Joint
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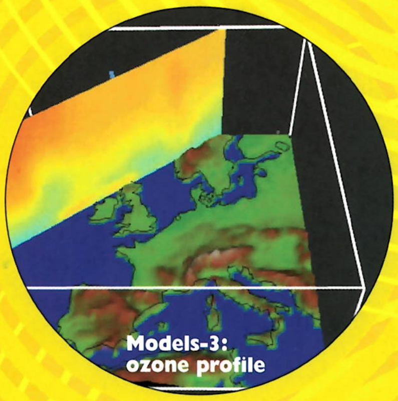
JEP

Characterisation of Power Plant Fuels for Compliance with LCP BREF Conclusion BAT 9

by
D J Eyre and D P Graham



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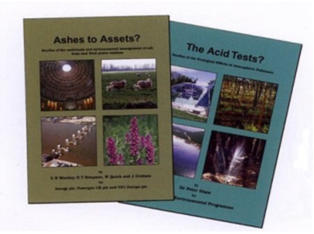

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JEP19EMB01 & JEP19EMC01: CHARACTERISATION OF POWER PLANT FUELS FOR COMPLIANCE WITH LCP BREF CONCLUSION BAT 9

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Executive Summary

The Large Combustion Plant Best Available Techniques Reference document, the LCP BREF, defines BAT Associated Emission Levels for a range of pollutants and emission monitoring requirements, along with seventy-five BAT Conclusions. BAT Conclusion number 9 (BAT 9) requires: (i) initial full characterisation of the fired fuels; (ii) regular testing of fuel quality, which may be based on supplier information, such as fuel specifications, and (iii) subsequent adjustment of plant settings as appropriate.

UK power plants have established procedures for fuel sampling and analysis to support commercial fuel valuation, and to ensure compliance with EU ETS, Pollution Inventory and European Pollutant Release and Transfer Register reporting. The routine data collected for these purposes satisfies the BAT 9 requirement to initially characterise and then regularly check the quality of fuels consumed. BAT 9 provides a list of required parameters for each fuel type; while the majority of the these are routinely determined, some (e.g. thallium and bromine in coal) are not standard parameters. For these non-standard parameters, this report provides typical values for each fuel type, which can be referenced.

Fuel quality variability is highest for coal, because coals from different countries of origin can have significantly different compositions. Coal specifications tend to be less prescriptive and there are no international standards mandating fuel quality limits. Instead, it is common for loadport analyses of individual vessel consignments to be treated as specifications for the basis of commercial transactions. Natural gas, fuel oil and wood pellets all exhibit low fuel quality variation. National and international standards and regulations are established which specify precise composition limits for each of these fuels.

BAT 9 requires that plant settings are adjusted to account for fuel quality ‘as and when needed and practicable’. Power plants have very sophisticated control systems which do account for impacts of fuel quality. Specific gas turbine combustion systems utilise online analysis of natural gas in order to determine firing temperatures or to protect the combustor from auto-ignition. In these instances, the control system automatically adjusts gas turbine operation using the measured fuel properties. However, more commonly, control systems utilise real-time plant data, rather than referring to fuel analysis data directly; for example, coal mill feeder speed is adjusted to deliver more fuel to mills when the boiler master pressure detects that heat input into the boiler is reducing, rather than using the fuel Net Calorific Value analysis data directly.

For each fuel, modifications to the Environmental Management System are recommended in order to comply with the BAT 9 Conclusion. This approach has been agreed with the UK Competent Authorities.

CONTENTS

1 INTRODUCTION

The Large Combustion Plant (LCP) Best Available Techniques (BAT) Reference document [1], the LCP BREF, defines BAT Associated Emission Levels (BAT-AELs) for a range of pollutants and emission monitoring requirements, along with seventy-five BAT Conclusions which are published separately [2].

BAT Conclusion number 9 (BAT 9) relates to the characterisation of fuels used in combustion or gasification plants. The exact wording is provided below[1].

BAT 9. In order to improve the general environmental performance of combustion and/or gasification plants and to reduce emissions to air, BAT is to include the following elements in the quality assurance/quality control programmes for all the fuels used, as part of the environmental management system (see BAT 1):

(i) Initial full characterisation of the fuel used including at least the parameters listed below and in accordance with EN standards. ISO, national or other international standards may be used provided they ensure the provision of data of an equivalent scientific quality;

(ii) Regular testing of the fuel quality to check that it is consistent with the initial characterisation and according to the plant design specifications. The frequency of testing and the parameters chosen from the table below are based on the variability of the fuel and an assessment of the relevance of pollutant releases (e.g. concentration in fuel, flue-gas treatment employed);

(iii) Subsequent adjustment of the plant settings as and when needed and practicable (e.g. integration of the fuel characterisation and control in the advanced control system (see description in Section 8.1)).

Description

Initial characterisation and regular testing of the fuel can be performed by the operator and/or the fuel supplier. If performed by the supplier, the full results are provided to the operator in the form of a product (fuel) supplier specification and/or guarantee.

Fuel(s)	Substances/Parameters subject to characterisation
Biomass/peat	— LHV — moisture
	— Ash — C, Cl, F, N, S, K, Na — Metals and metalloids (As, Cd, Cr, Cu, Hg, Pb, Zn)
Coal/lignite	— LHV — Moisture — Volatiles, ash, fixed carbon, C, H, N, O, S
	— Br, Cl, F
	— Metals and metalloids (As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Tl, V, Zn)

[1] Required parameters for industrial process fuels and waste are not shown here.

HFO	— Ash — C, S, N, Ni, V
Gas oil	— Ash — N, C, S
Natural gas	— LHV — CH_4, C_2H_6, C_3, C_4+, CO_2, N_2, Wobbe index

This report provides an overview of fuel characterisation activities undertaken at UK power plants. The report includes data from relevant fuel standards and specifications, which are commonly used to manage fuel quality. Some of the analysis parameters in the above table are non-standard (i.e. they are not routinely monitored); for these parameters supporting data is also provided. In addition, for each fuel, modifications to the Environmental Management System are recommended in order to comply with the BAT 9 Conclusion. This approach has been agreed with the UK Competent Authorities.

2 COAL

2.1 Coal Supply

UK coal-fired power plants were designed to fire indigenous coals, usually from several mines. Due to some quality variability between (and within) mines, the power plants were designed to operate with a range (or bandwidth) of coal qualities, for example, 8 – 20% moisture content, 19 – 26 MJ/kg Net Calorific Value (NCV) and 0.5 – 2.0% sulphur content. Changes to plant equipment (e.g. Flue Gas Desulphurisation (FGD) retrofit) and new operational constraints (e.g. lower emission limits) have led to tightening of fuel quality bandwidths, in some cases, since the plants were built. Conversely, upgrades to plant equipment (e.g. blending systems) may have been made to increase the fuel flexibility of the plant. Coal markets have changed dramatically over the last 20 years, and import coals now make up over 70% of coal consumed in the UK, with some power plants fired exclusively with import coal. The main sources of import coal to UK power stations are Russia, Colombia and the USA, but coals have also been supplied to the UK from South Africa, Poland, Ukraine, Kazakhstan, Australia and Indonesia in the past.

Coal is an inhomogeneous material, so the composition of different samples of the same coal can vary around the mean. Typically, coal quality parameters show normal distributions around the mean, such as those shown in Figure 1 for the sulphur content and NCV of Russian coal.

