT HEAT SUPPLY FOR THE APPLICATION AND LOCATION

The heat and electricity supply is affected by three main factors - the type of heat and power demand on the site, whether there are local planning or terrain issues and whether there is a local air pollution problem. Broadly this allows several categories of application and site to be identified. These are shown below and discussed in the following sections.

Site & usage category	Best solution
Locations with air quality issues, restrictions or AQMAs (B4.3)	
Low but steady heat load demand	Heat pumps– air, ground or water sourced
High hot water or year round heating demand with large roof area available	Solar Hot Water
High efficiency gas boilers are suitable in all locations where gas is available, or where neither of the above is appropriate (B4.4)	
Part-load; low return flow temperatures	Condensing boilers
Small or ad-hoc hot water demand	Combination boilers
Large, variable heat demand	Modular boilers
Locations without local air quality issues	
Sites with high steady heat and electricity demand and few site or planning restrictions	CHP and tri-generation, district heating
No steady or significant heat load requirements and unrestricted sites	Biomass boilers

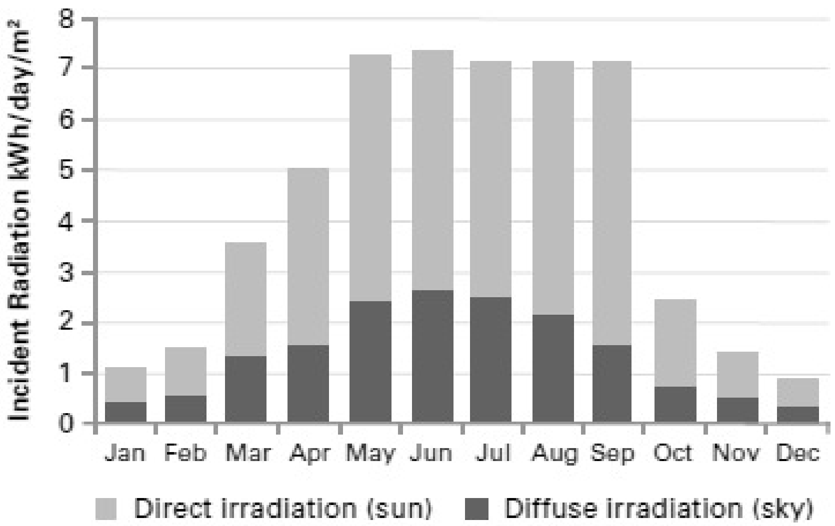
B4.3 HEAT PUMPS & SOLAR HOT WATER

Ground-source heat pumps (GSHPs) and **air-source heat pumps (ASHPs)** collect ambient heat and convert it into usable high-grade heat. GSHPs need a lot of underground pipework and are best in new build. ASHPs can be attached to the outside of existing buildings. Both require electricity or gas to drive their compressors. Their main disadvantage is that they can be inefficient if they are not specified with great care, installed properly and used only in well insulated buildings. When these criteria are met, they have significant advantages.

- They use about a third of the energy of an equivalent gas boiler to generate the same heat, although electricity to power them is more expensive than gas
- They produce no local pollution and need no flues or ventilation, unless gas-fuelled. If driven by renewable energy, they emit no CO_2
- They are versatile and can be used at different scales and applications. In some situations they can also be reversed to provide cooling
- The heat generated receives generous subsidies from the Feed-in Tariffs.
- They are very low maintenance and last 20-25 years.

As a very general guide, the installed cost of a typical system would be about £1,200 per kilowatt of heat capacity (kWth), excluding the costs of the heat distribution pipework.

Heat Pump Association's website contains further information: www.heatpumps.org.uk
The Carbon Trust also has some good guides on how to implement heat pumps: www.carbontrust.com



Average daily solar heating in the London Region (Carbon Trust)

Solar thermal or solar hot water (SHW) systems absorb energy from the sun to heat water. They work both in cloudy and clear conditions, contrary to conventional wisdom. They provide about 7 times more hot water in summer than winter (see above), so an auxiliary heat source may be needed to heat water during the winter months. Nonetheless they can still save 40%–60% of the energy required annually to provide hot water using conventional means.

