



Department
of Energy &
Climate Change



CHP – Environmental

A detailed guide for CHP developers – Part 3

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1. Introduction

For any given CHP plant and operating pattern, annual energy consumption/production can be used as the basis for calculating reductions in primary energy consumption and emissions that arise from the installation and operation of the CHP unit.

The main environmental issues, including current legislation, relevant atmospheric emissions data, and the environmental aspects of CHP installation and meeting environmental requirements are discussed in the linked sections.

2. Atmospheric Emissions

Combined heat and power is a highly efficient energy process that produces significantly fewer combustion products per unit of energy output than traditional discrete heat and power generation systems. This, in turn, has a beneficial effect on air pollution and its consequences. Although installing a CHP system usually increases the fuel consumption on-site, the use of cleaner combustion plant often results in a reduction in some of the pollutants produced. By generating electricity on-site, CHP also displaces the larger amounts of fuel otherwise used at central power generating stations, significantly reducing their emissions of pollutants. Included are sections dealing in depth with fossil fuels combustion, conventional energy supply emissions, CHP emissions, CHP emissions reductions, operations & maintenance requirements.

Fossil Fuels Combustion

Fossil fuel combustion is a reaction between oxygen and the constituents of the fuel. The combustion process gives off heat, which is usually the required and beneficial product of the process. However, fossil fuel combustion emits pollutant gases into the atmosphere, and these have damaging effects on the environment.

All fossil fuels contain carbon which is the main combustible constituent. Hydrogen is the other significant energy source. The combustion of carbon and hydrogen produces large amounts of carbon dioxide and water vapour in the exhaust products. Combustion processes also produce other gaseous pollutants such as sulphur dioxide, carbon monoxide, nitrogen oxides and particulates depending on the composition of the fuel and the type of combustion process.

Carbon Dioxide

Carbon dioxide is the gas produced in the greatest quantity by combustion processes. The aim of any combustion process is to convert all the available carbon to carbon dioxide to release the maximum available energy. Burning a carbon-bearing fuel produces carbon dioxide by combining atmospheric oxygen (O₂) with the carbon in the fuel.

Carbon dioxide is an inert gas that is present in the atmosphere as part of the earth's natural carbon cycle. However, increasing carbon dioxide levels enhances the 'greenhouse effect' and increases the risk of long-term climate change. There are now global agreements in place to reduce carbon dioxide emissions. The amount of carbon dioxide produced depends on the carbon content of the fuel concerned and the rate at which that fuel is used. Only by burning

less carbon can carbon dioxide output be reduced. Any technique that improves the efficiency with which fuel is used reduces the level of emissions per unit of heat or power output.

The following table gives approximate carbon dioxide emissions from the combustion of major fossil fuels. In some documents, carbon dioxide emissions are expressed in terms of the carbon content of the gas. This can be calculated by applying the ratio of the weights of the elements.

Fuel	Typical % carbon in fuel	Tonnes of carbon dioxide produced per tonne of fuel	CO ₂ content (kg) per MWh thermal input
Industrial Coal	58%	2.1	285
Fuel oil	88%	3.2	267
Gas-oil	87%	3.2	254
Natural gas	74%	2.7	185

Data based on the document: [2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting](#)

To calculate the quantity of carbon in CO₂ gas, multiply the weight of CO₂ by 12/44, or 0.273.

Example: 50 tonnes of CO₂ contain 50 x 12/44 = 13.64 tonnes of carbon.

Sulphur Dioxide

One kilogram of sulphur in a fuel results in two kilograms of sulphur dioxide in the exhaust. Sulphur dioxide is produced by the combustion of sulphur in the fuel. Further complex chemical reactions in the atmosphere can result in the production of acidic compounds such as sulphuric acid (H₂SO₄). These compounds are a major cause of 'acid rain' which can have damaging effects on the ecology of the earth's surface as well as causing corrosion damage to surfaces on which condensation occurs. Typical sulphur content and sulphur dioxide emissions are shown in the following table.

Sulphur content in fuels and typical SO ₂ emissions				
Fuel	Typical % sulphur in fuel	Kilograms of sulphur dioxide produced per tonne of fuel	Sulphur dioxide content (kg) per GJ 'available' energy (GCV)†	Sulphur dioxide content (kg) per MWh thermal input
Coal	1.2	24	1.08	3.47
Heavy fuel oil	2.0	40	1.16	3.33
Gas-oil	0.15	3	0.08	0.24
Natural gas	nil	nil	nil	nil

†Assumes 80% of total energy is 'available' from combustion.

The most effective way of reducing sulphur dioxide emissions is to reduce the amount of sulphur burned in combustion processes; the maximum permitted sulphur content of commercial fuels has been reduced in recent years, and further reductions are scheduled.

Pollution abatement techniques are available, and a process known as flue gas desulphurisation (FGD) can extract sulphur dioxide from combustion process exhaust.

Carbon Monoxide

Carbon monoxide is produced by the incomplete combustion of carbon, which can be caused by a number of different factors in a combustion process. The rate of production (parts of carbon monoxide per million parts of exhaust gas) is usually small, but is significantly increased as a result of poor combustion. Carbon monoxide is a toxic gas in high concentrations, and quantities of any significance in the atmosphere can contribute to local smog and respiratory problems. Its production can usually be limited by properly maintaining and controlling combustion equipment.