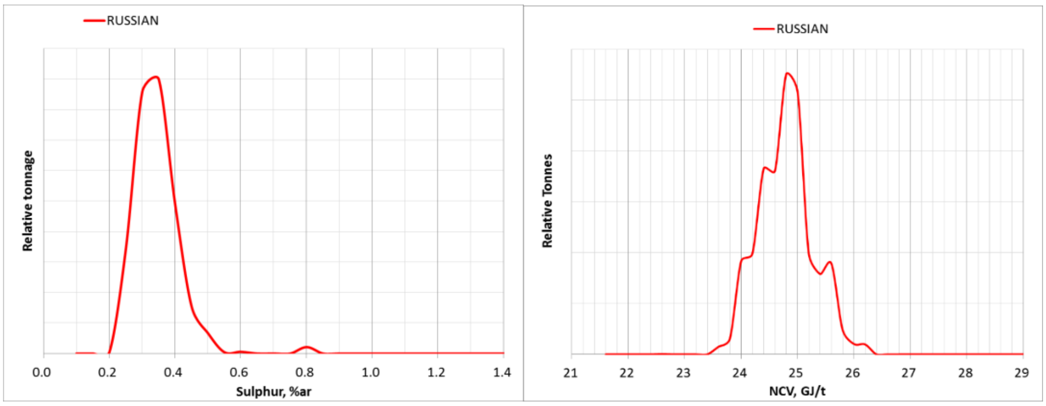

Figure 1: Typical coal quality distributions

Russian coals have very low sulphur content (typically 0.30 – 0.35%) and moderately high NCV (typically 25 MJ/kg), but individual shipments can range from 0.20 to 0.45 % sulphur and 24 to 26 MJ/kg. These differences are important for commercial transactions (since higher quality coal is more valuable), but these differences are small when considering the full scope of qualities of different coals around the world.

For the purpose of fuel characterisation for BAT 9, using typical (or average) qualities for each coal type is appropriate, where coals from different countries of origin, or sold to significantly different specifications, are considered to be different coal types. This is the same methodology that is applied for trace element reporting for the Pollution Inventory (PI) , Scottish Pollutant Release Inventory (SPRI) and the European Pollutant Release and Transfer Register (E-PRTR) [3].

The tonnage of each coal type delivered is recorded in the plant Fuel Management System (FMS). The FMS also records important coal quality parameters such as NCV and sulphur content.

2.2 Initial Characterisation

2.2.1 Specifications

Coal can be purchased against a specification, a mine sample analysis or the loadport (or disport) analysis of a specific vessel consignment. For internationally traded coals, globalCOAL's Standard Coal Trading Agreement (SCoTA) is commonly used to define the accepted quality of different coal types. Table 1 provides a summary of SCoTA specifications for six coal types: Colombian, Russian, US, South African, Polish and Australian.

Table 1: globalCOAL SCoTA Coal Specifications

Property	COL	RUS	USA	SAF	POL	AUS
NCV, kcal/kg ar - basis[2]	6000	6000	6000	6000	6000	6000
NCV, kcal/kg ar - min	5850	5850	5850	5850	5850	5850
Moisture, % ar - max	14 %	14 %	12 %	12 %	14 %	15 %
Ash, % ar – max	11 %	15 %	14 %	15 %	15 %	15 %
Volatile Matter, % ar	31-37 %	26-35 %	27-35 %	22 %	25-32 %	24-35 %
Sulphur, % ar – max	0.85 %	0.75 %	1.0 %	1.0 %	1.0 %	0.75 %
Chlorine, % ar – max	-	-	0.15 %	-	-	-
Hardgrove Index	45-70	45-70	45-70	45-70	45-70	45-70
Topsize, mm	50	50	50	50	50	50
Deformation Temp °C - min	1250	1250	1430	1250	1150	1250
CaO in ash, % - max	-	-	-	12 %	-	7 %

The parameters shown in the table are those that have the biggest impact on power plant operation, and therefore on the value of the coal. Many of the parameters required for BAT 9 compliance are not shown, while other parameters which are important for plant operation are not required for BAT 9.

[2] Industry practice is for coals to be priced on the basis of fixed calorific values – normally 6000 kcal/kg (25.1 MJ/kg). 1 kcal/kg is equal to 4.1868 kJ/kg

2.2.2 Loadport, Disport and Delivered Coal Analyses

All import coals are sampled and analysed at the port of loading (loadport) and are often sampled and analysed again at the port of discharge (disport). Sampling and analysis is undertaken to international standards (e.g. ISO 13909 for sampling [4], ISO 589 for moisture content [5], and ISO 1928 for calorific value determination [6]), which is standard industry practice while also being specified in BAT 9. The parameters included in loadport and disport analyses vary depending on the coal type and analysis laboratory, but typically only the most important parameters are included. A summary is provided in Table 2 below.

Table 2: Parameters included in loadport / disport analyses

Parameters always included	Parameters sometimes included	Parameters rarely or never included
• NCV[3] • Moisture, M • Ash, A • Volatile matter, VM • Sulphur, S • Hardgrove Index • (Fixed Carbon)[4]	• Elements: C, H, N, (O) [5] • Halogens: Cl, F • Metals/metalloids: As, Be, Cd, Cr, Co, Cu, Hg, Mn, Ni, Pb, Sb, V, Zn • Ash Fusion Temperatures • Ash composition: SiO_2 etc	• Halogens: Br • Metals/metalloids: Sn, Tl

In addition to the coal analysis provided by the coal supplier or third parties, coals are also sampled and analysed upon delivery at the power plant. These sampling procedures are already established and verified for EU Emission Trading System (EU ETS) compliance, as detailed in the JEP EU ETS Monitoring and Reporting Guidance [7]. The EU ETS requires that the coal is sampled every 20,000 tonnes as a minimum, but sampling is usually more frequent than this. Commonly, multiple samples of each coal source are collected each month. As with loadport and disport analyses, not all parameters are analysed on every sample. The EU ETS does require that carbon content is determined; an added benefit of this is that hydrogen and nitrogen content are usually determined at the same time for no additional effort, which in turn can allow oxygen content to be calculated too.

Table 3 provides typical values for coal quality parameters required for BAT 9 that are routinely analysed on all coals. These values are taken from Uniper's coal database, but the values are applicable for all operators, since the same coal types are utilised across the industry.

The LCP BREF provides new monitoring requirements for mercury (Hg), hydrogen chloride (HCl) and hydrogen fluoride (HF) emissions. A JEP Protocol is being finalised to enable operators to demonstrate when emissions are 'sufficiently stable' and therefore to allow lower frequency flue gas compliance testing for these species. This protocol requires that the Hg, Cl and F content in the coals consumed is maintained below pre-determined thresholds; to demonstrate this regular testing of these elements in the coal is required. Consequently, while Hg, Cl and F are currently not always analysed, from 2021 these species will be routinely determined for all coals.

