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Combustion plant: Recommendations for best practice

Report for the City of London Corporation

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Summary for combustion plant operators

Operating combustion plant such as generators and boilers/Combined Heat and Power plant can give rise to air quality impacts. This short summary highlights some steps that can be taken to avoid these problems, and points to where more detailed information can be found.

Key points for planning and equipment selection
KP1. Alternatives to combustion-based technologies are available and should be considered at the early stages of project development.
KP2. A range of combustion technologies are available, of which diesel fired generators are among the most polluting. These should be avoided if possible.
KP3. Different regulatory regimes apply to plant with different capacities, fuels, combustion technologies, and proposed uses. This will affect the range of applicable controls, and enforceable emissions limits.
KP4. Plant is designed to achieve different emissions levels, and plant performance may degrade over time. It is important to select plant with appropriate emissions limits and assess potential impacts on a robust basis.
KP5. When selecting a contractor, its credentials, remote monitoring capabilities, helpline facilities, location of and ability to offer consistent engineers and charges, should be considered.

Key Points for maintenance, service and testing
KP6. Maintenance and monitoring should be planned.
KP7. If testing causes problems, neighbours should be contacted to warn of upcoming tests, and identify the least disruptive times for testing to be carried out.
KP8. Tests may need to be scheduled to avoid periods of adverse weather conditions and/or high pollution levels.
KP9. Proper maintenance is vital to ensure the system functions well and does not suffer frequent outages.
KP10. Appropriate training for all operating staff (direct employees or contractors) should be undertaken, regardless of how much or how little involvement with operation they may have.
KP11. Operators should be familiar with and follow the manufacturer's guidance for the individual components of the system, including the generator/boiler itself, the flue system, power/ heat metering, fuel handling equipment, safety procedures, and lubrication of key components.

Key Points for optimal management and operation
KP12. Standby and prime powered diesel generators are usually optimised to run at 50-80% of total load rating. Natural gas generator sets, regardless of application and rating, are almost always optimised to run between 70-100% of total load rating.
KP13. Although systems are available for directly measuring the concentrations of emissions from combustion processes, emissions from smaller scale generators or boilers/CHPs are normally monitored only indirectly via plant performance.
KP14. A remote monitoring and advisory service can help to achieve maximum performance and cost benefits.

Key Points for flue heights and older / higher emitting plant

KP15. LAQM screening tools[1] (e.g. the D1 guidance[2]) provide a valuable first step in specifying a minimum stack height, however it may not be possible to meet all requirements, which may be an indication that the combustion-based solution should be reconsidered.

KP16. There is potential for higher emissions of air pollutants from older plant than for modern plant which may be subject to a higher standard of emission controls – either through type-approval or environmental permits.

KP17. It may be possible to retrofit an older plant with emissions abatement technology (e.g. particulate trap / filter or a catalyst), where the chimney height is not adequate to disperse emissions, however this will depend on the engine type.

Key Points for the regulation of combustion plant

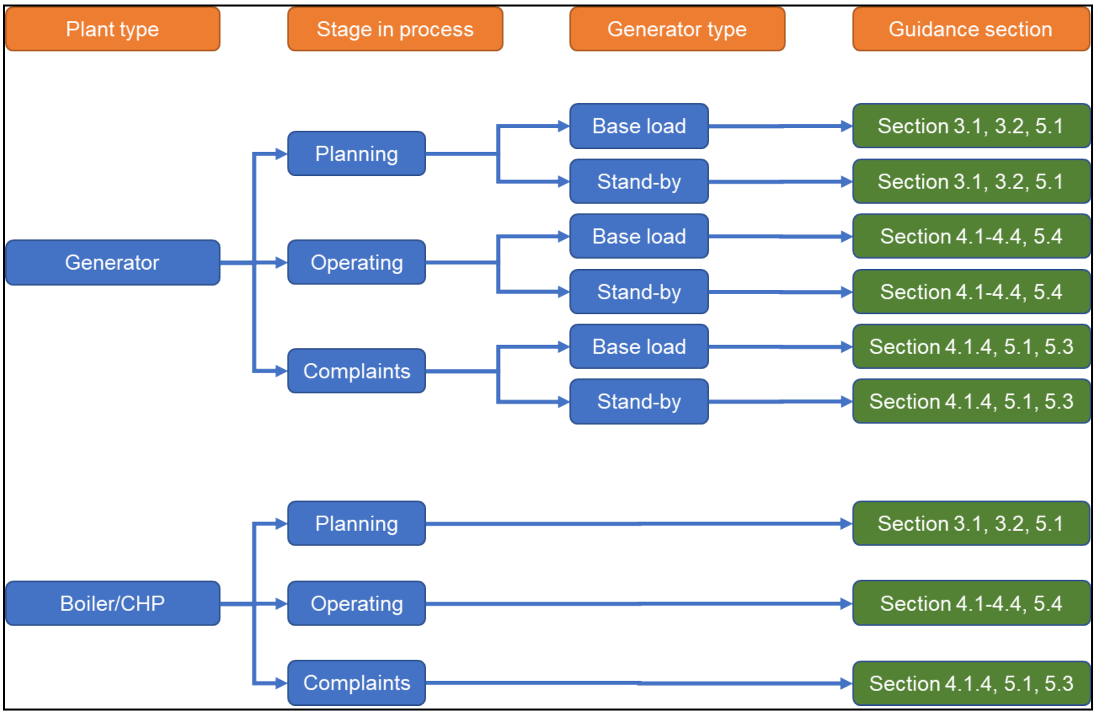
KP18. An air quality assessment should be carried out to confirm compliance of any proposed combustion plant with requirements on location, stack height, emissions and the absence of significant air quality impacts.

KP19. Voluntary measures to minimise impacts on air quality may be at zero cost or low cost to the operator, and in some cases, improvements may result in an economic benefit – for example, resulting from improved plant efficiency or availability.

KP20. Clean Air Act controls cannot be applied to combustion plant with an environmental permit (see below) but most permits include a provision regarding dark smoke; if dark smoke is an issue for such a plant then the appropriate regulator can be asked to intervene.

KP21. Prior to 2019, generator engines >560kW output were not subject to Non Road Mobile Machinery controls and consequently existing machines, if used as a stationary engine may be subject to the Medium Combustion Plant Directive, and hence require a permit.

Decision tree to identify relevant guidance



[1] https://laqm.defra.gov.uk/review-and-assessment/tools/modelling.html
[2] https://laqm.defra.gov.uk/laqm-faqs/faq89.html

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Abbreviations

Abbreviation	Definition	Abbreviation	Definition
BAT	Best Available Techniques	NOx	Oxides of nitrogen
CCHP	Combined cooling, heat and power	NRMM	Non-road mobile machinery
CHP	Combined heat and power	O&M	Operation and maintenance
EU	European Union	PM	Particulate matter
IED	Industrial Emissions Directive	PM_{10}	Particulate matter with a diameter less than 10 microns
IAQM	Institute for Air Quality Management	$PM_{2.5}$	Particulate matter with a diameter less than 2.5 microns
KP	Key point	SCR	Selective Catalytic Reduction
MCP	Medium combustion plant	SG	Specified Generator
MCPD	Medium Combustion Plant Directive	SWIP	Small Waste Incinerator Plant

1 Introduction

1.1 Background

The focus of this guidance is to provide advice on best practice for the operation of combustion plant for facilities managers responsible for standby generators, boilers and combined [cooling] heat and power plant (CCHP and CHP). The guide demonstrates how to minimise carbon emissions and impacts on local air quality.

Opportunities for control of emissions from combustion plant are available throughout the project lifetime – from the planning phase through consideration of maintenance and the details of how plant is operated. As well engineering and operational detail, this guide also provides suggestions for engaging with neighbouring building occupants to minimise impacts. Recommendations on best practice are detailed within this report and an outline given of the regulatory framework for air quality requirements.