Nitrogen Oxides

The high-temperature reaction of oxygen (O₂) with nitrogen (N₂) in the combustion process causes the formation of nitric oxide (NO) and nitrogen dioxide (NO₂). A typical combustion process generates more than 90% NO and less than 10% NO₂. However, during atmospheric cooling, some of the NO reacts with ozone (O₃) to form more NO₂.

Unlike CO₂ and SO₂, which vary with the carbon and sulphur contents of the fuel used, NO_x can be generated in two ways:

- Thermal NO_x is formed by a reaction between oxygen and atmospheric nitrogen and occurs to a greater or lesser extent in all combustion processes.
- Fuel NO_x is formed by a reaction involving the nitrogen in the fuel and is associated with the combustion of oils and solid fuels that contain chemically bound nitrogen.
- The rate of NO_x formation is determined by several factors within the combustion process, including combustion temperature, residence time in the combustion zone, and the concentrations of oxygen and nitrogen present.

There are several adverse environmental impacts of NO_x formation:

- NO₂, particularly when associated with atmospheric cooling, contributes to smog formation at ground level.
- NO₂ is considered harmful to the respiratory system.
- Atmospheric reactions involving NO result in the formation of nitric acid (HNO₃), which contributes to acid rain.

Particulates

Where unburned carbon particles or inert materials such as ash are present in the combustion exhaust, they are usually visible as coloration or 'smoke'. Any combustion process that uses solid or liquid fuels can generate solid particles if incorrectly designed or operated, and the degree to which particles are visible in the exhaust is often a warning sign that the combustion process is not being controlled correctly.

Most particles ultimately settle on surfaces around the point of discharge to atmosphere. They cause environmental damage only if they are toxic, corrosive or produced in large quantities. However, while airborne, they present a hazard to respiratory systems, and the sight of airborne smoke is frequently regarded as an intrusion on the local environment.

Other Compounds

Combustion processes can produce small quantities of various organic and chemical compounds which may include gases of unburned hydrocarbons (UHC). These compounds often occur alongside particle and carbon monoxide emissions and, therefore, tend to be associated with poorly controlled combustion or inadequate maintenance. However, under normal circumstances, the emissions levels of these compounds are not considered a major concern.

In CHP schemes that incorporate the combustion of by-product or waste fuels, there may be other compounds such as dioxins, furans, heavy metals etc. in the exhaust gases. Most plants of this type are regulated under the EP Regulations as incineration installations, and often incorporate techniques for cleaning exhaust gases before discharge to atmosphere.

Conventional Energy Supply Emissions

To assess the benefits that a CHP plant offers in relation to atmospheric emissions, it is necessary to examine those emissions arising from the operation of conventional energy plant – industrial and commercial boilers and centralised electricity generation.

Industrial & Commercial Boilers

It is important to be aware of the emission levels from industrial boiler plant as a part of the assessment of the overall environmental benefits that CHP can achieve. The heat recovered from a CHP plant replaces the fuel consumption and emissions from these boilers.

Most of the heat required by industrial sites and commercial premises comes from steam or hot water raised in boilers that burn a carbon-based fuel – usually natural gas, oil or coal. In general, carbon monoxide and NOX emissions are determined by the combustion characteristics of the burner and by the fuel used. Carbon dioxide and sulphur dioxide emissions are entirely dependent on, respectively, the carbon and sulphur contents of the fuel.

The following table shows typical NOx emission levels calculated from a survey of UK industrial boilers. The survey data are in kilograms of emissions per tonne of fuel used.

Average emissions of NOx from industrial boilers	
Fuel	NOx (kg/tonne of fuel)
Coal	4.65
Heavy fuel oil	7.54
Gas-oil	3.46
Natural gas	4.74

The above data clearly shows the higher NOX emissions from heavy fuel oil (HFO), which has a higher nitrogen content and usually burns at higher temperatures. The average NOX emissions from coal firing have fallen significantly in recent years, mainly because of the decommissioning of older types of boiler, together with improvements in equipment maintenance and control.

The next table uses the average NOx emissions level for each data group and summarises these emissions in grams per kWh of boiler heat output. The values assume typical fuel compositions and a boiler efficiency of 80%. The clear trend shown is that coal and HFO

generate the highest emissions levels, and levels decline progressively with the use of lighter oils and gas fuels.

Typical emissions from industrial boilers

	Coal-fired boilers	HFO-fired boilers	Gas-oil-fired boilers	Gas-fired boilers
NO _x (g/kWh)	0.75	0.79	0.34	0.40
CO ₂ (g/kWh)	425	328	313	241
SO ₂ (g/kWh)	3.89 (1.2% sulphur in fuel)	4.17 (2.0% sulphur in fuel)	0.29 (0.15% sulphur in fuel)	nil (no sulphur in fuel)

Most boiler installations aim to be energy efficient and to minimise levels of particles in the exhaust, in some cases using filtration or other techniques. However, most boiler design and operation does not include specific provisions for limiting SO₂, NO_x and CO emissions but relies on the maintenance and adjustment of burner equipment to keep emissions to a minimum.

