URS

# Ardagh Glass Ltd BAT Assessment Barnsley

47063542 LERP0001

September 2012

Prepared for: Ardagh Glass Ltd

UNITED
KINGDOM & IRELAND

| Rev | Date | Details | Prepared by | Checked by | Approved by |
|---|---|---|---|---|---|
| 1 | 24th August 2012 | Draft Report | Richard Wood<br>Principal Consultant | Dr Richard Lowe<br>Associate Director | Dr Richard Lowe<br>Associate Director |
| 2 | 14th September 2012 | Revised following model amendments | Richard Wood<br>Principal Consultant | Dr Richard Lowe<br>Associate Director | Dr Richard Lowe<br>Associate Director |
|  |  |  |  |  |  |

URS Infrastructure & Environment UK Ltd
West One, Wellington Street
Leeds
LS1 1BA
United Kingdom

Telephone: +44(0)113 204 5000
Fax: +44(0)113 204 5001

**Limitations**

URS Infrastructure & Environment UK Limited ("URS") has prepared this Report for the sole use of **Ardagh Glass Ltd**, in accordance with the Agreement under which our services were performed **(Proposal 03109578, May 2012)**. No other warranty, expressed or implied, is made as to the professional advice included in this Report or any other services provided by URS. This Report is confidential and may not be disclosed by the Client nor relied upon by any other party without the prior and express written agreement of URS.

The conclusions and recommendations contained in this Report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested and that such information is accurate. Information obtained by URS has not been independently verified by URS, unless otherwise stated in the Report.

The methodology adopted and the sources of information used by URS in providing its services are outlined in this Report. The work described in this Report was undertaken between [insert date] and [insert date] and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances.

Where assessments of works or costs identified in this Report are made, such assessments are based upon the information available at the time and where appropriate are subject to further investigations or information which may become available.

URS disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report, which may come or be brought to URS' attention after the date of the Report.

Certain statements made in the Report that are not historical facts may constitute estimates, projections or other forward-looking statements and even though they are based on reasonable assumptions as of the date of the Report, such forward-looking statements by their nature involve risks and uncertainties that could cause actual results to differ materially from the results predicted. URS specifically does not guarantee or warrant any estimate or projections contained in this Report.

Unless otherwise stated in this Report, the assessments made assume that the sites and facilities will continue to be used for their current purpose without significant changes.

Costs may vary outside the ranges quoted. Whilst cost estimates are provided for individual issues in this Report these are based upon information at the time which can be incomplete. Cost estimates for such issues may therefore vary from those provided. Where costs are supplied, these estimates should be considered in aggregate only. No reliance should be made in relation to any division of aggregate costs, including in relation to any issue, site or other subdivision.

No allowance has been made for changes in prices or exchange rates or changes in any other conditions which may result in price fluctuations in the future. Where assessments of works or costs necessary to achieve compliance have been made, these are based upon measures which, in URS' experience, could normally be negotiated with the relevant authorities under present legislation and enforcement practice, assuming a pro-active and reasonable approach by site management.

Forecast cost estimates do not include such costs associated with any negotiations, appeals or other non-technical actions associated with the agreement on measures to meet the requirements of the authorities, nor are potential business loss and interruption costs considered that may be incurred as part of any technical measures.

**Copyright**

© This Report is the copyright of URS Infrastructure & Environment UK Limited. Any unauthorised reproduction or usage by any person other than the addressee is strictly prohibited.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ........ 1

1 INTRODUCTION ........ 2

2 BACKGROUND ........ 3

2.1 Industrial Emissions Directive ........ 3
2.2 Air Quality Regulations ........ 4
2.3 $NO_x$ as a pollutant and its sources ........ 5
2.4 Other potential pollutants of concern ........ 6
2.5 The Barnsley Installation ........ 7
2.6 Furnace repairs ........ 8

3 OPTIONS FOR $NO_X$ CONTROL AT THE BARNSLEY INSTALLATION ........ 10

3.1 Introduction ........ 10
3.2 Option 1 – Baseline (Do Nothing) ........ 10
3.3 Option 2 – Baseline with B7 furnace re-commissioned ... 10
3.4 Option 3 – Primary Combustion Modifications ........ 10
3.5 Option 4 - Retrofit of Selective Catalytic Reduction (SCR) 12
3.6 Alternative Options Excluded from the Assessment ........ 13

4 OPTIONS FOR PARTICULATE AND $SO_2$ CONTROL AT THE BARNSLEY INSTALLATION ........ 15

5 AIR IMPACT ASSESSMENT OF OPTIONS ........ 16

5.1 Introduction ........ 16
5.2 Assessment Criteria ........ 16
5.3 Predicted Results ........ 23

6 EVALUATION OF OPTIONS FOR $NO_X$ CONTROL ........ 32

6.1 Baseline (Do Nothing) ........ 32
6.2 Re-commissioning of B7 ........ 32
6.3 Primary Combustion Modifications ........ 33
6.4 Retrofit of SCR ........ 34

6. COST-BENEFIT ASSESSMENT ........ 36

6.1 Risk Appraisal of Options ........ 36
6.2 Marginal Costs of Abatement ........ 36
6.3 Control of Sulphur Dioxide ........ 38

7. DEROGATION JUSTIFICATION ........ 40

7.1 Time Constraints for Scheduled Major Repairs ........ 40
7.2 Implications of Carrying Out an Unscheduled Major Repair ........ 40
7.2.1 Loss of Manufacturing Capacity ........ 41
7.2.2 Additional Costs ........ 41
7.3 Socio-Economic Factors ........ 42

8. CONCLUSION ........................................................ 43

APPENDIX A - FIGURES

## EXECUTIVE SUMMARY

URS Infrastructure & Environment UK Ltd ("URS") has been commissioned by Ardagh Glass Limited to undertake an assessment of the potential options available for retrofitted combustion emission control techniques on the existing container glass furnaces at their Barnsley installation, following the ratification of the Industrial Emissions Directive and the publication of the recent BAT conclusions for the glass sector.

The assessment also considers the potential impact of re-commissioning the B7 furnace, which is currently mothballed.

The main options assessed were (1) Current Operations; (2) Current Operations with B7 operating with Primary Control Measures; (3) Primary Control measures on all furnaces; and (4) SCR with Electrostatic Precipitator and lime sorbent injection.