1.2 Combustion plant and air quality

This section asks and answers some commonly encountered questions regarding combustion plant, and its effects on air quality.

Why are emissions to air from combustion plant significant?
The most significant source of anthropogenic air pollution is the combustion of fuels. In London, substantial attention and investment has been focused on reducing emissions from road traffic. Emissions of pollutants from standby generators and CHP can also impact local and regional air quality. In an urban setting, emissions can be particularly problematic if discharge points are relatively low. Emissions from standby generator plant can cause problems due to their intermittent nature. Emissions from CHP plant can cause problems due to their relatively low temperature which can lead to lower levels of dispersion. While emissions from CHP are typically lower than from conventional power generation, the benefit in terms of reduced emissions depend on the fuel and type of combustion plant, where it is located, and how it is operated.

Which pollutants are emitted?
The majority of CHP plants in London operate by burning natural gas, and consequently generate oxides of nitrogen (referred to as NOx, and made up mainly of nitrogen dioxide and nitric oxide) as well as smaller amounts of fine particulate matter (PM_{10} and $PM_{2.5}$). In the UK, diesel generators are most commonly used for emergency standby applications and have the highest emissions of PM and NOx of any type of generator.

Why are CHP plants now a focus for air quality?
Combustion-based CHP plant employed in London includes natural gas-fired engine CHP, biogas-fired engine CHP, and bio-diesel CHP. Evidence is growing on the emissions to the atmosphere from some types of CHP plant, and there are particular concerns about gas engine CHP plant because of its widespread use in London. Gas engine CHP is a significant air quality challenge, because of the prevalence of this technology, and the associated NOx emissions. A significant improvement to air quality in London was achieved historically by relocating electricity generation outside of the city. Most of the combustion-based power stations serving London are now located away from densely populated areas, and discharge emissions through a tall stack and at a high temperature. In contrast, although there is guidance on stack heights for combustion plant, emissions from combustion-based CHP plant in urban areas like London typically take place at a relatively low level (often below the height of nearby buildings), in close proximity to sensitive locations such as homes, schools and hospitals, and at low temperature (because heat is extracted from the flue gases to improve energy efficiency). These constraints present challenges for the effective control of emissions.

Why are standby generators now a cause for concern?

One of the challenges in controlling emissions from standby generators is that by their nature they are used or tested intermittently, resulting in small concentrated bursts of pollutant emissions which may result in smoke and/or noise which is more apparent to occupants of neighbouring buildings, and might result in complaints. Intermittent use can also result in maintenance and operational problems. A confounding factor is that generators are often located near residential areas or in close proximity to sensitive sites and where there can be poor dispersion and low wind speed. However, emissions and impacts can be limited through good practice.

Do emissions from CHPs/boilers and generators pose a risk to human health?

The most significant effects of air pollution on health are those associated with particulate matter (PM). The most important fractions are the finest particles, classified as PM_{10} or $PM_{2.5}$ according to their diameter. Exposure to PM_{10} is associated with a number of health impacts, including bronchitis, high blood pressure, heart attack, strokes and premature death. $PM_{2.5}$ (ultrafine particles) are the most dangerous as they can penetrate deep into the lungs, enter the bloodstream and even reach the brain. Exposure to NOx can also have direct and indirect effects on human health, causing problems such as headaches, breathing difficulties and reduced lung function. Based on our current understanding, these effects are controlled to minimal levels by compliance with air quality standards.

1.3 How to use this guidance

The guidance starts with a short summary providing guidance for operators of CHP plant, boilers and generators.

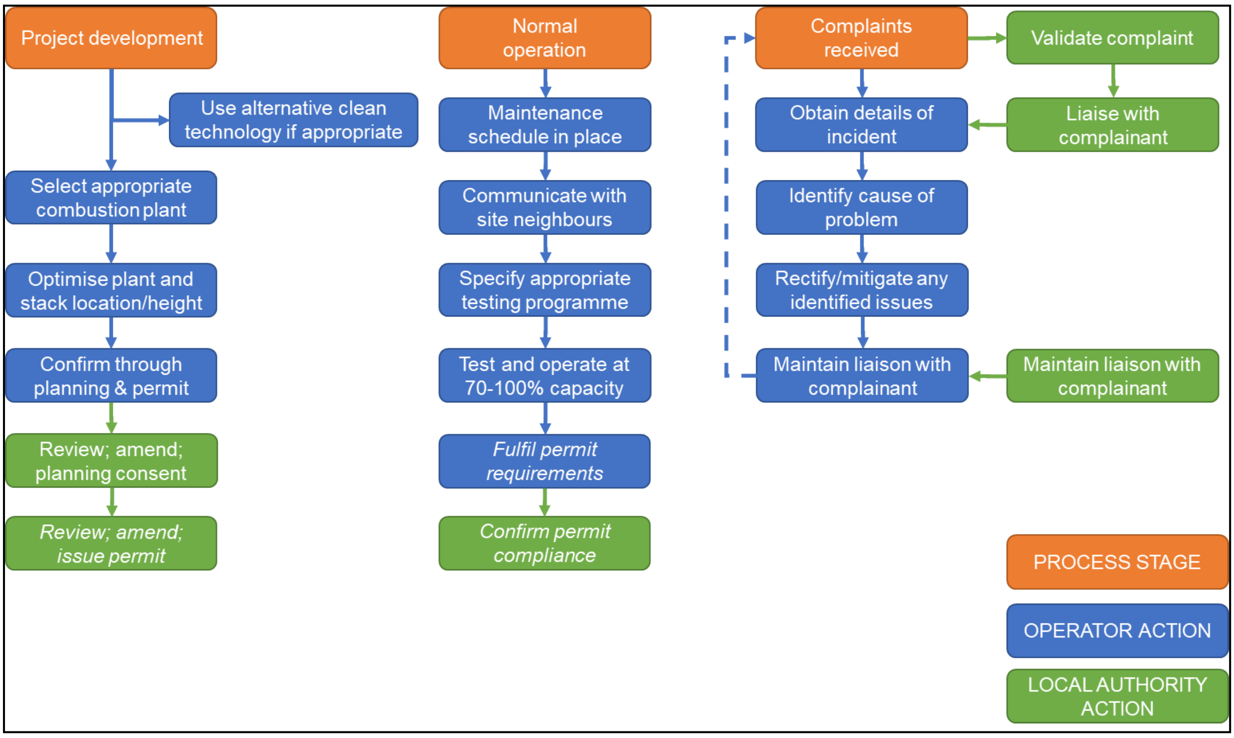
Supporting information is brought together in the following chapters which provides greater detail for users who will find this useful. These chapters include a series of Key Points, highlighting critical elements of the guidance. Decision Trees and flow charts are provided to point plant operators and local authority officers to appropriate actions, and the relevant sections of the guidance.

An online workshop was co-ordinated by City of London Corporation for facilities managers and Council officers to disseminate, share and discuss the best practice guidance in October 2020. The slides from the event are available to view by emailing cityair@cityoflondon.gov.uk.