To calculate the carbon in CO₂ gas, multiply the weight of CO₂ by 0.273.

Centralised Electricity Generation

Around 70% of the electricity consumed in the UK is produced by burning fossil fuels in central power stations. The remainder is generated in nuclear power stations, from renewable sources such as hydro power, wind and biofuels, or in on-site facilities – mainly by CHP plant. Some electricity is also imported from/exported to Europe.

Of the fossil fuel consumed in central power stations, almost 60% is pulverised coal. This is burned in boilers, and the resulting heat is used to raise high-pressure steam for steam turbine electricity generation. Coal-fired power stations typically have an efficiency of up to 38%, with the remaining energy content of the coal being rejected to atmosphere through large cooling systems. The average supply efficiency figure is around 35% at the point of use, allowing for losses during electricity transmission and distribution. A significant proportion of coal-fired plant has now been fitted with low-NO_x burners to minimise NO_x emissions, and some units have been fitted with flue gas desulphurisation equipment. The coal-fired power generation sector has also progressively closed down its older power stations as more efficient plant has come on-stream.

A limited number of oil-fired generating stations are still used for stand-by and peak-opping duties. This has represented around 2% of fossil fuel use in recent years.

The use of gas turbines for power generation is continuing to increase, with many combined cycle gas turbine (CCGT) power stations opened in recent years. This type of power station uses gas turbines to generate electricity, but increases the power output from the station by using heat recovered from the gas turbine exhaust to raise steam for use in a steam turbine. The generating efficiency of CCGT power plant ranges from 40% to 50%, depending on the mode of operation of the plant, with the remaining energy rejected to the environment. Supply efficiencies of up to 48% are considered achievable. Large gas-fired turbines that incorporate the latest combustion technology can achieve low-NO_x emissions levels – typically around 50 mg/Nm³ at 15% O₂.

Despite its greater efficiency and lower emissions levels, gas-fired power generation will not completely replace coal-fired systems, and a significant proportion of UK electricity will continue to be generated in coal-fired power stations. However, the oldest coal-fired plant will always be the least efficient, producing the highest emissions levels per unit of power provided and operating with high variable costs. It is, therefore, likely that future years will see the progressive closure of such plant on both environmental and economic grounds. The regulation of coal-fired power stations will require the maximum possible use of the cleanest and most efficient plants.

New CHP installations, with a supply efficiency of 70% or more, can achieve major environmental and economic benefits when compared with this declining central generating capacity. The implications, in terms of emissions, can be summarised as follows:

- Power produced by a CHP plant will reduce the demand for electricity from central generating stations. This, in turn, will reduce the emissions level associated with centralised power production.
- The actual level of avoided emissions will depend on the type of power station being displaced. It will also be determined by factors such as time of day, season and geographical location.

Estimate emissions from central power generating plant

Pollutant	Coal-fired plant (g/kWh)	Fossil fuel mix (50% coal, 47% gas, 3% oil) g/kWh	
		Emissions from fuel burning	Inclusive of 5% for transmission losses
CO ₂	930	685	720
NO _x	2.1	1.8	1.9
SO ₂	8.8	5.0	5.2

Note: To calculate the carbon in CO₂ gas, multiply the weight of CO₂ by 0.273.

The nature (in terms of emissions) and operating characteristics of renewable- and nuclear-powered stations dictate that they will not be displaced by CHP, and hence such plant is not considered in this analysis.

CHP Emissions

As in all combustion processes, the CO₂ and SO₂ produced by CHP prime movers depend on the carbon and sulphur content of the fuel. Other emissions vary according to the design characteristics of the individual machinery. Emissions from steam cycle CHP only come from the boiler in which the steam is raised and are not affected by using steam to generate electricity. More in depth information is available on the various plant items; gas turbines, compression ignition engines, spark ignition gas engines, heat recovery boilers.

Gas Turbines

Using alternative fuels in prime movers reduces emissions by replacing fuel burned in other combustion processes. It also offers significant environmental benefits when compared with flaring-off these 'waste' gases or venting them to atmosphere.

The combustion process in a gas turbine occurs with high levels of excess air since the power output obtained is related to the mass flow rate achieved through the turbine. Production of CO

and UHC is very low under normal conditions. NOX emissions are normally low. Gas turbines that cannot meet the appropriate levels are sometimes fitted with water or steam injection systems to reduce NOX output.

The NOX emissions shown in the table below are based on turbines complying with the current guidance value, and many units are capable of even lower NOX output. For turbines with a net thermal input of 50 MW and above, are 60 mg/m³ on gas firing and 125 mg/m³ on oil firing. For turbines with a net thermal input of 20-50 MW, the values are 125 mg/m³ on gas firing and 165 mg/m³ on oil firing .

Emissions from gas turbines			
	NOx (g/kWh)	CO₂ (g/kWh)	SO₂ (g/kWh)
Gas turbines of 50MW thermal input or greater			
Firing on natural gas	0.5	510	nil
Firing on gas-oil	1.0	670	1.2
Gas turbines of less than 50MW thermal input			
Firing on natural gas	1.1	610	nil
Firing on gas-oil	1.6	800	1.4

These data represent typical values based on the emissions criteria set in the relevant Guidance Notes and typical efficiencies of 35% for turbines with a thermal input of 50 MW and above, and 30% for turbines with a thermal input of 20-50 MW.

