BAT and Options Appraisal for Biomass Generation

Lynemouth Power Station

Lynemouth Power Limited

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Quality information

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1. Executive Summary

AECOM has been commissioned by Lynemouth Power Limited (LPL) to undertake an assessment of the Lynemouth Power Plant against the requirements of the revised Large Combustion Plant Best Available Techniques Reference document ("LCP BRef"), published in 2017. This document presents the assessment of application of BAT for the control of NO_x and dust (as total particulate matter) from the biomass combustion conversion project at the Lynemouth Power Station. This report should be read in conjunction with the Technical Evaluation of BAT for NOx and particulate control.

The overall gross output capacity of the biomass power station will be up to 420MWe. The existing plant and equipment for the coal fired power station was retrofitted over the period 2016/17 to enable 100% biomass-fired combustion. Additional measures to improve the efficiency of biomass combustion such as low NO_x burners and use of Boosted Over Fire Air (BOFA) have been implemented at the power station. The existing Electrostatic Precipitators (ESPs) have also been upgraded to improve control of dust (as total particulate matter) from the combustion of biomass. It is expected that the additional process improvements will enable the achievement of the IED Annex V emission limits for NO_x and dust by the power plant.

The retrofitted power station and additional associated measures, whilst meeting the Annex V emission limit values (ELVs) contained within the Industrial Emissions Directive (IED) will however not achieve the revised LCP BRef BAT-AELs for emissions of NO_x and dust of 160mg/Nm^3 and 10mg/Nm^3 respectively.

The plant is considered to be an existing combustion plant[1] under the definitions of 2017/1442/EU[2], as the installation was commissioned during 1972, has operated under an environmental permit since the introduction of the Integrated Pollution Prevention and Control (IPPC) regime and was permitted to operate firing 100% biomass on 28/07/2011 (EPR/BL6861IT/V009). As an existing combustion plant in operation prior to 7th January 2014, the applicable upper limit of the BAT-AEL for annual NO_x emissions from the Lynemouth Power Station is 160mg/Nm^3, in compliance with footnote 7 of Table 10.9 of the LCP BRef; this assessment has therefore been undertaken with a limit of 160mg/Nm^3 as a conservative baseline for the BAT scenario.

This assessment was undertaken to assess the potential additional BAT techniques that could be implemented at the installation to control NO_x and dust emissions to achieve the upper range of the LCP BAT-AELs. The associated technical review document[3] sets out the feasibility of whether additional abatement measures could in fact achieve the LCP BAT-AELs and concludes that it is highly unlikely that the installation would be able to achieve the BAT-AELs for NO_x and dust through the installation of additional abatement measures, based on the plant configuration. However, for the purpose of this assessment, these secondary abatement techniques have been assumed to be able to control of emissions of NO_x and dust emissions to meet the BAT-AELs, using theoretical abatement efficiencies and not considering the technical limitations to the performance of the abatement systems, in line with a conservative approach.

A BAT assessment and Cost Benefit Assessment (CBA) has been carried out in order to identify the BAT option for the retrofitted power station, in terms of the benefits of using primary measures to achieve IED Annex V limits when considered against the relative change in NO_x and dust emissions theoretically associated with the use of additional secondary abatement to achieve BAT-AELs. This includes consideration of the installation of SNCR and SCR abatement for NO_x emissions and of additional ESP upgrades for particulate control.

The viability of installing a bag filter system, identified by the LCP BRef as generally having a better dust removal performance than ESPs for large combustion plants, at the Lynemouth installation was also reviewed as part of this assessment. The guidance from the LCP BRef suggests that although generally applicable to large combustion plants, bag filters pose issues when used for biomass fired plants without supplementary equipment to prevent unburnt carbon in ash and sparks from reaching the filters. This is due to biomass fuels typically having a higher content of unburnt carbon in ash; the fuel being used at the Lynemouth installation has a design performance level of 30% for unburnt carbon in ash, which is significant. The installation of the additional

[1] Plant – existing: A combustion plant that is not a new plant, where; Plant – new: A combustion plant first permitted at the installation following the publication of these BAT conclusions or a complete replacement of a combustion plant on the existing foundations following the publication of these BAT conclusions
[2] Commission Implementing Decision (EU) 2017/1442 establishing best available techniques (BAT) conclusions, under Directive 2010/72/EU of the European Parliament and of the Council, for large combustion plants
[3] Technical Brief on Application of BAT for NOx and Particulates (document reference: 60565526-430-000-RP-PE-00001), AECOM for LPL, October 2018

techniques recommended by the LCP BRef, such as pre-coating of the filter fabric and installing a pre-collector upstream of the bag filter, require considerable space for installation as well as supplementary controls, which is difficult for retrofitted plants like the Lynemouth installation. It is recognised by the LCP BRef that in the absence of the additional preventative measures, there is a significant health and safety risk due to the likelihood of the bag filter catching fire in a biomass fired plant. The installation of bag filters at the installation was therefore discounted from this assessment. This is discussed in more detail in the Technical Report.

The BAT assessment evaluates the relative costs, energy use, reagent usage and ammonia slip impacts (for NO_x abatement measures), costs for the disposal of increased quantities of ammoniated ash as hazardous waste, and the impact on the quality of the fly ash produced by additional dust abatement measures for each of the options considered. The BAT assessment and Environment Agency CBA tool have been completed based on data provided by guidance from the LCP BRef document, the technology providers and the LPL project engineers.

The CBA tool for the NO_x emissions assessment demonstrates that the use of secondary measures such as SNCR/ SCR for abatement, in addition to the installed primary measures, to theoretically achieve compliance with the BAT-AEL upper range for NO_x of 160mg/Nm^3 shows disproportionate additional costs when considering the environmental benefit gained from the additional NO_x removed over the application of primary measures only, that achieve the design specification ELV for NO_x of 200mg/Nm^3. It should be noted that as the plant is in the process of undergoing combustion optimisation and performance guarantee testing and the achievable emissions performance of the power station is still to be determined. It must be stressed that this assessment is based on the assumption that implementation of additional abatement measures such as SNCR and SCR is technically feasible and will theoretically be able to achieve the required BAT-AEL, when, as outlined in the technical review document, in reality it is unlikely that these options can viably be implemented or achieve the BAT-AEL at the LPL installation.

The CBA tool for the dust emissions assessment demonstrates that Option 3 (i.e. the installation of additional ESP upgrades, in order to achieve compliance with the BAT-AEL for dust of 10mg/Nm^3) shows a disproportionate cost when considering the theoretical environmental benefit gained from the additional dust removed over the application of the current ESPs, which achieve the design dust emissions performance of 20mg/Nm^3. This is due to the additional CAPEX and OPEX of introducing the additional fields and the additional energy consumption from the operation of the abatement plant. As with the techniques for additional abatement of NO_x emissions, it must be noted that that the installation of additional dust abatement measures is technically not viable for the LPL installation, and is not considered to be able to achieve the required BAT-AEL.

Any upgrades to the installation to implement supplementary NOx and dust abatement would require extended major outages for the power station, over and above scheduled planned major outages, which would lead to loss of electricity generation revenue for the plant for the duration of the additional outages. Indicative revenue losses during these additional outages have been included in the CBA assessment.

The projected remaining lifetime of the power plant is less than 10 years, i.e. to the end of the Contract for Difference (CfD) contract with the Low Carbon Contracts Company (LCCC) in March 2027, which further renders the environmental benefits achieved by lower emissions of NO_x and dust not commensurate with the high level of additional CAPEX and OPEX costs.

This assessment therefore demonstrates that even if the installation were technically capable of meeting the BAT-AEL, the costs would still be disproportionate to the benefits of the reduced NO_x and dust emissions.

The abatement techniques currently installed at the installation for both NO_x and dust abatement comprising the use of the upgraded primary measures within the boilers for NO_x abatement, and operation of the upgraded existing ESPs, both of which will achieve the respective limits set by Annex V of IED, represent the options that are considered to represent BAT for the installation.

Consequently, LPL are applying for a derogation from the BAT-AEL for NO_x and dust emissions, based upon the technical characteristics of the installation that prevent compliance with the relevant BAT-AEL values and the limited environmental benefit of installing secondary abatement given the remaining lifetime of the plant. The proposed derogation values are set out within this derogation application.

These derogations are being applied for until the end of the existing generation contract in March 2027. Justification for this position is set out elsewhere in the derogation application.

2. Introduction

AECOM Infrastructure & Environment UK Ltd ("AECOM") has been commissioned by Lynemouth Power Limited ("LPL") to undertake an assessment of the application of Best Available Techniques (BAT) for the conversion of the existing power station from coal-fired to biomass-fired.

LPL has permanently converted the three 140MWe coal-fired units at Lynemouth Power Station, located in Ashington, Northumberland, to 100% biomass-firing. This converted power station utilises a sustainable biomass fuel source and significantly decreases the emissions associated with the power station. The overall gross output capacity following biomass conversion will be up to 420MWe.

The Large Combustion Plant BAT Reference document (LCP BRef)[4] sets out the expected emission levels associated with the application of Best Available Techniques (BAT-AELs) across a range of combustion technologies and feedstocks, including biomass.

The design for the biomass combustion units is capable of meeting the emissions limit values (ELVs) set by Annex V of the Industrial Emissions Directive (IED) for oxides of nitrogen (NO_x) and dust (as total particulate matter) as set out within the Industrial Emissions Directive (IED) through the use of upgraded primary control measures and the existing secondary abatement techniques applied at the plant. Compliance however with the recently issued LCP BRef BAT-AELs would require additional abatement techniques.

A BAT assessment and cost benefit analysis (CBA) has been carried out in order to identify BAT for the biomass fired Lynemouth Power Station, in terms of the costs of the application of the potential techniques to achieve the BAT-AELs against the relative change in NO_x and dust emissions.

[4] European Commission. (2017). Best Available Techniques (BAT) Reference Document for Large Combustion Plants, Joint Research Centre, 2017.

3. Background Information

3.1 Regulatory Requirements

3.1.1 Existing Plant and New Plant Emission Limit Values (ELVs)

The Lynemouth power plant has been in operation since 1972, with original operations comprising coal fired combustion. However, the coal-fired operations at the plant ceased in December 2015 in order to allow for the conversion of the plant to combust biomass instead of coal. The environmental permit (EPR/BL6861IT and subsequently EPR/FP3137CG) was determined prior to the publication of the revised Large Combustion Plant BRef (LCP-BRef) and the associated BAT Conclusions (BATc). The plant is therefore considered to be an existing combustion plant[5] under the definitions under the definitions of 2017/1442/EU[6], where the installation was commissioned during 1972, has operated under an environmental permit since the introduction of the IPPC regime, and was permitted to operate firing 100% biomass on 28th July 2011 (EPR/BL6861IT/V009).

The conversion, comprising retrofitting of existing plant and equipment, is now complete, with combustion optimisation and performance guarantee testing currently in progress. It should be noted that although the fuel handling and combustion systems have been upgraded to suit the combustion of the biomass fuel, the retrofits have been installed within the constraints of the existing plant infrastructure and significant aspects of the installation have not been modified to any extent, e.g. the furnaces.

Footnotes (7) and (8) of Table 10.9 of the LCP-BRef establishing BAT-AELs for NO_x emissions to air from the combustion of solid biomass in the Large Combustion Plant BRef specifies alternative upper range BAT-AELs for existing plants in operation prior to 7th January 2014. Based on the regulatory definition of 'plant – existing' within the LCP Bref Conclusions (2017/1442/EU), the extent of the upgrades undertaken for biomass-firing and the environmental permitting history of the installation, LPL considers that the applicable upper range of the BAT-AELs for NO_x emissions are those specified under footnotes (7) and (8) of Table 10.9.

3.1.2 Industrial Emissions Directive: Chapter III and Annex V

The Industrial Emissions Directive (European Council Directive 2010/75/EU) (IED) forms the basis of regulation for Large Combustion Plant (LCP) (combustion units >50MWth), such as the existing Lynemouth Power Station.

The IED lays down rules on integrated prevention and control of pollution arising from specified industrial activities (listed as Annex 1 within the Directive) which are designed to prevent or, where that is not practicable, to reduce emissions into air, water and land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole.

Central to the principle of the IED is the requirement for operators to take appropriate preventative measures against pollution through the application of Best Available Techniques (BAT).

Chapter III and Annex V, Part 1 of the IED sets out the expected performance requirements for Large Combustion Plant which were in operation before 1st January 2016, and specifically includes monthly average Emission Limit Values (ELVs) for combustion gases. Limits for daily and hourly averages are set at 110% and 200% of these ELVs respectively.

The ELVs provided in Annex V of the IED which are applicable to the Lynemouth Power Station are presented in Table 3-1.

[5] Plant – existing: A combustion plant that is not a new plant, where; Plant – new: A combustion plant first permitted at the installation following the publication of these BAT conclusions or a complete replacement of a combustion plant on the existing foundations following the publication of these BAT conclusions
[6] Commission Implementing Decision (EU) 2017/1442 establishing best available techniques (BAT) conclusions, under Directive 2010/72/EU of the European Parliament and of the Council, for large combustion plants

Table 3-1: IED Annex V, Parts 1 and 4 – Emission Limit Values (ELVs) for Biomass Generation

Combustion Unit	Pollutant	Monthly Average ELV (mg/Nm^3)
Solid fuels – biomass >300MW_{th}	SO_2	200
	NO_x	200
	Dust	20

The detailed engineering design, contract placement and commencement of works for the conversion of the Lynemouth Power Station from coal to biomass feedstock was developed prior to the publication of the revised Large Combustion Plant BRef note and BAT Conclusions. Therefore, in view of uncertainty of the final applicable BAT-AELs in the revised BRef at that time, the conversion project was designed to comply with the emission limit values defined in the Industrial Emissions Directive (IED) as presented above.

