Air Quality
CONSULTANTS

Detailed Assessment of Biomass Boiler in Haunton - Lichfield District Council

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Experts in air quality
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Lichfield District Council confirms that it accepts the recommendations made in this report.

1 Introduction

1.1 Air Quality Consultants Ltd has been commissioned by Lichfield District Council to undertake a Detailed Assessment of a biomass boiler, burning Miscanthus, in Haunton. Miscanthus, which is commonly known as Elephant Grass, is a high yielding energy crop that produces a crop every year without the need for replanting.

1.2 In 2012, Lichfield District Council completed an Updating and Screening Assessment for air quality, which concluded that a Detailed Assessment was required following a screening assessment of emissions of PM_{10} and nitrogen dioxide from a biomass boiler in Haunton.

1.3 The aim of this Detailed Assessment is to determine whether the annual mean nitrogen dioxide and daily mean PM_{10} objectives are likely to be exceeded at relevant locations and, if so, the extent of those exceedences in order to determine the boundary of the Air Quality Management Area (AQMA) that would be required. In order to be thorough, the assessment also includes annual mean PM_{10} and hourly mean nitrogen dioxide.

Background

1.4 The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Defra, 2007) sets out a framework for air quality management, which includes a number of air quality objectives. National and international measures are expected to achieve these objectives in most locations, but where areas of poor air quality remain, air quality management at a local scale has a particularly important role to play. Part IV of the Environment Act 1995 requires local authorities to periodically review and assess air quality in their areas. The role of this process is to identify areas where it is unlikely that the air quality objectives will be achieved. These locations must be designated as AQMAs and a subsequent Air Quality Action Plan (AQAP) developed in order to reduce pollutant emissions in pursuit of the objectives.

1.5 Review and Assessment is a long-term, ongoing process, structured as a series of 'rounds'. Local Authorities in England, Scotland and Wales have now completed the first, second, third and fourth rounds of Review and Assessment, with the fifth round currently underway.

1.6 Technical Guidance for Local Air Quality Management (LAQM.TG(09)) (Defra, 2009) sets out a phased approach to the Review and Assessment process. This prescribes an initial Updating and Screening Assessment (USA), which all local authorities must undertake. It is based on a checklist to identify any matters that have changed since the previous round. If the USA identifies any areas where there is a risk that the objectives may be exceeded, which were not identified in the previous round, then the Local Authority should progress to a Detailed Assessment.

1.7 The purpose of the Detailed Assessment is to determine whether an exceedence of an air quality objective is likely and the geographical extent of that exceedence. If the outcome of the Detailed Assessment is that one or more of the air quality objectives are likely to be exceeded, then an AQMA must be declared. Subsequent to the declaration of an AQMA, a Further Assessment should be carried out to confirm that the AQMA declaration is justified; and that the appropriate area has been declared; to ascertain the sources contributing to the exceedence; and to calculate the magnitude of reduction in emissions required to achieve the objective. This information can be used to inform an Air Quality Action Plan, which will identify measures to improve local air quality.

1.8 This report represents a Detailed Assessment in the fifth round of Review and Assessment, following the findings of Lichfield District Council's USA published in 2012, which concluded that there was a risk of nitrogen dioxide and PM_{10} objectives being exceeded at locations of relevant exposure (AECOM, 2012).

The Air Quality Objectives

1.9 The Government's Air Quality Strategy (Defra, 2007) provides air quality standards and objectives for key air pollutants, which are designed to protect human health and the environment. The 'standards' are set as concentrations below which health effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of a particular pollutant. The 'objectives' set out the extent to which the Government expects the standards to be achieved by a certain date. They take account of the costs, benefits, feasibility and practicality of achieving the standards. The objectives are prescribed within The Air Quality (England) Regulations 2000 (Stationary Office, 2000) and The Air Quality (England) (Amendment) Regulations 2002 (Stationary Office, 2002). Table 1 summarises the objectives which are relevant to this report. Appendix A1 provides a brief summary of the health effects of nitrogen dioxide and PM_{10}.