Gas turbines for CHP can also use other gaseous fuels:

- Methane-based fuel gases from landfill sites, sewage treatment works and mine ventilation systems contain high levels of inert constituents such as nitrogen and CO₂. However, using these fuels in place of natural gas reduces NOX emissions by more than 50% because of the lower combustion temperatures involved.
- Refinery gases have a high hydrogen content and their use results in NOX emissions that are up to 2.5 times higher than those obtained with natural gas, although the lower carbon content of the fuel reduces CO₂ emissions.

Compression-ignition Engines

Compression-ignition engines generally operate with lower air-to-fuel ratios and higher combustion temperatures than gas turbines. The aim is to maximise efficiency but the result in environmental terms is to give relatively high NOX emissions levels per unit of power generated. Actual NOX emissions vary widely between different engine designs: in some cases, it is possible to reduce NOX emissions by operating at a lower engine efficiency, albeit with a small increase in CO₂ emissions.

Compression-ignition engines can operate on gas fuels if a small quantity of 'pilot oil' is injected to ignite the gas. This fuel option gives lower NOX emissions than fuel oil but usually reduces the power output of the engine.

Emissions from compression-ignition engines

	NO _x (g/kWh)	CO ₂ (g/kWh)	SO ₂ (g/kWh)
Firing on natural gas (with pilot oil)	5-10	500-600	0.1
Firing on heavy fuel oil	8-15	700-800	10.8

Spark-ignition Gas Engines

Spark ignition gas engines are now a viable option for industrial CHP applications, thanks to recent advances in the manufacture of larger and more efficient engines. These engines operate on natural gas and are based on lean-burn combustion technology to enable them to meet the strict NO_x emissions limits that apply in most European countries. Typical emissions from spark-ignition gas engine CHP units are given below.

Emissions from spark-ignition gas engines

	NO _x (g/kWh)	CO ₂ (g/kWh)	CO (g/kWh)	SO ₂ (g/kWh)
Firing on natural gas	5-20	500-600	1-2	Negligible

Note: These data represent typical values based on the emissions criteria set in the relevant Guidance Notes and typical engine efficiencies of 35% to 40%.

Heat Recovery Boilers

Replacing conventional boilers with the supplementary firing of a heat recovery boiler increases the environmental benefits of a CHP installation.

The heat recovery boiler in a CHP installation is where heat is recovered from the prime mover exhaust and used to raise steam or hot water. Heat recovery has no effect on the composition of the prime mover exhaust gases, although it can result in acid condensation if temperatures fall too low.

However, a heat recovery boiler can incorporate supplementary firing to improve boiler output. This uses the prime mover exhaust in place of ambient air and is a more energy-efficient way of raising additional heat than using a conventional boiler. Carbon dioxide emissions are up to 10% less than CO₂ emissions from conventional boilers.

Because the exhaust gases used in supplementary firing contain less oxygen than ambient air, the NO_x emissions level is typically about half that produced by a conventional boiler burning the same quantity and type of fuel. Furthermore, tests have shown that, under certain firing conditions, supplementary firing adds no further NO_x to the prime mover exhaust gases.

CHP Emission Reductions

A CHP plant that is well designed and operated will always improve energy efficiency and significantly reduce CO₂ emissions. Where power from a CHP plant replaces electrical power from older coal-fired power stations, there is also a significant reduction in SO₂ and NO_x emissions because of the lower sulphur content of the fuel and the use of more modern combustion equipment.

Typical emissions from a range of CHP installations, based on emissions from the prime movers and boilers, enable emissions savings to be calculated for a range of CHP options and existing boiler types. Such data are indicative of the benefits that can be achieved using CHP. The actual benefits in respect of emissions reductions will depend on the specific characteristics and operating conditions of a plant. The principles can, however, be applied to determine the predicted benefits of a scheme once the major components are selected. Actual benefits can be determined through plant monitoring once the system is operational.

The following table summarises typical emissions from a range of CHP installations. It is based on emissions from the prime movers and boilers. The table also shows the typical heat to power ratio for each scheme.

Typical emissions from CHP systems								
	A	B	C	D	E	F	G	H
CHP system type	Gas turbine with heat recovery boiler	Gas turbine with heat recovery boiler and back-pressure steam turbine	Boiler and back-pressure steam turbine	Boiler and back-pressure steam turbine	Boiler and back-pressure steam turbine	CI engine with heat recovery boiler	CI engine with heat recovery boiler	Lean-burn SI engine with heat recovery boiler
Fuel type	Natural gas	Natural gas	Natural gas	HFO	Coal	Natural gas	HFO	Natural gas
Emissions in g/kWh of electrical power produced								
CO ₂	610	510	1,510	2,220	2,700	570	800	500
NO _x	1.1	0.9	1.5	5.3	5.2	5-10	8-15	3
SO ₂	nil	nil	nil	28.2 (2.0% sulphur in fuel)	20.6 (1.2% sulphur in fuel)	nil	8.4 (2.0% sulphur in fuel)	nil
Ratio of recovered heat to power generated	1.6:1	1.1:1	5.5:1	5.5:1	5.5:1	1.4:1	1.4:1	1.6:1
Note 1: NO _x emission/kWh from gas turbines increase/decrease in proportion to the turbine emissions rate expressed in parts/million (ppm)								
Note 2: Datum used is 60ppm for natural gas firing								
Note 3: So ₂ emissions from all plant increase/decrease in proportion to sulphur content of fuel								

The next table provides an example of how emissions savings can be calculated for a range of CHP options and existing boiler types.