3.1.3 Large Combustion Plant BRef and BAT Conclusions

European BAT Reference documents, or BRefs, have been drawn up for each of the principal sectors defined within the IED, to provide guidance on the techniques that may be considered to represent BAT. The Final BRef for Large Combustion Plant was published by the European Commission at the end of July 2017. In addition to the BRef, clarification of the requirements for BAT is published in a BAT Conclusion document[7].

According to Article 14(3) of the IED, BAT conclusions shall be the reference for setting the permit conditions for installations covered by the Directive.

The BRef and BAT Conclusion documents detail BAT-AELs for the release of combustion gases from Large Combustion Plant. The BAT-AELs for emissions are lower than the ELVs specified in the IED Annex V (Table 3-1) over the different averaging periods, and are shown below in Table 3-2.

Table 3-2: Large Combustion Plant BAT-AELs for Existing Solid Fuel Plant

Combustion Unit	Pollutant	Daily Average BAT-AEL (mg/Nm^3)	Yearly Average BAT-AEL (mg/Nm^3)
Solid fuels – biomass >300MW_{th}	SO_2	<20 - 85(1)	<10 – 50(1)
	NO_x	95 – 200(2)	40 – 160(2)
	Dust	2 - 16	2 - 10
	HCl	1 – 12(3)	1 - 5(3)
	HF	<1 (4)	
	Mercury	<1-5 ug/m^3 (4)	

Notes:

(1) Fuel specification for the biomass intended to be used at the plant, states that the sulphur content of fuel will be limited to <0.05% by weight for fuel delivered until 30th September 2019, after which the sulphur content of fuel will be limited to <0.02% by weight. Therefore, footnotes (3) and (5) of Table 10.10 of the LCP-BRef related to operation of combustion plants operating on fuels having sulphur contents of 0.1% by weight and above are not applicable to the Lynemouth installation.

(2) For existing combustion plant in operation prior to 7th January 2014, the applicable upper limit of the BAT-AEL for NO_x emissions is 160mg/Nm^3 as annual average and 200mg/Nm^3 as a daily average, in line with footnotes 7 and 8 of Table 10.9 of the LCP BRef.

(3) Fuel specification for the biomass intended to be used at the plant, states that the chlorine content of fuel will be limited to <0.01% by weight. Therefore footnote (1) of Table10.11 related to operation of combustion plants with fuels having chlorine contents of ≥0.1% is not applicable to the Lynemouth power plant.

(4) As an average over the sampling period.

Environment Agency guidance[8] states that for the approach to BRef Ranges, 'DEFRA/ Welsh Government has issued Part A Guidance to the Environment Agency and Natural Resources Wales that instructs inspectors to

[7] European Commission. (2017). Commission Implementing Decision (EU) 2017/1442 of 31 July 2017 establishing best available techniques (BAT) conclusions, under Directive 201/75/EU of the European Parliament and of the Council , for Large Combustion plants. "BAT Conclusions"

[8] UK Regulators' Large Combustion Plant Best Available Techniques Interpretation Document, Working Document V1.1, 09/05/2018

take the top of the range as the permitting value, unless compliance with an Air Quality standard requires a lower value.' Therefore, this report presents the BAT assessment on the basis of the relevant upper BAT-AEL range.

The LCP BRef and BAT Conclusion documents also detail energy efficiency levels associated with the best available technique (BAT-AEELs), which refer to the net electrical efficiency and the net total fuel efficiency of the plant.

The BAT-AEELs for the combustion of solid biomass are 28-38% net electrical efficiency and 73-99% net total fuel efficiency for existing plant.

The determination of BAT is specific to a particular installation in a particular location. This is due to the fact that there may be geographical, technological or local environmental reasons why a particular technique cannot be applied to the installation's process, therefore precluding the use of certain specific techniques on the basis of site sensitivity or characteristics. In some cases this could mean that the competent authority permits emission concentrations above those stated as BAT-AELs through the application of a derogation, provided a justification is given for the departure. However, emission limits would not be permitted to exceed those set out in IED Annex V.

4. Pollutants of Concern and their Abatement

4.1 Oxides of Nitrogen (NOx)

The oxides of nitrogen emitted during the combustion of fuels are nitric oxide (NO), nitrogen dioxide (NO_2), and nitrous oxide (N_2O). The first two of these form the mixture known as NO_x, which is typically released from combustion processes in the ratio 9:1 NO:NO_2. NO is oxidised to NO_2 in the atmosphere relatively quickly and it is primarily nitrogen dioxide that is associated with adverse effects upon human health and the environment and as such has associated ambient air quality objectives.

The formation of NO_x within a combustion process is governed by the following three mechanisms; characterised by the origin of the nitrogen and the environment where the reaction takes place:

- Thermal NO_x, which results from the reaction between oxygen and nitrogen from the air;
- Fuel NO_x, which is formed from the nitrogen contained within the fuel; and
- Prompt NO_x, which is formed by the conversion of molecular nitrogen in the flame front, in the presence of intermediate hydrocarbon compounds.

NO_x levels can be controlled at source, through the application of primary measures such as low combustion temperatures, during the combustion process. This typically focuses on the limitation of thermal NO_x generation.

In addition to the low combustion temperature, boosted over fire air (BOFA - a staged air injection process) has been implemented by LPL to reduce NO_x emissions. This consists of a sophisticated secondary air system enabling two combustion zones in the furnace. Staged air injection helps to minimise the excess air ratio, which contributes to the generation of both thermal and fuel NO_x. Secondary air ports have been installed in addition to the primary fluidising air inlets. Some combustion air is injected through these ports, which are located in the upper part of the furnace, and this additional injection ensures more efficient burnout. The lower part of the furnace can then be operated with a lower air ratio, inhibiting NO_x formation.

Additional primary techniques such as the recirculation of the flue gases may also be installed to reduce NO_x formation; but this technique is not considered appropriate for Lynemouth Power Station, as summarised in the associated LPL derogation technical review document[9].

Secondary techniques such as selective catalytic or non-catalytic reduction (SCR and SNCR) have been applied to many biomass- and/or peat-fired boilers, especially new boilers.

SNCR has been widely used and is now a well-established technique for new build biomass firing. However, for existing boilers (as is the case at Lynemouth), if SNCR has not been applied as part of the initial boiler design, it can be less effective due to the lack of a suitable temperature window within the combustion plant. The process design or the high heat load of an existing boiler can have too short a reaction time as the temperature in the upper part of the furnace remains too high, and there is insufficient space in the convective section for the ammonia/urea injection. As a consequence, the efficiency of NO_x abatement for retrofitted SNCR is less than for units designed with SNCR from the outset.

SCR requires somewhat lower temperatures to work than for SNCR, and is generally located downstream of the economiser. Low-dust (tail-end) SCR can be installed at flue-gas temperatures of 190ºC and upwards (typically in the region of 220ºC), whilst high-dust SCR can operate safely from temperatures of 300ºC and upwards. When fitting SCR to an existing boiler, the main challenges are layout, ductwork, flue-gas draft system and structural changes. In particular, space availability for the catalyst and layout modification of the flue-gas ductwork need to be considered as part of the retrofit.

[9] Technical Brief on Application of BAT for NOx and Particulates (document reference: 60565526-430-000-RP-PE-00001), AECOM for LPL, October 2018

4.2 Sulphur Dioxide (SO_2) and Acid Gases (Hydrogen Chloride (HCl) and Hydrogen Fluoride (HF))

The sulphur content of biomass is often low to moderate and consequently the emissions from installations using biomass as a fuel are generally below the BAT-AEL level for SO_2 and often no desulphurisation abatement is applied. Given the relatively low sulphur content commercially available pelletised wood biomass[10] up to 90% reduction in sulphur emissions can normally be expected; with the conversion thereby providing an effective primary measure for the reduction of emissions of sulphur dioxide, through lower sulphur fuel usage.

However, with higher sulphur content biomass, and for the control of acid gas (HCl and HF) emissions, post-combustion dry injection processes are usually applied. The injection of calcium hydroxide or sodium bicarbonate in a dry form before a bag filter can achieve sufficient SO_x emissions reduction, whilst also removing HCl and HF emissions.

The LCP-BRef identifies use of wet scrubbing and wet sorbent injection in combination with dust filtration systems as suitable techniques for mitigation of acid gas emissions. However, with LPL's current contractual fuel chlorine levels of <0.01% by weight, in conjunction with the low sulphur content of the fuel, the formation and emissions of HCl and other halide emissions are expected to be insignificant.

Sorbent use however, increases the amount of ash produced by the combustion plant, and may lead to an increase in particulate emissions if an electrostatic precipitator (ESP) rather than a bag filter is used for dust removal. There is the possibility that the sorbent properties may also reduce the electrostatic precipitation efficiency, causing higher dust emissions, especially when using larger amounts of sorbent to reduce SO_x emissions.

4.3 Dust

In installations using pelletised wood biomass as a fuel, a relatively small proportion of the ash (less than 20% of the total ash) is collected as bottom ash. The remaining ash leaves the furnace as fly ash (within the flue gases) and is collected via dust abatement systems. Both bag filters and ESPs are widely used as dust abatement systems; however the efficiency and suitability of the abatement system depends on the nature of the fuel, the ash produced and temperature and flow of waste gas.

ESPs are commonly used for large pulverised fuel biomass combustion plants or where solid fossil fuel plants are converted to be dedicated biomass plants. However, ESP's struggle to achieve dust emission levels at the lower end of the BAT-AEL range (in the 2 – 5mg/Nm^3). These levels are achievable by bag filters; however it is generally accepted that bag filters are not safe for application to biomass fired boilers due to fire hazard.

The Lynemouth installation has three ESPs (one for each boiler, each with two parallel streams consisting of two fields) installed for the abatement of dust emissions. However, the ESPs were been designed to enable the plant to comply with the ELVs as defined in Annex V of the IED, and not with the BAT-AELs which had not been published at the time of design and conversion project contract placement.

4.4 Mercury

Mercury can be present within the biomass albeit in trace quantities. When biomass containing mercury is combusted, it adheres to the dust particles and in the absence of any abatement measures can be released to the atmosphere via the flue gas. Therefore, a fuel naturally low in mercury content would inevitably lead to low mercury emissions. LPL's current biomass fuel specification includes a fuel mercury limit of ≤0.1mg/kg. Additionally, Lynemouth has high levels of carbon in the ash and an ESP, and it is likely that much of the mercury will be captured within the ash and not released to the atmosphere. Mercury emissions from the Lynemouth power station are therefore predicted to be in compliance with the BAT emissions levels presented in Table 3-2.

In addition to optimised fuel use, additional dust abatement measures can be implemented when combusting biomass to control mercury emissions from the plant.

[10] Available fuel specification for the plant states that the sulphur content of the fuel will be limited to <0.05% by weight for fuel delivered until 30th September 2019, after which the sulphur content will be restricted to <0.02% by weight.

4.5 Energy Efficiency

The LCP BRef defines electrical efficiency as the ratio of delivered or generated effective electrical output of a power plant to the supplied fuel input.

The BRef states that operators and suppliers are continuously improving the energy efficiency of combustion plant by optimising the combustion process and through new developments in materials and cooling techniques. Although higher efficiency is typically observed in large-scale pulverised fuel combustion plants converted to operate on biomass, the change in temperature distribution in the boiler associated to the change in fuel can lead to minor reductions in the efficiency of a fully converted unit compared to a coal unit operating at the same load factor.

The biomass combustion plant is designed with energy efficiency in mind, and will be capable of achieving conversion efficiency levels of around 37% (net electrical efficiency). It is therefore expected to achieve the BAT-AEEL as defined in the BRef.

4.6 Compliance with BAT – AELs

Based on the BAT-AELs provided in the LCP-BRef and presented in Table 3-2, for the potential pollutants of concern (see Sections 4.1 - 4.4), and the nature of the biomass fuel feedstock and abatement measures in place at the power plant, it is considered that emissions of SO_2, acid gases (HCl and HF) and mercury will be in compliance with BAT-AELs, as shown below in Table 4-1.

Table 4-1: BAT-AELs applicable to the Lynemouth installation and Design Emission Limit Values

Combustion Unit	Pollutant	Yearly Average BAT-AEL (mg/Nm^3)	Design Emission Limits (mg/Nm^3) (1)
Solid fuels – biomass >300MW_{th}	SO_2	50	Expected to be compliant based on biomass fuel specification
	NO_x	160	<200
	Dust	10	<20
	HCl	5	Expected to be compliant based on biomass fuel specification
	HF	<1	Expected to be compliant based on biomass fuel specification
	Mercury	5 ug/m^3	Expected to be compliant based on biomass fuel specification

Notes:

(1) the design emissions levels are based on the performance guarantees provided by LPL. Actual emission levels to be confirmed once plant is commissioned.

(2) BAT-AEL upper range presented only (see Section 3.1.3)

Emissions of NOx and dust from the plant are expected to be higher than the applicable BAT-AELs, but compliant with the IED Annex V emission limit values. As a consequence, the key pollutants to review with regard to compliance with BAT AEL values are emissions of NO_x and dust.

4.7 Basis of the Derogation Application

The current design emissions performance for the biomass conversion of LPL's existing power plant does not meet the BAT-AELs for oxides of Nitrogen (NO_x) and dust, as specified within the LCP BRef and BAT Conclusions, and as a consequence it would be necessary to install or improve secondary abatement equipment to enable the site to ensure compliance with the BAT-AELs. As a consequence, the key pollutants to review with regard to compliance with BAT AEL values are emissions of NO_x and dust.

The design for the biomass conversion of the existing power plant can meet the ELV's contained within Annex V of the IED.

There are several technical difficulties in achieving the revised BAT-AELs for NO_x and dust when working with a biomass conversion of existing combustion plant, and further assessment is included in LPL's associated derogation technical review document.