Table 1: Air Quality Objectives for Nitrogen Dioxide

Pollutant	Time Period	Objective
Nitrogen Dioxide	1-hour mean	200 $\mu g/m^3$ not to be exceeded more than 18 times a year[a]
	Annual mean	40 $\mu g/m^3$
Fine Particles (PM_{10})	24-hour mean	50 $\mu g/m^3$ not to be exceeded more than 35 times a year[b]
	Annual mean	40 $\mu g/m^3$

[a] This approximates to the 99.8th percentile of the hourly mean concentrations

[b] This approximates to the 90th percentile of the daily mean concentrations

1.10 For a year of complete data, the 99.8th percentile of 1-hour mean concentrations corresponds with the 19th highest hour - which in turn corresponds with the 1-hour mean objective for nitrogen dioxide (which allows 18 exceedences of 200 $\mu g/m^3$ as a 1-hour mean). Similarly, the 90th percentile of 24-hour mean concentrations corresponds with the 36th highest daily mean - which in turn corresponds with the 24-hour objective for PM_{10} (which allows no more than 35 exceedences of 50 $\mu g/m^3$ as a daily mean concentration).

1.11 The air quality objectives only apply where members of the public are likely to be regularly present for the averaging time of the objective (i.e. where people will be exposed to pollutants). For annual mean objectives, relevant exposure is limited to residential properties, schools and hospitals. The 1-hour objective applies at these locations as well as at any outdoor location where a member of the public might reasonably be expected to stay for 1 hour or more, such as shopping streets, parks and sports grounds, as well as bus stations and railway stations that are not fully enclosed.

2 Assessment Methodology

Monitoring

2.1 Lichfield District Council does not carry out any air quality monitoring in the vicinity of Haunton; therefore this assessment is based on dispersion modelling.

Modelling

2.2 Annual mean nitrogen dioxide and PM_{10} concentrations, as well as the 99.8th percentile of 1-hour mean concentrations of nitrogen dioxide, and the 90th percentile of 24-hour mean concentrations of PM_{10}, have been predicted using detailed dispersion modelling (ADMS-5). ADMS-5 is a new generation model that incorporates a state-of-the-art understanding of the dispersion processes within the atmospheric boundary layer. Entrainment of the plume into the wake of buildings has been simulated within the model. The input data used are described in Appendix A2.

2.3 Concentrations have been predicted at a number of worst-case receptor locations (Figure 1) as well as a grid of receptors across the study area. Concentrations were predicted at 1.5 m and 4.5 m heights to represent ground and first floor window height.

Figure 1 Location of Specific Receptors, Flue and Buildings

Uncertainty

2.4 Uncertainty is inherent in all measured and modelled data. All values presented in this report are the best possible estimates, but uncertainties in the results might cause over- or under-predictions. Emission data were not available for the boiler in question (Dragon D35) using Miscanthus as a fuel, which necessitated a number of assumptions in the model set-up. As there is limited information available regarding Miscanthus as a fuel source, the decision was made to model a number of scenarios in order to ensure that the worst case assumptions could be considered. Further details of the emissions data used are provided in Appendix A2.

2.5 Data such as the height, usage and burn-rate have been provided by the plant operator, and any uncertainties inherent in these data will carry into this assessment. There will be additional uncertainties introduced because the modelling has simplified real-world processes into a series of algorithms. For example: it has been assumed that wind conditions measured at East Midlands Airport during 2012 will have occurred throughout the study area during 2012; and it has been assumed that the dispersion of emitted pollutants will conform to a Gaussian distribution over flat terrain.

2.6 The limitations to the assessment should be borne in mind when considering the results set out in the following sections. Given the number of conservative assumptions that have had to be made, the model output will present a worst case picture which can be used to screen out impacts. Details of the assumptions used in this assessment are provided in Appendix A2.