Summary of emissions reductions from a range of CHP options (g/kWh)				
Scenario	CO ₂	C	NO _x	SO ₂
Gas turbine with heat recovery boiler replacing coal-fired boiler	560	153	1.9	10.4
Gas turbine with heat recovery boiler replacing HFO-fired boiler	436	119	1.9	8.9
Gas turbine with heat recovery boiler and back-pressure steam turbine replacing HFO-fired boiler	370	101	1.7	6.8
Lean-burn SI engine with heat recovery boiler replacing HFO-fired boiler	546	149	nil	8.9

Operation & Maintenance Requirements

A programme of plant inspection and maintenance should be implemented if the environmental benefits and energy efficiency of CHP are to be maintained. The key to achieving and maintaining reductions in energy costs and emissions is to ensure high levels of prime mover availability and performance. Monitoring systems can track both performance and the condition of a CHP installation, thereby helping the early diagnosis of problems to minimise downtime and repair costs.

3. CHP Design: Environmental Aspects

Installing a CHP system usually increases the heat and power plant on a site. The effects on the local environment of such expansion need to be addressed at an early stage in the project, as part of the planning and evaluation process.

The size and type of installation will determine whether any consent is required under the Town and Country Planning Acts. These Acts have established the regulatory framework that controls the development and use of land for many purposes, including the construction of new plant and buildings. An early approach to the Planning Department of the appropriate Local Authority will help to clarify the requirements.

Any planning application may also need to be supported by a study showing the effects of the development on the local environment. The initial evaluation of project viability and acceptability will need to consider a range of environmental issues to help minimise the impact on the surrounding area. Some projects may need a detailed environmental impact assessment (EIA) for the planning and consultation procedure.

Combustion Products Dispersal

The combustion products from any industrial boiler-house or CHP plant can represent a toxic hazard to the local environment if the installation is not correctly designed and operated.

Environmental legislation requires the installation to minimise the production of airborne pollutants, and those that are released must be adequately dispersed within the atmosphere. The UK Government and the devolved administrations published the latest Air Quality Strategy for England, Scotland, Wales and Northern Ireland in July 2007 - setting out a way forward for work and planning on air quality issues and the air quality standards and objectives to be achieved; introducing new policy framework for tackling fine particles and identifying potential new national policy measures which modelling indicates could give further health benefits and move closer towards meeting the Strategy's objectives

Adequate pollutant dispersion can be achieved by ensuring that atmospheric discharge occurs at a sufficient height above the surrounding area. The required chimney height for any installation is determined by a wide range of factors, including the content of the exhaust and its temperature and velocity, the quality of the background air, and the topography and climate of the local area. Details are given in two documents:

- Technical Guidance Note (Dispersion) D1, Guidelines on Discharge Stack Heights for Polluting Emissions.
- Chimney Heights: Third Edition of the 1956 Clean Air Act Memorandum.

Erecting a new chimney has a visual impact on the surrounding area. However, chimney height can be minimised by combining the cleanest practicable combustion technology with low-sulphur fuel. Modern computer modelling systems can assess ground level impact by predicting the local concentration of pollutants that will arise from any combustion plant and any chimney height for specified local conditions.

Noise

All CHP systems have a prime mover/electrical generator which emits ambient noise into the adjacent area and exhaust noise from the exhaust stream. Most CHP systems also have items of auxiliary equipment which generate noise either continually or intermittently.

The following table gives typical noise levels for a range of sources and locations

Typical noise levels for a range of sources and locations	
Source	Typical noise level dB(A)
Public library	35-40
Business premises/offices	55-65
Passing vehicle	75-90
Pneumatic road-breaking drill	95-110
Jet aircraft on take-off	110-125
CHP plant with normal acoustic equipment	Around 80

In practice, all noise sources emit sounds over a range of audible frequencies. The 'A' scale of measurement simulates the sensitivity of the human ear to different frequencies.

Although the human ear is less sensitive to sound below 1,000Hz, noise at lower frequency is attenuated less by acoustic shielding. It is, therefore, important to consider the characteristics of different noise sources and the effect of acoustic insulation on sound reduction over the full frequency range detected by the human ear.

Both intermittent noise and noise sources that emit discrete tones can cause a nuisance. CHP installations usually operate continuously, but care must also be taken to shield sources of intermittent noise such as safety vents, pumps and compressors.

Designing a CHP installation often involves investigating the effects of the plant on the existing local noise profile. This should include surveying existing noise levels at relevant points around the site and assessing how each part of the system contributes to the total level.