An assessment of the impact of the likely emissions of $NO_x$, $SO_2$ and particulates from these options was conducted. This assessment demonstrated that Option (1) contributed up to 34% of the short-term $NO_2$ NAQS level and 8% of the long-term $NO_2$ NAQS level in the locality. Option (2) increased off-site $NO_2$ levels by 5% in the short-term and 2% in the long-term. Option (3) reduced the short-term $NO_x$ impact by 24% against Option (2), whilst Option (4) reduced the short term $NO_x$ impact of Option (2) by 30%.

A risk appraisal then considered the potential for compliance with regulatory requirements, costs for implementation of the options and the feasibility of installation and operation on site.

When assessing the options through application of a cost-benefit curve, the option considered to represent BAT for the installation, based on the cost per tonne of NOx abated is Option 3, the application of primary control measures on all furnaces.

For $SO_2$ control, based upon the minimal change in off-site environmental impact, the increased generation of filter dust requiring off-site disposal and subsequent potential impact on process operations, the application of the <200-500mg/m$^3$ BAT-AEL for $SO_2$ is considered inappropriate for the installation. It is considered that the existing sulphur dioxide emissions performance represents BAT for the installation given the degree of recycle undertaken. It is therefore proposed that the installation will continue to operate to the current standards, with emissions unlikely to exceed 600mg/m$^3$ as an annual average.

# 1 INTRODUCTION

URS Infrastructure & Environment UK Ltd ("URS") has been commissioned by Ardagh Glass Limited to undertake an assessment of the potential options available for controlling air emissions from the four operational container glass furnaces (B1, B3, B4 and B6) at their installation in Barnsley, South Yorkshire. Ardagh Glass also wish to bring a mothballed furnace (B7) back into commission, and the consequences of this proposed development are incorporated into the assessment.

The objective of the assessment is to determine what combination of primary or secondary control or abatement techniques for the control of nitrogen oxides, sulphur dioxide and particulate emissions can be considered as application of Best Available Technique or "BAT" for this installation, taking into account its particular geographical and technical considerations and the recently published BAT conclusions for the glass sector. In light of those BAT conclusions, the emphasis in this report is on the control of NOx emissions.

Section 2 provides a summary of the legislation and background to the assessment. Sections 3 and 4 detail the options available to the installation for the control of $NO_x$, particulates and $SO_2$. These options are evaluated in Sections 5 and 6 of the report, with a discussion of the possible justifications for a derogation from the recent BAT conclusions and final conclusions in Sections 7 and 8.

## 2 BACKGROUND

### 2.1 Industrial Emissions Directive

European Council Directive 2010/75/EU the Industrial Emissions Directive (IED) recasts seven existing pieces of legislation as outlined below:

- the Large Combustion Plant directive (LCPD);
- the Integrated Pollution Prevention and Control directive ( IPPCD);
- the Waste Incineration directive (WID);
- the Solvent Emissions directive (SED); and
- the three existing directives on Titanium dioxide on (i) disposal (78/176/EEC), (ii) monitoring and surveillance ( 82/883/EEC) and (iii) programs for the reduction of pollution (92/112/EEC).

The Directive lays down rules on integrated prevention and control of pollution arising from industrial activities (listed as Annex 1 within the directive) and lays down rules 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.

Included within Annex 1 is the *Manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day.*

In England and Wales, the IED is scheduled to be transposed into law by 6 January 2013, with respect to installations developed after that date and by January 2014 for installations already in existence before 6 January 2013 (except large combustion plants). Central to the principle of IED, is the requirement on operators to take appropriate preventative measures against pollution through application of Best Available Techniques ("BAT"). The terms of BAT are defined within the Directive, but include the use of technological and managerial measures, which are developed on a scale suitable for implementation in the sector under economically and technically viable conditions, to achieve a high level of environmental protection as a whole.

Under the terms of definition, the principles of BAT can therefore be considered to be applied firstly through use of "primary means" or measures to prevent generation of pollutant emissions within a process, for example through careful control of the process or use of alternative raw materials which are less hazardous, 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. However BAT would only be considered to be applied if such substitutions or treatment resulted in an overall reduction in emissions or in generation of a less harmful emission. For example a treatment process to remove emissions to air which resulted in generation of a large amount of waste requiring further treatment, may not be considered to be BAT, depending on the relative impacts of the air emissions, waste emissions and associated ancillary requirements.

The determination of BAT is specific to a particular installation in a particular location, as there may be technological reasons why a particular technique cannot be applied to the installation process and further there may be specific environmental receptors in the locality which preclude the use of a particular technique on the basis of pollutant sensitivity. In some cases this could mean that the competent authority permits emissions concentrations from a process above those stated as Achievable Emission Levels through the application of BAT (BAT-AELs) (a derogation), provided a justification is given for the departure; typically an annex is added to the permit conditions stating the reasons.

European BAT Reference documents, or BREFs, have been drawn up for each of the principal sectors defined within the Industrial Emissions Directive, to provide guidance on techniques that may be considered to represent BAT. In general, for existing installations the determination of BAT is often less straightforward than for new-build installations, due to the economic and technical impediments that can be involved in modification of existing plant or process steps. The BREF for the Manufacture of Glass was originally produced in December 2001, but has been substantially revised and was reissued in March 2012. The assessment of BAT undertaken within this report is based upon the March 2012 reissued BREF for the glass sector.

As a consequence of the IED and the reissued BREF, a European Commission Implementing Decision "establishing the best available techniques (BAT) conclusions under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions for the manufacture of glass" was issued on 28th February 2012. This document summarises what is considered to represent BAT for all facets of the glass manufacturing industry. The Implementing decision also states:

"Article 15(4) of Directive 2010/75/EU provides for derogations from the requirement laid down in Article 15(3) [setting emission limit values to meet BAT-AELs within the BAT conclusions] only where the costs associated with the achievement of emissions levels disproportionately outweigh the environmental benefits due to the geographical location, the local environmental conditions or the technical characteristics of the installation concerned."