[3] Net Calorific Value, NCV, is referred to as LHV, Lower Heating Value, in the BAT Conclusions
[4] Fixed Carbon (FC) is not analysed but can be easily calculated as: 1 – M – A – VM (fractional values)
[5] Oxygen is not analysed but can be easily calculated as: 1 – M – A – C – H – N – S – Cl (fractional values)

Table 3: Main coal quality parameters (Uniper coal database)

Property	Coal type[6]	Average	*Typical Min*	*Typical Max*	Coal type	Average	*Typical Min*	*Typical Max*
NCV MJ/kg	**UK 1**	24.3	*21.5*	*26.5*	**USA**	26.3	*24.0*	*29.5*
	UK 2	12.9	*11.5*	*15.0*	**SAF**	24.5	*23.0*	*25.5*
	COL	24.6	*23.0*	*26.5*	**POL**	25.7	*24.5*	*27.0*
	RUS	24.7	*23.5*	*26.0*	**AUS**	25.2	*23.0*	*28.0*
Moisture % ar	**UK 1**	12.3	*7.0*	*18.0*	**USA**	10.0	*6.0*	*13.5*
	UK 2	17.4	*13.0*	*21.0*	**SAF**	8.5	*6.5*	*11.0*
	COL	13.1	*9.0*	*17.0*	**POL**	8.9	*7.0*	*11.5*
	RUS	12.2	*9.0*	*15.5*	**AUS**	10.6	*6.5*	*13.0*
Ash % ar	**UK 1**	12.2	*6.0*	*19.0*	**USA**	9.6	*6.5*	*13.5*
	UK 2	39.0	*33.0*	*45.0*	**SAF**	14.7	*12.5*	*16.5*
	COL	7.8	*4.5*	*12.5*	**POL**	13.1	*9.0*	*16.0*
	RUS	9.3	*6.5*	*13.0*	**AUS**	12.4	*7.0*	*15.5*
Volatile Matter % ar	**UK 1**	29.2	*25*	*33*	**USA**	32.4	*26*	*38*
	UK 2	16.2	*14*	*19*	**SAF**	24.0	*21*	*27*
	COL	32.9	*29*	*37*	**POL**	27.3	*24*	*30*
	RUS	31.5	*28*	*35*	**AUS**	26.9	*22*	*35*
Fixed Carbon % ar	**UK 1**	46.3	*40*	*53*	**USA**	48.0	*43*	*53*
	UK 2	27.4	*24*	*34*	**SAF**	52.8	*47*	*57*
	COL	46.2	*43*	*51*	**POL**	50.7	*46*	*55*
	RUS	47.0	*43*	*51*	**AUS**	50.1	*45*	*59*
Carbon % ar	**UK 1**	62.0	*56*	*68*	**USA**	66.3	*61*	*73*
	UK 2	33.8	*30*	*38*	**SAF**	63.7	*60*	*68*
	COL	63.1	*58*	*68*	**POL**	65.5	*62*	*69*
	RUS	63.2	*60*	*67*	**AUS**	63.9	*58*	*74*
Hydrogen % ar	**UK 1**	3.9	*3.5*	*4.3*	**USA**	4.4	*3.6*	*5.1*
	UK 2	2.2	*1.9*	*2.6*	**SAF**	3.6	*3.0*	*4.1*
	COL	4.3	*3.7*	*4.8*	**POL**	4.0	*3.6*	*4.5*
	RUS	4.2	*3.7*	*4.7*	**AUS**	4.0	*3.1*	*4.9*
Nitrogen % ar	**UK 1**	1.3	*0.9*	*1.6*	**USA**	1.3	*1.1*	*1.6*
	UK 2	0.7	*0.5*	*0.9*	**SAF**	1.5	*1.2*	*1.9*
	COL	1.3	*1.1*	*1.6*	**POL**	1.2	*0.9*	*1.5*
	RUS	1.9	*1.4*	*2.3*	**AUS**	1.4	*1.2*	*1.8*
Sulphur % ar	**UK 1**	1.4	*0.7*	*2.1*	**USA**	1.8	*0.4*	*3.0*
	UK 2	0.9	*0.6*	*1.3*	**SAF**	0.6	*0.4*	*1.0*
	COL	0.7	*0.4*	*1.0*	**POL**	0.6	*0.4*	*0.8*
	RUS	0.3	*0.2*	*0.5*	**AUS**	0.5	*0.3*	*0.8*
Oxygen % ar	**UK 1**	5.6	*4.0*	*9.5*	**USA**	6.5	*4.0*	*9.0*
	UK 2	4.7	*4.0*	*6.5*	**SAF**	7.4	*5.0*	*10.0*
	COL	9.7	*7.0*	*12.0*	**POL**	6.6	*4.5*	*9.0*
	RUS	8.9	*6.5*	*11.0*	**AUS**	6.5	*4.0*	*9.5*

2.2.3 PI and E-PRTR Reporting

There is already a requirement on operators of coal-fired power plants to determine emissions of many trace species for the Pollution Inventory and European Pollutant Release and Transfer Register. The methodology employed for determining emissions of trace elements is to use concentrations of the elements in the coal and apply retention and emission factors for each element to calculate the emissions to air, ash and water. This calculation approach is considered to be more accurate than measuring actual emissions of trace elements from the

[6] UK 1 is a standard power station fuel, UK 2 is a low grade fuel

power plant, because emissions are often below limits of detection that can be achieved in a power plant test environment. Details of the calculations are provided in the Pollution Inventory methodology [3].

Therefore, while trace element concentrations in coal are not routinely determined in all loadport, disport or delivered coal samples, there is sufficient data collected to determine average or typical concentrations for each coal type. This data is collated as a historic dataset which is updated each year as new analyses are received. For the purpose of BAT 9 compliance, reference to this dataset is considered to be sufficient and appropriate.

The trace metals that are reported in the PI and/or E-PRTR are: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), and zinc (Zn). The halogen species hydrogen chloride (HCl) and hydrogen fluoride (HF) are also reported. The average trace element concentrations in each coal type are shown in Table 4.

Table 4: Trace element concentrations in coals (Pollution Inventory database)[7]

All values mg/kg dry	UK	COL	RUS	USA	SAF	POL	AUS
Cl	1380#	289#	110#	2050#	170#	1626#	153#
F	116	52	105	77	200	72	150
As	19.1	3.7	5.6	7.3	1.8	3.6	8.3
Cd	0.30	0.18	0.12	0.24	0.29	0.09	0.42
Cr	37	12	14	18	28	19	35
Cu	37	7	8	11	14	19	27
Hg	0.11	0.06	0.10	0.09	0.08	0.07	0.12
Ni	41	9	14	16	20	18	34
Pb	36	4	5	12	9	11	17
Se	1.8	3.9	0.6	2.2	0.9	0.7	2.9
Zn	57	16	18	27	16	22	24

Prior to 2012, beryllium (Be), boron (B), manganese (Mn), antimony (Sb) and vanadium (V) were also reported before this requirement was removed. Concentrations of cobalt (Co) and molybdenum (Mo) were also recorded in the PI database, although these were not required to be reported. Of these elements, cobalt, manganese, antimony and vanadium are listed in BAT 9. Average concentrations of these elements in each coal type are shown in Table 5.