Noise levels that damage health, or are a nuisance, are classified as 'statutory nuisances' under the Environmental Protection Act 1990, and Local Authorities have a duty to investigate any complaints.

Exhaust Noise

Engines and gas turbines frequently require a silencer in the ductwork or chimney to reduce exhaust noise. Factors that determine this requirement include chimney height, the type of engine or turbine, and the design of the waste heat recovery system. However, it may be possible to reduce the size or specification of a silencer where a heat recovery boiler attenuates the sound of the prime mover.

The following table illustrates typical exhaust noise profiles for gas turbines and reciprocating engines. It clearly shows that, in general, all prime movers give out more noise at lower frequencies, particularly reciprocating engines. The noise level from gas turbines is less variable over the spread of frequencies examined.

Typical exhaust noise levels from CHP prime movers							
	Frequency (Hz)						
	125	250	500	1,000	2,000	4,000	8,000
Gas turbine (dB)	120	120	116	112	110	105	95
Reciprocating engine (dB)	125	126	120	112	100	92	82

To meet local environmental requirements, exhaust silencer design for prime mover exhausts must consider the sound level profile. Silencers are available that reduce noise levels to 80 dB(A) at the chimney outlet. However, such a unit must operate without creating an excessive pressure drop across the silencer, as this can affect the prime mover's performance and efficiency.

Irrespective of whether the waste heat recovery system acts as an effective noise attenuator or incorporates its own silencer, most CHP systems include an exhaust bypass, sometimes with a separate stack, so that the prime mover can operate for short periods without any heat recovery. These bypass arrangements must incorporate a silencer if noise levels at the stack exit are to be acceptable.

Ambient Noise

An acoustic enclosure is usually installed around the CHP prime mover/electrical generator to reduce ambient noise levels, and the plant itself is often installed in a building that has been specially designed to attenuate noise.

The design of the acoustic enclosure should take into account the fact that, at low frequencies, reciprocating engines tend to make more noise than gas turbines. Foundations and engine mountings therefore need to control engine vibrations, particularly from the larger low-speed

machines. Gas turbines do not vibrate as much, but the design of a turbine's combustion air intake requires acoustic control. The ventilation inlet and outlet ducts on the acoustic enclosures of both engines and gas turbines will probably require small silencers.

The range of auxiliary equipment associated with a CHP system – fans, pumps and motors – may also require noise attenuation. Fuel or air compression systems, in particular, require acoustic enclosures or buildings to suppress the noise they generate.

Visual Impact

A CHP installation requires buildings for the prime mover and boiler, and for auxiliary equipment such as pumps and compressors. These buildings are often constructed on the edge of an industrial site to be close to gas and electricity systems. The design should, therefore, take into account the building's visual impact on the local area, particularly where it can be seen by the public.

Local Authority planning requirements may place restrictions on building design and require trees or other barriers to screen the site. The relevant Local Authority departments should be able to provide the necessary advice. Early consultation with these departments and with other community organisations is essential to identify possible problem areas that might otherwise delay the project.

Liquid Effluents Disposal

A CHP plant does not generate large quantities of liquid effluent. However, the following effluents can cause environmental damage if not controlled, and appropriate account should be taken of these at the system design stage:

- Boiler blowdown and drain effluent contain suspended solids and quantities of the chemicals used for treating boiler feed-water. The total water content of the boiler needs to be drained through the system for boiler maintenance and inspection purposes. There are limits on the temperature at which any effluent can be discharged.
- Effluent is generated by plant cleaning procedures such as turbine washing systems. Where periodic washing and system regeneration has necessitated the installation of a water treatment plant, this will also give rise to effluent.
- Pipework flushing and the chemical cleaning of equipment during installation and commissioning produces effluent.

Disposing of any liquid effluent to a public sewerage system or into the environment must have approval from the appropriate authority. Some form of treatment may be required for these effluents, and some sites have a suitable existing effluent treatment system. In some cases, effluent will need to be put in containers, removed from site, and disposed of by specialist contractors.

Containment & Storage

A range of potentially environmentally damaging materials is used in operating CHP plant and its auxiliary equipment. Precautions must be taken both at the design stage and during operation to prevent accidental releases. This may mean incorporating detection and alarm systems.

There are numerous design and engineering standards and codes of practice to improve safety and reduce the risk to the environment of accidental leaks or spills of hazardous substances such as natural gas, oils & chemicals and coal.

Natural Gas

- All fittings and pipework must be designed, and installed, to meet specifications and regulations.
- The system must be specified and tested for soundness throughout its service life.

Oils & Chemicals

In areas of risk, gas leakage detection systems are recommended, together with an automatic supply shut-off facility in the event of a leakage.

- All liquid substances used in bulk by a CHP plant, for example, fuels, lubricants and chemicals, should be stored in tanks.
- All tanks should be located within a catchment bund (secondary containment system) that is large enough to contain 110% of the tank's maximum capacity.
- Unloading points for bulk delivery vehicles should be designed to contain any spillages in a safe area.
- Water treatment plant and similar facilities should be sited in a bunded area to contain spillages.
- A bunded area should be available for storing materials supplied in portable containers, together with procedures and equipment for safe handling.