2 Decision trees

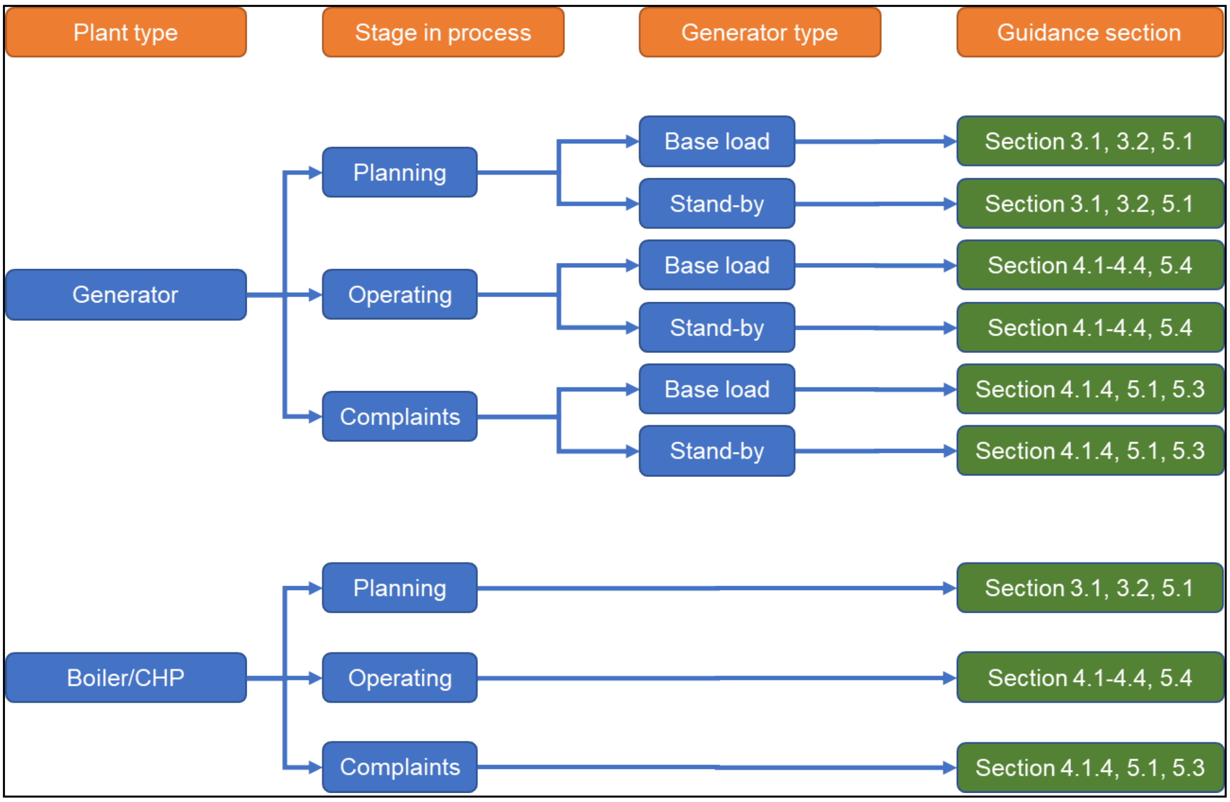
The decision tree below highlights an outline course of action for preventing and dealing with problems resulting from combustion plant.

Figure 2-1: Decision tree for action to prevent or mitigate air quality problems



The decision tree below highlights where relevant guidance can be found in this document.

Figure 2-2: Decision tree to identify relevant guidance



3 Planning and equipment selection

At the planning stage, developers and planning authorities should consider a full range of alternatives to combustion technologies for providing the heat and technology requirements of a new development.

3.1 Alternative technologies

Alternative technologies may include the following:

Solar panels and wind turbines • These are more likely to be deployed as part of a building-wide power solution • Capacity and availability unlikely to be sufficient for all building needs • Typically unsuitable for backup power supply, unless used in conjunction with a battery energy storage system	 
Biomass generation • Utilise fuel from sustainable plant sources, such as wood. • Not considered suitable for backup power supply, as regular use and maintenance is required to keep the feed mechanism working reliably. • No longer favoured in urban areas due to concerns about air pollution impacts	
Heat pumps (including ground, air and water source) • Relatively high installation cost • Cheaper to run than some alternatives (less clear when compared with gas boilers) • Low carbon solution as electricity requirements outweighed by carbon savings • Back-up provision may be needed • No fuel storage requirements • Can provide cooling as well as heating • Require expertise in design and installation	

District heating systems • Only relevant for larger scale developments • High installation cost • Can harness energy that would otherwise be wasted • Well designed scheme may be cheaper for consumers • Lack of flexibility: no alternative provider, and back-up provision may be needed • Require expertise in design and installation	
Battery storage • Costly, most commonly used for short duration back-up supply, or in critical applications • Zero emitting at the point of use • Examples exist of battery installations being used in combination with other technologies • May be challenges with space in city installations • Some fire risk, but this is manageable and proportionate with other technologies	
Hydrogen fuel cell • A developing technology, currently relatively small in comparison to diesel generators • A fuel cell system running on hydrogen is highly efficient relative to combustion engines and has much lower emissions but high flammability • More expensive than standard generators so uneconomical for back-up/emergency situations	

3.2 Combustion technologies

3.2.1 Combustion technologies

When considering combustion technologies, the following considerations should be taken into account.

- **CHP:** Some London authorities, do not support the use of CHP for provision of electricity over and above the needs of the development.
- **Fuel type** is very important in determining emissions. In general, natural gas fired plant has lower emissions than diesel fuelled plant. Natural gas should be used in preference to diesel where this is practicable.
- **Emissions standards** applicable to diesel generators are variable. In general, the highest available/practicable standard should be used

3.2.2 Emission standards

The EU Directive 2015/2193 on Medium Combustion Plant (MCPD)[3] sets minimum requirements for stationary combustion plant ≥1 MW thermal (and <50MW) including emission limit values for sulphur dioxide (SO_2), nitrogen oxides (NOx) and dust (PM). The MCPD has been transposed into UK law and an environmental permit has been required for new MCP from December 2018; existing MCP are subject to a phased implementation programme which will require permitting by 2029 (2024 for MCP >5MWth).

A Specified Generator is a combustion plant that generates electricity but excludes generators only used for standby/emergency use. The specified generator regulations apply to generators with a capacity up to 50MW thermal input burning any fuel. The regulations extend MCPD emission limits for NOx to generators with low annual operating hours.

Mobile generating equipment are subject to the EU Regulation 2016/1628 on non-road mobile machinery[4] (NRMM) or preceding Directives. The legislation sets requirements on engines used in NRMM, including emission standards, sold in the EU. Emission requirements are demonstrated by type testing and have been amended over time. For example, prior to 2019, generators >560kW output were not classed as NRMM and hence not subject to NRMM emission controls. In general emission controls increase with NRMM ‘stage’, for example Stage V sets lower emission limits than Stage III. Stage V NRMM NOx emission limits are more stringent than MCPD.

Although gas (spark ignition) engines can achieve MCPD and NRMM emission standards through primary measures (management of the combustion process), diesel generators require use of an exhaust additive fluid to achieve MCPD and NRMM Stage V emission standards. This is a non-hazardous urea-based solution that’s sprayed into the exhaust stream of diesel engines to reduce NOx emissions.

NRMM generators can be subject to Specified Generator controls but MCPD controls are not applicable. Prior to 2019, generator engines >560kW output were not subject to NRMM controls and consequently existing machines, if used as a stationary engine may be subject to MCPD, and hence require a permit.

3.3 Key points for planning and equipment selection

KEY POINTS
KP1. Alternatives to combustion-based technologies are available and should be considered at the early stages of project development.
KP2. A range of combustion technologies are available, of which diesel fired generators are among the most polluting. These should be avoided if possible.
KP3. Different regulatory regimes apply to plant with different capacities, fuels, combustion technologies, and proposed uses. This will affect the range of applicable controls, and enforceable emissions limits.
KP4. Plant is designed to achieve different emissions levels, and plant performance may degrade over time. It is important to select plant with appropriate emissions limits and assess potential impacts on a robust basis.
KP5. When selecting a contractor its credentials, remote monitoring capabilities, helpline facilities, location of and ability to offer consistent engineers and charges should be considered.