The legacy infrastructure of the Lynemouth power station makes the retrofitting of secondary abatement technologies such as SCR and SNCR difficult to apply, for example, as mentioned earlier the temperature window for efficient use of SNCR occurs within only a small zone of the combustion units. In addition the space available for the installation of SNCR/SCR equipment, and for extending or replacing the existing dust abatement plant is extremely limited. Finally, the requirement to comply with the BAT-AELs by July 2021 would mean extended unplanned outages of the plant to allow the installation of the additional abatement equipment, resulting in significant loss of output and associated revenue.

LPL are therefore applying for derogation from the LCP BRef and BAT Conclusion NO_x and dust BAT-AELs.

Derogations from specified emission limits as defined within the LCP BRef can be applied for on the basis of three criteria:

- Geographical location;
- Local environmental conditions; or
- The technical characteristics of the installation.

The derogation from the NO_x and dust BAT-AELs for the LPL installation is being made based on the technical characteristics of the installation and also with due consideration of the local environmental conditions. The technical characteristics to be considered for a derogation from the BAT-AELs generally include the following:

- The recent history of pollution control investment in the installation in respect of the pollutant(s) for which the derogation is sought;
- The general investment cycle for a particular type of installation;
- The configuration of the plant on a given site, making it more technically difficult and costly to comply;
- The practicability (particularly bearing in mind Health & Safety and other relevant legal obligations) of interrupting the activity so as to install improved emission control upon the pollutant(s);
- The effect of reducing the excess emission(s) upon other pollutant emissions, energy efficiency, water use or waste arising from the installation as a whole; and
- The intended remaining operational lifetime of the installation as a whole or of the part of it giving rise to the emission of the pollutant(s), where the operator is prepared to commit to a timetable for closure.

LPL consider that a derogation based upon the technical characteristics of the site is considered to be appropriate. A conservative approach has been used in this assessment to review if the NO_x and dust emissions from the installation could be controlled by implementation of the best available techniques (BAT) outlined in the LCP BRef to achieve the BAT-AEL, assuming technical viability. Further details on the identification of appropriate justification criteria for each relevant BAT technique are included in the main derogation application document.

The review of available technologies and their application at the Lynemouth site have been assessed using the Environment Agency's (EA's) IED Derogation Cost-Benefit Analysis Tool (v 6.17, September 2017). Details of the options considered are presented in Section 5.

5. Proposed BAT Options for Assessment

The design for the conversion of the coal combustion plant to biomass was developed prior to the publication of the LCP BRef and BATc; therefore the plant conversion was designed to achieve the IED Annex V ELVs. The plant was designed to apply primary measures such as low NO_x burners and boosted over-fire air to limit NO_x emissions to 200mg/Nm^3, and modifying the existing ESPs to achieve dust emissions of up to 20mg/Nm^3.

These emissions levels are however, higher than the revised BAT-AELs implemented through the LCP-BRef and BAT Conclusions.

The CBA for NO_x and dust emissions has been undertaken separately as these pollutants have limited interaction, and require separate abatement systems to be in place. Consequently the options for NO_x and dust emissions included in the assessments have been shown separately below.

As discussed in Section 4, the revised NO_x emission limits can, in theory, be achieved by the installation of SNCR or SCR, whilst particulate control can theoretically be achieved through electrostatic precipitators or bag filters; although the characteristics of the installation may make applicability of the technique challenging on a site specific basis.

Six options were assessed for consideration at the Lynemouth site for NO_x abatement:

- Option 1: Business as Usual – Control of NO_x emissions through primary means;
- Option 2: Proposed Derogation – Control of NO_x emissions through primary means;
- Option 3: Installation of SNCR to achieve emissions at the Upper Limit of BAT-AEL for NO_x;
- Option 4: Installation of SNCR to achieve emissions at the Lower Limit of BAT-AEL for NO_x;
- Option 5: Installation of SCR to achieve emissions at the Upper limit of BAT-AEL for NO_x; and
- Option 6: Installation of SCR to achieve emissions at the Lower limit of BAT-AEL for NO_x.

NO_x options 4 & 6 were assessed for completeness but are not presented in the main report as the UK regulatory approach is to take the top of the BAT-AEL range as the permitting value (see Section 3.1.3), unless compliance with an Air Quality Standard or a requirement to prevent 'backsliding' requires a lower value to be applied. See Appendix D for details of the NO_x Options 4 & 6 assessments.

Four options are presented within this assessment for consideration at the Lynemouth site for dust abatement:

- Option 1: Business as Usual – Dust emissions controlled through existing upgraded ESPs achieving 20mg/Nm^3;
- Option 2: Proposed Derogation – Dust emissions controlled through existing upgraded ESPs achieving 20mg/Nm^3;
- Option 3: Installation of additional ESP upgrades to achieve emissions at the Upper Limit of BAT-AEL for dust; and
- Option 4: Replacement of the existing ESP with a Bag Filter to achieve emissions at the Lower Limit of BAT-AEL for dust.

As with NO_x options 4&6, dust option 4 was assessed for completeness but is not presented in the main report as the UK regulatory approach is to take the top of the BAT-AEL range as the permitting value, unless compliance with an Air Quality Standard or a requirement to prevent 'backsliding' requires a lower value to be applied. See Appendix E for details of the dust Option 4 assessments.

5.1 Proposed BAT Options - NO_x Abatement

5.1.1 Option 1 - Business as Usual – Control of NO_x Emissions through Primary Means

5.1.1.1 Emissions

Emissions of NO_x will be controlled by primary means, including the use of low NO_x burners and a Boosted Over Fire Air (BOFA) staging system, operated and controlled through an automated process control system in accordance with BAT.

The equipment supplier has indicated that the low NO_x biomass burner is designed to achieve consistent NO_x reduction to meet current emissions requirements by the creation of axially generated swirl to the various air streams. The boiler design ensures that a stable flame is maintained close to the burner throat. In addition to the low NO_x burner, use of Boosted Over Fire Air (BOFA) equipment will enable the plant to achieve NOx emissions of 200mg/Nm^3 as an annual average, equivalent to the IED Annex V emission limits for NO_x of 200mg/Nm^3 as a monthly average. The expected emissions are based on the design performance for the plant, with specific performance to be confirmed following combustion optimisation and performance guarantee testing.

Use of primary measures to manage NO_x emissions without use of ammoniated reagents (like in SNCR or SCR) also lead to the fly ash from the combustion process being classed as non-hazardous (EWC 10 01 01 & 10 01 03), similar to the fly ash produced by the plant when combusting coal. LPL own and operate ash lagoons adjacent to the power station installation to deposit the captured bottom and fly ash. This non-hazardous landfill is currently proposed for the disposal of ash from biomass combustion in parallel to the investigation of options to find a beneficial reuse or recycling option for the waste. The operation of the ash lagoons is covered under a separate Environmental Permit (reference - EPR/FP3437CZ).

5.1.1.2 Feasibility

This option represents the base condition, and the use of primary measures comprising low NO_x burners and BOFA at the power plant was an integral component of the biomass conversion project.

Annex V of the IED does not include annual average emission limit values. Therefore, for the purpose of this assessment, it has been assumed that the plant will comply with an annual ELV of 200mg/Nm^3, which is equivalent to the monthly ELV set out in Annex V of the IED, However, specific performance will be confirmed during performance guarantee testing following combustion optimisation.

5.1.2 Option 2: Proposed Derogation – Control of NO_x Emissions through Primary Means

This option proposes that the NO_x and dust emissions continue in compliance with the ELVs specified by Annex V of the IED, i.e. the same as the Business as Usual Option (Option 1).

This option achieves the IED Annex V emission limit for NO_x of 200mg/Nm^3 as a monthly average for biomass combustion in plants with rated thermal capacity of >300MW.

5.1.3 Option 3: Installation of SNCR to Achieve Emissions at the Upper Limit of BAT-AEL for NO_x

5.1.3.1 Emissions

The implementation of secondary abatement measures, such as SNCR, would be required for the plant to hypothetically achieve emissions below the upper limit of the annual average BAT-AEL of 160mg/Nm^3, although significant uncertainty remain over the achievable performance of SNCR as a retrofit to the LPL installation.

The SNCR technique is a secondary control measure comprising reduction of NO_x with ammonia or urea, without a catalyst, at a high temperature, typically between 950°C and 1000°C. The temperature window depends on the reagent used, with the temperature range being higher for urea.

It is understood from a potential technology provider that in the case of application at the LPL installation, a 40% urea solution could be used as the reagent. A consequence of the injection of ammonia-forming reagents is the potential for the release of ammonia in the flue gas, known as ‘ammonia slip’. The LCP BRef presents an expected level of ammonia slip equivalent to 3mg/Nm^3.

5.1.3.2 Cross Media Effects of SNCR

Cross-media effects of SNCR include additional electrical energy requirements for the operation of the abatement equipment and the thermal/electrical parasitic load of the SNCR plant, which reduces the overall efficiency of the installation. Moreover, water injected with the reagent generally acts as a heat sink, and lead to a reduction in plant efficiency by 0.25-0.50%. In accordance with the conservative approach used for this assessment, indicative reduced generation and lost revenue resulting from the lower efficiency due to SNCR has been considered in the CBA, as the impact over the project lifetime is likely to be significant.

Cross media effects of SNCR are partially dependent on the reagent used.

The use of urea as a reagent for SNCR leads to a higher likelihood of furnace component corrosion than when using ammonia or caustic ammonia. It will also result in increased ammonia releases, in the form of ammonia slip, due to non-homogeneous reactions between NO_x and NH_3. The BAT-AEL associated with ammonia slip emission is <3-10mg/Nm^3, as a yearly average, and the assessment has assumed the lower level is achieved as a conservative approach.

If the SNCR system is retrofitted to the existing boiler structures, the injection location would need to be in the convective section between tube banks. Based on previous AECOM experience, it is expected that if the reagent is injected at this level, it will lead to a sharp temperature gradient which could likely lead to corrosion of the tubes. This would result in frequent forced outages to repair tube leaks. LPL may therefore need to change the material specification for the material for the tubing, requiring significant CAPEX and OPEX implications for the installation. The costs for installing SNCR in to the combustion units at the installation have been taken in to consideration within the CBA, using costs provided by a potential supplier, assuming these include all costs for the required retrofits.

Any additional retrofit for the installation would require unplanned major plant outages, leading to a considerable impact on the revenue generated by the plant. An indicative value for the revenue likely to be lost by LPL during additional outages (outside of scheduled major planned outages) due to lost generation capacity has been included in the CBA. It should be noted that the figures for lost revenue does not represent actual financial figures which are likely to be much higher than the costs included in this assessment, and are commercially confidential; this is however considered to be in line with the conservative approach followed for this assessment.

The use of SNCR also leads to the accumulation of ammonia within the ash residue; the level of ammonia in the fly ash can affect the available disposal options or the potential onward use of the ash. Moreover, if the ash is significantly ammoniated it is likely to be classed as a hazardous waste, and not permitted for disposal in the LPL ash lagoon installation. This would therefore require higher off-site disposal or treatment costs. Additionally, the presence of ammonia in the ash may preclude potential beneficial recycling options without further treatment.

Other qualitative and indirect effects include potential fugitive emissions from on-site storage and handling of urea, the upstream additional emissions of NO_x, CO, CO_2 from the urea manufacturing process itself and the additional NO_x, CO, CO_2 and particulates from the transport fuel combustion on delivering urea.

5.1.3.3 Feasibility

Although it would lead to additional costs it would be possible to install SNCR equipment on to the existing site boilers. There are however significant uncertainties in the achievable NOx abatement efficiency of SNCR retrofitted in the LPL installation due to the limitations imposed by the existing plant design and infrastructure. As such, as retrofitted plants are custom designed for site specific requirements, data regarding the efficiency of SNCR use at retrofitted power plants is limited.

However, due to the limited space that is available to locate the reagent injection, SNCR would produce very limited results at Lynemouth. It is estimated that a reduction of only 10% would be achievable for this application which, depending upon the NO_x emissions performance on primary measures only, will most likely not result in compliance with the BAT-AEL. Details of the technical restrictions at the LPL installation with regards to implementation of SNCR are provided within the technical review document.

In line with a conservative approach, this CBA assumes that the option is physically and technically feasible and theoretically able to meet the BAT-AELs, and has been assessed further within this assessment.

5.1.4 Option 5: Installation of SCR to Achieve Emissions at the Upper Limit of BAT-AEL for NO_x

5.1.4.1 Emissions

The assessment assumes that Selective Catalytic Reduction (SCR) could be feasibly implemented for the plant to achieve emissions below the upper limit of the annual average BAT-AEL of 160mg/Nm^3.

The SCR technique is a secondary control measure that involves the injection of ammonia or urea into the waste gas in the presence of a catalyst, so as to reduce the NO_x to nitrogen and water, at an optimum operating temperature of 300 - 400°C. Discussion with one potential supplier has identified a 29.4% aqueous ammonia solution as a potential reagent.

No details of the operation of the SCR and how it would connect to the power plant are available; assumptions have therefore been made where required. As outlined within the technical review document for the LPL installation, to operate at the optimal temperature, the SCR would normally be installed downstream of the economiser and upstream of the air heater. At this location, the presence of the dust would require sootblowers to keep the catalyst clean. There would also be a concern that the dust would absorb some of the ammonia, and that this would affect its classification for disposal purposes.

An alternative would be to install a low-temperature SCR downstream of the ESP. However, since the flue gas temperature at this location is too low for the reactions to occur across the catalyst, it would be necessary to reheat the flue gas. The most common approach would be to install a bypass around the economizer and air heater, which could then increase the temperature of the flue gas entering the SCR from 150ºC up to about 230ºC. However, this would result in a decrease in the net unit heat rate of about 4% representing a significant loss in generation capacity and revenue over the plant lifetime.

The additional pressure drop across the catalyst would also be a major concern. This would require the installation of new, larger induced draught (ID) fans to maintain the generating capacity of each unit. The larger fans would increase the electrical consumption and as a result, the cost to operate the plant.