Table 5: Trace element concentrations in coals (Historic Pollution Inventory database) [7]

All values mg/kg dry	UK	COL	RUS	USA	SAF	POL	AUS
Co	11.8	3.0	5.1	5.4	9.4	8.1	10#
Mn	141	44	60	37	74	83	180
Sb	2.1	1.0	0.4	1.0	0.5	1.2	0.7
V	66	24	20	42	28	34	41

2.2.4 Thallium and Bromine

Two additional elements, thallium and bromine, are listed in BAT 9 but have never been required to be reported in the PI or E-PRTR. The inclusion of these elements in the BAT 9 list is surprising considering that selenium, beryllium and boron are not required for BAT 9 but are (or have been) reportable in the PI. Thallium is not discussed in the LCP BREF document, except

[7] Values marked # uses data from the Uniper coal database, as no data are available in the PI database

briefly in the context of waste co-incineration plant, and bromine is only mentioned in the context of its use as an additive for mercury emissions reduction (adding bromine to the fuel can aid the oxidation of Hg^0 to Hg^{2+} and therefore increase mercury capture efficiency in wet FGD units). In the USA, the National Research Council has classified the level of concern for each trace element in coal [8]. The trace elements of greatest concern to the environment and human health were identified as arsenic, boron, cadmium, lead, mercury, molybdenum and selenium, which corresponds closely with the PI and E-PRTR list. Thallium was identified as an element of concern due to its detrimental impact on health but the very low concentrations were considered to have negligible impact. Bromine was reported as an element of 'little environmental concern'.

Neither thallium nor bromine are included in the standard suite of elements analysed when coal trace element content is determined. That is, even when trace element concentrations are analysed in loadport, disport or delivered coal samples, these two elements are not included.

Some limited data on coal thallium content is available in an historic version of the Pollution Inventory database. Most of the data relates to UK coals and was provided by UK Coal plc, with some additional data from TXU Europe, which includes limited data on import coals. Swaine [9] provides further limited data on thallium concentrations in coal, but the data is highly variable: USA coals 0.05 – 2.8 mg/kg, Australian coals <0.02 – 2 mg/kg, Russian coals <0.1 – 2.3 mg/kg and UK coals 0.6 – 1.7 mg/kg. The Uniper coal database also contains limited data on coal thallium content (note that there is some overlap between this database and the Pollution Inventory database). The majority of data entries are reported as below limit of detection, but the actual limit of detection reported varies greatly: for example, results for Colombian coals range from "<0.5 mg/kg" to "<10 mg/kg", and results for Russian coals range from "<0.1 mg/kg" to "<14 mg/kg". These different limits of detection may also explain the high variability reported by Swaine. This data indicates that even if thallium analysis is included in the trace element analysis suite, there is no guarantee that meaningful data will be obtained because detection limits are often far above actual concentrations. Thallium is believed to be associated with sulphide minerals (e.g. pyrite), which means that concentrations correlate with coal sulphur content. The limited data available is consistent with this theory but further data would be required to confirm the relationship.

Table 6 provides a summary of the available thallium data. It is noted that an IEA Clean Coal Centre report on trace elements in coal [10] failed to find any further information on thallium concentrations in coal.

Table 6: Thallium concentrations in coals (Historic industry and literature data)

mg/kg dry	UK	COL	RUS	USA	SAF	POL	AUS
Tl	0.6	0.2	0.1	0.7	0.1	0.1	1.1

Available data on bromine concentrations in coal is even more sparse. No data is recorded in the Pollution Inventory or Uniper coal databases, but some data is available in academic papers and other literature. Swaine reports bromine contents for a wide range of coal types but states that the data shows 'great variability'. Two more useful sources are a report by Kolker of the US Geological Survey [11] and a paper by Vassilev of the Bulgarian Academy of Sciences [12]. In each report, the relationship between chlorine and bromine content is discussed. It is thought that both chlorine and bromine in coal are associated with coal moisture (especially inherent moisture), and high levels of both species are believed to have originated due to coal forming in saltwater environments. (Seawater typically contains 19400 ppm chlorine and 67 ppm bromine, a ratio of 290:1).

Kolker reports the relationship between chlorine and bromine in a wide range of US coals: for bituminous coals, i.e., the type of US coal also exported to Europe, the bromine content was shown to be between 0.5 – 2.0% of the coal's chlorine content. Vassilev's data indicates that on average bromine levels in US coals are 4% of their chlorine levels, and similar relationships (bromine content between 2 – 4% of chlorine content) are also shown for Australian and South African coals. Reviewing data from Swaine where both chlorine and bromine levels have been reported for a range of coals from different countries again indicates that bromine levels are typically 0.5 – 4.0% of chlorine levels. Since chlorine is a standard coal parameter analysed on nearly all coals, it is proposed that bromine content are estimated as being 4% of chlorine levels. This provides the following typical levels for the coal types consumed in UK power plants.

Table 7: Bromine concentrations in coals (Estimated from literature data)

mg/kg dry	UK	COL	RUS	USA	SAF	POL	AUS
Br	55	12	4	82	7	65	6

2.2.5 New coal types

International coal markets are well established and the coal types currently being imported into Europe and the UK are not expected to change over the anticipated remaining lifetime of UK coal-fired power plant. Nevertheless, there remains a possibility that a new coal type may be delivered in the future for which full characterisation data is not readily available. In this instance, full characterisation of the coal (i.e. including trace element content) would need to be undertaken on the loadport, disport or delivered coal samples.

2.3 Regular Testing

The coal sampling and analysis activities described previously for the initial assessment of coal quality are applied to all coal deliveries to power plants, even when coals have been previously tested and accepted. Regular testing is undertaken to ensure commercial and contractual obligations of the coal supplier are met, and to satisfy the power plant EU ETS (and IED) requirements.

Not every coal sample is analysed for all parameters, but the standard analysis data obtained on all coals (i.e., NCV, moisture, ash, volatile matter, sulphur, carbon etc) is sufficient to determine whether coal quality has materially changed from the initial characterisation. Therefore, to comply with BAT 9 it is proposed that standard coal quality parameters are reviewed to ensure that the coal quality falls within the expected range for each coal type (i.e., by comparing against the typical minimum and maximum ranges shown in Table 3, or equivalent site-specific historic data). It should be noted that the typical minimum and maximum values in Table 3 equate approximately to 95% confidence levels, so when comparing 20 values one value (5%) will statistically fall outside of the ranges given.

If review of the standard analysis parameters shows that the coal quality is different from the initial characterisation, then the coal shall be treated as a new coal type and will require full re-characterisation.

2.4 Adjustment of Plant Settings

BAT 9 requires that plant settings are adjusted to account for fuel quality 'as and when needed and practicable'. Coal-fired power plants have very sophisticated control systems which do account for impacts of fuel quality. In general, these systems utilise real-time plant data, rather than referring to coal analysis data directly, noting that different coal types may be blended or co-fired which would add significant complexity if using fuel data for direct process control. For example, mill feeder speed is adjusted to deliver more coal to mills when the boiler master pressure detects that heat input into the boiler is reducing, rather than using coal NCV analysis data directly. Likewise, limestone dosing rate into the FGD is increased when the flue gas SO_2 level increases, rather than using coal sulphur content data directly.

Plant control systems have minimum and maximum settings, such that adjustments to account for fuel quality changes are achieved while the fuel quality remains within the power plant's design limits (fuel quality bandwidth). Operators ensure that fuel quality remains within design limits by planning coal deliveries to site and by selecting coals (or coal blends) for firing in advance of operation.

2.5 Compliance with BAT 9 Requirements for Coal Fired Plants

Compliance with the BAT 9 requirements can be defined within the plant Environmental Management System as follows.