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L2193&from=EN
[4] Available here https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1628&from=EN

4 Best practice guidance for operators

This section outlines some best practice principles for the use of combustion plant, covering generators, boilers and CHP plant.[5]

4.1 Maintenance, servicing and testing

4.1.1 Why is it important?

Like any equipment, properly planned maintenance and monitoring of generation plant is vital in ensuring that:

- The safe operation of the system is maintained.
- The system continues to function as designed and commissioned.
- Outages (breakdowns) are minimised.
- The service lifetime of plant is maximised.

Maintenance usually covers two areas:

- Prime mover (e.g. engine) maintenance; and
- Site maintenance.

4.1.2 How often is maintenance required?

The complexity and frequency of maintenance varies for different plant items, and this influences the options for selecting the best source of maintenance and repair expertise. Reliable and efficient operation can only be achieved and optimised if the plant is correctly operated and maintained.

While responsibility for plant maintenance rests with the plant owner or operator, maintenance of embedded generation plant usually forms part of an out-sourced Operation and Maintenance (O&M) contract and often does not involve on-site staff. A contract with the equipment supplier or a specialist O&M company is an effective way of providing the necessary maintenance support that will ensure the long-term reliability and performance of the plant. It should cover all the maintenance needed to achieve a defined level of plant availability. This approach allows an operator to make better decisions on the total life-cycle costs and benefits of the project. The contract should also provide for some assurance regarding the quality and suitability of replacement parts and components.

For a packaged generator or boiler/CHP plant, relatively little routine maintenance is needed to allow the unit to operate continuously for long periods. Provided that utility supplies to the plant are kept at their required conditions, the unit should only require maintenance attention at planned service intervals. Regular brief visual checks by site staff are the only tasks required during operating periods, with remaining tasks carried out by the O&M contractor.

It is normal for plant to experience a slight degradation in output and efficiency between stoppages for scheduled servicing. This is almost entirely caused by the gradual wear of components. For example, with engine technology, spark plugs, in particular, require regular attention and replacement to maintain engine performance. Other items that need regular attention include air filters, valve clearances and turbocharger operation.

Consideration should always be given to the availability of a suitable long-term maintenance contract when procuring plant: the best time to negotiate a long-term maintenance contract is at the time of purchase. Contractors are often less willing to take on old and/or unfamiliar plant, and if such contracts are available, there is likely to be a significant cost premium. Various levels of maintenance

[5] This guidance document does not cover non-road mobile machinery (NRMM) used at construction and demolition sites. Guidance on NRMM in the construction industry in London is provided by the Cleaner Construction for London Initiative, with useful information in a practical guide (available at https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/nrmm)

agreement may be available, but the choice of service must be considered in conjunction with the degree of responsibility that comes with the contract. Typical options could include the following:

- Planned maintenance only, whereby the supplier carries out only a predefined list of maintenance tasks to a predetermined time schedule. This would include all labour costs and may include or exclude the cost of providing replacement parts and materials.
- The monitoring of plant parameters remotely to provide plant condition diagnosis.
- Specified response periods for call-outs to unplanned outages or breakdowns.
- Comprehensive maintenance cover, to include all parts and labour costs associated with both planned and unplanned maintenance requirements.
- Availability and installation of exchange or replacement unit to cover periods of prolonged outage associated with failure or servicing requirements.

The actual range of options available will vary across service agents and can be varied according to the levels of on-site staffing and expertise available.

4.1.3 Optimal load settings

Standby and prime powered diesel generators are usually optimised to run at 50-80% of total load rating. Natural gas generator sets, regardless of application and rating, are almost always optimised to run between 70-100% of total load rating.

Many diesel generators designed to meet recent emission standards are less tolerant to light loading than older models. This is largely due to the fact that the selective catalytic reduction (SCR) components, which were introduced to reduce NOx emissions, must operate within a very narrow temperature range. Operating at lighter loads typically results in emissions at lower temperature, resulting in poorer performance of SCR aftertreatment.

Table 4-1: Smoke signals – types of smoke associated with combustion plant and potential causes

Smoke Type	Description	Potential causes
Black	Black smoke is the most common smoke emitted from diesel engines. It occurs due to poor and incomplete combustion of the diesel fuel. Black smoke is high in carbon or soot, which is an undesirable product of combustion. When starting up a generator, dark smoke is very likely for a few seconds, however dark smoke for 1 minute or more indicates a problem.	• Incorrect air/fuel ratio • Poor quality fuel • Excessive carbon build-up in combustion and exhaust spaces • Cool operating temperatures
Blue	Blue smoke is an indication of engine oil being burnt. At cold start, blue smoke is often evident, and can reflect reduced oil control due to fouling deposits around piston rings or cylinders. Blue smoke should not be evident at any time, but it is worth noting, that engines with good compression can burn quite a lot of oil without evidence of blue smoke. Good compression allows oil to burn cleanly, as part of the fuel.	Oil can enter the combustion chamber for several reasons, including: • Worn valve seals • Incorrect grade of oil • Fuel dilution in the oil
White	Occurs when raw diesel comes through the exhaust completely intact and unburned.	• Faulty or damaged injectors • Incorrect injection timing or worn timing gear • Low cylinder compression (possibly caused by leaking or broken valves, piston ring sticking, cylinder and/or ring wear, or glazed cylinder bores) • Water in fuel or entering combustion spaces can also create white smoke or water vapour

4.1.4 Generator testing

Where emergency or backup systems are installed, there is a requirement to regularly test the units to ensure that they are fit for purpose when the need to operate arises. Testing of generators can cause particular problems, because generator plant is often unused for long periods. A testing event can give rise to relatively high emissions of air pollutants (including smoke and/or odours), as well as causing disturbance due to noise.

Duration and nature of testing

The period of regular testing will be determined by the system users requirements, combined with installation requirements and the manufacturer's instructions.

Load bank testing is usually part of a preventative generator maintenance plan. This test artificially boosts the load placed on a generator, usually to the generator's output capacity. This helps to clear any effects of wet stacking or other build-up, and to verify that a generator is actually capable of performing at its peak output rate. It is generally recommended that load bank testing be conducted at least once per year. Conversely, it is recommended that "no load" testing is avoided, as this can give rise to dark smoke emissions due to incomplete combustion. Where abatement is fitted (e.g. SCR), it is important to test at the correct load to ensure the technology is operating effectively.

Timing of generator tests

Often, generator testing is undertaken during out-of-hours periods to avoid unnecessary disruption to users. However, this typically does not consider the likelihood of causing nuisance to nearby receptors, or during times of poor dispersion or pollution episodes. When scheduling generator tests, operators should seek to avoid times which are likely to be particularly sensitive for the occupants of neighbouring buildings. Examples of times to be avoided where possible include the following:

Table 4-2: Generator testing timing constraints

Neighbouring premises	Timing constraints
Residential	Avoid early mornings/weekends
Residential	Testing during school hours may be preferable
Residential	Individual circumstances vary, so contacting neighbours is recommended
School	Avoid working hours during school term
School	Testing during school holidays would be best
Office	Avoid working hours
Office	Testing at weekends would be best
Leisure (e.g. parks, sports facilities)	Avoid evenings (after school hours)/weekends

Operators may wish to pro-actively contact site neighbours in order to seek their advice on the most sensitive time periods which should be avoided for the purpose of testing.