3 Results

Modelling

3.1 Predicted annual mean nitrogen dioxide concentrations, together with the predicted 99.8th percentile of 1-hour mean concentrations in 2012, are set out in Table 2 and Table 3. These predictions are shown for each of the first floor receptor locations shown in Figure 1, along with the highest concentration predicted at any of the grid locations. Results for ground floor receptors were slightly lower than those predicted at the first floor. Results are shown for each of the emissions factors calculated from different sources. The data and method used to calculate each of these emission factors is shown in Appendix A2. Predicted concentrations are below or well below the relevant objective at all receptors.

Table 2: Modelled Annual mean (µg/m^3) Nitrogen Dioxide Concentrations Calculated using each of four Emission Factors[a]

Emission Factor / Receptor	Straw Emission Factor	Measured Wood Fuelled Emissions	Standard Emissions from Biomass Boiler	Miscanthus and Straw Emissions
1	32.5	32.4	32.3	32.5
2	32.3	32.3	32.2	32.3
3	32.3	32.2	32.2	32.3
4	32.6	32.4	32.3	32.6
Grid	32.7	32.2	32.4	32.7
Objective	**40**			

[a] Full details of the different emission factors used are provided in Appendix A2.

Table 3: Modelled 99.8th percentile of hourly mean (µg/m^3) Nitrogen Dioxide Concentrations Calculated using each of four Emission Factors[a]

Emission Factor / Receptor	Straw Emission Factor	Measured Wood Fuelled Emissions	Standard Emissions from Biomass Boiler	Miscanthus and Straw Emissions
1	134.7	134.4	131.9	134.6
2	134.6	134.3	130.8	134.6
3	134.5	132.7	128.9	134.4
4	134.6	134.4	131.5	134.6
Grid	134.8	134.5	134.3	134.8
Objective	**200**			

[a] Full details of the different emission factors used are provided in Appendix A2.

3.2 Predicted annual mean PM_{10} concentrations as well as the 90th percentile of daily average concentrations in 2012 at each of the receptor locations and for each of the emission factors calculated in Appendix A2 are set out in Table 3 and Table 4. Predicted concentrations are well below the relevant objective at all receptors.

Table 4: Modelled Annual Mean (µg/m³) PM_{10} Concentrations Calculated using each of three Emission Factors[a]

Emission Factor / Receptor	Straw Emission Factor	Standard Emissions from Biomass Boiler	Miscanthus and Straw Emissions
1	22.2	18.7	18.7
2	20.2	18.7	18.7
3	19.7	18.7	18.7
4	22.6	18.8	18.8
Grid	23.9	18.8	18.8
Objective	40		

[a] Full details of the different emission factors used are provided in Appendix A2.

Table 5: Modelled 99.8th percentile of hourly mean (µg/m³) PM_{10} Concentrations Calculated using each of three Emission Factors[a]

Emission Factor / Receptor	Straw Emission Factor	Standard Emissions from Biomass Boiler	Miscanthus and Straw Emissions
1	36.3	32.8	32.8
2	34.3	32.8	32.8
3	33.8	32.8	32.8
4	36.7	32.8	32.8
Grid	38.2	32.9	32.9
Objective	50		

[a] Full details of the different emission factors used are provided in Appendix A2.

3.3 Predicted annual mean and 99.8th percentile of 1-hour mean concentrations of nitrogen dioxide are below the relevant objectives at all locations modelled across the grid of receptors. Predicted annual mean and 90th percentile of daily mean concentrations of PM_{10} are well below the relevant objective at all locations. Isopleth maps have therefore not been produced for either pollutant.

4 Conclusions and Recommendations

4.1 A Detailed Assessment has been carried out for nitrogen dioxide and PM_{10} within Haunton, Lichfield. This area was identified as being at risk of exceeding the annual mean air quality objective for nitrogen dioxide and the daily mean PM_{10} objective in Lichfield District Council's 2012 Updating and Screening Assessment due to the presence of a biomass boiler. An assessment of the hourly mean nitrogen dioxide and annual mean PM_{10} concentrations has been included for completeness.

4.2 The Detailed Assessment has been carried out using modelled concentrations. Concentrations of nitrogen dioxide and PM_{10} have been modelled for 2012 using the ADMS-5 dispersion model.