(i) Initial fuel characterisation. When firing previously supplied coals, coal quality is determined by reference to the database properties defined in *Tables 3 to 6 [*]* for different coal types/countries of origin. The tonnages of each fuel, the assigned fuel properties and the annual, tonnage weighted, average properties are recorded. Due to commercial confidentiality considerations, these records are held on site for regulatory inspection as required. Alternatively, equivalent site-specific analysis data may be referenced provided that this has been obtained using EN standards (or ISO, national or other international standards provided that the data is of an equivalent scientific quality). Any new coal type consumed shall be subject to full characterisation for all of the fuel quality parameters defined in BAT 9.

(ii) Regular testing. This is undertaken for all coal deliveries, for the main coal quality parameters only, to ensure that the commercial and contractual obligations of the coal suppliers are met, and to satisfy EU ETS and IED requirements. The main coal quality parameters, defined in *Table 3 [*]* shall be reviewed to ensure that the coal quality falls within the expected range for each coal type, i.e., by comparing with the stated typical minimum and maximum ranges, or equivalent site-specific historic data. On this basis, if the coal quality is different from the initial characterisation, then the coal shall be treated as a new coal type and will require full re-characterisation (as (i) above).

(iii) Subsequent adjustment of plant settings. Control systems at coal-fired power plants utilise real-time plant data that is indirectly related to the fired coal quality, rather than directly utilising coal quality information which is taken into account for longer term planning and compliance purposes. It is not practicable to integrate fuel quality data into the control system.

[*] Insert reference to this report or reproduce the tables in the EMS.

3 NATURAL GAS

3.1 Natural Gas Supply

Combined cycle gas turbine (CCGT) and open cycle gas turbine (OCGT) power plants usually utilise natural gas directly from the high pressure National Transmission System (NTS). Gas turbines and boilers within Combined Heat and Power (CHP) systems either utilise natural gas from the NTS or from the local distribution network.

Natural gas supplies in the UK have diversified significantly over the last 20 years. Imports (via pipelines from Europe and liquefied natural gas, LNG, from countries such as Qatar) now supply over half of the gas consumed in the UK.

3.2 Initial Characterisation

All natural gas entering the NTS must comply with the Gas Safety (Management) Regulations, 1996 (GS(M)R) [13]. The GS(M)R specifies minimum and maximum limits for Wobbe Index and maximum limits on a number of gas impurities (see Table 8). However, the GS(M)R does not provide limits on each hydrocarbon component of natural gas or NCV.

Table 8: Selected Gas quality criteria from GS(M)R

Parameter	Limit
Wobbe Index[8]	47.2 – 51.41 MJ/m^3
Hydrogen Sulphide	< 5 mg/m^3
Sulphur	< 50 mg/m^3
Hydrogen	< 0.1 %
Oxygen	< 0.2 %

Wobbe Index is an important parameter for gas appliances, and is calculated as the calorific value divided by the square root of relative density[9]. Two gases with the same Wobbe Index will deliver the same heat input at constant supply pressure, even if they have different calorific values and relative densities. Wobbe Index, calorific value and relative density are calculated from bulk gas composition data obtained from a gas chromatograph (GC).

Generally, the degree of variability experienced at each operating site is smaller than the total variation seen across the whole network. This is demonstrated by Figure 2, which shows Wobbe Index data for a range of sites across a single year – each site shows limited variability, but the combined variability (black line) shows close agreement with the GS(M)R limits. However, it should be noted that the Wobbe Index range of natural gas may be significantly widened in the future, in which case, the gas quality criteria in Table 8 will need to be revised [14].

Gas chromatographs are installed at strategic points within the NTS and distribution networks to analyse gas composition. On-line chromatographs can provide gas composition data continuously – a result is usually obtained every 5 minutes. Most CCGT power plants have a dedicated GC for EU ETS reporting purposes and these are calibrated annually by an independent accredited laboratory. Where GC instruments are not installed on site, gas composition may be taken from the NTS or local distribution gas composition analysis and it is also possible to extract gas samples and analyse using a GC off-line. Analysis is undertaken in accordance with international standards (e.g., ISO 6974).

[8] Volume reference conditions of 15°C and 101.325 kPa.
[9] Relative density to air, at the defined reference conditions, also known as specific gravity

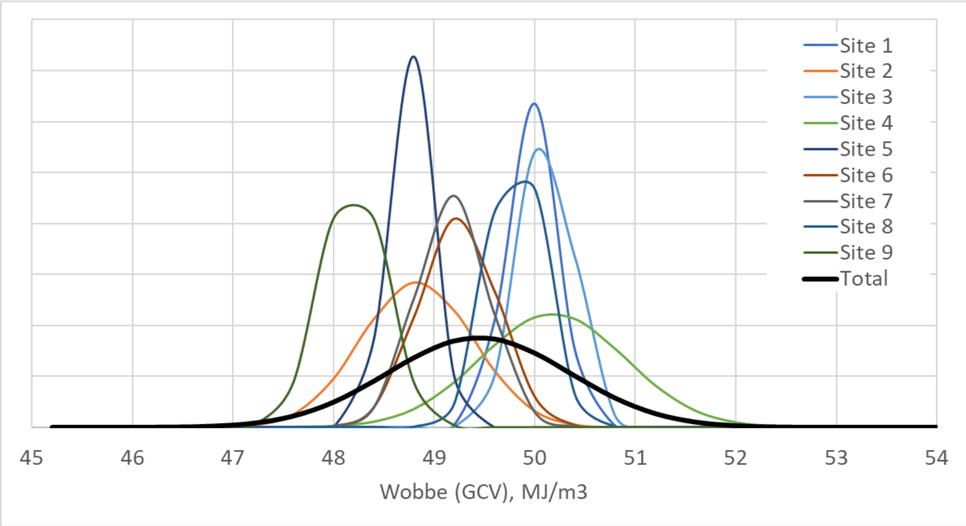

Figure 2: Gas quality distributions

The GC instruments may be located on the power plant site or they may be owned and controlled by the gas network operator. All of the parameters identified in BAT 9 for natural gas are determined from the GC analysis, and all power plants have access to GC data for the gas supplies used either on site or via the NTS or local distribution gas composition analysis.

Typical values of natural gas in the UK NTS are shown in Table 9, based on a typical (Lupton) gas composition and supply ranges provided by the Institution of Gas Engineers (IGE) [15] and somewhat wider ranges given in a Material Safety Data Sheet (MSDS) published by National Grid [16]. Typical NCV ranges are also shown based on industry gas quality data.

The IED defines natural gas as *'naturally occurring methane with not more than 20 % (by volume) of inerts and other constituents'*[10]. The minimum methane contents in Table 9 are higher than 80%, therefore it is anticipated that UK natural gas will always comply with the IED definition.