A typical SHW system for a small office needs about 4m² of roof space, costs about £5,000, and yields around 2,000kWh/year. Maintenance costs for solar are generally very low and most systems come with a five-year or ten-year warranty. Some SHW systems are eligible for funding under the Enhanced Capital Allowance scheme or Renewable Heat Incentive tariffs

B4.4 GAS BOILERS

The key advantages of using boilers in an area with air quality problems are:

- They are available in Low-NO_x or Ultra-low NO_x versions at little or no cost
- Large capacity range available
- Good seasonal efficiencies (especially condensing type, ~92%)
- Flexible fuel choice
- Modular systems provide flexibility to match loads

Low & ultra low-NO_x boilers

There are many types of boilers available and low and ultra-low NO_x variants of most are available. In these primary NO_x abatement methods have been used to reduce NO_x exhaust emissions to Class 5 or better (see below). In many cases these variants are the same cost as higher NO_x emitting systems and can be more efficient too. Installation of low or ultra-low NO_x boilers should be the preferred option, as they reduce pollution for little or no cost.

BS EN 297:1994 Boiler NO_x emissions classifications

CSH/BREEAM ultra low-NO_x standard is also shown.

Boiler Class	Maximum NO_x Emissions, mg/kWh
1	260
2	200
3	150
4	100
5	70
CSH/BREEAM Ultra-Low NO_x	40

Gas Boiler variants and applications

The main types of boiler and their applications are.

- **Condensing boilers** extract waste heat from exhaust gases and are the most efficient on the market. Since April 2005 regulations require that they must be considered as the first choice for all new or replacement space heating installations. However they don't work efficiently at full load.
- **High-efficiency boilers** are the minimum required by current regulations. They use less water, a larger heat exchanger and greater insulation than older "standard boilers," and work with all types of heating system. These are most efficient at part load.
- **Combination (or 'combi') boilers** provide hot water instantaneously, so there is no need for a hot water storage cylinder and associated cold water feed tank and pipework.
- **Modular boilers** link several boilers together to meet very variable heating demands, while maintaining maximum efficiency, and can mix condensing and high-efficiency boilers.

Costs of condensing & low NO_x boilers

SPONS M&E (2011) provides the following average prices for heating systems

- Gas Fired conventional/standard:
    - o 80 – 100kW circa £4,000
    - o 280 – 330kW circa £10,000
- Low NO_x Condensing, floor standing:
    - o 100kW circa £4,300
    - o 300kW circa £11,200

B4.5 CHP, TRI-GENERATION AND DISTRICT HEATING

Combined heat and power systems (CHP, co-generation or tri-generation) generate electricty and usable heat from the same equipment, and sometimes cooling also. The aim is to improve overall efficiency for electricity generation by using the waste heat from the generation plant. CHP is most suitable for installations with high, steady demand for heat and electricity at the same time, more than 4500 hours per year. It is a poor choice where the main demand is for heat, as CHP systems are less efficient than modern gas boilers, and considerably more expensive. CHP is typically very polluting and should be avoided in air quality restricted areas, unless a specific low-emission form is use or additional abatement is fitted. Costs vary from £750 per kW of electricity for large scales schemes and to £11,000 per kW for small systems.

District Heating (DH) systems distribute heat and hot water from a central boiler or CHP plant to several buildings or dwellings. DH is often used to help balance demand from CHP systems. The boiler or CHP plant must be located close to recipient populations so local pollution emissions are of particular concern. Cost and disruption from installing pipework under roads are the major limiting factors of DH, though pipes can last for decades. Many DH schemes are financed through an **Energy Service Company (ESCo)** or an **Energy Performance Contract**. ESCos develop, install, and finance projects to improve the energy efficiency in facilities over a long time period.

Good Quality CHP does not refer to air pollution emissions

The DECC definition of Good Quality CHP does not reflect its air pollution impacts and in some cases can incentivise systems that emit high levels of NO_x and PM_{10} air pollution.