As with SNCR, a consequence of the injection of ammonia-forming reagents is the potential for release of ammonia in the flue gas, known as ‘ammonia slip’. The LCP BRef presents an expected level of ammonia slip equivalent to 3mg/Nm^3.

5.1.4.2 Cross Media Effects of SCR

Ammonia releases from the SCR process are expected to occur from ammonia slippage due to incomplete reaction. The BAT-AEL associated with ammonia slip emission is <3-10mg/Nm^3, as an annual average, and the assessment has assumed as a conservative assumption that the lower level i.e. 3mg/Nm^3 is achieved.

In addition, SCR generates a solid waste stream when the catalyst is required to be changed. As noted by the UK LCP BRef Technical Working Group (TWG), commercially available biomass fuels have a tendency to poison catalyst used in SCR systems, therefore requiring frequent catalyst replacement. This adds additional cost for the replacement, recovery, regeneration or disposal of the catalyst. This adds additional cost for the replacement, recovery, regeneration or disposal of the catalyst.

More qualitative and indirect effects include fugitive emissions from on-site storage and handling of ammonia solution, increased environmental risk from the site due to the storage of ammonia solution and the associated upstream life cycle emissions from the manufacture and transportation of ammonia, resulting in additional emissions.

Although not all of these impacts can be easily quantified, the consequences of the transport of ammonia to the site in terms of fuel use have been taken into consideration in the CBA assessment.

5.1.4.3 Feasibility

This scenario would require the installation of three new SCR units, one for each combustion unit. This would require an extended plant outage of at least 12 months per unit, as it would be necessary to make significant modifications to the duct and the support structure. The existing plant has significant restrictions on availability of space due to constraints imposed by the existing infrastructure, and the spatial constraints make it physically and technically difficult to install three SCR units. Additionally, it is considered highly likely that the new induced draft fans, installed during 2016/17, would require replacement to provide additional draught in addition to the upgrade or replacement of other new plant.

It is likely that there will be also be implications under the Control of Major Accidents and Hazards (COMAH) Regulations 2015 ("COMAH") for the storage of ammonia solution on site, due to the hazardous nature of the substance.

Based on the guidance in the LCP BRef, the initial investment required for SCR equipment is considerably higher than that required for SNCR equipment, with up to three times more capital required for SCR compared to SNCR equipment.

It is envisaged that the complexity of implementing this option would require a much greater outage period than that for SNCR application. No major outages are planned for the plant until 2021/22, with an outage period of 8 weeks expected for each unit. Based on previous AECOM experience on similar projects, it is considered likely that the outage period would be >12 months for each unit. In order for the installation to be compliant with BAT-AELs by the required compliance date of 17th August 2021, it is envisaged that the planned outage would require to be brought forward by a year (to 2020), with a staggered shut-down of the units to install the SCR and associated infrastructure. This would mean that in 2021, there would be one unit operating at IED Annex V ELVs, and one unit at BAT-AEL; assuming equal loading of the two units, it is expected that overall emissions from the installation will be compliant with the BAT-AEL. This is considered to be in line with a conservative approach, as it represents minimal, but still significant, loss of generation capacity for the installation whilst additional plant is installed.

Details of the technical constraints at the LPL installation with regards to implementation of SCR are provided within the technical review document.

Similar to the installation of SNCR, it is expected that LPL would face considerable revenue losses due to the lost generation capacity during major planned outages to install SCR plant at the installation. Indicative lost revenue for LPL during the additional outage period i.e. 12 months less 8 weeks of scheduled outage for each unit has been included within the CBA. It should be noted that as the figures for lost revenue are commercially confidential, indicative figures, likely to be considerably lower than the actual revenue, have been used in the CBA in line with a conservative approach.

Installation of the SCR is considered to represent an option that is technically and spatially unviable for this site; however, this assessment assumes that this option is feasible, as a conservative approach, and is assessed further in this document.

5.2 Proposed BAT Options - Dust Abatement

5.2.1 Option 1: Business as Usual – Dust Emissions Controlled Through Existing Upgraded ESPs

5.2.1.1 Emissions

The existing two-field ESPs at the site underwent upgrades to their electrical systems to improve their dust removal efficiency to meet the IED Annex V limit for biomass combustion; however no modifications were made to the size and number of the collection plates, or to the number of fields. The modifications will allow the site to achieve the IED Annex V emission limits for dust of 20mg/Nm^3.

5.2.1.2 Feasibility

This option comprises optimisation of the upgraded ESP operation to enable the most efficient capture of biomass fly ash as the base condition. This is considered feasible.

5.2.2 Option 2: Proposed Derogation – Dust Emissions Controlled Through Existing Upgraded ESPs

This option is the same as the Business as Usual Option and comprises achievement of the IED Annex V emission limit for dust (20mg/Nm^3) by the power plant.

5.2.3 Option 3: Installation of an Additional Upgrades to the ESP to Achieve Emissions at the Upper Limit of BAT-AEL for Dust

5.2.3.1 Emissions

To reduce emissions of dust to the top end of the BAT-AEL range of 10mg/Nm^3 (annual average), additional upgrades to the existing ESPs would be required. The technical review document produced alongside this CBA assessment reviews several options for potential upgrades to the ESP at the power plant to improve their dust removal efficiency; however there are limitations to the effectiveness of expanding the size of an ESP. As such, there is a limited amount of space between the boiler house and the stack, where the existing ESPs are situated.

5.2.3.2 Feasibility

In the case of the Lynemouth units, the first two fields will have taken out the fraction of the dust that was most easily captured; however the remaining dust in the flue gas presents a greater challenge, so that doubling the collection area of the EPS does not correlate to similar removal efficiency on top of what was originally achieved.

The technical review document discusses the following options for upgrading the existing ESPs:

1. Installation of Collection Plate in Maintenance Access Space – Most ESPs used in the European market are designed with gaps between the fields that allow for ease of maintenance. One approach that could be used to increase the dust removal efficiency of an ESP without changing the footprint would be to add collection plates in these maintenance gaps. Another benefit of this option is that it would likely not increase the pressure drop to the extent that it would negatively impact the unit generating capacity. The retrofit would need to include provisions to creating a different means to access the unit internals to perform routine maintenance. However, a modification of this type would require a unit outage of several months to complete, resulting in lost generation revenue for the unit. More importantly, this approach is typically used when only moderate additional reductions are needed, and so it would not be capable of lowering the outlet dust emissions by 50%, to meet the BAT limit of 10 mg/Nm^3.

   Therefore, this approach for dust control at Lynemouth installation is not recommended.

2. Increase the Field Height – Another option for increasing the dust removal efficiency without altering the footprint of the existing ESP is to increase the height of the fields. For this option, it would be necessary to create a structure that would support the additional weight of the taller field. The transition ducting at the ESP outlet could be readily modified to accommodate the change in height, and it would not be necessary to change the inlet ducting to the ID fan. However, the transition ducting between the boiler house and the ESP inlet would present a major concern due to the rapid expansion of the duct in a short amount of space. In an effort to even out the vertical distribution of the gas, it would be necessary to install some internal guide vanes within the duct, along with a perforated plate at the ESP inlet. These modifications would produce a significant pressure drop that would require an ID fan upgrade to avoid a loss of generating capacity. This would be a major construction effort and would necessitate a unit outage that could take up to one year to complete, resulting in lost generation revenue for the unit. It should further be noted it may not be physically possible to add enough height to the fields to accomplish the desired reduction of the dust down to the BAT limit of 10 mg/Nm^3.

   Therefore, this approach for dust control at Lynemouth installation is not recommended.

3. Add Additional Field(s) – Generally, the most effective way to upgrade an ESP to achieve a desired outlet emission rate is to increase the number of fields, and modern installations often have six or seven fields to achieve high removal efficiencies. The issue with applying this approach at Lynemouth is that the space to expand the ESPs is severely limited. While there is room to potentially add up to two more fields on two of the ESPs (Units 1 and 3), there is no room for any expansion behind the remaining ESPs (unit 2). The installation of additional field(s) to the ESPs would likely be a complicated and expensive retrofit which would require a complete reconfiguration of the outlet ducting, ID fans, and a corresponding reconfiguration of the ducting from the ID fans to the stack. There would be a significant increase in pressure drop that would require an ID fan upgrade to avoid a loss of generating capacity. In addition, this would be a major construction effort and would necessitate a unit outage that could more than one year to complete, resulting in significant lost generation revenue for the unit. So, whilst it would be possible to meet the BAT limit of 10 mg/Nm^3 on Units 1 and 3, there would be no decrease in the dust emissions from Unit 2.

   As a result of the lost generation due to the extended outage, the lack of improvement to the Unit 2 dust emissions, and the high cost to construct and operate the expanded ESP, this approach for dust control at Lynemouth installation is not recommended.

Details of the technical restrictions at the LPL installation with regards to implementation of additional upgrades of the ESPs are provided within the technical review document.

Although the above options for upgrading the ESPs are not recommended at the LPL installation due to the considerable technical challenges, they have been assumed to be viable for the purpose of this assessment as a conservative approach.

In order to carry out the above upgrades, it is expected that extended plant outages, likely to be in the region of 12 months for each unit considering the extensive infrastructure changes, will be required. Although LPL has scheduled major outages over the period 2021/22 (likely to require an outage of 8 weeks per unit), it is anticipated that to make the ESP upgrades required to meet the upper limit of the BAT-AELs by the required compliance date, the planned outage would need to be brought forward by a year, assuming a staggered outage schedule for each unit, to minimise revenue losses during the additional outage period. Indicative revenue losses have been included within the CBA.

6. Evaluation of Options for NO_x and Particulate Abatement

Following a review of the viability of each proposed option outlined in Section 5, only the following options have been assessed using the Cost Benefit Assessment (CBA) Tool:

- Options for NO_x abatement:
  - Option 1: Business as Usual – Control of NO_x emissions through primary means;
  - Option 2: Proposed Derogation – Control of NO_x emissions through primary means;
  - Option 3: Installation of SNCR to achieve emissions at the Upper Limit of BAT-AEL for NO_x;
  - Option 5: Installation of SCR to achieve emissions at the Upper limit of BAT-AEL for NO_x; and

Options 4 and 6 for NO_x abatement (see section 5) are not included in this section on the basis of EA's guidance (see section 3.1.3); details of these options are provided within Appendix D for completeness.

- Options for dust abatement:
  - Option 1: Business as Usual – Dust emissions controlled through existing upgraded ESPs achieving 20mg/Nm^3;
  - Option 2: Proposed Derogation – Dust emissions controlled through existing upgraded ESPs achieving 20mg/Nm^3;
  - Option 3: Upgrade of existing ESPs to achieve emissions at the Upper Limit of BAT-AEL for dust.

Option 4 for dust abatement (see section 5) is not included in this section on the basis of EA's guidance (see section 3.1.3); details of this option are provided within Appendix E.

Each option has been considered for the following aspects:

- Emissions and the levels of reduction achieved with the application of revised BAT-AELs beyond the IED Annex V ELV's;
- Environmental damage costs; and
- Installation cost (based on capital cost plus estimated annual operating costs annualised in accordance with the assessment methodology, using LPL data and publicly available data, as appropriate).

These factors have been used to present a generic assessment as to which option is considered to represent BAT for the biomass power plant at the Lynemouth installation. It must be reiterated that the above abatement measures have been assessed on the basis of the assumption that they are technically viable for the installation; however, it has been demonstrated in the technical review document that their implementation and efficiency (if implemented) will be severely limited by the technical restrictions of the LPL installation, and will likely not be able to achieve the required BAT-AELs.

A summary of the inputs for the CBA tool for assessing the financial and environmental impact of the current and abated emissions of NO_x and dust is included in Appendix C.

Appendices A and B present the CBA Tool spreadsheets for the NO_x and Dust abatement options presented in Section 5.

6.1 Proposed BAT Options for NO_x Abatement

6.1.1 Option 1 - Business as Usual – Control of NO_x Emissions through Primary Means

6.1.1.1 Emissions

The assumed annual average NO_x emission level would be 200mg/Nm^3, and therefore would be compliant with the requirements of IED Annex V ELVs for biomass combustion in plants with rated thermal input of >300MW$_{th}$, but not with the BAT-AELs specified in the LCP BRef (see Table 3-2). Although the combustion and emissions equipment supplier has indicated that lower annual average emissions may be possible, the emissions are not projected to consistently achieve the revised BAT-AEL values contained within the LCP BRef and hence an annual average emission level of 200mg/Nm^3 has been assumed here as a conservative baseline.

The annual NO_x release has been based on an assumed 90% load factor, or 7,884 hours operation per year, as this is considered to be the expected level of plant operation. The annual operational period and a projected total flue gas flow rate of 381Nm^3/s from the three boilers is estimated to result in an annual NO_x release of up to 2,163 tonnes.

The information provided by LPL states that the total annual ash generation rate from the plant is likely to be approximately 20,000 tonnes per annum[11] (tpa). It is understood from previous LPL analysis that up to 80% of the total ash is released as pulverised fly ash (PFA), with the remaining 20% forming furnace bottom ash (FBA); therefore the plant would be expected to produce 16,000tpa of PFA, and 4,000tpa of FBA. When the fraction of dust (at ELV of 20mg/Nm^3 or 216tpa) lost to atmosphere is excluded, this results in the quantity of PFA collected being 15,784tpa.

The LPL ash lagoon environmental permit (EPR/FP3437CZ) allows for the on-site disposal of both PFA and FBA (if classified as non-hazardous). The ash (both PFA and FBA) produced by the plant in this scenario will continue to be classified as non-hazardous (due to the absence of use of reagents), and can be disposed of in the ash lagoons on site.

LPL is currently investigating the potential outlets for reuse or recycling of FBA and PFA. In the meantime however, they intend to retain the capability to dispose of the ash (conditioned PFA and FBA) in the existing permitted ash lagoons. Alternative options may be pursued as and when identified.