It is recommended that operators of generator plant should contact the owners of neighbouring premises to make them aware of upcoming testing events. This should ideally take place 1-2 weeks ahead of the testing taking place, to give neighbours the opportunity to take steps to avoid the nuisance if possible and appropriate. The notification should specify:

1. The location of the premises where the generator is located, and the exact location of the generator to be tested
2. Expected time of test (or a time window if a specific time cannot be identified)
3. Expected duration of test
4. What the test will consist of
5. Name and address of an individual to contact to discuss further

If testing has been found to cause problems linked to weather or wider air pollution conditions, it is recommended that tests should be scheduled to avoid these periods. This may include consideration of the following aspects:

- Avoid periods when baseline levels of air pollution are typically high – e.g. during peak traffic periods in the winter
- Aim to avoid periods when episodes of high air pollution levels are forecast – e.g. by consulting the Defra air quality forecast (https://uk-air.defra.gov.uk/forecasting/)
- Avoid periods when the wind is forecast to blow towards the most sensitive nearby properties

Generator testing is often carried out by an external contractor. Facility managers will need to liaise with the external contractor in order to identify the expected timing of generator tests. This should be achievable on an informal basis but may in some cases require an amendment to a testing contract, in order to ensure that the facility manager has sufficient notice of an engine test to enable neighbours to be notified.

4.1.5 Record-keeping

To ensure effective maintenance is carried out, a maintenance plan should be put in place. This will detail what maintenance tasks are to be carried out, the frequency of these tasks and who is responsible. This plan should also include details of age and efficiency of plant items, so that it is clear when upgrade to improve efficiency should be considered. A maintenance manual should be produced and updated regularly, that includes:

- The maintenance plan.
- Block diagram of the generation plant showing key components and controls.
- Schematic diagrams of the electrical/heating system and the controls.
- Operating instructions and control settings
- Emergency shutdown procedures.
- Contact details of installation/maintenance technicians and equipment manufacturers.
- Documents from construction for reference, such as the construction contract, operating and maintenance manual, installation photos, safety file, system design specification and as-built drawings, commissioning certificates, and meter calibration certificates.
- Copies of warranties.
- A schedule of the warranties so it is clear when they expire.

Particular attention should be paid to specific instructions from manufacturers as these will ensure the optimum performance of the plant. Also, failure to follow them may invalidate warranties.

A maintenance logbook should be kept giving detailed records of maintenance tasks, including which actions were taken, the person responsible, and when they were completed. This logbook will ensure that tasks are carried out at the correct frequency and will highlight on-going problems.

An issue and resolution log should be kept that covers ongoing and historical issues and related actions and resolutions. The log should include information on complaints made directly to the organisation or via the local authority. This makes it easier to rectify repeat issues and keep on top of current ones.

Where any financial support schemes are part of an installation then the related record-keeping requirements should be verified and adhered to.

Operating hours should be verified and monitored as some warranties are based on whichever occurs first – a given time period or a number of operating hours. Schedule a service before the end of the warranty to ensure any repairs and replacements can be identified and rectified under the warranty. Replacement parts may have their own warranties and a record of these should be kept in case the part requires a second replacement within that warranty period.

4.1.6 Key Points for maintenance, service and testing

KEY POINTS
KP6. Maintenance and monitoring should be planned
KP7. If testing causes problems, neighbours should be contacted to warn of upcoming tests, and identify the least disruptive times for testing to be carried out
KP8. Tests may need to be scheduled to avoid periods of adverse weather conditions and/or high pollution levels
KP9. Proper maintenance is vital to ensure the system functions well and does not suffer frequent outages
KP10. Appropriate training for all operating staff (direct employees or contractors) should be undertaken, regardless of how much or how little involvement with operation they may have.

KP11. Operators should be familiar with and follow the manufacturer's guidance for the individual components of the system, including the generator/boiler itself, the flue system, power/heat metering, fuel handling equipment, safety procedures, and lubrication of key components.

4.2 Optimal management / operation

4.2.1 Optimal load settings

Running a generator under non-optimal conditions is not like running a car which is overdue for an oil change. With a car engine, it is possible to continue beyond the recommended distance before getting the engine oil changed, but running a generator without keeping up with maintenance or while "light loaded" will inevitably shorten the lifespan of the generator.

One of the most prevalent problems with diesel engines running below their designed load capacity for extended periods of time is the phenomenon known as "wet stacking." Wet stacking occurs when unburned fuel is exhausted due to low operating temperatures. When unburned fuel is exhausted from the combustion chamber, it starts to build up in the exhaust side of the engine, resulting in fouled injectors and a build-up of carbon on the exhaust valves, turbo charger and exhaust.

Extended run times and excessive idling at low loads causes a range of problems, such as poor combustion, wet stacking, the formation of deposits on cylinders/turbocharger components and internal glazing. Because of these effects, long term low load operation below 45% of nameplate rating can reduce engine service life. Notably, newer engines increasingly rely on increased turbocharger output to optimise the balance between performance and emissions. This increase in turbocharger output has the effect of narrowing the operating range which should be used to avoid wet stacking.

Standby and prime powered diesel generators are usually optimised to run at 50-80% of total load rating. Natural gas generator sets, regardless of application and rating, are almost always optimised to run between 70-100% of total load rating.

Many diesel generators designed to meet recent emission standards are less tolerant to light loading than older models. This is largely due to the fact that the selective catalytic reduction (SCR) components, which were introduced to reduce NOx emissions, must operate within a very narrow temperature range. Operating at lighter loads typically results in emissions at lower temperature, resulting in poorer performance of SCR aftertreatment.

It is essential to monitor the performance of an operating plant to ensure it remains within the desired operating mode, and so deliver acceptable performance from an emissions point of view.

4.2.2 Operational monitoring and control

To enable generating plant to operate safely and effectively without supervisory staff, most units are fitted with a monitoring system that checks a range of operating parameters at regular intervals (usually every few minutes). The data collected can be either stored for later review or passed on immediately.

The main purposes of a monitoring system are:

- Plant condition monitoring – to check the reliability and performance of the generating plant, and to assist in planning maintenance.
- Plant performance monitoring – to check the inputs and outputs and to monitor the unit's energy efficiency.

Although systems are available for directly measuring the concentrations of emissions from combustion processes, emissions from smaller scale generators or boilers/CHPs are normally monitored only indirectly via plant performance.

An advisory system is an effective management tool which provides a rapid review of the energy and flow data collected, and advises on the optimum operating mode of the unit. The advisory system needs to contain data relating to the costs and values of the energy inputs and outputs, such as the cost of fuel, the avoided cost of purchased electricity, and the avoided costs of providing heat to the site. Such systems typically also take account of information relating to the overall maintenance costs of a generating plant, usually expressed as a cost per operating hour or per unit of electrical output. By using this information in conjunction with up-to-date data on the unit's performance and the site's energy demands, an advisory system can make recommendations on the most cost-effective mode of operation.

Under normal circumstances, there is no requirement for active control by site staff, and the unit will continue to operate without constant attention. In the event of conditions changing beyond defined limits, the control system will usually trigger an alarm to attract attention. If the event is potentially harmful to the equipment, the unit will shut down automatically.

Where the plant is a CHP package, control is largely automated and requires little regular input from site staff. Provided the systems connected to the unit continue to function correctly, the unit should be capable of continuous operation using its own control system.

The capabilities of individual plant control systems to be integrated within overall plant monitoring schemes should be a key factor in plant and system selection.

4.2.3 Supplier support

Often, an equipment supplier will offer a remote monitoring and advisory service. This is usually based on the use of a telephone line to transmit data between the site and the supplier's monitoring and control centre. This approach ensures that the condition of the plant is effectively monitored and that it is controlled to achieve maximum performance and cost benefits. The system can also be configured to avoid a pattern of frequent stops and starts that may be harmful to the equipment.