It is advisable to incorporate a sump to contain any liquids from surface drains in and around the CHP plant. This ensures that all types of liquid can be disposed of safely.

Coal storage & handling

- Coal must be delivered into a safe and secure storage area.
- The coal storage area must be ventilated to prevent a build-up of methane gas.
- Coal should be handled in a way that minimises the creation of airborne dust and particles. It may be necessary to install water sprinklers to dampen down material prior to handling.
- Run-off water must be collected and treated to meet appropriate discharge requirements.

4. Legislation

Legislation and regulations are subject to frequent change. The contents of this section are not, therefore, definitive and are intended for guidance purposes only. Readers must make their own judgements and take responsibility for how they use the information. Included are sections on:

- UK legislation for combustion processes and

- CHP Pollution Control

Combustion Processes: UK Legislation

Environmental regulation in the UK is based on a number of Acts of Parliament enacted for the benefit of the UK, together with legislation designed to meet EU environmental requirements.

The Environmental Protection Act 1990 (EPA) was introduced as the main legislation controlling atmospheric emissions and other types of pollution in the UK. It established an integrated system to control pollution from industry, and encompassed many of the diverse requirements of previous pieces of legislation such as the Public Health Acts, the Alkali Act and the Control of Pollution Act. It was also the means by which the UK complied with the EU Directive on Large Combustion Plant.

The EPA introduced a formal system of permits and reviews to ensure acceptable levels of environmental performance for a wide range of industrial processes. For each environmental medium, the EPA defined 'prescribed' substances, i.e. substances that are potentially harmful and need to be controlled to prevent, or minimise, their discharge into the environment. The Act also introduced the principle of Best Available Techniques Not Entailing Excessive Cost (BATNEEC) as the criterion for regulating the release of these prescribed substances.

The EPA does not apply in Northern Ireland, where pollution control is regulated by the Environment and Heritage Service.

The Environment Act 1995 created a unified Environment Agency (EA) in England and Wales, and the Scottish Environment Protection Agency (SEPA) in Scotland.

The Act made provision for a National Air Quality Strategy, under which the Government has set out its policies regarding the assessment and management of air quality. The implementation of EC legislation and international agreements is included within the scope of the strategy. This strategy is required to determine:

- Standards relating to air quality.
- Objectives for restricting the levels at which particular substances are present in the air.
- Measures to be taken by local authorities and other persons for the purposes of achieving these objectives.

The Environment Act 1995 also places a requirement on Local Authorities to carry out air quality reviews.

The Pollution Prevention and Control Act 1999 made changes in environmental legislation with effect from 1 November 1999. These changes were initiated by the EU Directive on Integrated Pollution Prevention and Control (IPPC), and the new Act replaced Part 1 of the Environmental Protection Act 1990. Under this new Act, the Pollution Prevention and Control (PPC) Regulations 2000 formed the basis for the new IPPC regime for the UK.

The IPPC directive required operators of regulated plants to use Best Available Techniques (BAT), which is very similar in principle to the BATNEEC defined in earlier UK legislation; the issue of both economic and technical feasibility is contained within both definitions. The Act confirmed the role of the UK's Environment Agencies and Local Authorities as the regulators/enforcers of pollution control for a widened range of commercial and agricultural activities.

The Environmental Permitting Regulations (EPR) came into force on 6 April 2008. These new regulations will make existing legislation more efficient by combining Pollution Prevention and Control (PPC) and Waste Management Licensing (WML) regulations.

Following a review of existing European industrial emissions legislation, the European Commission adopted a proposal for a Directive on Industrial Emissions on the 21st December 2007. The Industrial Emissions Directive (IED) is a recast of the following seven existing directives into a single clear and coherent directive:

- Large Combustion Plant Directive (LPC)
- Integrated Pollution Prevention Control Directive (IPPC)
- Waste Incineration Directive (WID)
- Solvents Emissions Directive (SED)
- Three Titanium Dioxide Directives

The IED aims to remove the ambiguities and uncertainties in the component directives which it replaces but does not change the underlying principles.

The IED was adopted by the European commission on 24th November 2010 and came into force on the 6th January 2011. Member states must transpose the IED into national legislation by the 6th January 2013. The IED will then be implemented from:

- 6th January 2013 for any new installation from this date onwards
- 6th January 2014 for installations in existence prior to 6th January 2013
- 6th January 2015 for installations not subject to current IPPC

In England and Wales the IED will be implemented through a revision of the EPR. DEFRA has recently undertaken a consultation on the transposition of the IED in England and Wales, the results of which are expected imminently.

CHP Pollution Control

For CHP plants, the regulatory system takes no account of whether heat is recovered from a prime mover, or whether steam from a boiler is used to drive a turbine; it is the fuel-burning components, i.e. the gas turbines, the engines and the boilers, that are regulated as combustion processes. The only aspect of CHP that may be treated as a different case is that of supplementary firing.

The degree of environmental regulation that applies to CHP plants depends on the size and type of the plant. Within the Pollution Prevention and Control (PPC) Regulations, a thermal input capacity of 50MW was retained as the threshold above which a combustion process or installation will be regulated as a 'Part A' plant under either IPPC or IPC. These plants are regulated by the EA in England and Wales, and by SEPA in Scotland.