6.1.1.2 Damage Costs

The damage costs that have been applied to the NO_x emissions within the CBA tool are those developed for the electrical supply industry[12] (labelled as "NO_x ESI"), and are £1,263 per tonne of NO_x. The annual damage costs of approximately 2,163 tonnes of NO_x being released is therefore £2,731,539.

6.1.1.3 Costs

As this option is considered to be the base case, the upgraded equipment installed at the power plant for emissions control for NO_x, i.e. low NO_x burners with Boosted Over Fire Air (BOFA) equipment, is installed for all options proposed in this assessment. It is therefore not deemed necessary to include the costs for installation for these primary measures here.

The ash lagoons are owned and operated by LPL, and only the nominal landfill disposal costs (£2.80/tonne) estimated to be around £55,440 per annum and routine operational costs will apply for the on-site disposal of the non-hazardous ash.

6.1.2 Option 2: Proposed Derogation – Control of NO_x Emissions through Primary Means

The emissions, environmental damages and associated costs for the power plant in this option will be the same as those stated above in Option 1.

6.1.3 Option 3: Installation of SNCR to Achieve Emissions at the Upper Limit of the BAT-AEL for NO_x

For the purpose of the CBA assessment, this Option is considered as the "BAT-AEL" case within the accompanying CBA spreadsheet tools.

It should be noted that as outlined in Section 5.1.3, it is considered unlikely that the installation of SNCR will be able to considerably reduction in the emissions to achieve the upper end of the BAT-AEL; however this option has been assessed assuming the BAT-AEL will be achieved by installation of SNCR in line with a conservative approach.

[11] Permit EPR/FP3137CG, Pre-Operational Condition PO07 - Ash Handling and Treatment, Lynemouth Power Ltd, 06th July 2017
[12] Defra. (2015). Damage Costs by Location and Source. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/460398/air-quality-econanalysis-damagecost.pdf

6.1.3.1 Emissions

The NO_x emission levels would be around the upper limit of the LCP BRef BAT-AEL (160mg/Nm^3), with annual NO_x releases in the region of 1,730tpa. This represents a reduction in the annual NO_x released over Option 1 of approximately 433 tonnes per year.

The use of urea in the SNCR can result in the release of ammonia in the flue gases (known as ammonia slip) as well as ammonia within the resulting ash.

An emission concentration of 3mg/Nm^3 ammonia has been assumed in the flue gas (at the lower range of the BAT-AEL for ammonia associated with the use of SNCR), which equates to an annual ammonia release of 32tpa).

6.1.3.2 Cross-media Effects

Urea will be required for the operation of the SNCR. The rate of urea injection required for the SNCR to affect NO_x reduction has been assumed to be 284kg/hour for every 20mg/Nm^3 reduction in NO_x emissions, based on previous AECOM experience. It is therefore estimated that the total annual usage of urea (as a 40% aqueous solution) to achieve the BAT-AEL of 160mg/Nm^3 for NO_x emissions would be 4,478tpa. This would result in 150 deliveries of urea solution per year (assuming 30 tonnes per delivery).

The urea solution will also require transport to site. The quantity of fuel used for transport has been estimated assuming that the urea solution delivered from an identified supplier located at a distance of 280km. Assuming 4,478 tonnes of urea are required per year, and the distance of 280km, the total diesel fuel required for the round-trip for delivery has been estimated as 36,522 litres/year[13]. This has been entered into the CBA tool as "Road Diesel" usage.

Based on the total ash content of the biomass fuel comprising biomass ash content, and unburnt fuel as char, it is estimated that a total of 20,000 tonnes of ash will be generated from the combustion of biomass, comprising 80% PFA and 20% FBA.

In this option, up to 108tpa of dust is expected to be emitted to the atmosphere from the dust abatement plant; leading to the quantity of collected PFA being 15,892tpa, which would likely need to be treated prior to disposal as hazardous waste at an off-site landfill, as the LPL ash lagoons used as the current disposal route are not permitted to accept hazardous waste.

The FBA (4,000tpa) would continue to be uncontaminated in this case, and will continue to be sent for disposal to the on-site lagoons as a non-hazardous waste stream. However, the PFA will most likely be classified as a hazardous waste stream, requiring off-site disposal, or additional pre-treatment to allow recycling.

There would also be the potential for fugitive emissions of ammonia during unloading and storage, although these have not been quantified for the assessment.

SNCR also has an auxiliary load of 20kWh[14], therefore requiring an annual electricity consumption of 158MWh.

It is further expected that there would be a loss of revenue for LPL for the installation of SNCR at Lynemouth installation on account of reduced generation capacity during the major plant outage. This is likely to be in the region of £10 million in total.

6.1.3.3 Damage Costs

The damage costs that have been applied to the NO_x emissions within the CBA tool are those developed for the electrical supply industry (£1,263 per tonne of NO_x emitted). The annual damage costs of approximately 1,730 tonnes of NO_x being released is therefore £2,185,231, which is £546,308 less than Option 1.

There are additional damage costs for the emissions of ammonia. The damage cost assigned to ammonia in the CBA tool is £2,363 per tonne, which equates to an annual cost of £76,658 on the basis of 32 tonnes of ammonia released per annum. Note that this damage cost does not consider nitrogen deposition effects on Habitat sites.

Consequently the total annual environmental damage costs for this option are £2,261,890.

[13] EMEP/EEA Air Pollutant Emissions Inventory Guidebook - Fuel consumption of a HDV (g/km) = 240 98/69/EC (Euro 3) & 99/96/EC (Euro III) Reference Diesel Fuel - min density 0.833, max 0.837 https://www.dieselnet.com/standards/eu/fuel_reference.php
[14] Lynemouth Power Station Biomass Conversion – White Pellet, Section 5 Technical Specification, Doosan Babcock, 26th October 2015

6.1.3.4 Costs

The capital costs associated with the installation of SNCR have been provided by the LPL project engineers. A total cost of £8,300,000 has been provided for the purchase and installation of the units. This is considered to be very conservative compared to CAPEX costs determined independently, e.g. £20.7M calculated by RWE[15].

The operating costs of the SNCR units have been calculated based on the purchase and transport of urea to the plant, and the disposal of ammoniated ash. A cost per tonne of urea solution has been provided by the material suppliers of £168.02/tonne, which equates to a total annual cost of £752,400.

The annual disposal cost for 15,892tpa of ammoniated ash is expected to be around £2,491,000, at the rate of £156.67 per tonne. The hazardous waste disposal cost comprises the cost for hazardous waste treatment, haulage costs and consignment note costs. The off-site treatment and disposal of PFA would lead to a saving of approximately £44,500 in terms of landfill disposal costs, at the rate of £2.80/tonne, compared to the baseline operations.

In addition to the hazardous waste, there will continue to be the cost for disposal of the non-hazardous FBA in the on-site lagoons, which is estimated to be £11,200 per year, at £2.80/tonne of ash disposed of.

The total cost for the disposal of the ash is therefore estimated to be around £2,456,481.

There would also be an associated operating cost comprising reagent costs, loss of efficiency for the host plant and maintenance costs. The LCP-BRef estimates this to be €1,500 (£1,250 based on an Exchange Rate of £1 = €1.20) per tonne of NO_x removed by the SNCR when using urea (as a 40% aqueous solution) solution. This equates to around £540,700 per annum for the removal of NO_x by the SNCR at the Lynemouth Power Plant. This is considered to be conservative compared to OPEX costs independently determined, e.g. £0.96M/annum calculated by RWE[16] including thermal losses.

6.1.4 Option 5: Installation of SCR to Achieve Emissions at the Upper Limit of the BAT-AEL for NO_x

6.1.4.1 Emissions

The NO_x emission levels would be at the LCP BRef BAT-AEL of 160mg/Nm^3, with annual NO_x releases in the region of 1,730 tonnes. This represents a reduction in the annual NO_x released over Option 1 of approximately 433 tonnes per year.

The use of ammonia in SCR can result in the release of ammonia in the flue gases (known as ammonia slip). An emission concentration of 3mg/Nm^3 has been assumed (which is at the lower range of the BAT-AEL for ammonia associated with the use of SCR). This equates to an annual ammonia release of 32tpa.

6.1.4.2 Cross-media Effects

Aqueous ammonia will be required for the operation of the SCR units. Based on previous AECOM experience with similar facilities, it is assumed that 375kg/hour of aqueous ammonia injection will be required to achieve the 50mg/Nm^3 reduction in NO_x emissions, down to 160mg/m^3 (annual average). It is therefore estimated that the annual usage of ammonia (as a 29.4% aqueous solution) in the SCR would be in the region of 1,618 tonnes per year. This would result in 54 deliveries of ammonia per year (assuming 30 tonnes per delivery).

SCR also has a parasitic electrical load due to the pumps and fan systems involved. Previous experience with similar facilities has shown that the electrical parasitic load for SCR is nominally 0.48MW for 7,884 annual operating hours[17] for reagent injection. This corresponds to an additional 3,784MWh of electricity usage per year.

The ammonia solution will also require transport to site, which will generate NO_x, CO, CO_2 and particulate emissions from the combustion of transport fuel. The quantity of fuel used for transport has been estimated assuming that the ammonia is manufactured at a site located 96km distant from the LPL installation. Assuming 1,618 tonnes of ammonia is required per year, the total diesel fuel required for delivery has been estimated as 4,508 litres[18] (assuming a round trip).

[15] Lynemouth Power Station: Appraisal of BAT for NOx, Dust and CO, RWE, TECH/TEF/3026/18, November 2018
[16] Lynemouth Power Station: Appraisal of BAT for NOx, Dust and CO, RWE, TECH/TEF/3026/18, November 2018
[17] BAT and Options Appraisal for CCGTs, AECOM for Eggborough Power Ltd, March 2018
[18] EMEP/EEA Air Pollutant Emissions Inventory Guidebook - Fuel consumption of a HDV (g/km) = 240 98/69/EC (Euro 3) & 99/96/EC (Euro III) Reference Diesel Fuel - min density 0.833, max 0.837 https://www.dieselnet.com/standards/eu/fuel_reference.php

There would also be the potential for fugitive emissions of ammonia during unloading and storage, although these have not been quantified for the assessment.

Lastly, the SCR will generate waste spent catalyst, which requires periodic replacement. The LCP BRef states that SCR plants typically require catalyst regeneration once every five years; this is likely to be more frequent at the Lynemouth installation due to the tendency of biomass fuels to poison SCR catalysts because of high potassium levels. Although specific waste quantities for this aspect are to be defined, the annual costs for the operation of the SCR units have included reagent purchase, catalyst handling and replacement and additional labour for the operation of the SCR units (as defined within the LCP BRef).

Considering the significant restrictions posed by the current site configuration, installation of SCR at the installation is likely to require major plant outage, leading to reduced generation capacity and therefore loss in revenue. This is likely to be in the region of £108 million in total.

6.1.4.3 Damage Costs

The damage costs that have been applied to the NO_x emissions within the CBA tool are those developed for the electrical supply industry (£1,263 per tonne of NO_x emitted). The annual damage costs of approximately 1,730 tonnes of NO_x being released is therefore £2,185,231, which is £546,308 less than Option 1.

There are additional damage costs for the emissions of ammonia. The damage cost assigned to ammonia in the CBA tool is £2,363 per tonne, which equates to an annual cost of £76,658 on the basis of 32 tonnes of ammonia released per annum. Note that this damage cost does not consider nitrogen deposition effects on Habitat sites.

Consequently the total annual environmental damage costs for this option are £2,261,890.

6.1.4.4 Costs

The capital costs associated with the installation of the SCR units has been estimated based on the guidance from the LCP BRef for the operation of coal fired power plants, due to the lack of more suitable operational data. The LCP BRef states that the capital cost for a coal fired power plant emitting flue gas in the region of 1,000,000m^3/hour is in the region of €15 million. It is therefore estimated that it would cost a total of £17,145,000 for the purchase and installation of three units (assuming a currency exchange rate of £1 = €1.20).

Based on AECOM experience with similar installations and the site constraints at Lynemouth, including but not limited to modifications that would need to be made to the duct and the supporting structure, it is expected that in reality it could cost LPL up to £100,000,000 to purchase and install SCR for the three units. However, the costs included in the CBA are reflective of the costs recommended by the LCP BRef in accordance with the conservative approach followed for this assessment. The upper estimate of £100M is considered more realistic that then £17.1M cost assumed in the CBA (in line with a conservative approach) and this is supported by CAPEX costs determined independently, e.g. £68.5M calculated by RWE[19].

The operating costs of the SCR units have been calculated based on the purchase of ammonia and the handling and treatment of the catalyst. A cost per tonne of ammonia has been provided by the LPL project engineers of £700/tonne, which equates to a total annual cost of £1,132,863.

Additional maintenance costs would include the costs for catalyst replacement, maintenance and wear and tear on the equipment. This cost has been estimated using guidance for coal fired power plants from the LCP-BRef and equates to an additional £241,506 per year.

The OPEX costs utilised in this study are considered conservative compared to those determined independently, e.g. £4.1M/annum calculated by RWE[20] including works power, catalyst and reagent.

6.2 Proposed BAT Options for Dust Abatement

6.2.1 Option 1: Business as Usual – Dust Emissions Controlled Through Existing Upgraded ESPs

6.2.1.1 Emissions

The existing ESPs at the site have been modified to better suit biomass combustion. The modifications will allow the site to achieve the IED Annex V emission limits for dust of 20mg/Nm^3.

[19] Lynemouth Power Station: Appraisal of BAT for NOx, Dust and CO, RWE, TECH/TEF/3026/18, November 2018
[20] Lynemouth Power Station: Appraisal of BAT for NOx, Dust and CO, RWE, TECH/TEF/3026/18, November 2018

This results in an estimated release of 216 tonnes of dust annually.

6.2.1.2 Damage Costs

The damage costs that have been applied to the dust emissions within the CBA tool are those developed for the electrical supply industry[21] (labelled as "PM10 ESI"), and are £2,906 per tonne of dust.