4.3 The assessment has identified that the annual mean and short-term objectives for nitrogen dioxide and PM_{10} are not exceeded.

4.4 There is some uncertainty regarding the modelled concentrations, however, this is strongly biased in favour of overestimating concentrations and it is therefore likely that concentrations are lower than those shown.

4.5 Based on the modelled results, there is no need to declare an AQMA for either pollutant. No further action is required regarding this biomass boiler.

5 References

AEA (2008) *Technical Guidance: Screening assessment for biomass boilers*.

AECOM (2012) *2012 Air Quality Updating and Screening Assessment for Lichfield District Council*.

Defra (2007) *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland*, Defra.

Defra (2009) *Review & Assessment: Technical Guidance LAQM.TG(09)*, Defra.

Defra (2013a) *Defra Air Quality Website*, [Online], Available: http://www.defra.gov.uk/environment/quality/air/airquality/.

Defra (2013b) *Defra AURN Archive*, [Online], Available: aurn.defra.gov.uk.

Department for Trade and Industry (2003) *Miscanthus: Practical Aspects of Biofuel Development*.

EMEP and EEA (2009) *Air Pollutant Emission Inventory Guidebook*.

Environment Agency (2005) *CONVERSION RATIOS FOR NOX AND NO2*, [Online], Available: .

Environment Agency (2011) *Environment Agency 2011. Horizontal Guidance Note H1 – Annex (f) published at www.environment-agency.gov.uk* .

Stationary Office (2000) *The Air Quality Regulations, 2000, Statutory Instrument 928*, HMSO, London.

Stationary Office (2002) *The Air Quality (England) (Amendment) Regulations, 2002, Statutory Instrument 3043*, HMSO.

6 Glossary

ADMS-5	Atmospheric Dispersion Modelling System for Point Sources
AQMA	Air Quality Management Area
AURN	Automatic Urban and Rural Network
Defra	Department for Environment, Food and Rural Affairs
Exceedence	A period of time where the concentration of a pollutant is greater than the appropriate air quality objective.
LAQM	Local Air Quality Management
$\mu g/m^3$	Microgrammes per cubic metre
NO_X	Nitrogen oxides (taken as NO + NO_2)
NO	Nitric Oxide
NO_2	Nitrogen dioxide.
Objectives	A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date, taking into account costs, benefits, feasibility and practicality. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides.
PM_{10}	Small airborne particles, more specifically particulate matter less than 10 micrometres in aerodynamic diameter
Standards	A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal.

A1 Appendix 1 – Summary of Health Effects of Nitrogen Dioxide and Particulate Matter

Table A1: Summary of Health Effects of Nitrogen Dioxide and Particulate Matter

Pollutant	Main Health Effects
Nitrogen Dioxide	Short-term exposure to high concentrations may cause inflammation of respiratory airways. Long term exposure may affect lung function and enhance responses to allergens in sensitised individuals. Asthmatics will be particularly at risk (Defra, 2007).
Particulate Matter (PM_{10})	Both short-term and long-term exposure to ambient levels of PM are consistently associated with respiratory and cardiovascular illness and mortality as well as other ill-health effects. The associations are believed to be causal. It is not currently possible to discern a threshold concentration below which there are no effects on the whole population's health (Defra, 2007).

A2 Appendix 2 – Dispersion Modelling Methodology

Meteorological Data

A2.1 The model has been run using a full year of meteorological data for 2012 from the meteorological station near East Midlands Airport.

Background Concentrations

A2.1 Two separate sources have been used to estimate background pollutant concentrations; national pollution maps published by Defra (Defra, 2013a) and background concentrations measured at the Urban Background Automatic Monitor run by AURN at Birmingham, Tyburn (Defra, 2013b).

A2.2 Background concentrations measured at the Birmingham, Tyburn AURN site have been downloaded from the Defra AURN website (Defra, 2013b). These data have been used to calculate the NO_2 and PM_{10} annual mean, the 99.8th percentile of hourly 'background' total oxidant, the 99.8th percentile of hourly 'background' NO_2 and the 90th percentile of 24-hour 'background' PM_{10} concentrations.