## 2.2 Air Quality Regulations

European Council Directive 2008/50/EC (May 2008) defines limit values for sulphur dioxide, nitrogen dioxide and particulate matter and lead in ambient air, for the purposes of protection of human health and the environment. This Directive has been transposed into national legislation in EU member states.

In the UK, the EU Directive was transposed into national legislation in June 2010. Current controls in the UK are based upon the Air Quality Standards Regulations 2010 and the National Air Quality Strategy (NAQS) 2007, which defines air quality objectives that must be achieved on a national scale by a set date, currently subject to a consultation. Objectives are set for so-called 'criteria pollutants' including nitrogen dioxide, sulphur dioxide and carbon monoxide and the objectives can be regarded as legislative limits that cannot be exceeded. There are additional National Objectives for the Protection of Vegetation and Ecosystems (NOPVEs) for emissions of nitrogen dioxide and sulphur dioxide and Critical Levels for the Protection of Vegetation and Ecosystems (CLPVEs) defined for ammonia.

Local Authorities in the UK hold the responsibility for ensuring that NAQS objectives are met and this is achieved through implementation of air quality management plans, which can include the use of planning restrictions, development of alternative transport plans and imposing a requirement on operators of industrial processes to meet certain emission benchmarks via implementation of the Environmental Permitting (EP) Regulations.

## 2.3 $NO_x$ as a pollutant and its sources

Nitrogen oxides (primarily as nitrogen dioxide ($NO_2$) and nitric oxide (NO)) are generated by combustion processes, largely in the form of nitric oxide, which is then oxidised to nitrogen dioxide, mainly as a result of reaction with ozone in the atmosphere. It is primarily nitrogen dioxide that is associated with adverse effects upon human health and the environment and as such has associated air quality objectives, as described in the above section.

Nitrogen oxides also have the potential to affect global warming, although this is primarily due to the species nitrous oxide ($N_2O$) which is only emitted in very low concentrations from combustion sources. Nitric oxide and nitrogen dioxide have no significant recorded adverse effect on global warming.

According to the European Environmental Agency, in 2009 the main sources of $NO_x$ emissions in Europe are road transport, which accounts for 38% of total European emissions, the energy production and distribution industry (which accounts for around 22% of European emissions) and the industrial sector which accounts for about 13%. In most urban areas, the contribution of road transport to local emissions is much greater than these figures, and for example, accounts for more than 75% of $NO_x$ emissions in London.

In the glass industry, nitrogen oxides ($NO_x$) are generated within the melting and refining stages of a typical fossil-fuel container glass furnace, principally as a result of high temperature oxidation of atmospheric nitrogen from the combustion air. Other sources of nitrogen within the furnace can also contribute to $NO_x$ generation, including nitrogen contained within the furnace fuel (for example if light fuel oil is used) and nitrates that may be used as refining agents in some specialised glass recipes, typically where very high clarity glass ("flacconage") is required.

The generation of $NO_x$ is dependent on the relative concentrations of nitrogen and oxygen, the temperature (typically greater than 1300°C) and the residence time for these combined conditions within the furnace according to the equation shown below:

$$[NO_x] = A \times \exp(-B/T) \times [N_2] \times [O_2]^{0.5} \times t$$

where T= flame temperature, t = residence time, A and B are constants (dependent on the burner type and furnace design).

Typically from combustion sources, nitrogen oxides are emitted as nitric oxide (NO) with small amounts of nitrogen dioxide ($NO_2$) present in the ratio 9:1 $NO:NO_2$. NO is typically oxidised to $NO_2$ in the atmosphere relatively quickly, with the result that it is normal practice to assume that up to 50% of the NO will oxidise to $NO_2$ in proximity to the emission source over short (hourly) time-scales. However the available ozone concentration affects the rate of conversion, such that in areas with low ozone concentrations (often urban areas) the $NO_2$ conversion rate could be much lower.

A number of different techniques have been trialled and implemented within container glass furnaces to prevent or minimise the formation of $NO_x$ including optimisation of furnace conditions to minimise NOx formation. These techniques are described in the current BREF for the Glass Manufacturing Industry (March 2012), the draft version (June 2011) and the previous BREF document (Dec 2001) and have been compared in this report in order to determine BAT for the Barnsley installation.

## 2.4 Other potential pollutants of concern

**Oxides of sulphur** include sulphur dioxide and sulphur trioxide, but by far the most prevalent form in the glass industry is sulphur dioxide ($SO_2$). $SO_2$ is an acid gas. The main man-made source of sulphur dioxide is from the combustion of sulphur-containing fossil fuels, particularly coal and oil.

In the glass industry, the two main sources of $SO_2$ emissions are the oxidation of sulphur in fuels and the decomposition/ oxidation of sulphur compounds in batch materials.

The retention of sulphur compounds in the glass is usually low, meaning the majority of sulphur entering the furnace is emitted to atmosphere as $SO_2$. Some of the $SO_2$ will react to form sulphates, which condense to form dust.

Primary control of $SO_2$ is achieved through use of low-sulphur content fuels, particularly natural gas, and reduction of sulphates in batch materials. However, sulphur content cannot be eliminated completely from fuel or batch materials, so production of $SO_2$ in the waste gases is inevitable and may require secondary abatement, generally dry scrubbing through lime injection into the waste gas stream.

The March 2012 BREF and BAT conclusions decision state that it may be difficult to achieve the BAT-AEL limits in combination with filter dust recycling and the rate of recycling of external cullet, and that the lower BAT-AEL levels stated are associated with conditions where the reduction of $SO_2$ is a high priority over a lower production of solid waste corresponding to the sulphate-rich filter dust.

**Particulates** have always been a constituent of air pollution, although the control of such pollutants has improved enormously following the imposition of a wide range of regulatory controls on industrial, domestic and traffic sources.

Particulates can have the following range of impacts including:

- Health effects;
- Deposition on Habitats sites or sensitive receptors.

The three main sources of dust from glass melting are:

- batch material carryover;
- volatilisation and reaction of substances from batch materials and the glass melt; and
- metals impurities in the fuels.

For fossil-fuelled furnaces the volatilisation and subsequent reaction/ condensation of volatile materials released from the hot glass surface represents by far the largest proportion of the overall dust emission. In general, 80 to 95% of the dust emission will be produced in this way.