The estimated annual damage cost of 216tpa of dust being released from the power plant is £628,492.

6.2.1.3 Costs

Modifications to the existing ESPs at the site, to meet the IED Annex V ELVs, are already installed. It is therefore not deemed necessary to include the costs for the installation of the primary measures in the assessment of this option.

6.2.2 Option 2: Proposed Derogation – Dust Emissions Controlled Through Existing Upgraded ESPs

The emissions, environmental damages and associated costs for the power plant in this option will be the same as those stated above in Option 1.

6.2.3 Option 3: Installation of an Additional Upgrades to the ESP to Achieve Emissions at the Upper Limit of BAT-AEL for Dust

6.2.3.1 Emissions

The dust emissions would comply with the upper limit of the LCP-BRef BAT-AEL of 10mg/Nm^3 (annual average), with annual dust emissions being 108 tonnes; thereby reducing the dust emission by 50% in comparison to Option 1.

The nature of fly ash captured by this option will continue to be non-hazardous, assuming continued operations as present. The disposal route for the fly-ash will therefore continue to be the same as now i.e. to the on-site ash lagoons (until alternative treatment routed are identified)..

6.2.3.2 Cross-media Effects

The additional ESP upgrades would have an additional electrical parasitic load. Based on the LCP-BRef guidance that 0.1% of the thermal input to the power plant is typically required for ESPs for current plant, it is estimated that approximately 189kW of additional power will be required for each additional ESP field; with the total annual consumption for three additional fields required for the three ESPs being 4,474MWh.

It should be noted that this would be in addition to the electricity consumption by the existing ESPs, which is estimated to be 1,135kW or 8,949MWh annually. Therefore, the total electricity consumption of the ESPs if additional fields are installed will be 13,424MWh per year.

However, as discussed in Section 5.2.3, it is unlikely that the upgrades to the ESP would be able to achieve emissions compliant with BAT-AELs.

Furthermore, installation of additional upgrades to the ESPs at the installation is likely to require major plant outage due to the restrictions posed by the current site configuration, leading to reduced generation capacity and therefore loss in revenue. This is likely to be in the region of £108 million in total.

6.2.3.3 Damage Costs

The damage costs that have been applied to the dust emissions within the CBA tool are those developed for the electrical supply industry (£2,906 per tonne).

The annual damage cost of 108 tonnes of dust being released is therefore £314,246, which is £418,995 less than Option 1 (i.e. roughly half of the cost).

6.2.3.4 Costs

Based on previous AECOM experience with ESPs installed in similar installations and site specific constraints at Lynemouth, it is considered that the actual cost for the upgrades to the ESPs is likely to require modifications that would need to be made on the back end to rearrange the ducting and replace the ID fans, which are very likely to

[21] Defra. (2015). Damage Costs by Location and Source. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/460398/air-quality-econanalysis-damagecost.pdf

cost between £5million to £10million. Therefore a capital cost of £5,000,000 has been used in this assessment in line with the conservative approach followed by this assessment. This cost is comparable to the £3.0-4.0M determined by RWE in their separately reported technical review.

The LCP-BRef states that the typical operating cost for an ESP is £0.0003/kWe. On this basis, the cost for the operation of each of the current ESPs is estimated to be £993,384. As each ESP contains two fields, this implies that the cost for operating one field is £165,564. The cost for operating an additional field on each ESP unit (of which there are three units) has therefore been taken to be £496,692 per year. The operating cost of the ESPs at the site will therefore rise to a total of £1,490,076 per year.

The fly-ash generated would likely be non-hazardous if the ESP upgrades are applied with no changes to current operations. In this case, all ash (bottom ash and fly ash) from the installation would be permitted to be disposed of in the on-site ash lagoons. This is anticipated to cost the installation around £55,697 per annum for the disposal of 19,892tpa of ash.

6.3 Summary of Available Options

A summary of the annual total emissions and damage costs for the options assessed for NO_x and dust abatement is provided in Table 6-1.

Table 6-1: Emissions and Damage Costs for the Proposed Options

Option	ELV or BAT-AEL (mg/m^3)		Emissions to Air (Tonnes/Year)			Damage Costs (£/Year)			
	NO_x	Dust	NO_x	Dust	NH_3	NO_x	Dust	NH_3	Total
NO_x Abatement Options									
Option 1: Business as Usual – Control of NO_x Emissions through Primary Means	200	-	2,163	-	0	£2,731,539	-	0	**£2,731,539**
Option 2: Proposed Derogation - Control of NO_x Emissions through Primary Means	200	-	2,163	-	0	£2,731,539	-	0	**£2,261,890**
Option 3: Use of an SNCR to achieve upper limit of NO_x BAT-AELs	160	-	1,730	-	32	£2,185,231	-	£76,658	**£2,261,890**
Option 5: Use of an SCR to achieve upper limit of NO_x BAT-AELs	160	-	1,730	-	32	£2,185,231	-	£76,658	**£2,261,890**
Dust Abatement Options									
Option 1: Business as Usual – Dust emissions controlled through existing upgraded EPs	-	20	-	216	-	-	£628,492	-	**£628,492**
Option 2: Proposed Derogation - Dust emissions controlled through existing upgraded EPs	-	20	-	216	-	-	£628,492	-	**£628,492**
Option 3: Installation of an Additional Upgrades to the ESP to Achieve Emissions at the Upper Limit of BAT-AEL for Dust	-	10	-	108	-	-	£314,246	-	**£314,246**

7. Cost Benefit Assessment

Central to the principle of Integrated Pollution Prevention and Control ("IPPC"), now regulated under the IED, is the requirement on operators to take appropriate preventative measures against pollution through the application of BAT.

The definition of BAT includes the use of technological (and managerial) measures, which are developed on a scale suitable for implementation under economically and technically viable conditions, to achieve a high level of environmental protection as a whole. It is recognised that prevention of an emission in the first place is preferable to the use of secondary abatement to control an emission, and secondary abatement should only be considered once primary means have been exhausted.

Under the terms of this definition, the principles of the BAT hierarchy can therefore be considered to be applied firstly through the use of "primary means" or measures to prevent the generation of pollutant emissions within a process, for example through the use of low NO_x burners and lower combustion temperatures, and secondly through use of "secondary means" or measures to prevent those emissions entering the environment, for example through use of an emission treatment or abatement process.

A detailed review of the options to potentially achieve BAT, incorporating the costs and benefits (both environmental and fiscal) can then determine the most appropriate technique to apply at the specific facility.

7.1 Discounted Cash Flow Analysis

An assessment of the costs associated with each of the options using a Discounted Cash Flow (DCF) analysis technique is the recommended assessment method for consideration of BAT and derogation applications.

A DCF has been prepared using the Environment Agency's Industrial Emissions Directive Cost-Benefit Assessment (IED CBA) Tool (Version 6.17, September 2017). This is a method developed within the UK to allow a full cost-benefit assessment for derogation applications; using capital and operating costs for the site options and the cost 'savings' (or benefits) of the reduced pollution emissions. The tool incorporates the cost of accessing financial capital into the calculations, but this is discounted using the social discount rate.

For each option the tool takes the investment as the initial upfront investment, the interest rate as the central weighted average cost of capital (WACC) percentage is entered into the tool, and the length of the investment as the length of the appraisal.

The tool allows the user to enter identified costs of each proposed option (for example, capital project costs, operational costs, and associated additional emissions) and benefits (for example, the welfare value of the emissions removed) across the lifetime of the equipment. Cost and benefits reflect 'additional' costs and benefits of each option. This produces an overall Net Present Value (NPV) for each option, compared against the presented derogation option. Options are then ranked to show an overall preferred option.

7.2 CBA Assessment

The following aspects were taken in to consideration within the CBA tool:

- CAPEX costs for the converted power plant, including SNCR/SCR abatement where appropriate.
- Additional OPEX costs for SNCR/SCR abatement; including reagent and catalyst use (in SCR only) and additional labour.
- Electricity, gas and diesel usage (where appropriate).
- Emissions of ammonia as ammonia slip and ammoniated ash.
- Additional costs for disposal of ammoniated ash as hazardous waste.

The CBA assessment assumes that the abatement measures are technically viable for the installation and will therefore achieve the required BAT-AELs; however, it has been demonstrated (see the technical review document) that their implementation and efficiency (if implemented) will be severely limited by the technical restrictions of the LPL installation.

The power plant will commence operation as a 100% biomass-fired installation this year (2018) with an assumed project lifetime running to the end of the existing CfD contract in 2027. Justification for the derogation request to 2027 is provided elsewhere. The period of assessment has therefore been considered to be 10 years, with 2018 representing the baseline.

The first step in the CBA assessment is a simple risk appraisal of the options, as summarised in Table 7-1, based on a qualitative analysis of the options compared to each other.

Table 7-1: Qualitative Appraisal of Options

Option	Cost	Emissions	Feasibility	Ranking
NO_x Abatement Options				
Option 1: Business as Usual – Unabated NO_x emissions except through primary means	Negligible	Medium Negative	Negligible	0
Option 2: Proposed Derogation – Unabated NO_x emissions except through primary means	Negligible	Medium Negative	Negligible	1
Option 3: Installation of an SNCR to achieve emissions at the Upper Limit of BAT-AEL for NO_x	Medium Negative	Negligible	Medium Negative	2
Option 5: Installation of an SCR to achieve emissions at the Upper limit of BAT-AELs for NO_x	Large Negative	Negligible	Large Negative	4
Dust Abatement Options				
Option 1: Business as Usual – Unabated dust emissions except through primary means	Negligible	Medium Negative	Negligible	0
Option 2: Proposed Derogation – Unabated dust emissions except through primary means	Negligible	Medium Negative	Negligible	1
Option 3: Installation of an Additional Upgrades to the ESP to Achieve Emissions at the Upper Limit of BAT-AEL for Dust	Large Negative	Negligible	Large Negative	2

A summary of the outcome of the cost – benefit assessment is presented in Table 7-2. The emissions and damage costs for individual pollutants (NO_x, dust and ammonia) have not been included below, for avoidance of repetition of information included in Table 7-1.

The assessment compares the cost and benefits of all options against the current baseline option of primary control measures with no SNCR/SCR abatement for NO_x (NO_x Option 1), and operation of the existing upgraded ESPs for dust (Dust Option 1).

A positive Net Present Value (NPV) indicates that the benefits exceed the costs, whilst a negative NPV demonstrates that the costs outweigh the benefits. The basis of the calculation, using the UK's Environment Agency's IED Cost Benefit Analysis Tool (Version 6.17, September 2017) including a breakdown of capital and operating costs for each year of the assessment, is presented in Appendix A and Appendix B for the options.

Table 7-2: Cost/Benefit Assessment of Options for NO_x and Dust Abatement

Option	ELV or BAT-AEL (mg/m^3) (mg/Nm^3)	Emissions (tonnes/year)	Capital Costs[(1)] (£m)	Operating Costs (£m)	Pollution Reduction Benefit (£m)	NPV (£m)	Ranking Based on NPV
NO_x Emissions							
Option 1: Business as Usual	200	2,163	-	-	0	-	0
Option 2: Proposed Derogation	200	2,163	-	-	0	-	1
Option 3: Upper Limit of BAT-AEL (SNCR)	160	1,730	-22.559	-20.901	3.726	-39.734	2
Option 5: Upper limit of BAT-AELs (SCR)	160	1,730	-156.122	-9.079	5.334	-159.867	3
Dust Emissions							
Option 1: Business as Usual	20	216	-	-	0	-	0
Option 2: Proposed Derogation	20	216	-	-	0	-	1
Option 3: Upper Limit of BAT-AEL	10	108	-141.05	-2.878	2.297	-141.63	2

Note: (1) The capital cost reflects the Weighted Average Cost of Capital, with a range of 4.5% - 9.8%.

The CBA output for NO_x emissions demonstrates that Options 3 – 4 for NO_x abatement (i.e. the use of secondary measures such as SNCR/SCR for abatement in addition to primary measures, which could hypothetically achieve compliance with the BAT-AEL for NO_x of 160mg/Nm^3) show disproportionate additional costs when considering the environmental benefit gained from the additional NOx removed over Options 1 (Business as Usual) and 2 (Proposed Derogation).

This is due to:

- The additional CAPEX and OPEX of the SNCR and SCR plants;
- The additional energy consumption from both the operation of the plant and the transport of the reagents to site (either urea or ammonia);
- The damage cost attributed to the release of ammonia as ammonia slip;
- The classification and disposal of ammoniated fly ash as hazardous waste; and
- The revenue lost by the installation during extended plant outage for the installation of the additional abatement measures.

It can be therefore be demonstrated that Option 2 (achievement of IED Annex V limits for NO_x emissions of 200mg/Nm^3 by using primary measures only) represents the preferred option; against the implementation of Options 3 and 5, which could both, in theory, achieve compliance with the LCP BAT-AEL of 160mg/Nm^3 (annual average). This is based on the assumption that there are no technical limitations to the implementation and abatement efficiency (if implemented) of options 3 and 5 at the LPL installation.

The CBA output for dust emissions shows that Option 3 (upgrade of ESP fields to potentially achieve the LCP BAT-AEL of 10mg/Nm^3) would lead to significant additional costs for the site, whilst not implementing substantial environmental benefits, i.e. only a drop from 20mg/m^3 to 10mg/m^3 for dust is achieved. The CBA therefore shows Option 3 to have very high associated costs, which are disproportionate to the environmental benefit achieved.

It can be therefore be demonstrated that Option 2 (achievement of IED Annex V limits for dust emissions of 20mg/Nm^3 by using current ESPs) represents the preferred Option; against the implementation of dust Option 3 which could theoretically achieve compliance with the LCP BAT-AEL of 10mg/Nm^3 (annual average).