Table 9: Typical UK NTS Gas Quality Data

	IGE data			National Grid MSDS		
Component %vol	**Typical**	**Min**	**Max**	**Mid-range**	**Min**	**Max**
CH_4	87.2	86.8	93.0	89.5	82.0	97.0
C_2H_6	6.2	3.1	7.1	6.5	2.8	10.2
C_3H_8	1.7	0.7	2.3	1.9	0.1	3.7
C_4+	0.7	0.4	1.0	0.9	0.0	1.7
CO_2	2.5	0.8	2.2	2.0	0.0	4.0
N_2	1.7	1.0	2.5	3.9	0.1	7.7
NCV [8]	**Typical**	**Min**	**Max**			
MJ/m^3	35.5	34.7	37.5			

[10] IED Annex V, Part 1(6)

3.3 Regular Testing

Data obtained from the GC is supplied continuously on site (for on-line instruments), or from the NTS or local distribution gas composition analysis, as is often the case for large Open Cycle Gas Turbine plants, or at regular intervals within the calendar year (for off-line instruments). Gas composition data is recorded by the plant operator based on their own measurements or as supplied by the network operator. All of the parameters identified in BAT 9 are either determined directly or they are calculated from the natural gas composition.

3.4 Adjustment of Plant Settings

Gas-fired power plants have highly automated control systems. Large gas turbine units, with lean premix combustion technology, have finely tuned combustion systems to deliver low NO_x emissions, whilst ensuring acceptable levels of acoustic pulsations. To ensure optimum performance, combustion systems are re-tuned every few years following major outages with the exact time-scales between outages determined by the number of annual operating hours and the number of starts. Boiler combustion systems, operating at atmospheric pressure, require less sophisticated tuning relating to air:fuel ratio trimming in order to optimise NO_x and CO emissions performance.

Gas turbine combustion systems are usually designed to cope with a defined range in Wobbe Index, e.g., ± 5% of the specified design value. In exceptional circumstances, when there are unanticipated step changes in fuel quality, or the gas turbine needs to fire different gaseous fuels, more frequent tuning events may be required. This may also be the case when plant degradation is more severe than anticipated. More recently, auto-tune options have become available in which the plant control system can adjust the fuelling based on the level of acoustic pulsations and, in some cases, the measured or estimated flue gas emissions.

In relation to NCV, the control system usually adjusts the fuel flow rate until the required firing temperature and power output are achieved, without reference to fuel quality data, although performance is strongly dependent upon ambient conditions which are often used in the control algorithms. However, certain gas turbine combustion systems require online measurement of the NCV, using either a gas chromatograph or a fast response calorimeter, in order to accurately calculate and control the firing temperature.

In relation to Wobbe Index, direct online measurement is usually only required when firing process fuels with a variable composition, e.g., refinery gas or blast furnace gas. However, this approach is exceptionally used for natural gas firing in order to very accurately prescribe the pilot fuel heat input, for example. However, as noted previously, the Wobbe Index range of natural gas may increase significantly in the UK in the mid-term.

Gas turbine combustion systems can also be sensitive to gas composition variations when firing natural gas within GS(M)R specifications. The presence of elevated levels of higher hydrocarbons can lead to auto-ignition issues in lean premix combustion systems. For example, the GT26 sequential combustion system is sensitive to the content of higher hydrocarbons. In this case, the GC analysis is too slow for control purposes and infra-red analysers are fitted to the fuel supply lines to provide an indication of the C_2+ content which is then used to automatically adjust the control settings.

3.5 Compliance with BAT 9 Requirements for Natural Gas Fired Plants

Compliance with the BAT 9 requirements can be defined within the plant Environmental Management System as follows.

(i) Initial fuel characterisation. Natural gas fuel quality is stable within the UK and is prescribed by the Gas Safety (Management) Regulations (GS(M)R), with regards to Wobbe Index (47.2 – 51.4 MJ/m^3 at 15°C, 101.3 kPa, based on the Gross Calorific Value). Most gas turbines and boilers can tolerate this Wobbe Index variation, about the mid-range point, but actual variations are currently smaller than this in practice. Natural Gas composition is not prescribed by the GS(M)R and there is some variation in the concentrations of methane, other hydrocarbons, and inert gas components. However, the methane concentration is always above 80%, in compliance with the IED definition of natural gas. The BAT 9 requirement is therefore satisfied by reference to the GS(M)R requirements, for Wobbe Index, as defined in *Table 8 [*]*, and typical NCV and compositional variations, as defined in *Table 9 [*]*.

(ii) Regular testing. This is undertaken using a gas chromatograph, based on *continuous/discontinuous** natural gas sampling. The gas chromatograph is installed *on site/within the NTS or distribution network/within a third party laboratory when sampling discontinuously*.* The Net Calorific Value (NCV) and the carbon content of the fuel are calculated from the natural gas composition for EU ETS reporting purposes. Records of NCV and the detailed fuel composition are held on site for additional regulatory inspection as required. The detailed data simply confirms that that the natural gas is within UK specifications and no further characterisation is required. The Wobbe Index can also be calculated from the fuel composition, as required, where not already undertaken.

(iii) Subsequent adjustment of plant settings. Boiler plants firing natural gas do not utilise fuel quality parameters within the plant control system. Gas turbine plants have highly automated control systems and finely tuned combustion systems which are regularly checked and re-tuned to maintain NO_x performance. In relation to NCV, the control system adjusts the fuel flow rate until the required firing temperature and power output are achieved, *without reference to fuel quality data*/based on measurement of the NCV using a local gas chromatograph/fast response calorimeter*.*

*The gas turbine combustion system is also sensitive to the presence of elevated levels of higher hydrocarbons and this is mitigated by fast response measurement of C_2+ which is used to adjust the control settings.**

The gas turbine combustion system uses online measurement of Wobbe Index/NCV for control of the pilot fuel flow rate.**

[*] Insert reference to this report or reproduce the tables in the EMS.
** Delete as applicable or replace with any other instances of fuel properties being used for direct control.*

4 OIL

4.1 Oil Supply

Different grades of oil are utilised on UK power plant, including distillate oils such as gas oil, and residual oils such as light fuel oil (LFO), processed fuel oil (PFO) and heavy fuel oil (HFO). BAT 9 requires that HFO and gas oil are characterised, but does not explicitly include LFO or PFO. However, it is assumed that characterisation of LFO and PFO is also required where these are used. Oil consumption may be metered or may be determined by recording delivered volumes and changes in oil tank levels at the beginning and end of reporting periods. Oil consumption and stock levels are recorded in the plant FMS.

4.2 Initial Characterisation

4.2.1 Specifications

Fuel oils are commodity products purchased to standard specifications. BS 2869 (2017) *Fuel Oils For Agricultural, Domestic And Industrial Engines And Boilers* provides specifications for different grades of oil [17]. Each producer will also provide a specification for their products. Limits are specified for several chemical and physical properties, as shown in Table 9.

PFO is produced by recovering and processing waste lubricating oils. In 2011, the Environment Agency and WRAP published a Quality Protocol for PFO which includes quality criteria [18]. The Quality Protocol requires that specifications for the equivalent grade of oil are achieved, as shown in Table 9, but some additional criteria are also specified, including trace species content.

Analysis to ensure that oils comply with specifications is generally undertaken by suppliers prior to dispatch.

Table 9: Fuel Oil Specifications

Property	Gas Oil (Class A2 / D)	LFO (Class E)	HFO (Class G)
Kinematic viscosity at 40°C, cSt	2.0 - 5.0	-	-
Kinematic viscosity at 100°C, cSt	-	> 8.2	20 - 40
Flash point, °C	> 55	> 65	> 65
Sulphur, %	< 0.1[11]	< 1.0	< 1.0
Water, %	< 0.02	< 0.5	< 1.0
Ash, %	< 0.01	< 0.10	< 0.15
Sediment, %	-	< 0.10	< 0.15
NCV, MJ/kg	42.7 - 43.3	-	> 42

4.2.2 Delivered Oil Analysis

For power plants consuming large volumes of oil, the EU ETS places obligations on plant operators to measure the NCV and carbon content of oil for CO_2 accounting. For small power plants, or where oil is consumed as a minor (<10%) or de minimis (<1%) source stream, default values can be used rather than actual analysis data. These National Inventory Factors [19] are taken from the UK Greenhouse Gas National Inventory Report, and are shown in Table 10.