Secondary abatement techniques (generally fabric filters or electrostatic precipitators) as well as primary measures are usually required in order to meet the particulate emission limit for furnaces.

## 2.5 The Barnsley Installation

The Ardagh Glass site at Barnsley manufactures glass packaging, mainly for the food and beverage sector, based on a fully automated soda-lime based process using virgin material and recycled cullet. The installation includes a central batch plant, mixing and manufacturing machinery, five end fired furnaces (4 in operation, 1 currently mothballed) and two particulate abatement units (electrostatic precipitators) incorporating sulphur dioxide scrubbing. All production output is automatically packaged for delivery to customers. Production of glass containers is carried out on a 24 hours a day, year round basis. Operations at Barnsley are described in the original IPPC application for the installation. The installation is regulated by Barnsley Metropolitan Borough Council under Permit ref. IPPC/A2/01/2009/V2.

The main environmental emissions associated with glass production occur as a result of the furnace operations, as it is a high temperature, energy intensive process. This results in the emission of products of combustion, primarily sulphur dioxide, carbon dioxide, and oxides of nitrogen. Furnace emissions also contain dust and traces of chlorides, fluorides and metals present as impurities in the raw materials. Technical solutions are possible for minimising all of these emissions, but each technique has associated financial and cross-media environmental implications, and it is essential that this is taken into consideration when determining BAT for such installations.

***Furnace Design and configuration***

The selection of furnace design employed in glass manufacturing is particularly dependent on the required capacity, the glass formulation and customer requirements for product quality, fuel prices, the age of the furnace, existing infrastructure and its environmental performance.

The furnaces at the Barnsley plant are end-fired regenerative furnaces and are powered by a combination of a supply of natural gas (all furnaces), electric boost and limited gas-oil back-up in case of an interruption to the gas supply. The melting capacities of furnaces B1, B3, B4, B6 and B7 are between 185 to 425 tonnes of glass per day (tpd) each and operate at temperatures between 1300°C and 1600°C. The total glass manufacturing capacity at the Barnsley installation is currently 1,050tpd, which will be extended to 1,475tpd with the re-commissioning of B7.

Typical throughput can vary, dependent on production demand and product profile, from approximately 75% of maximum capacity upwards, although efforts are made to maximise furnace utilisation via good scheduling to obtain optimum energy efficiency. Average production rates are currently 855tpd, and will increase to 1,230tpd with the proposed recommissioning of B7.

The furnaces B1 and B3 vent through a combined stack to atmosphere, via the particulate (electrostatic precipitator) and sulphur dioxide abatement system. This is release point A1 in the permit. Furnaces B4 and B6 vent through a combined stack to atmosphere via the particulate (electrostatic precipitator) and sulphur dioxide abatement system, release point A2 in the permit. B7 furnace is currently mothballed and is being considered for restart. If this happens, the upgraded furnace will either be equipped with its own particulate (electrostatic precipitator) and sulphur dioxide scrubber abatement system and discharge to atmosphere via its own extended stack, or be combined with an upgraded system serving furnaces B4 and B6 and discharged via release point A2. For the purposes of this assessment, it assumed that B7 will be discharge through a separate stack (designated A3).

Regenerative furnaces are generally more energy efficient than other conventional fossil fuel fired furnaces, due to the more efficient combustion air preheating system. This results in a lower energy use per tonne of glass melted and therefore lower overall mass release of pollutants from the whole combustion process. The configurations of the furnaces at the Barnsley site have been designed to enable the optimum level of glass production, whilst operating efficiently and controlling environmental emissions.

The current emission limits set in the permit are set out in Table 2.5-1.

**Table 2.5-1: Emission limit values for release points A1 and A2**

| Emissions Limit Values | | | | | | |
|---|---|---|---|---|---|---|
| Substances | A1 | | | A2 | | |
| | Concentration (mg/m$^3$) | Emissions Rate (g/s) | Emissions Rate (kg/hr) | Concentration (mg/m$^3$) | Emissions Rate (g/s) | Emissions Rate (kg/hr) |
| Oxides of Nitrogen | 2,700 | 46.15 | 166.2 | 2,700 | 17.13 | 61.7 |
| Oxides of Sulphur | 800 | 13.68 | 49.2 | 800 | 5.08 | 18.3 |
| Particulate Matter | 30 | 0.51 | 1.8 | 30 | 0.19 | 0.7 |

## 2.6 Furnace repairs

In general, container glass furnaces operate continuously, or with only minor intermediate repairs, for approximately 15 - 20 years, after which time they are "rebuilt" with either partial or major replacement of the structure, depending on its condition. The recently published BAT conclusions define two levels of furnace rebuild:

- **Normal furnace rebuild** - A rebuild between campaigns without a significant change in furnace requirements or technology and in which the furnace frame is not significantly adjusted and the furnace dimensions remain basically unchanged. The refractory of the furnace and, where appropriate, the regenerators are repaired by the full or partial replacement of the material;
- **Complete furnace rebuild** - A rebuild involving a major change in the furnace requirements or technology and with major adjustment or replacement of the furnace and associated equipments.

In terms of terminology, a "normal" rebuild is referred to as a "repair", and a "complete" rebuild is referred to as a "major repair" within the Ardagh Group, and therefore also within this report.

The major repair of a furnace takes in excess of 1.5 years to plan and implement and can cost millions of pounds in lost production, additional labour and repair materials and therefore for these reasons it is essential within the industry that a furnace lifetime is extended wherever possible, and that major repairs are only undertaken at the end of the furnace lifetime in accordance with a schedule applied across the company.

The production life of a furnace is dependent on a number of factors, including the furnace type, the product manufactured within the furnace, how the furnace is operated during its lifetime and the level of ongoing maintenance carried out.

At Ardagh, thermographic surveys are carried out on each furnace structure every three months, so that areas of concern can be identified. Following the identification of a concern (e.g. a "hot spot"), their deterioration rate can be tracked, in order to determine whether a minor hot repair is required for the continued safe operation of the furnace.

Through effective maintenance and the considerable experience in furnace management within the Ardagh Group, the life of many furnaces exceeds 20 years. This, in part, has been achieved due to the quality of product manufactured by the Ardagh Group, which does not entail manufacturing rates at maximum furnace production capacity, which would reduce the furnace lifetime. In addition, Ardagh Glass has a dedicated maintenance team who are responsible for the upkeep of furnaces across the Ardagh Group. It is therefore not unusual within the Ardagh Group for furnaces to extend their expected life of 15 – 20 years.