As with the CBA assessment of the options for NO_x abatement, this is based on the assumption that there are no technical limitations to the implementation and abatement efficiency (if implemented) of option 3 at the LPL installation.

8. Conclusions

8.1 Proposed Derogation for NOx and Dust Emissions

A BAT assessment and CBA has been carried out in order to identify the BAT options for NO_x and dust control for the converted biomass power station at Lynemouth. As a combustion plant retrofitted to operate with biomass instead of coal, and permitted prior to the publication of the LCP-BRef, the plant is considered to be an existing plant, with the associated BAT-AELs applicable to the plant. This considers the installation of SNCR and SCR abatement for NO_x emissions, and of an additional ESP upgrades for dust abatement. The BAT assessment and CBA tool have been completed based on data provided from the LCP BRef document, the technology providers and the LPL project engineers.

Some techniques recommended by the LCP BRef for NO_x and dust abatement respectively were discounted from the assessment due to technical characteristics of the installation. These included use of bag filters for dust abatement due to the substantial risk of fire due to the high levels of unburnt carbon in the ash that would likely result in sparks reaching the bag filters. In addition to these options, technology options to achieve the lower end of the BAT-AEL range were considered, although these have not been assessed as part of the main assessment, based on the guidance from the EA (see section 3.1.3). For completeness, details of these discounted options are included within Appendix D (for NO_x abatement) and Appendix E (for dust abatement).

The CBA tool for the NO_x emissions assessment demonstrates that Options 3 and 5 (i.e. the use of secondary measures such as SNCR/SCR for abatement in addition to primary measures, which could theoretically achieve compliance with the BAT-AEL for NO_x of 160mg/Nm^3) shows disproportionate additional costs when considering the environmental benefit gained from the additional NO_x removed over Option 2 (i.e. the application of primary measures only, achieving an ELV for NO_x of 200mg/Nm^3).

This is due to:

- The additional CAPEX and OPEX of the SNCR and SCR plants;
- The additional energy consumption from both the operation of the plant and the transport of the reagents to site (either urea or ammonia);
- The damage cost attributed to the release of ammonia as ammonia slip;
- The classification and disposal of ammoniated fly ash as hazardous waste
- The revenue likely to be lost by LPL during extended plant outages to install additional abatement measures.

The CBA tool for the dust emissions assessment demonstrates that Option 3 (i.e. the installation of additional ESP upgrades, which could achieve compliance with the BAT-AEL for dust of 10mg/Nm^3) shows a disproportionate cost when considering the environmental benefit gained from the additional dust removed over Option 2 (i.e. the application of the current ESPs, achieving an ELV for dust of 20mg/Nm^3). This is due to the additional CAPEX and OPEX of introducing the additional fields, the additional energy consumption from the operation of the abatement plant and the lost generation and revenue resulting from the extended unplanned outage required for installation.

In order to present a conservative assessment, the CBA assessment ignores the technical limitations to the feasibility of implementation of the additional emissions abatement measures, detailed within the technical review document (and listed below), in line with a conservative approach. In reality, it is likely that even if these techniques were applied at the LPL installation, the technical restrictions at the installation would mean that the installation would still not be able to achieve the required BAT-AELs.

The technical basis of the derogation application is confirmed below, and is based upon:

- The need for unplanned major outages for the power station to install the additional upgrades of abatement systems, which would lead to loss of electricity generation revenue for the plant for the duration of the outages. This would inevitably lead to a substantial loss in revenue for LPL, likely putting the viability of the overall conversion plan in jeopardy;

- The limited remaining lifetime of the power plant of less than 10 years renders the environmental benefits achieved by lower emissions of NO_x and dust not commensurate with the excessive additional CAPEX and OPEX;
- The limited space available at the installation, which would increase both the cost of applying the technology and the time required to install additional equipment;
- The fuel composition is likely to cause catalyst poisoning in SCRs resulting in increased downtime for maintenance and therefore lost generation capacity;
- The significant risk of fire if bag filter system is used, due to the high unburnt carbon in ash;
- The limited effect of the additional abatement techniques due to the requirement to retrofit (for example, the limited temperature window for efficient application of SNCR in process); and
- The associated increase in cost of hazardous waste disposal, additional raw materials, storage and management, electricity and other energy uses.

8.2 Derogation Request

As the plant is still in the combustion optimisation stage awaiting performance guarantee testing, the final performance details of the boilers are still to be confirmed. It is expected that as a minimum, the plant will operate at the designed performance output levels, which are compliant with the ELVs specified in Annex V of the IED.

Therefore, a derogation of the NOx emission limit to 200mg/Nm^3 and of 20mg/Nm^3 dust for the installation is proposed, based upon the technical restrictions within the installation that prevent compliance with the BAT-AEL.

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Appendices

Appendix A - CBA Tool – NOx Emissions

Electronic spreadsheet.

Appendix B - CBA Tool – Dust Emissions

Electronic spreadsheet

Appendix C – Inputs for CBA for NO_x and Dust Abatement

Inputs for CBA for NOx Abatement

Parameter	Primary Measures only (target – 200mg/Nm3)	SNCR (target - 160mg/Nm^3)	SCR (target - 160mg/Nm^3)	SCR (target - 40mg/Nm^3)[4]	Comment
Total actual flue gas flow rate (m^3/s)		557			AECOM calculation based on reported air emissions from the plant
Total actual flue gas flow rate (Nm^3/hr)		2,005,200			AECOM calculation based on reported air emissions from the plant and 90% plant availability or 7,884 hours of operation
Normalised flue gas flow rate (Nm^3/s)		381			Normalised flue gas flow rate based on actual flue gas flow rate
Total normalised flue gas flow rate (Nm^3/hr)		1,371,600			Normalised flue gas flow rate based on actual flue gas flow rate
Capital Cost (£) [1]	-	£8,300,000	£17,145,000		SNCR costs based on information provided by LPL. SCR costs based on LCP-BRef guidance for coal fired power stations with similar flue gas flow rates.
Operating Cost (£)[1]	-	£540,685	£241,506	£966,023	Operating costs based on LCP-BRef guidance for cost of NO_x reduction by SNCR and SCR, specified as €1,500/tonne of NO_x removed when using SNCR with aqueous urea as a reagent, and €670/tonne of NO_x removed when using SCR with aqueous ammonia as a reagent.
Additional power consumption (kWh/5,000hours of operation)[1]	-	20	480	960	SNCR utility consumption details based on information from supplier (expected performance and performance guarantee). SCR utility consumption based on previous AECOM experience for similar facilities.
Additional power consumption per year (kWh/year)	-	157,680	3,784,320	7,568,640	
Expected reagent [1]	-	Urea (40%)	Ammonia (29.4%)		Assumed concentrations of reagents based on information from potential supplier and previous AECOM experience.

Parameter	Primary Measures only (target – 200mg/Nm3)	SNCR (target - 160mg/Nm^3)	SCR (target - 160mg/Nm^3)	SCR (target - 40mg/Nm^3)[4]	Comment
Unit cost of reagent (£/tonne) [1]	-	£168.02	£700		Cost for urea and ammonia based on information from potential suppliers
Expected reagent quantities to be used (tpa) [1]	-	4,478	1,618	6,474	Reagent quantities estimated as follows: • Urea – 284kg for every 20mg/Nm^3 reduction in NO_x emissions (previous AECOM experience) • Ammonia – 375kg for every 50mg/Nm^3 reduction in NO_x emissions (previous AECOM experience)
Annual cost of reagent (£/year)[1]	-	£752,412	£1,132,863	£4,531,800	
Mass NO_x emissions (tpa)	2,163	1,730	1,730	433	AECOM calculation based on NO_x emissions
Mass ammonia emissions (tpa)	-	32.4	32.4	54.1	Assumed emissions of ammonia due to 'ammonia slip' from SNCR and SCR; it has been assumed that use of either SNCR or SCR will be compliant with the lower BAT-AEL for ammonia emissions of 3mg/Nm^3.
Annual biomass fuel throughput (tpa) [2]	1,500,000				Information from LPL
Ash content of biomass (%)	1.30%				Information from LPL, with the ash content of fuel being 1%, and the carbon in ash (i.e. unburnt fuel) being an additional 30%, leading to a total ash content of the fuel to be 1.3%.
Annual expected ash quantities (tpa)	20,000				Information from LPL
Fly ash content of total ash (%)	20				Information from LPL

Parameter	Primary Measures only (target – 200mg/Nm3)	SNCR (target - 160mg/Nm^3)	SCR (target - 160mg/Nm^3)	SCR (target - 40mg/Nm^3)[(4)]	Comment
Dust emitted to atmosphere via fly ash (tpa)	216	108	108	22	AECOM calculation based on dust abatement measures applied to enable emissions of dust of 20mg/Nm^3 when NO_x emissions are 200mg/Nm^3, 10mg/Nm^3 when NO_x emissions are 160mg/Nm^3, and 2mg/Nm^3 when NO_x emissions are 40mg/Nm^3.
Quantity of captured ash (fly ash and bottom ash) (tpa)	19,784	19,892	19,892	19,978	Total ash captured via dust abatement systems.
Quantity of bottom ash (tpa)	4,000				Estimated based on 20% of the captured ash comprising bottom ash.
Quantity of fly ash captured by dust abatement system (tpa) [(3)]	15,784	15,892	15,892	15,978	Estimated based on 80% of the captured ash comprising fly ash.
Cost of hazardous waste disposal (£/tonne) [(3)]	-	£2,456,481	-	-	It is assumed that due to use of primary measures only for NOx abatement, and therefore absence of ammoniated (or similar reagents) will lead to the ash in Option 1 being non-hazardous, which can be disposed of in the storage lagoons as is current practice, thereby avoiding disposal costs. The lagoons are not permitted to accept hazardous waste therefore requiring ash from Option 3 to be disposed of off-site. As SCR is usually installed following dust abatement, it is assumed that all ash in Options 4 and 5 will be non-hazardous and can be disposed of in the onsite ash lagoons.
No. of reagent deliveries per year	-	150	54	216	Based on each delivery comprising 30t of reagent.
Distance from reagent supplier (km)	-	280	96	96	Distance from the potential reagent supplier facilities to the LPL power station.
Diesel for delivering reagent to site (l/year)	-	36,522	4,508	18,031	Quantities estimated using mileage for diesel operated lorries by Department for Transport statistics in 'Average heavy goods vehicle fuel consumption: Great Britain, 2003-2015'

Notes:

1. As use of Primary Measures has been designed into the existing plant, this represents the base case for the plant. The capital and operational costs, and associated power consumption have not been included in the CBA. No additional reagents will be applied to the plant when operating with primary measures only.
2. Annual biomass throughput to the power plant will remain the same, whether only primary measures for emissions abatement are applied or additional abatement measures are implemented.
3. The ash produced by the plant when operating on primary measures only is not expected to be hazardous, as it does not involve the use of any reagents.
4. This option has been assessed using the CBA tool for completeness; however is not included within the main assessment on the basis of EA guidance (see section 3.1.3). Details of this option are provided within Appendix D.

Inputs for CBA for Dust Abatement

Parameter	Primary Measures only (target – 20mg/Nm3)	Additional EP Field (target - 10mg/Nm^3)	Comment
Total actual flue gas flow rate (Nm^3/s)	557		AECOM calculation based on reported air emissions from the plant
Total actual flue gas flow rate (Nm^3/hr)	2,005,200		AECOM calculation based on reported air emissions from the plant and 90% plant availability or 7,884 hours of operation
Normalised flue gas flow rate (Nm^3/s)	381		Normalised flue gas flow rate based on actual flue gas flow rate
Total normalised flue gas flow rate (Nm^3/hr)	1,371,600		Normalised flue gas flow rate based on actual flue gas flow rate
Capital Cost (£) [(1)]	-	£5,000,000	Capital investment for installation of additional field in the existing ESPs is based on previous AECOM and LPL experience.
Operating Cost (£)[(1)]	-	£496,692	Operating costs based on LCP-BRef guidance for ESP - £0.0003/kWe
Additional power consumption [(1)]	-	567.57	Additional power consumption estimates based on guidance from LCP-BRef for ESPs - Based upon 0.1% consumption of thermal input for EP for current plant, and reduced to a third to represent additional field
Additional annual power consumption (kWh/year)[(1)]	-	4,474,703	Only for additional ESP upgrades and not including existing ESP operations.
Dust emitted to atmosphere via fly ash (tpa)	216	108	AECOM calculation based on dust emission levels of 20mg/Nm^3, 10mg/Nm^3 and 2mg/Nm^3.
Annual biomass fuel throughput (tpa) [(2)]	1,500,000		Information from LPL
Ash content of biomass (%)	1.33		Information from LPL
Annual expected ash quantities (tpa)	20,000		Information from LPL
Fly ash content of total ash (%)	20		Information from LPL
Quantity of captured ash (fly ash and bottom ash) (tpa)	19,784	19,892	Total ash captured via dust abatement systems.
Quantity of bottom ash (tpa)	4,000		Estimated based on 20% of the captured ash comprising bottom ash.

Parameter	Primary Measures only (target – 20mg/Nm3)	Additional EP Field (target - 10mg/Nm^3)	Comment
Quantity of fly ash captured by dust abatement system (tpa) (3)	15,784	15,892	Estimated based on 80% of the captured ash comprising fly ash.
Cost of waste disposal (£/tonne) (3)	£55,394	£55,697	Assumed that ash generated in Option 3 will be slightly more than the baseline operations due to increased abatement, and will be non-hazardous on the basis of continued current operations.

Notes:

1. As use of Primary Measures has been designed into the existing plant, this represents the base case for the plant, The capital and operational costs, and associated power consumption have not been included in the CBA. No additional reagents will be applied to the plant when operating with primary measures only.
2. Annual biomass throughput to the power plant will remain the same, whether only primary measures for emissions abatement are applied or additional abatement measures are implemented.
3. The ash produced by the plant when operating on primary measures only is not expected to be hazardous, as it does not involve the use of any reagents.