[11] For ultra-low sulphur gas oil, sulphur content limit is 20 mg/kg or 0.002%.

Table 10: National Inventory Factors for Oils (2017)

Property	Gas oil	Fuel Oil (LFO, HFO)	Waste derived Oil (PFO)
Carbon emission factor, kg_C/tonne	870.0	872.8	864.8
Carbon, %	87.0	87.3	86.5
NCV, GJ/tonne	42.6	40.8	42.6

Aside from sulphur, ash and carbon content, which are all routinely analysed, BAT 9 also requires that nitrogen content is determined for all oil types, and that nickel and vanadium content is determined for HFO. Nitrogen content is not routinely determined on oil deliveries, but historic data from ad hoc analyses are available (a dataset of oil deliveries to six UK power plant between 2009 – 2014 and to one power station in 2018 includes 36 nitrogen values for gas oil, two for LFO, 18 for HFO and 53 for PFO). For comparison with the average analysis results shown below, the LCP BREF (Table 6.2) quotes the nitrogen content of HFO as 0.16 – 0.5%.

The average nitrogen content of all gas oil samples analysed was 0.07%, but the most recent data and discussions with boiler suppliers indicate that 0.02% is a more typical value. For gas oil-fired boilers, fuel nitrogen content will directly affect NOx emissions, so limits should be agreed with fuel suppliers to ensure that NOx compliance is maintained.

The nickel and vanadium content of oil is also not routinely determined on oil deliveries (except for PFO), but again ad hoc historic analysis data is available. Values for HFO have been extracted from the Pollution Inventory database, which are consistent with values quoted in the LCP BREF for a 0.96% sulphur content HFO (<60 mg/kg V and 20 mg/kg Ni). While not required for BAT 9, average analysed values for the other oil types are presented for reference.

Table 11: Typical Oil Analysis Data (historic UK power plant analyses)

Property	Gas oil	LFO	HFO	PFO
Sulphur, %	0.03	0.60	0.92	0.45
Ash, %	0.00	0.03	0.1	0.4
Carbon, %	86.0	87.9	86.5	85.0
Nitrogen, %	0.07	0.30	0.34	0.15
Ni, mg/kg	< 1	14	20	1.5
V, mg/kg	< 1	27	28	0.7

4.3 Regular Testing

Regular testing of fuel oil properties is undertaken by suppliers to ensure compliance against specifications. Oil sampling and analysis procedures are already documented in EU ETS Monitoring Plans for sites which consume large volumes of oil. Since each product has a fixed specification, fuel quality does not vary significantly from initial characterisation.

4.4 Adjustment of Plant Settings

Fuel oil and gas oil are homogeneous products so there is no requirement to adjust plant settings to account for fuel quality variations.

4.5 Compliance with BAT 9 requirements for oil fired plants

Compliance with the BAT 9 requirements can be defined within the plant Environmental Management System as follows.

(i) Initial fuel characterisation. Fuel oils are commodity products purchased to standard specifications with very little variation in fuel quality. For NCV and carbon content, the BAT 9 requirement is satisfied by reference to the relevant fuel specifications used for EU ETS reporting, *e.g., Table 9, 11* [*]*. For sulphur and ash contents, the BAT 9 requirement is satisfied by reference to the relevant fuel specifications, *e.g., Table 9 [*]*. For nitrogen, the BAT 9 requirement is satisfied by reference to the *supplier fuel specifications**/*supplier data*/analysis data*/typical analysis data in Table 11 [*]*. For the nickel and vanadium content of HFO, the BAT 9 requirement is satisfied by reference to supplier fuel specifications*/typical analysis data in Table 11 [*]**. There is no annual reporting requirement although any available fuel quality specifications and analyses are held on site for regulatory inspection, as required.

(ii) Regular testing. Regular testing of fuel oil properties is undertaken by suppliers to ensure compliance against specifications. *Site based oil sampling and analysis procedures are already documented in the EU ETS Monitoring Plan*.* Since each product has a fixed specification, fuel quality does not vary significantly from initial characterisation. There is no ongoing reporting requirement.

(iii) Subsequent adjustment of plant settings. Fuel oil and gas oil are homogeneous products so there is no requirement to adjust plant settings to account for fuel quality variations.

[*] Insert reference to this report or reproduce the tables in the EMS or refer to local fuel specifications if different.
** Delete as applicable*

5 BIOMASS

5.1 Biomass Supply

Biomass can be a very diverse feedstock, including wood, grass, straw, cereal, manure and other organic residues. However, in the UK electricity supply industry, the dominant type of biomass utilised is white wood pellets. Most white wood pellets consumed in UK power plants are imported from Europe and North America.

5.2 Initial Characterisation

5.2.1 Specifications

Wood pellets are an established commodity product that is traded around the world. EN ISO 17225-1 provides general requirements for solid biofuels [20], while EN ISO 17225-2 provides specifications for wood pellets, for small-scale and industrial use [21]. Three grades of wood pellet are specified for industrial use, known as I1, I2 and I3 (Table 12).

Table 12: Industrial Wood Pellet Specifications (selected)

Property	I1	I2	I3
NCV, MJ/kg	> 16.5	> 16.5	> 16.5
Moisture, %	< 10	< 10	< 10
Ash, %dry	< 1.0	< 1.5	< 3.0
Durability, %	97.5 – 99.0	97.0 – 99.0	96.5 – 99.0
Fines, %	< 4.0	< 5.0	< 6.0
Nitrogen, %dry	< 0.3	< 0.3	< 0.6
Sulphur, %dry	< 0.05	< 0.05	< 0.05
Chlorine, %dry	< 0.03	< 0.05	< 0.1
As, mg/kg dry	< 2	< 2	< 2
Cd, mg/kg dry	< 1.0	< 1.0	< 1.0
Cr, mg/kg dry	< 15	< 15	< 15
Cu, mg/kg dry	< 20	< 20	< 20
Pb, mg/kg dry	< 20	< 20	< 20
Hg, mg/kg dry	< 0.1	< 0.1	< 0.1
Zn, mg/kg dry	< 200	< 200	< 200

The majority of wood pellets imported into the UK meet the I2 standard.

5.2.2 Delivered Biomass Analysis

Power plants receiving wood pellets have established fuel sampling and analysis procedures for commercial compliance. While all samples may not be analysed for all parameters, sufficient data has been collected on wood pellets to determine typical (or average) values for all parameters. Typical data, collected on fuel delivered to a UK power plant over a three year period is summarised in Tables 14 and 15.