At the Barnsley installation, furnace B7 is to be extensively modified as a consequence of the re-commissioning of the furnace. Improvements to be applied to B7 include:

- Use of low NOx burners;
- Lifting of the crown to increase combustion space;
- Port geometry redesign; and
- Improved furnace control system to allow accurate control of temperature and air flow.

Improvements to the remaining furnaces (B1, B3, B4 and B6) will be undertaken on a staged basis over the next 10-15 years.

# 3 OPTIONS FOR $NO_X$ CONTROL AT THE BARNSLEY INSTALLATION

## 3.1 Introduction

Within the Sector BREF Note, the benchmark associated with the use of BAT for control of $NO_x$ (expressed as $NO_2$) emissions for container glass manufacture covers a range from <100mg/$m^3$, to 800mg/$m^3$, dependent upon the furnace design control techniques applied.

Electric melting, a recently adopted technique set out within the March 2012 BREF, is considered to achieve emission levels of <100mg/$m^3$, which generally equates to 0.3kg/tonne of glass melted. Such benchmarks should be achievable in a smaller-scale new build plant where electric melting is a feasible option on cost terms.

For secondary abatement (such as Selective Catalytic Reduction (SCR)), limits of <500mg/$m^3$, equivalent to <0.75kg/tonne are considered achievable. For comparison, the previous Sector BREF Note (2001) yielded BAT-AELs for NOx emissions of 500-700mg/$m^3$ or 0.5 – 1.1kg/tonne of melted glass in relation to the use of secondary abatement techniques.

The benchmark associated with the use of primary control techniques only is 500-800mg/$m^3$, or 0.75-1.2kg/tonne of glass melted. These benchmarks have been used as the range of performance figures when determining achievable emissions concentrations from existing plant.

In this assessment, 4 main options for the control of $NO_x$ emissions from the Barnsley furnaces have been considered and these are discussed in turn below.

## 3.2 Option 1 – Baseline (Do Nothing)

The furnaces that are due to be refurbished would be returned to their current configuration. This would require no extra infrastructure or equipment cost, but would not achieve any significant reduction in $NO_x$ emissions.

Whilst it is recognised that this approach cannot be maintained in the long-term as the Sector BAT-AELs would not be achieved, a baseline for comparison is required to demonstrate the scale of emission improvement through the other proposed options.

## 3.3 Option 2 – Baseline with B7 furnace re-commissioned

This option sets out the current operation (as per option 1), but incorporates the re-commissioned B7 furnace with primary NOx control measures applied.

This option represents a possible near-future operation until such time that primary and/or secondary measures are applied to the remaining furnaces.

## 3.4 Option 3 – Primary Combustion Modifications

A number of primary combustion modification (PCM) techniques have been implemented within the glass sector to minimise the formation of thermal $NO_x$, as detailed in the Glass BREF and outlined below.

### Reduced air/fuel ratio

Reduction in the air/fuel ratio within the furnace to sub-stoichiometric levels[Ψ] reduces $NO_x$ emissions through minimising the excess nitrogen present in the flame. Sub-stoichiometric conditions are achieved through use of feedback monitoring of oxygen, $NO_x$ and carbon monoxide concentrations to automatically control the air and fuel inputs. However, carbon monoxide emissions from incomplete combustion increase exponentially with reduced air/fuel ratio and can cause refractory problems.

### Staged combustion

Air-staged or fuel staged combustion both involve forms of reducing the oxygen concentration within the flame, increasing the soot (unburned hydrocarbon) content of the flame and thus lowering the flame temperature, resulting in lower thermal $NO_x$ generation. In fuel-staged combustion a secondary flame fires at the base of the primary flame to reduce the oxygen concentration within the primary flame and thus lowers its temperature.

In air-staged combustion, sub-stoichiometric firing is undertaken with the remaining air added into the furnace to achieve complete combustion and minimise CO formation.

A further technique, Oxygen Enriched Air Staging, uses the same principle but oxygen rather than air is added at the secondary combustion stage. Such a technique would involve use of pure oxygen, although in more limited quantities than for oxyfuel melting, nevertheless with the associated additional energy and cost.

Staged combustion has been largely developed in USA and as of 2010 (when the BREF sector note was drafted) there are no cases of this techniques being used in Europe. As a consequence, this is not considered further within this report.

### Low $NO_x$ burners

Low $NO_x$ burners are available, incorporating the principles of the above techniques, and the techniques listed below:

- Slower mixing of fuel and air to reduce peak flame temperatures (flame shaping);
- Minimum injection velocities that still allow complete combustion (delayed but complete combustion);
- Increased (radiation) emissivity of the flame, with optimisation of the heat transfer to the glass melt. Therefore, a lower temperature level can still provide the required energy for melting due to the high flame luminosity (effective emission of heat);
- Different nozzles and nozzle designs enable to generate multiple fuel jets per burner; some jets are shielded from the air by other fuel jets, creating soot to improve heat transfer and cooling of the flame, with a consequent reduction of NOX formation. The production of soot may represent a potential problem for the quality of glass; and
- Complete combustion with the minimum air/fuel ratio.

It is noted that the reported reductions in $NO_x$ emissions (Glass BREF) may not be achievable on an additive basis as these depend on the $NO_x$ baseline concentration. The effect of

---

[Ψ] Air/fuel ratio at stoichiometric levels indicates that oxygen and fuel are present at concentrations proportional to molar quantities required for complete reaction; sub-stoichiometric levels are therefore close to these levels, but with a slight excess of air.

primary combustion modifications on $NO_x$ emissions will also be specific to the existing techniques employed on individual furnaces, however it is considered likely that a $NO_x$ reduction of 40% from the baseline level is achievable using a range of primary techniques only. This can result in $NO_x$ emission concentrations of around 800 mg/$m^3$ or less, which is at the top end of the benchmark range associated with the use of BAT identified in the Glass Sector BREF.