4.2.4 Key Points for optimal management and operation

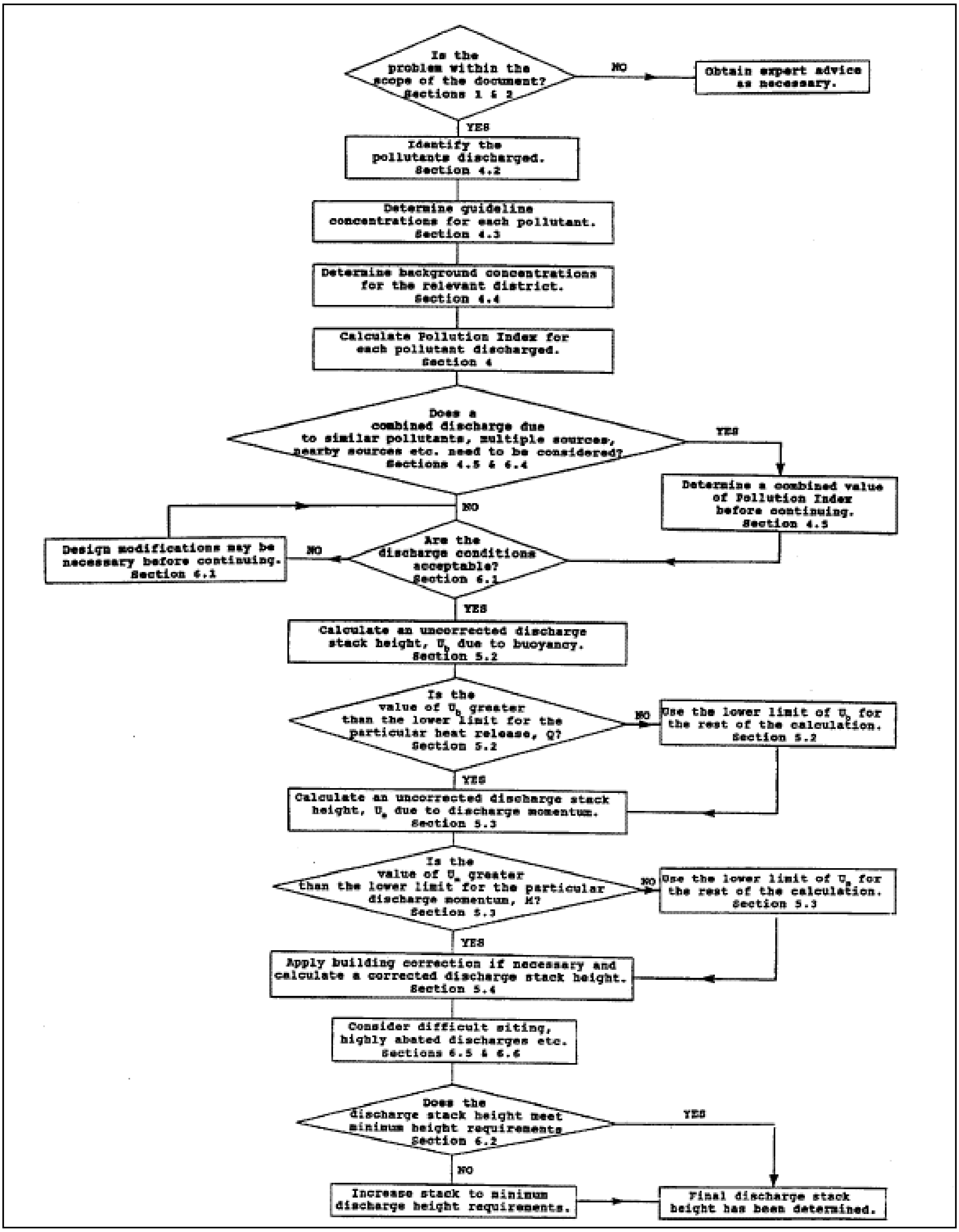
KEY POINTS
KP12. Standby and prime powered diesel generators are usually optimised to run at 50-80% of total load rating. Natural gas generator sets, regardless of application and rating, are almost always optimised to run between 70-100% of total load rating.
KP13. Although systems are available for directly measuring the concentrations of emissions from combustion processes, emissions from smaller scale generators or boilers/CHPs are normally monitored only indirectly via plant performance.
KP14. A remote monitoring and advisory service can help to achieve maximum performance and cost benefits.

4.3 Flue height

Identifying the optimum location for a generator or CHP flue is frequently difficult in an urban setting. A combustion plant may be surrounded by relatively high buildings, which makes it harder to identify a suitable release point.

Useful guidance to assist in specifying a suitable discharge height can be found in the D1 guidance produced by Her Majesty's Inspectorate of Pollution (a forerunner to the Environment Agency). This provides similar guidance to that set out in the Chimney Height Memorandum, produced to fulfil requirements of the Clean Air Act, but is more relevant and flexible for application to boiler/CHP and generator plant. [NB. D1 is no longer in print and the Environment Agency now uses other approaches to assess stack heights for Part A activities however, D1 is still referenced in statutory guidance for many Part B activities and provides a simple tool to assess stack heights and covers a wider range of technologies than the Chimney Heights Memorandum. Further guidance on identifying appropriate stack heights is available via the LAQM website[1]].

Figure 4-1: D1 guidance: procedure for determining discharge stack height



This guidance enables a minimum stack height to be calculated, based on the details of the combustion plant, expected emission rate, background levels of the key air pollutants, and the applicable air quality standards. As it is now approaching 30 years old, the information on background levels and air quality standards needs to be updated when applying this guidance. This information should be available from the relevant local authority.

Table 4-3: Information required for D1 stack height calculation

Item	Note
Discharge rate of each pollutant	Units of grams per second. Can be calculated from emission measurements, manufacturer data or published emission factor compilations
Guideline concentration of each pollutant	NA
Background concentration of each pollutant	Units of milligrams per cubic metre. Obtain from local authority monitoring records or Defra interpolated datasets Defra background mapping data. Default data in D1 guidance is now out of date
Heat release from the stack	Units of megawatts. Can be calculated from fuel throughput and discharge temperature
Discharge velocity	Units of metres per second*
Discharge volumetric flow	Units of cubic metres per second*
Stack diameter	Units of metres*
Building dimensions	Units of metres. The height and width of nearby buildings is required.

*Note any two of these three items are required

The D1 guidance document enables a minimum required stack height to be identified. It also sets overriding minimum requirements, that a discharge stack should be no lower than the height of surrounding buildings, and no lower than 3 m higher than ground level, openable windows or any area where there is general access. The guidance also confirms that discharge stacks should be vertical, and not be impeded by cowls or covers.

Specifying a minimum stack height on the basis of the D1 guidance note is a valuable first step. In some cases, it may not be possible to meet all these requirements, but there is likely to be flexibility in building design for new developments. If these requirements cannot all be met for a new development, this may be an indication that the combustion-based solution as proposed should be reconsidered. For an existing installation, if these requirements cannot all be met, it may still be possible to make some improvements – for example, by raising the discharge point above the height of the closest sensitive receptors, by upgrading a horizontal discharge to a vertical discharge, and/or removing a cap or cowl from a discharge point.

Figure 4-2: Example generator plant with horizontal discharge

4.4 Older / high-emitting plant

In general, efficiency and emission performance of combustion plant has improved over time – a boiler or engine put on the market in 1990 is likely to have lower efficiency and higher emissions than an equivalent appliance placed on the market in 2020. Older combustion plant will often predate any legislative emission control apart from the limited smoke aspects of the Clean Air Act (see section 5.3). Consequently, there is potential for higher emissions of air pollutants from older plant than for modern plant which may be subject to a higher standard of emission controls – either through type-approval or environmental permits.

Older combustion plant is likely to be less efficient technology and may have less sophisticated control systems than on a new boiler or engine which means greater fuel use and hence higher emissions than for a newer combustion plant.