A2.3 The measured data from the Birmingham Tyburn monitor have been used in preference to the mapped background as this is worst case.

A2.4 The backgrounds used in this assessment are shown in Table A2.

Table A2: Background Concentrations (2012)

	Measured (µg/m^3)	Mapped (µg/m^3)[a]
NO_2 Annual Mean	**32.2**	10.5 – 10.7
Total oxidant (NO_2 + O_3) 99.8th percentile of hourly concentrations	**134.0**	-
NO_2 99.8th percentile of 1-hour mean concentrations	**122.0**	-
PM_{10} Annual Mean	**18.6**	15.7 – 15.9
PM_{10} 90th percentile of 24-hour mean concentrations	**32.7**	-

[a] The area lies within a number of grid squares.

Model Inputs

A2.5 The impacts of emissions from the biomass boiler have been predicted using the ADMS-5 dispersion model. ADMS-5 is a new generation model that incorporates a state-of-the art understanding of the dispersion processes within the atmospheric boundary layer. The model was run to predict the contribution of the biomass boiler emissions to annual mean concentrations of nitrogen oxides and PM_{10}, the 99.8th percentile of 1-hour mean nitrogen oxides concentrations, and the 90th percentile of 24-hour mean PM_{10} concentrations.

A2.6 Defra have no published emission factors for biomass boilers burning Miscanthus, and emission testing has not been carried out for the Dragon D35 boiler using this fuel. Requests for further information from the LAQM helpdesk and from the NAEI identified that there is very little data available for this emission source and therefore an alternative approach was used. This approach was to model using a variety of emission factors to represent likely worst-case scenarios:

- Based on the properties of Miscanthus, it is expected that emissions are higher than emissions from wood burning sources, but lower than straw. As a worst case assessment, emissions data for straw burning provided by the LAQM helpdesk were applied to the bales of Miscanthus used in this boiler.
- Emission testing has been carried out for Dragon D35 biomass boilers burning wood. It is likely that applying emission factors from this source for modelling a boiler burning Miscanthus would underestimate the impact on local air quality, however, this was included in order to fully explore the possible outcomes.
- Following the advice of NAEI, the emission factor for biomass boilers provided in the Air Pollutant Emission Inventory Guidebook (EMEP and EEA, 2009) was included in the assessment. As this is based on wood burning biomass, it is expected that this will underestimate emissions.

- The Department of Trade and Industry (DTI) has carried out research into the possible use of Miscanthus as a large scale energy crop (Department for Trade and Industry, 2003) at the Elean plant near Ely. This research was carried out at a large scale (36MW) biomass burning facility which has been optimised to burn straw. During the trial, a mix of approximately equal parts straw and Miscanthus was burned. Given the substantial differences in scale and design between the two facilities, it is unlikely that emissions at the Elean facility accurately reflect those in Haunton, however, it does indicate the scale of the emission.

A2.7 The building dimensions and flue location were obtained from drawings provided by Lichfield District Council. The location of the flue is shown in Figure 1. The flue has been modelled at a height of 10.45 m (5.45 m above the barn roof level).

A2.8 The following assumptions have been made regarding the Miscanthus biomass boiler:

(a) The boiler operates throughout the year;

(b) The boiler burns fuel at a rate of 1 x 0.63 tonne bale per day in the winter (Oct to May) and 1 x 0.63 tonne bale per 2 days in the summer (June to Sept) ; and

(c) The boiler operates between 8 am and 4 pm every day.

A2.9 The parameters entered into the model are shown in Table A3 and Table A4.

Table A3: Biomass Boiler Model Input Parameters for Nitrogen Oxides

Parameter	Straw Emission Factor	Measured Wood Fuelled Emissions	Standard Emissions from Biomass Boiler	Miscanthus and Straw Emissions
Emission rate (g/s)	0.035[a]	0.020	0.013	0.034
Boiler capacity (kW)	456			
Temperature (deg C)	80[b]			
Flue height above ground (m)	10.45			
Stack Diameter (m)	0.3			
Exit Velocity (m/s)	2.3[c]			
Operation	8 hours a day, throughout the year			

[a] Calculated using the emission rate provided by LAQM helpdesk in ktonne pollutant / Mtonne fuel, assuming fuel is consumed at capacity (1 x 0.63 tonne bales / day at full power).