It is considered that $NO_x$ concentrations below 800mg/$m^3$, such as are typically only achievable with sub-stoichiometric air/fuel ratios, are likely to result in increased carbon monoxide formation within the exhaust gas which can damage refractory and lead to reduced furnace lifetime. CO concentrations of 1000-10000ppm are reported at excess air levels below 5%. The March 2012 BREF introduced a CO limit, and it is possible that reducing $NO_x$ concentrations significantly below 800mg/$m^3$ through low excess air levels could result in breaches of the CO BAT-AEL.

It is assumed in this assessment that the specific fuel consumption of the furnace will be unaffected by primary combustion modifications.

### Flue-gas recirculation

Waste gas from the furnace can be re-injected into the flame to reduce the oxygen content and therefore the temperature and the $NO_x$ formation efficiency. A plant in Germany has successfully implemented recirculation since 2007 using a special Glass FLOX technology burner with automatic recirculation of the waste gas. In this case, flue-gas recirculation takes place directly in the combustion chamber the combusted gases are used to dilute the FLOX flames. The application shows a reduction efficiency of $NO_x$ emissions in the range of 46 – 59% from the initial value. Difficulties have been encountered by applying this technique in the glass industry at full scale and it is therefore still considered an emerging technique. It is therefore not considered further within this report.

### Fuel Choice

It is typical within the glass industry that gas-fired furnaces result in higher $NO_x$ emissions than oil-fired furnaces. The differences vary widely between furnace type and application but a variation of 25 – 40% between gas-fired and oil-fired operating conditions is not uncommon. In general, approximately 5% energy consumption savings are observed when using fuel oil instead of natural gas. This is largely due to gas flames having a lower thermal emissivity than fuel oil flames, therefore requiring higher flame temperatures to enable the same heat transfer to the glass melt and thus more favourable conditions for $NO_x$ formation.

It is intended that the Barnsley installation will continue to operate on gas-firing, with oil available for back-up purposes only in the event of an interruption to the gas supply; switching to oil firing has wider environmental consequences from sulphur and particulate emissions, fuel transportation and storage etc. The potential effects of this option are therefore not considered further in this report.

## 3.5 Option 4 - Retrofit of Selective Catalytic Reduction (SCR)

The Selective Catalytic Reduction (SCR) technique is a secondary control measure that involves the injection of ammonia into the waste gas in the presence of a catalyst to oxidise the $NO_x$ to nitrogen and water. The catalyst is typically titanium dioxide or vanadium oxide held within a matrix, and the necessary temperature range for optimum reaction is 300-450°C, although this is dependent on the catalyst type.

Using SCR, emission concentrations below 500 mg/m$^3$ are reported for some applications within the glass industry and an emission level of 450mg/m$^3$ has been used to reflect this in this assessment when considering the long-term environmental impact.

The NOx emission levels achieved will depend mainly on the inlet concentration and on the amount of catalyst and ammonia used. The level of ammonia is usually kept below the ratio 1.1:1 to limit the potential for ammonia breakthrough (Glass Industry BREF, 2012). This is equivalent to an ammonia usage (25% w/w solution) of 2.37kg per kg (unabated) $NO_x$ emission. The March 2012 BREF states that container glass and flat glass furnaces obtained best values of between 460 – 500 mg/Nm$^3$ with this technique, without exceeding $NH_3$ concentrations of 30 mg/Nm$^3$ downstream of the SCR (although there are only two examples of SCR on container glass facilities with the EU). This reflects the approach taken within this assessment.

Fugitive ammonia releases from the SCR process are assumed to occur from ammonia slippage due to incomplete reaction. The ammonia slippage increases with higher $NH_3$ to $NO_x$ ratios. A potential emission limit value of 30mg/m$^3$ is applied to represent the BAT-AEL for ammonia.

Cross-media affects of SCR include fugitive emissions from on-site storage and handling of 25% ammonia solution, the use of electrical energy and the production of solid waste at the end-of-life of the catalyst. However, provided that BAT is applied for storage and handling of ammonia, such as back-venting to tankers during delivery and use of scrubbers to abate any breathing losses, these fugitive emissions should be minimal. Operational data suggests that any extra $NO_x$ emissions associated with increased electricity use typically account for only 0.3 to 0.5 % of the amount of $NO_x$ reduced by SCR although there are additional $CO_2$ emissions from the increased power demand as well. Waste material is produced when the catalyst must be renewed after its lifetime. Typical catalyst lifetimes are 4 – 5 years (>10 years have been reported for container glass). These emissions sources are not considered to be significant and have not been considered further in this assessment.

To prevent potential catalyst poisoning from high $SO_2$ levels and ensure compliance with sector benchmarks for particulates and sulphur dioxide, each furnace is assumed to be fitted with particulate and sulphur dioxide abatement.

## 3.6 Alternative Options Excluded from the Assessment

### Primary Controls

A number of other primary control techniques and alternative furnace designs have been trialled or implemented within the European glass sector to minimise $NO_x$ emissions, however these have been excluded from this assessment due to concerns over technical application to existing container glass manufacturing facilities, or their proven track record in achieving the required performance. These include:

- Special furnace designs, including the Sorg LoNox melter;
- Fenix process;
- Chemical Reduction by Fuel (3R process, reburning)
- Oxyfuel melting.

### SNCR

Selective Non-Catalytic Reduction (SNCR) has been excluded from this assessment as there are technical impediments to the application of the technique within regenerative furnaces such as those installed at Barnsley.

Ammonia injection within the correct temperature window (800-1100°C) presents control difficulties as this temperature range typically occurs within the regenerator, which has a variable temperature and limited access. Failing to inject in the required temperature window would affect the performance of the ammonia treatment. Emissions of ammonia (low temperature slippage) and nitrogen oxides (high temperature reaction) can occur as a result. Furthermore, for glass mixtures using sulphate-based refining agents, ammonium bisulphate generation can occur as the temperature window requires sulphur scrubbing to be undertaken downstream of the ammonia injection. This technique is therefore not considered to be technically viable for retrofit on regenerative furnaces and has been discounted from this assessment.

### Electric Melting

The replacement of existing furnaces with electric melting furnaces has been excluded from this assessment due to the excessive capital investment that is required and high running costs for larger furnaces, although it is recognised that this technology does offer the potential for high levels of $NO_x$ mitigation.