One area to consider is whether the envisaged use of a combustion plant may have changed since installation – is the appliance being used more frequently or for longer periods than originally expected. This may require reconsideration of whether emission dispersal is adequate for a higher level of activity.

In the event that a chimney height increase may not be possible, then a particulate trap/filter may be used to reduce emissions of PM_{10} from standby generators however these may not be readily available for a particular engine type. As standby generators are used infrequently, non-regenerative particle traps are likely to be the most suitable. Particle traps will generally be required for very large generators and if the proposed chimney height is not adequate to disperse emissions.

Selective catalytic reduction can be used to reduce NOx emissions from diesel generators. This involves injecting urea into the exhaust stream. Selective catalytic reduction may be required for very large standby generators, and/or in situations where the chimney height is not adequate to disperse emissions.

4.5 Key Points for flue heights and older / higher emitting plant

KEY POINTS
KP15. LAQM screening tools[1] (e.g. the D1 guidance[2]) provide a valuable first step in specifying a minimum stack height, however it may not be possible to meet all requirements, which may be an indication that the combustion-based solution should be reconsidered.

KP16. There is potential for higher emissions of air pollutants from older plant than for modern plant which may be subject to a higher standard of emission controls – either through type-approval or environmental permits.

KP17. It may be possible to retrofit an older plant with emissions abatement technology (e.g. particulate trap / filter or a catalyst), where the chimney height is not adequate to disperse emissions, however this will depend on the engine type.

5 Regulation of combustion plant

5.1 Development controls

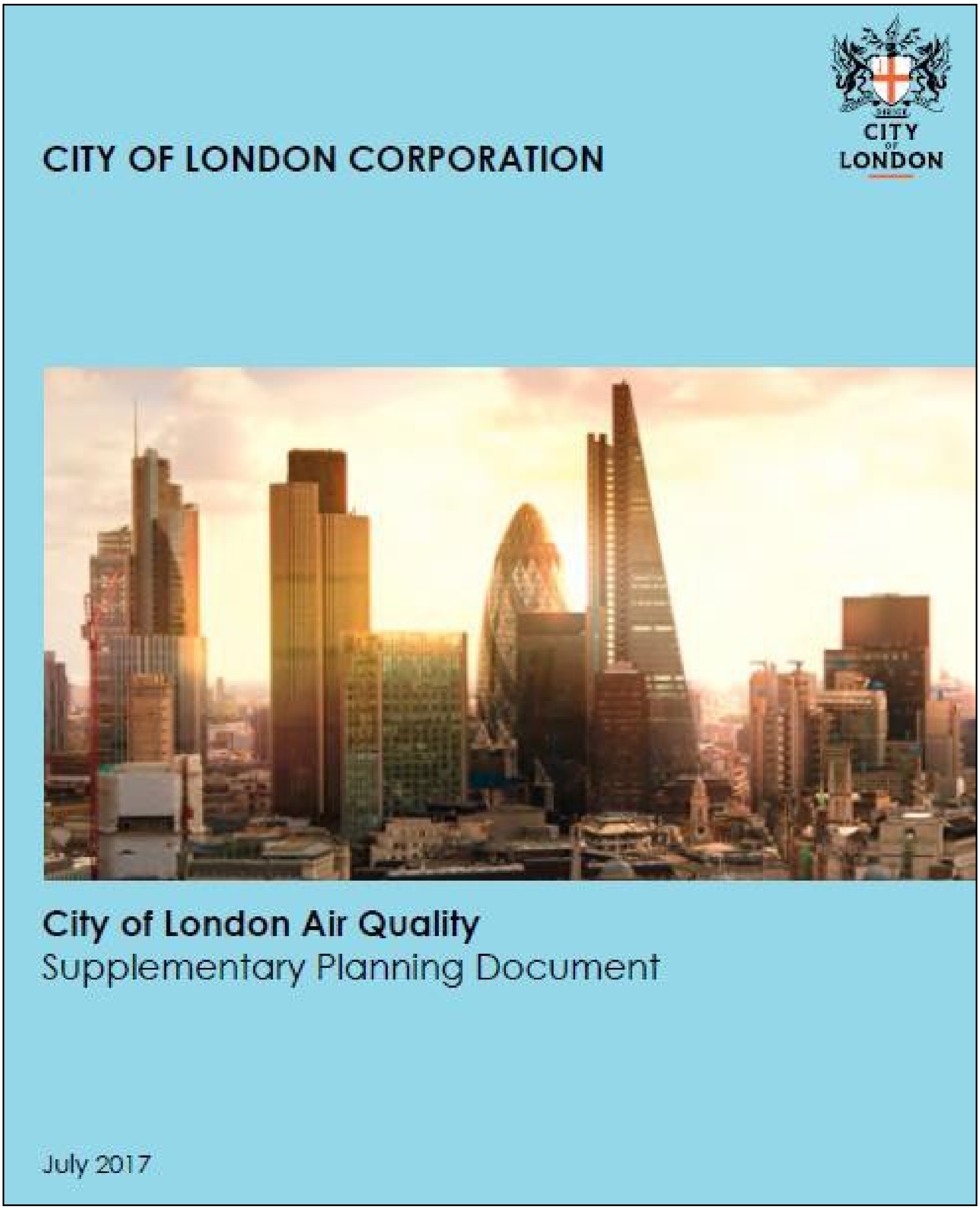
The National Planning Policy Framework sets out planning policies and a framework for managing development for England. This includes consideration of air quality including requirements on authorities that planning policies and decisions '*sustain and contribute towards compliance with relevant limit values or national objectives for pollutants, taking into account the presence of Air Quality Management Areas and Clean Air Zones, and the cumulative impacts from individual sites in local areas*'. This framework provides a clear basis for planning authorities to ensure that combustion plant associated with new development does not compromise the achievement of air quality standards. The case for ensuring effective control of air quality impacts is strengthened in an Air Quality Management Area.

The pre-application / planning consent stage is the appropriate time for consideration of the selection of appropriate technology for provision of heat and/or power, both in terms of baseload and back-up plant. If it seems likely that combustion-based technologies would give rise to adverse air quality impacts, either alone or in combination with other developments, this could form a reason to require alternative technologies to be used for provision of heat and power.

The City of London Corporation's Supplementary Planning Document entitled "*City of London Air Quality*" (July 2017) specifies that stand-by combustion plant in new developments cannot be used to fulfil external contracts relating to electricity generation (e.g. Short Term Operating Reserve (STOR) contracts, or Triad Avoidance contracts). The City's AQ SPD is regularly reviewed/updated in line with the City's Planning policy.

A policy document with political approval such as the City of London Corporation document provides a robust basis for an authority to prevent excessive use of combustion plant in unsuitable areas, and to require consideration of alternative technologies where this is justified. Alternative technologies for part or all of the base load and backup heat and power requirements of new developments are likely to be available and should be considered if there is a risk of adverse impacts on air quality from new development, either alone or in combination with other impacts.

Figure 5-1: “City of London Air Quality” document



Local authority development plans now have policies which require the air quality impacts of new developments to be assessed and, if required, mitigation of impacts should be provided. It is well established practice, confirmed in guidance such as that produced by the Institute for Air Quality Management (IAQM),[6] that such assessments should take account of the air quality impacts of combustion plant. These policies may be reinforced by the declaration of Air Quality Management Areas where relevant, and by the approval of more detailed local policy such as the City of London Corporation’s Supplementary Planning Document entitled “City of London Air Quality Supplementary Planning Document,” (July 2017). The outcome of such evaluations should demonstrate that:

[6] IAQM and EPUK, “*Land-Use Planning & Development Control: Planning For Air Quality*,” v1.2, 2017, available at http://www.iaqm.co.uk/text/guidance/air-quality-planning-guidance.pdf

- The proposed location of combustion plant is suitable;
- Emissions can be adequately controlled (by reference to applicable regulatory regimes if relevant);
- Discharge stack height is appropriate;
- No significant air quality impacts will be caused; and
- Nuisance will be avoided.