[b] Minimum temperature in range provided by boiler operator.

[c] The exit velocity was estimated based on the information in Technical Guidance: Screening assessment for biomass boilers (AEA, 2008).

Table A4: Biomass Boiler Model Input Parameters for PM_{10}

Parameter	Straw Emission Factor	Standard Emissions from Biomass Boiler	Miscanthus and Straw Emissions
Emission rate (g/s)	0.241[a]	0.007	0.006
Boiler capacity (MW)	456		
Temperature (deg C)	80[b]		
Flue height above ground (m)	10.45		
Stack Diameter (m)	0.3		
Exit Velocity (m/s)	2.3[c]		
Operation	8 hours a day, throughout the year		

[a] Calculated using the emission rate provided by LAQM helpdesk in ktonne pollutant / Mtonne fuel, assuming fuel is consumed at capacity (1 x 0.63 tonne bales / day at full power).

[b] Minimum temperature in range provided by boiler operator.

[c] The exit velocity was estimated based on the information in Technical Guidance: Screening assessment for biomass boilers (AEA, 2008).

A2.10 Entrainment of the plume into the wake of the barn (adjacent to the boiler, 5 m high) and the five nearest buildings (7 and 4 m high) has been taken into account in the model. This entrainment is known as the building downwash effect. The buildings included in the model are shown in Figure 1.

Post-Processing

A2.11 Emissions from the biomass plant will be predominantly in the form of nitrogen oxides (NO_x) and $PM_{10.}$

A2.12 ADMS-5 was run to predict the contribution of the boiler emissions to annual mean concentrations of nitrogen oxides and PM_{10} as well as to the 99.8th percentiles of 1-hour mean nitrogen oxides and 90^{th} percentiles of 24-hour mean concentrations. The approach recommended by the Environment Agency (Environment Agency, 2005) was used to predict annual mean nitrogen dioxide concentrations and 99.8^{th} percentiles of 1-hour mean nitrogen dioxide concentrations. This assumes that:

- Annual mean nitrogen dioxide concentrations = Annual mean nitrogen oxides x 0.7; and
- 99.8^{th} percentiles of 1-hour mean nitrogen dioxide concentrations = 99.8^{th} percentiles of 1-hour mean nitrogen oxides x 0.35.

Long-term

A2.13 Where long-term (annual mean) objectives need to be assessed the following post-processing has been carried out:

- Nitrogen dioxide – calculated as the sum of the nitrogen dioxide background concentration and the nitrogen dioxide process contribution;
- PM_{10} - calculated as the sum of the PM_{10} background concentration and the PM_{10} process contribution.

Short-term

A2.14 In order to predict total 1-hour mean nitrogen dioxide concentrations, the worst-case approach set out in LAQM TG(09) has been followed, which is summarised as follows: The 99.8th percentile of total hourly nitrogen dioxide concentrations is equal to the minimum of either G or H, where H is the maximum of either H1 or H2, and where:

G = 99.8th percentile hourly 'background' total oxidant + 0.05 x 99.8th percentile process contribution NOx concentration

H1 = 99.8th percentile process contribution NOx + 2 x 'background' annual mean nitrogen dioxide concentration

H2 = 99.8th percentile hourly 'background' nitrogen dioxide + 2 x annual mean process contribution NOx concentration

A2.15 In order to predict the 90th percentile of 24-hour mean PM_{10} concentrations to determine compliance with the 24-hour objective, the worst-case approach set out by (Defra, 2009) has been followed. This states that the 90th percentile total 24-hour mean PM_{10} concentration is equal to the maximum of either K or L where:

K = 90th percentile 24-hour mean 'background' PM_{10} + annual mean process PM_{10}

L = 90th percentile 24-hour mean process contribution + annual mean 'background' contribution