The absence of combustion in electric melting means that the waste gas volumes are extremely low, resulting in low particulate carryover and a reduced size of any secondary abatement equipment. Associated $NO_x$ emissions are expected to be below $100mg/m^3$. Electric furnaces can usually achieve higher melt rates per square metre of furnace, and the thermal efficiency of electric furnaces (based on the energy delivered to the furnace, not on the primary energy necessary to generate the electricity) is two to three times higher than fossil fuel fired furnaces.

The 2012 BREF note suggests that the installation of an electric melting furnace could cost an extra £2.34 million (€3 million) to install than a standard end-fired regenerative furnace. There is an upper size limit to the economic viability of electric furnaces which is closely related to the prevailing cost of electricity compared with fossil fuels. With regards to larger furnaces (>300 tonnes melt/day) the benefits from electric melting are often not sufficient to compensate the higher costs of electricity. Given the furnaces at the Ardagh Barnsley facility range from 185 to 425 tonnes this option is not seen as economically viable.

## 4 OPTIONS FOR PARTICULATE AND $SO_2$ CONTROL AT THE BARNSLEY INSTALLATION

For particulate control, the following secondary abatement techniques have been identified in the Sector BREF Note:

- Electrostatic Precipitators (EPs) have achieved reported particulates emissions of 5 - 20 mg/m³. Installation can cost between £1.7 million and £3.7 million (€2.2-4.7 million) (including dry scrubbing system) with the cost dependent of the size of the furnace. Annual operating costs are reportedly between £129,000 (€166,000) and £524,000 (€673,000);
- Bag filters are more efficient at removing particulates than EPs with particulate emissions expected to be between 0.5 - 5 mg/m³. Installation of bag filters may vary between £935,000 and £1.6 million (€1.2-2.0 million), depending on the size of the furnace with an annual operational cost of £125,000 (€160,000) and £400,000 (€526,000);
- Wet scrubbers – no current operational data is available for particulate abatement with regards to wet scrubbers. For an oxy-fired furnace of 100 – 150 tonnes/day producing E-glass an initial investment of approximately £2.1 million (€2.65 million) is expected with annual operational costs of around £225,000 (€285,000). For a conventional air/gas furnace of 100 – 150 tonnes/day producing E-glass, the investment is estimated at £2.3 million (€3 million), with annual operating costs of £230,000 (€300,000);
- Mechanical collectors have a reported particulates collection efficiency of between 45 and 90% but are only appropriate for the collection of particulate $PM_{10}$. Cost estimates for the installation and operation of mechanical collector are not given in the Sector BREF note; and
- High-temperature filter media – several sites have reported particulate levels of less than 10mg/m³. The BREF notes states that the costs of installation and operation are relatively high; however specific cost estimates are not stated.

For $SO_2$ control, dry lime injection is typically used to reduce emissions, with the reacted lime captured in the particulate abatement.

The use of EPs is more commonly associated with the application of SCR, as they can operate at higher temperatures and so do not require cooling of the waste gas stream, which would then affect the operation of the SCR. Two EPs are already installed at the Barnsley installation, with a further EP proposed for controlling emissions from furnace B7. It is intended that the Barnsley installation will continue to apply electrostatic precipitation as the main particulate control measure.

# 5 AIR IMPACT ASSESSMENT OF OPTIONS

## 5.1 Introduction

In order to assess the potential impact of the emissions to air from the installation on the environment for the different emissions release scenarios presented in Section 3, detailed dispersion modelling has been undertaken, utilising the new generation model ADMS4.2, which has been developed for UK regulatory use; its use in such assessments is approved by the Environment Agency (EA).

An assessment has also been made of the potential impact of emissions on designated Habitat sites identified within 10km of the installation.

## 5.2 Assessment Criteria

As outlined in Section 2, air quality objectives are defined in the National Air Quality Strategy (NAQS) that must be achieved on a national scale by a set date – typically 2010. These so-called criteria pollutants include nitrogen dioxide, particulates, sulphur dioxide and carbon monoxide and the objectives can be regarded as legislative limits that cannot be exceeded.

These values are shown in the Table 5-1 below. Particulates objectives are defined for $PM_{10}$ or particles of diameter of 10 µm or less, since these particles are understood to have potential health impacts as they can become entrained into the lung. NAQS Objectives, are set for both short term and long term averaging periods.

**Table 5-1: NAQS Objectives ($\mu g/m^3$)**

| Pollutant | NAQS objectives | |
|---|---|---|
| | Limit | Averaging Period |
| $NO_2$ | 200 | 1 hour 99.8th percentile |
| | 40 | Annual average |
| $NO_X$ (as $NO_2$) | 30[V] | Annual average |
| | 75[V] | Daily Critical Mean |
| CO | 10,000 | Running 8-hour average |
| $PM_{10}$ | 50 | 24 hr mean, 90.41th percentile |
| | 40 | Annual average |
| $SO_2$ | 266 | 15 minute mean – not to be exceeded more than 35 times a year |
| | 350 | 1 hour mean – not to be exceeded more than 24 times a year |
| | 125 | Not to be exceeded more than 3 times a year |
| | 20[V] | Annual mean |
| $NH_3$ | 2500* | 1 hour mean |
| | 180* | Annual mean |
| | 3[V] | Annual mean |

[V] For the protection of vegetation and ecosystems. Other standards are for the protection of human health

* These are not NAQS objectives, but are current Environmental Assessment Levels (EALs) as set out in the Environment Agency's H1 Annex (f) – Air Emissions

Since the emissions from the installation are mixed into the ambient air, an assessment must also include the contribution to pollutant levels derived from the ambient background levels. The Process Contribution (PC) must therefore be added to an appropriate Ambient Concentration (AC) to give the total Predicted Environmental Concentration (PEC). It is the PEC that must be compared with the appropriate EAL to ensure that air quality is not being significantly affected.

It is unrepresentative to add the worst case short term PC to the worst case short term AC since it is highly unlikely that the two will coincide at the same event. Therefore, the AC added to the short term PC is typically a multiple of the annual average concentration, rather than the short-term ambient concentration over the equivalent averaging period.