Table 13: Wood Pellet Analysis Data: Main Parameters

Property	Typical	*Typical min*	*Typical max*
NCV, MJ/kg ar	17.5	*16.8*	*18.2*
Moisture, % ar	7.0	*5.0*	*9.0*
Ash, %dry	1.0	*0.3*	*1.6*
Carbon, %dry	51.6	*50*	*53*
Nitrogen, %dry	0.3	*0.2*	*0.4*
Sulphur, %dry	0.01	*0.01*	*0.03*
Chlorine, %dry	0.02	*0.01*	*0.03*

Table 14: Wood Pellet Analysis Data: Trace elements

Trace element	Typical mg/kg dry
F	10
Na	100
K	1000
As	0.2
Cd	0.05
Cr	2
Cu	2
Pb	1.2
Hg	<0.01
Zn	11

5.3 Regular Testing

Regular sampling and analysis of biomass is undertaken as part of normal commercial operations. For wood pellets, all of the parameters required in BAT 9 except carbon, fluorine, potassium and sodium content are included in the I2 specification and are therefore routinely tested.

Review of the analysis data ensures that fuel quality is maintained within specification and is therefore consistent with the initial characterisation. When all of the analysed parameters are consistent, it is a reasonable assumption that levels of carbon, fluorine, potassium and sodium also remain consistent.

5.4 Adjustment of Plant Settings

Biomass-fired power plants have sophisticated control systems which do account for impacts of fuel quality. In general, these systems utilise real-time plant data, rather than referring to biomass analysis data directly. For example, mill feeder speed is adjusted to deliver more biomass to mills when the boiler master pressure detects that heat input into the boiler is reducing, rather than using biomass NCV data directly.

5.5 Compliance with BAT 9 requirements for biomass fired plants

Compliance with the BAT 9 requirements can be defined within the plant Environmental Management System as follows.

(i) Initial fuel characterisation. Wood pellets are commodity products purchased to standard specifications with very little variation in fuel quality. EN ISO 17225-2 provides specifications for wood pellets for industrial use with reference to three grades (I1, I2, I3). For NCV, moisture, ash, sulphur, nitrogen and chlorine, the BAT 9 requirement is satisfied by reference to the relevant fuel specification in EN ISO 17255-2, *Table 12 [*]*. For carbon, the BAT 9 requirement is satisfied by reference to typical analysis values, *Table 13 [*]*. For the metals and metalloids trace elements (As, Cd, Cr, Cu, Hg, Pb, Zn), the BAT 9 requirement is satisfied by reference to the relevant fuel specification in EN ISO 17255-2, *Table 12 [*]*. For other trace elements (F, K, Na), the BAT 9 requirement is satisfied by reference to typical analysis values, *Table 14 [*]*.

    Any available fuel quality specifications and analyses are held on site for regulatory inspection, as required. A new biomass type that is sold to a standard specification will be treated in the same way. Otherwise, a full characterisation for all of the fuel quality parameters defined in BAT 9 is required.

(ii) Regular testing. Regular testing of wood pellet properties is undertaken by suppliers to ensure compliance with specifications. Regular sampling and analysis of biomass is also undertaken as part of normal commercial operations to ensures that fuel quality is maintained within specification and is therefore consistent with the initial characterisation. All of the parameters required in BAT 9, except carbon, fluorine, potassium and sodium content are included in the EN ISO 17225-2 specification and are therefore routinely tested. When all of the analysed parameters are consistent, it is a reasonable assumption that the remaining BAT 9 parameters also remain consistent. There is no ongoing reporting requirement.

(iii) Subsequent adjustment of plant settings. Control systems at biomass-fired power plants utilise real-time plant data that is indirectly related to the fired coal quality, rather than directly utilising fuel quality information which is taken into account for longer term planning and compliance purposes. It is not practicable to integrate fuel quality data into the control system.

[*] Insert reference to this report or reproduce the tables in the EMS.

6 SUMMARY

UK power plants have established procedures for fuel sampling and analysis to support commercial fuel valuation, and to ensure compliance with EU ETS, PI and E-PRTR emissions reporting. The routine data collected for these purposes satisfies the BAT 9 requirement to initially characterise and then regularly check the quality of fuels consumed. BAT 9 provides a list of required parameters for each fuel type; while the majority of the these are routinely determined, some (e.g. thallium and bromine in coal) are not standard parameters. For these non-standard parameters, this report provides typical values for each fuel type, which can be referenced.

Fuel quality variability is highest for coal, because coals from different countries of origin can have significantly different compositions. Coal specifications tend to be less prescriptive and there are no international standards mandating fuel quality limits. Instead, it is common for loadport analyses of individual vessel consignments to be treated like specifications for the basis for commercial transactions.

Natural gas, fuel oil and wood pellets all exhibit low fuel quality variation. International standards and regulations are established which specify precise composition limits for each of these fuels.

BAT 9 requires that plant settings are adjusted to account for fuel quality ‘as and when needed and practicable’. Power plants have very sophisticated control systems which do account for impacts of fuel quality. Specific gas turbine combustion systems utilise online analysis of natural gas in order to determine firing temperatures or to protect the combustor from auto-ignition. In these instances, the control system automatically adjusts gas turbine operation using the measured fuel properties. However, more commonly, control systems utilise real-time plant data, rather than referring to fuel analysis data directly; for example, coal mill feeder speed is adjusted to deliver more fuel to mills when the boiler master pressure detects that heat input into the boiler is reducing, rather than using the fuel Net Calorific Value analysis data directly.

For each fuel, modifications to the Environmental Management System are recommended in order to comply with the LCP BREF BAT 9 Conclusion.

7 REFERENCES

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ABBREVIATIONS

ar	As received basis
BAT	Best Available Techniques
BAT-AEL	BAT Associated Emission Level
BREF	BAT Reference document
BS	British standard
CCGT	Combined cycle gas turbine
CHP	Combined heat and power
EMS	Environmental Management System
EN	EuroNorm
E-PRTR	European Pollutant Release and Transfer Register
EU ETS	European Union Emissions Trading System
FGD	Flue Gas Desulphurisation
FMS	Fuel Management System
GC	Gas chromatograph
GS(M)R	Gas Safety (Management) Regulations,
HFO	Heavy Fuel Oil
IED	Industrial Emissions Directive
ISO	International Standards Organisation
JEP	Joint Environmental Programme of the Electricity Supply Industry
LCP	Large Combustion Plant
LFO	Light Fuel Oil
LHV	Lower Heating Value
LNG	Liquefied natural gas
NTS	National Transmission System
NCV	Net Calorific Value
PI	Pollution Inventory
PFO	Processed Fuel Oil
QP	Quality Protocol
SCoTA	Standard Coal Trading Agreement
SPRI	Scottish Pollutant Release Inventory
WRAP	Waste and Resources Action Programme

Fuel and flue gas components		**Trace metals/metalloids**	
A	Ash	As	Arsenic
FC	Fixed carbon	B	Boron
M	Moisture	Be	Beryllium
VM	Volatile Matter	Cd	Cadmium
C	Carbon	Cr	Chromium
H	Hydrogen	Co	Cobalt
O	Oxygen	Cu	Copper
N	Nitrogen	Hg	Mercury
S	Sulphur	Mn	Manganese
Br	Bromine	Mo	Molybdenum
Cl	Chlorine	Ni	Nickel
F	Fluorine	Pb	Lead
CH_4	Methane	Sb	Antimony
HCl	Hydrogen chloride	Sn	Tin
HF	Hydrogen fluoride	Tl	Thallium
NO_x	Nitrogen oxides	V	Vanadium
SO_2	Sulphur dioxide	Zn	Zinc