B5

USE APPROPRIATE HEATING CONTROLS

B5.1 INTRODUCTION

Good heating controls are essential to maximise energy efficiency, thus reducing air pollutant emissions. They are three main types which you should incude:

- Boiler controls - which control water temperature from the boiler
- Time controls - which control the times the boilers provide heat
- Temperature controls - which manages heat in rooms and zones

These will interact so careful design is required to ensure they behave as planned. Before deciding on the appropriate level of controls required it is important to take into account building function, likely occupancy and the overall size and complexity of the building. As a rule of thumb:

- For small individual buildings or those with a likely uniform pattern of occupancy, pre-set or self-adaptive controls with an override option for out-of-hours working should provide an appropriate level of comfort
- Bigger buildings with more varied requirements need more a Building Management System (BMS) with zoning

There are 3 golden rules for controlling your heating

1. Use plant ONLY when necessary

2. Do not heat & cool simultaneously – It is essential to ensure that controls do not interfere or conflict with each other

3. Provide flexibility

As a general rule, it is best not to complicate a system unnecessarily. However, the more complex systems give the greatest potential for energy savings, provided they are correctly applied and maintained.

B5.2 BOILER CONTROLS

At the most basic level, boiler controls simply turn the system on and off or provide a high or low setting, but more sophisticated controls respond to heat demand, weather and accidental ventilation and will greatly reduce th amount of fuel consumed and the comfort of occupants. The main types are:

- Burner controls, which control the fuel-to-air ratio to exactly match the heat demand at that time in the building
- Sequence controls, which choose which boilers to run if several are installed so the boilers always run at optimal load
- Interlocks, which swtich off boilers if there is no demand or doors or windows are left open
- Weather compensators, which reduce the flow temperature when external temperatures are higher

B5.3 TIME CONTROLS

Time controls ensure the system operates at the times when the building is occupied or hot water is required. These are available at various levels of sophistication from basic time clocks that set start and stop times to motion sensitive room thermostats. The main types are:

- Timer controls
- Optimisers, which check internal and external temperatures and switch the heating on only when needed
- Night and weekend setbacks, which reduce the heating at times when it's not needed, such as night-time and weekends
- Boosters and Delayed Off Controls, which increase heating out of hours or in specific rooms where usage is unpredictable
- Passive infra-red (PIR) switches or motion detectors, which provide heating only when a room is occupied.

B5.4 TEMPERATURE CONTROLS

Temperature controls ensure heating is comfortable without wasting energy and money and operate both on a room by room and a zonal basis:

- Wall or room thermostats and programmable room thermostat, which if correctly set ensure rooms are heated only to the desired temperature and when occupied
- Frost protection termostats, which switch the heating system on to prevent damage to pipework during cold spells
- Thermostatic radiator valves, which cheaply and simply help to manage room temperatures
- Zonal heating systems use separate thermostats, pipework, pumps and air handling units to heat different parts of buildings that will be occupied at different times.

B5.5 BUILDING MANAGEMENT SYSTEMS

BAT should include the installation of a Building Management System (BMS or BEMs). This monitors conditions throughout the building, and determine the operation of the plant such as boilers, pumps, fans and lighting in response to changing conditions like time, temperature and light levels. The system can be linked using a simple communication network, and a PC can be connected to this network to observe its performance and adjust settings. Many systems now make use of web-based platforms, allowing viewing anywhere, and user-friendly interfaces to make them intuitive to users The main advantage of a BMS installation is the ease with which users can review the performance of controls and conveniently make adjustments. Other advantages include:

- Close control of environmental conditions
- Logging and archiving of data for energy management purposes
- Rapid information on plant status
- Automatic generation of alarms to alert appropriate personnel
- Identification of maintenance requirements, both planned and reactive (e.g. systems can record the number of hours that motors have run, or identify filters on air supply systems which have become blocked).

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Reducing air pollution from your building Manual B -Minimising air pollution from new developments

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