5.2 Voluntary measures

The first stage when dealing with problems resulting from combustion plant should be to discuss and agree voluntary measures to be taken by the operator. In many cases, voluntary measures may be at zero cost or low cost to the operator, and in some cases, improvements may result in an economic benefit – for example, resulting from improved plant efficiency or availability. Voluntary measures are likely to be focused on the topics discussed in the previous sections:

1. Changes to plant operation and management – in particular, enhanced maintenance and repair
2. Engagement with occupants of neighbouring buildings to identify appropriate testing regimes and give notice when testing will take place
3. Improvements to discharge stack locations and design
4. Facility upgrades to comply with current best practice

However, informal discussions do not always result in improvements in plant emissions performance. In this case, it may be necessary to identify duties and options under the relevant regulatory provisions.

5.3 Clean Air Act 1993 and Environmental Protection Act 1990

Local Authorities are the regulatory authority for the Clean Air Act[7] and nuisance provisions of the Environmental Protection Act[8].

The Clean Air Act 1993 was originally introduced to address issues arising from widespread use of coal in industry, commercial and residential heating. Controls mainly apply to solid fuel use but key provisions relevant to combustion plant are in three areas :

- Dark smoke controls
- Chimney height approval
- Smoke control areas

It is an offence to emit dark smoke from a chimney or industrial premises. Chimney height approval is required for appliances above a defined burning threshold (366.4kW for liquid or gaseous fuels) to assure chimney height is sufficient to prevent emissions "from becoming prejudicial to health or a nuisance".

Smoke control areas can be designated by local authorities and within these areas it is an offence to emit smoke unless arising from use of an Authorised fuel or Exempt appliance. In practice, most modern combustion plant are gas-fired and gas is an Authorised fuel. Similarly, an appliance designed to burn a liquid fuel is Exempt.

The Environmental Protection Act 1990 includes statutory nuisance controls for smoke, noise and odour which may be applicable. However, if in a Smoke Control Area some statutory nuisance controls relating to smoke cannot be applied.

Clean Air Act controls cannot be applied to combustion plant with an environmental permit (see below) but most permits include a provision regarding dark smoke; if dark smoke is an issue for such a plant then the appropriate regulator can be asked to intervene.

[7] Available here https://www.legislation.gov.uk/ukpga/1993/11/contents
[8] Available here https://www.legislation.gov.uk/ukpga/1990/43/contents

5.4 Pollution Prevention and Control Act

5.4.1 Industrial emissions directive

Directive 2010/75/EU on industrial emissions (IED) requires a permit and application of Best Available Techniques (BAT) for combustion plant ≥50MW thermal input. These installations are regulated through the Environmental Permitting Regulations in England and Wales (other legislation is applicable in Scotland and Northern Ireland). The Regulatory Authority is the Environment Agency in England.

The IED also contains requirements relating to incineration and Small Waste Incineration Plant (SWIPs). These are not the focus of the present document.

5.4.2 UK 'Part B' Combustion plant controls

Controls exist through the Environmental Permitting Regulations in England and Wales (other legislation is applicable in Scotland and Northern Ireland) for these 'Part B' combustion activities:

- Combustion plant >20MW but <50MW thermal input (boilers, gas turbines and diesel engines each unit >20MWth)
- Small Waste Incineration Plant burning clean waste wood >50kg/hr

The regulatory authority in England is the Local Authority.

5.4.3 Medium Combustion Plant directive and Specified Generators

The EU Directive 2015/2193 on Medium Combustion Plant (MCPD)[9] sets minimum requirements for stationary combustion plant ≥1 MW thermal (and <50MW) including emission limit values for sulphur dioxide (SO_2), nitrogen oxides (NOx) and dust (PM). The MCPD has been transposed into UK law and an environmental permit has been required for new MCP from December 2018; existing MCP are subject to a phased implementation programme which will require permitting by 2029 (2024 for MCP >5MWth).

A Specified Generator is a combustion plant that generates electricity but excludes generators only used for standby/emergency use. The specified generator regulations apply to generators with a capacity up to 50MW thermal input burning any fuel. The regulations extend MCPD emission limits for NOx to generators with low annual operating hours.

Mobile equipment subject to the EU Directive on non-road mobile machinery (NRMM) can be subject to Specified Generator controls but not MCPD. Prior to 2019, generator engines >560kW output were not subject to NRMM controls and consequently existing machines, if used as a stationary engine may be subject to MCPD, and hence require a permit.

The Regulatory Authority is the Environment Agency in England. However, many existing MCP and Specified Generators will not be subject to Environment Agency regulation until 2029.

5.5 Ecodesign regulations

A number of EU regulations are in place which cover residential and small combustion plant. These are derived from the EU Directive 2009/125/EC establishing a framework for the setting of Ecodesign requirements for energy-related products. The Ecodesign directive provides a framework for setting minimum requirements for the energy efficiency of specified products including, for combustion devices, emission limits. The product performance is demonstrated through use of harmonised product testing EN Standards and declaration/type approval when products are placed on the market. The requirements are set in EU regulations and do not apply to existing products, but all **new** products must meet requirements after date(s) set in the regulation.

In general, performance to harmonised Standards should be recorded on equipment data plates attached to the equipment but can be provided through the manufacturers' product fiches.

[9] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L2193&from=EN

A summary of Ecodesign regulations for combustion plant is provided in Table .

Table 5-1: Ecodesign Regulations and product groups

Product group	Regulation	Date	Fuel	Emission controls
Local space heater ≤120kW output	2015/1188	1/1/2018	Gaseous, liquid	NOx
Solid fuel boilers ≤500kW output	2015/1189	1/1/2020	Wood, solid mineral fuel	PM, VOC, CO, NOx
Space and combination heaters ≤400kW heat output, including cogeneration ≤50kW electricity output	813/2013	26/9/2018	Gaseous, liquid	NOx
Water heaters ≤400kW output including products with engines	814/2013	26/9/2018	Gaseous, liquid	NOx
Air heating products ≤1MW output, air conditioners including products with engines	2016/2281	26/9/18	Gaseous, liquid	NOx

5.6 Other controls

Other potential controls on combustion plant may be through greener procurement schemes and incentivisation schemes. For example, the Renewable Heat Incentive scheme sets emission limits for PM and NOx emissions for biomass boilers however these are non-mandatory and generally demonstrated through type approval using EN Standards.

European Standards for products including smaller boilers and water heaters include NOx and other pollutant testing requirements and, in some cases, emission limits or classes. However, in general these have now been superseded by the Ecodesign Regulations.

5.7 Key Points for the regulation of combustion plant

KEY POINTS
KP18. An air quality assessment should be carried out to confirm compliance of any proposed combustion plant with requirements on location, stack height, emissions and the absence of significant air quality impacts
KP19. Voluntary measures to minimise impacts on air quality may be at zero cost or low cost to the operator, and in some cases, improvements may result in an economic benefit – for example, resulting from improved plant efficiency or availability.
KP20. Clean Air Act controls cannot be applied to combustion plant with an environmental permit (see below) but most permits include a provision regarding dark smoke; if dark smoke is an issue for such a plant then the appropriate regulator can be asked to intervene.
KP21. Prior to 2019, generator engines >560kW output were not subject to NRMM controls and consequently existing machines, if used as a stationary engine may be subject to MCPD, and hence require a permit.

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