In addition, a CHP plant that is part of any industrial installation regulated under IPPC is considered as being part of that installation, since it is a directly associated activity that is technically connected to the main installation. The CHP plant must therefore be included in the operator's IPPC application; if the CHP plant is under the control of a separate operator, then that operator must submit a separate IPPC application in conjunction with the one submitted by the operator of the main installation. Combustion plant that is rated at 20-50MW thermal input is regulated as 'Part B' plant in terms of emissions. In England and Wales, Part B regulation is the responsibility of the Local Authority, and is known as Local Authority Pollution Prevention and Control (LAPPC). In Scotland, SEPA are responsible for Part B plants.

All CHP plants, including plants that do not fall into either of the above two categories, are required to comply with any general legislation on pollution control (and in particular the Clean Air Acts), and the remaining sections of the EPA which cover nuisance to neighbours and the public.

The Environmental Permitting (EP) Regulations came into force on 6 April 2008. These new regulations will make existing legislation more efficient by combining Pollution Prevention and Control (PPC) and Waste Management Licensing (WML) regulations.

Since the introduction of Part A processes/ installations and Part B processes/installations under the EPA in 1990, a series of Process Guidance Notes has been produced to give information and guidance on the operation of combustion plant to both the regulatory organisations and to the operators of regulated sites. These have been produced and updated since 1990, and are now the responsibility of the EA/SEPA.

Part A Processes/Installations

CHP plants with a thermal input capacity of more than 50MW are regulated as Combustion Activities (as are any CHP plants that are part of a broader industrial installation) within the Environmental Permitting (EP) Regulations that came into force on 6 April 2008. The thermal input of all plant items is aggregated for comparison with the 50MW threshold. For example, a plant that consists of three gas turbines, each with a thermal input of 18MW, will be considered as a single gas turbine plant of 54MW and will be subject to Part A regulation. Likewise, a boiler-house containing five boilers, each with a thermal input of 12MW, will be regulated as a 60MW boiler plant. A plant consisting of one gas turbine with a thermal input of 18MW, with two boilers each of 20MW thermal input, will be regulated as a 58MW combustion installation.

Defra has produced a series of guidance documents including Core Guidance which describes the general permitting and compliance requirements and guidance on the European directives which are implemented through the Environmental Permitting Regulations. The documents also include guidance on the Large Combustion Plant Directive (Article 6 covers CHP permitting requirements).

In addition to Defra's guidance, the EA have produced guidance on the parts of the regulations that they are responsible for (Part A(1) activities and Waste Operations). Their guidance includes Technical Guidance Notes, risk assessment tool, application form and form guidance.

These documents are intended as guidance to the regulators and to plant operators in general, and provide a basis for the conditions and environmental performance that will be required under a permit from the EA/SEPA.

One of the key legislative issues that affects authorisations is the Air Quality Strategy and the need for the UK to achieve its targets on Ambient Air Quality, so plants located in areas with a risk of poor air quality may be expected to achieve tighter emission limits.

Part B Processes / Installations

Combustion plant with a thermal input capacity of 20-50MW will generally be regulated by Local Authorities in England and Wales (under LAPPC) and by SEPA in Scotland.

The relevant Guidance Notes issued by Defra, are:

- PG1/3 Boilers and Furnaces, 20-50MW Net Rated Thermal Input.
- PG1/4 Gas Turbines, 20-50MW Net Rated Thermal Input.
- PG1/5 Compression-ignition Engines, 20-50MW Net Rated Thermal Input.

These Guidance Notes are issued as a guide to local enforcing authorities on the techniques appropriate for the control of air pollution for the process.

In the case of Part B plants, it is the rated input of the individual gas turbine, engine or boiler that is compared with the 20-50MW threshold and regulated accordingly. Aggregation of the rating of multiple units of plant is not carried out.

5. Meeting Environmental Requirements

Increasing levels of environmental regulation will encourage the more efficient use of primary fuels and energy, and the replacement of older equipment and techniques. Any organisation considering the viability of CHP should therefore make a quantitative assessment of the reduction in emissions that CHP can achieve.

When assessing the viability of a CHP scheme, an early approach to the Local Authority Planning and Environmental Departments should give an indication of the potential environmental sensitivity of the scheme. In particular, it should be possible to assess the design aspects required to meet air quality targets and other local requirements. It may be appropriate at this stage to prepare a brief initial statement defining the extent of the scheme and assessing its environmental effects. This can be published early on for consultation with local interest groups.

Once the size and type of scheme have been defined, it is important – if appropriate – to discuss the proposals with the regulatory authority. This should confirm which pollution control authority will regulate the operation of the CHP scheme and give firm guidance on the environmental performance conditions that will be applied.

As a general rule:

- If the CHP scheme proposed has a fuel input of 50MW or more, contact the Environment Agency, the Scottish Environment Protection Agency or, for Northern Ireland, the Environment and Heritage Service.
- If the CHP scheme proposed has a fuel input of 20-50MW, contact the Local Authority Environmental Health Department or the Scottish Environment Protection Agency.
- If the CHP scheme proposed has a fuel input below 20MW, refer to the Clean Air Act 1993 requirements and contact the Local Authority.

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