Appendix D - Assessment of Options for achieving Lower limit of BAT-AEL for NOx

D.1 Option 4: Installation of SNCR to Achieve Emissions at the Lower Limit of BAT-AEL for NO_x

D1.1 Emissions

The implementation of secondary abatement measures, such as SNCR, would be required for the plant to achieve emissions below the lower limit of the annual average BAT-AEL of 40mg/Nm^3.

Urea injection at larger levels than applied in NOx option 3 would be needed, increasing the potential for ammonia slippage. Emissions of ammonia equivalent to 5mg/Nm^3 are expected for this option.

D1.2 Cross Media Effects of SNCR

The cross-media effects of this option will be comparatively higher than those observed for Option 3, primarily in terms of higher electricity use, urea usage and associated costs.

The corresponding corrosion issues from the use of urea as a reagent for SNCR would be expected to be higher with this Option when compared to Option 3. In addition to this, ammonia releases in the form of higher ammonia slippage and the quantity of ammonia in the ash would also be higher consistent with the higher urea use. As with Option 3, if the ash is ammoniated it is likely to be classed as a hazardous waste; and not permitted for disposal in the LPL ash lagoons resulting in higher off-site disposal or treatment costs.

Injection of urea solution at the cross-over tubing junction in the boilers is expected to have corrosion impact on the tubing material, similar to Option 3 as described in Section 5.1.3.2, but greater in scale due to the higher urea injection rate.

There would also be the same implications (as Option 3) relating to the transport and storage of aqueous urea to the site.

D1.3 Feasibility

The restrictions stated for Option 3 (see Section 5.1.3.3) would also apply to this case, and would in fact be more limiting in this scenario, due to the lower NO_x ELV to be achieved. It is anticipated that this Option would entail a higher quantity of reagent in the SNCR, requiring additional storage. Furthermore, due to the limited space that is available to locate the reagent injection, it is considered that it would not be possible to inject reagent quantities greater than those required to achieve the upper end of the BAT-AEL.

Due to the limited space that is available to locate the reagent injection, SNCR would produce very limited results at Lynemouth. Previous AECOM experience has shown that SNCR struggles to achieve the upper BAT-AEL, and would therefore is unlikely to be able to achieve the lower end of the BAT-AEL.

This option has therefore not been considered any further.

D.2 Option 6: Installation of SCR to Achieve Emissions at the Lower Limit of BAT-AEL for NO_x

D2.1 Emissions

The implementation of higher ammonia injection and additional catalyst could be applied through SCR to achieve emissions at the lower limit of the annual average BAT-AEL (40mg/Nm^3).

The operation of the SCR would be largely the same as that described in Section 5.1.4, and may use a 29.4% aqueous ammonia solution or equivalent as the reagent, albeit in considerably higher quantities to meet the BAT-AEL.

Ammonia injection above the levels applied in Option 5 would be needed, increasing the potential for ammonia slippage. Consequently emissions of ammonia equivalent to 5mg/Nm^3 are expected for this option.

Similar issues to Option 5 will be encountered for this option. Therefore, it is considered that sootblowers will be required to keep the catalyst clean due to the presence of dust, if the SCR is installed downstream of the economiser and upstream of the air heater. The potential for the dust to absorb some of the ammonia is also likely to affect its classification for disposal purposes.

As with Option 5, an alternative would be to install a low-temperature SCR downstream of the ESP. However, since the flue gas at this location is too low for the reactions to occur across the catalyst, it would be necessary to reheat the flue gas. The most common approach would be to install a bypass around the economizer and air heater, which could then increase the temperature of the flue gas entering the SCR from 150ºC up to about 230ºC. However, this would result in a decrease in the net unit heat rate of about 4%.

The additional pressure drop across the catalyst would also be a major concern. This would require the installation of new, larger induced draught (ID) fans to maintain the generating capacity of each unit. The larger fans would increase the electrical consumption and as a result, the cost to operate the plant.

The NO_x emission levels would be at the LCP BRef BAT-AEL of 40mg/Nm^3, with annual NO_x releases in the region of 433tpa. This represents a reduction in the annual NO_x released over Option 1 of 1,730 tonnes per year.

The use of ammonia in the SCR can result in the release of ammonia in the flue gases (known as ammonia slip). Due to the increased rate of injection required to achieve the lower emission levels for NO_x, the amount of ammonia slip will be higher than that in Option 4. An emission concentration of 5mg/Nm^3 for this option equates to an annual ammonia release of 54tpa.

D2.2 **Cross Media Effects of SCR**

Ammonia releases from the SCR process are expected to occur from ammonia slippage due to incomplete reaction. The BAT-AEL associated with ammonia slip emission is <3-10mg/Nm^3, as an annual average, and the assessment has assumed a level of 5mg/Nm^3 is achieved at higher ammonia injection rates than Option 5.

It is expected that higher ammonia injection rate will entail a higher catalyst usage, leading to more frequent catalyst replacement. As noted by the UK LCP BRef Technical Working Group (TWG), commercially available biomass fuels have a tendency to poison catalyst used in SCR systems, therefore requiring frequent catalyst replacement. This adds additional cost for the replacement, recovery, regeneration or disposal of the catalyst. This issue will make this option, with higher ammonia injection than Option 5, particularly uneconomical.

More qualitative and indirect effects include fugitive emissions from on-site storage and handling of ammonia solution, increased environmental risk from the site due to the storage of ammonia solution and the associated upstream life cycle emissions from the manufacture and transportation of ammonia, resulting in additional emissions.

Although not all of these impacts can be easily quantified, the consequences of the transport of ammonia to the site have been taken into consideration in the CBA assessment.

Aqueous ammonia will be required for the operation of the SCR units. Using the assumption that 375kg/hour of aqueous ammonia will be required to reduce 50mg/Nm^3 of NO_x emissions, it is estimated that around 6,474 tonnes of ammonia (as a 29.4% aqueous solution) will be required per year. This would result in circa 216 deliveries of ammonia per year (assuming 30 tonnes per delivery).

SCR also has an auxiliary electrical load due to the pumps and fan systems involved. Previous experience with similar facilities has shown that the electrical parasitic load for SCR is 0.96MW for 7,884 annual operating hours. This corresponds to an additional 7,568MWh of electricity usage per year.

The ammonia solution will also require transport to site, which will generate NO_x, CO, CO_2 and particulate emissions from the combustion of transport fuel. The quantity of fuel used for transport has been estimated assuming that the ammonia is manufactured in a site 96km distant from the LPL installation. Based on an annual usage of 6,474tpa of aqueous ammonia, and the distance of 96km, the total diesel fuel required for the round trip to deliver the ammonia has been estimated as 18,031 litres[22].

There would also be the potential for fugitive emissions of ammonia during unloading and storage, although these have not been quantified for the assessment.

Finally SCR will generate waste spent catalyst, which requires replacement. The LCP BRef states that SCR plants typically require catalyst regeneration once every five years; this is likely to be more frequent at the Lynemouth installation due to the tendency of biomass fuels to poison SCR catalysts because of high potassium levels. Although specific waste quantities for this aspect are to be defined, the annual costs for the operation of the SCR units have included reagent purchase, catalyst handling and replacement and additional labour for the operation of the SCR units (as defined within the LCP BRef).

D2.3 Damage Costs

The damage costs that have been applied to the NO_x emissions within the CBA tool are those developed for the electrical supply industry (£1,263 per tonne of NO_x). The annual damage costs of 433 tonnes of NO_x being released is therefore £546,308, which is £2,185,231 less than Option 1.

The annual damage cost for emissions of ammonia as 'ammonia slip' is estimated to be £127,764 on the basis of damage costs of £2,363 per tonne (as per CBA tool) and an annual emissions of 54 tonnes of ammonia. Note that this damage cost does not consider nitrogen deposition effects on Habitat sites.

The total annual environmental damage costs for this option are £674,072.

D2.4 Costs

The capital costs associated with the installation of the SCR units have been estimated based on the operation of coal fired power plants, emitting flue gas in the region of 1,000,000m^3/hour, due to lack of available operational data. It is estimated that it would cost a total of around £17million for the purchase and installation of the units; however, as discussed above in Section 6.1.4.4, it is likely that this cost would approach £100million in reality.

The operating costs of the SCR units have been calculated based on the purchase of ammonia, and the handling and treatment of the catalyst. A cost per tonne of ammonia has been provided by the LPL project engineers of £700/tonne, which equates to a total annual cost of £4.5million.

Additional maintenance costs would include the costs for catalysts replacement, maintenance and wear and tear on the equipment. This cost has been estimated using guidance for coal fired power plants from the LCP-BRef and equates to an additional £966,023 per year.

D2.5 **Feasibility**

The restrictions stated for Option 5 (see Section 5.1.4.3) would also apply to this case. It is anticipated that this Option would entail the use of a higher quantity of reagent (ammonia) and catalyst in the SCR; leading to greater operational costs in terms of reagent use and catalyst replacement.

This Option would likely require greater storage space for ammonia, which will be used as a reagent, leading to elevated COMAH implications for the storage of hazardous substances.

The spatial constraints, higher capital and operating costs for the operation of SCR equipment in this scenario are likely to limit the application of this option both physically and technically. Further details are included in the associated derogation technical review document.

[22] EMEP/EEA Air Pollutant Emissions Inventory Guidebook - Fuel consumption of a HDV (g/km) = 240 98/69/EC (Euro 3) & 99/96/EC (Euro III) Reference Diesel Fuel - min density 0.833, max 0.837
https://www.dieselnet.com/standards/eu/fuel_reference.php

This would require a significant amount of extended plant outage (anticipated to be >12 months for each unit), as it would be necessary to make significant modifications to the duct and the support structure as described in Section 5.1.4.3. It is envisaged that the complexity of implementing this option would require a much greater outage period than that for SNCR application. No major outages are planned for the plant until 2021; however in order to comply with the BAT-AELs by the LCP compliance date of 17th August 2021, the installation may need to bring forward the planned outages for the installation. In order for the installation to be compliant with BAT-AELs by the required compliance date of 17th August 2021, it is envisaged that the planned outage would require to be brought forward to 2019, due to the considerable difference between the IED Annex V ELVs and the lower end of the BAT-AELs, which would make even one unit operating at IED Annex V ELV result in the installation being in breach of the BAT-AEL.

Assuming a staggered outage to install SCR systems on each of the combustion units, the additional outage would still be expected to have a significant impact on the revenue generated by the power station. As outlined in section 5.1.4.3, indicative figures for revenue losses expected to be incurred by LPL have been included in the CBA assessment, to demonstrate the costs to the installation for SCR installation.

As with Option 5, the installation of SCR is therefore considered to represent an option that may be technically and spatially unviable for this site, but is included in the CBA assessment consistent with a conservative approach.

D2.6 CBA Assessment

For completeness, a comparison of the output of the CBA tool for Option 2 (Proposed Derogation) and Option 6 are shown below.

Table D.2-1: Cost/Benefit Assessment of Options for NO_x Abatement

Option	ELV or BAT-AEL (mg/m^3) (mg/Nm^3)	Emissions (tonnes/year)	Capital Costs(1) (£m)	Operating Costs (£m)	Pollution Reduction Benefit (£m)	NPV (£m)	Ranking Based on NPV
NO_x Emissions							
Option 1: Business as Usual	200	2,163	-	-	0	-	0
Option 2: Proposed Derogation	200	2,163	-	-	0	-	1
Option 6: Lower limit of BAT-AELs (SCR)	40	433	178.834	37.316	-16.441	199.709	4

Note:

(1) The capital cost reflects the Weighted Average Cost of Capital, with a range of 4.5% - 9.8%.

(2) Options 3 and 5 are not shown above as these are provided in Table 7-2.

(3) Option 4 was not assessed using CBA tool due to the inability of the technology to achieve the lower end of the BAT-AEL range ($40mg/Nm^3$).

Appendix E - Assessment of Options for achieving Lower limit of BAT-AEL for Dust

E.1 Option 4: Replacement of the Existing ESPs with a Bag Filter to Achieve Emissions at the Lower Limit of BAT-AEL for Dust

E1.1 Emissions

The modifications to the existing ESPs at the installation will not achieve the lower limit of the BAT-AEL i.e. in the region of 2 – 5mg/Nm^3 (as an annual average).

Based on the LCP-BRef it is understood that this level of emission could be achieved through the use of bag filters. This option therefore assumes that the existing ESPs will be decommissioned / demolished and replaced with a new bag filtration system.

E1.2 Feasibility

For this option to be put in place at the site, the existing ESP building will need to be demolished and replaced with a new bag filtration system. This would involve substantial investment for the site, in additional to considerable operational implications. For comparison, significant rebuild of the LPL unit 2 ESPs following a significant fire which occurred during late-August 2012 resulted in a CAPEX cost of £4.6million and an outage of 9 months duration (from September 2012 to May 2013).

The LCP BRef recognises that bag filters generally provide a very high efficiency dust removal solution for large combustion plants. However, it is acknowledged that due to typical biomass fuel composition of high unburnt carbon in ash, there is a strong likelihood for sparks or glowing particles to reach the bag filters leading to a considerable risk of fire. Additional supplemental controls such as suitable pre-coating of the filter fabric and installing a pre-collector upstream of the bag filter is recommended to reduce the risk of fire damage in biomass fired plants.

LPL's design specification includes a limit for an unburnt carbon in ash of up to 30%, which is considered to be a high risk of resulting in bag filter fires, thereby posing significant health and safety risks for the installation. Furthermore, it is considered that installation of the additional retrofits to reduce fire risks at the installation is not feasible, since installation of these additional measures would likely mean a complete reconfiguration of the combustion units, which is not a viable option for Lynemouth installation.

Therefore, AECOM does not recommend further consideration of fabric filters as a viable dust control technology solution for Lynemouth, and this option has been discounted from further assessment.

This option has not been assessed using the CBA tool.