**Ambient Concentrations**

The ambient concentrations of criteria pollutants ($SO_2$, $NO_2$, $PM_{10}$) are available from the DEFRA background pollutant database (http://www.airquality.co.uk), and are averaged over 1km$^2$ grids across the UK. Ambient concentrations in the 1km$^2$ grid containing the Barnsley installation for 2010/11 are shown in Table 5-2 below.

**Table 5-2: Background concentrations for Ardagh Barnsley**

| Year | $NO_x$ (µg/m$^3$) | $SO_2$ (µg/m$^3$) | $PM_{10}$ (µg/m$^3$) |
|---|---|---|---|
| 2010 | 25.4 | - | 16.5 |
| 2011 | - | 3.6 | - |

Notes: Data taken from pollutant maps, UK Air Quality Strategy at grid reference 437500, 408500.

The data provided quotes $NO_x$, and converts the result for 2010 to 17.5µg/m$^3$ $NO_2$, against which compliance with the NAQS is assessed.

For comparison, data published by Barnsley Metropolitan Borough Council (BMBC)[1] provides diffusion tube monitoring results from Faith Street in West Green, approximately 300m to the east of the Ardagh Barnsley emission points. This is considered to be representative of background measurement of industrial emissions as it is located close to the Ardagh installation and other industrial units at West Green, and is also away from the A628 to avoid significant roadside emissions impact. The annual mean $NO_2$ concentration at Faith Street is reported at 25.9µg/m$^3$ for 2011. To provide a conservative assessment, this background concentration is applied when assessing the maximum off-site impact as it is greater than the DEFRA data quoted in Table 5-2. As the monitoring point is close to the Ardagh Barnsley installation it is likely that the measured data already includes a contribution from the current installation emissions and therefore lead to some double counting, however to maintain the conservative nature of this assessment no correction is made for this.

Barnsley Metropolitan Borough Council (BMBC) has completed the Air Quality Review and Assessment process and has declared five Air Quality Management Areas (AQMAs). Three of these AQMAs (numbers 3, 4 and 5) are less than 3km to the south-west of the installation although the installation is not within an AQMA itself. Diffusion tube monitoring data published by BMDC provides an annual adjusted concentration for 2011 at AQMA5 of 37.9µg/m$^3$ for $NO_2$. This level is used for assessment of the modelled process impact upon the AQMA5.

---

[1] 2012 Air Quality Updating and Screening Assessment for Barnsley Metropolitan Borough Council in fulfilment of Part IV of the Environment Act 1995 Local Air Quality Management; May 2012.

The ambient concentrations of gaseous ammonia ($NH_3$) are monitored across the UK by CARA (Coordinated Ammonia Research Activities), part of the DEFRA sponsored Centre for Ecology and Hydrology. Interpolated data from 2005 is mapped for the whole UK and has been used to determine the ambient concentration for the subject area. The monitoring station located in Sheffield has been deemed the most appropriate due to its urban location, and an ammonia concentration of 1.7$\mu$g/m$^3$ has been used to represent the ammonia concentrations in the vicinity of the Barnsley Installation.

**Dispersion Modelling**

Dispersion modelling has been used to assess the impact of emissions on the environment by calculating the predicted ground level concentrations arising from the emissions to atmosphere, based on Gaussian approximation techniques. The worst-case concentration derived when using a series of conservative assumptions has been compared with appropriate air quality standards to determine whether releases from the furnace stacks are likely to cause a significant impact on the receiving environment.

The degree of turbulence in the atmosphere affects the rate at which pollutants from point sources are dispersed in the environment. The more unstable the atmosphere – for example due to high solar insolation – the greater the degree of mixing. While this is in principle the desired effect for the release of pollutants through stacks at elevated heights, this can also lead to localised peak concentrations if the plume is rapidly brought to ground level.

Various parameters can affect the degree of dispersion from a source, and these are accounted for in the modelling scenario where appropriate. The presence of elevated or complex terrain in the vicinity of the source can affect the flow pattern of the wind field, which can in turn bring a plume to ground more rapidly. Buildings of sufficient height located close to the emissions sources can affect dispersion – inducing downwash in the emitted plume and entraining pollutants towards ground level.

ADMS4.2 utilises site-specific hourly sequential meteorological data to enable a realistic assessment of dispersion from point sources to be conducted for weather conditions that are directly applicable to the site.

**Modelled Emission Parameters**

The modelled emission parameters for furnaces B1, B3, B4, B6 and B7 used in this modelling assessment are shown in Table 5-3 below. A number of emission release scenarios have been modelled for the installation, these are:

- Scenario 1 – Current Emission Concentrations for furnaces B1, B3, B4 and B6

Long-term emissions have been modelled at monitored emission concentrations, using the average monitoring results recorded for 2010 and 2011 for the main plant emissions.

Short-term emissions have been modelled at the current emissions limit values, as detailed in the installation's Environmental Permit. This is considered to represent a conservative approach for $NO_x$ as current emission levels for Ardagh Barnsley are approximately 50% of the emission limit values.

- Scenario 2 – Current Emissions for B1-B6, plus predicted emissions from re-commissioned B7

Long-term emissions have been modelled at monitored emission concentrations, using the average monitoring results recorded for 2010 and 2011 for the main plant emissions.

Short-term emissions have been modelled at the current emissions limit values, as detailed in the installation's Environmental Permit. As stated for Scenario 1, this is considered to be conservative for $NO_x$.

For B7, long-term and short-term releases are based upon predicted release levels of 800mg/m$^3$ from application of primary measures on B7. Results of between 700-800mg/m$^3$ have been observed in similar rebuilt furnaces within Ardagh Group, so the use of 800mg/m$^3$ is considered to be conservative.

- Scenario 3 – Emissions at Benchmark Levels for Primary Measures

Emissions from all furnaces have been modelled at the benchmark value of 800mg/m$^3$ provided in the Sector BREF note, for $NO_x$ control by primary measures only.

Emissions of particulate matter (PM) have been assessed at the revised BAT-AEL of 20mg/m$^3$, which is currently achievable with the electrostatic precipitators applied at Barnsley.

$SO_2$ levels have been reduced to 500mg/m$^3$ to reflect the reduced benchmark value within the recently adopted BREF note. This is not indicative of the application of primary measures, but reflects a possible future level of operation through increased use of lime injection to meet the reduced benchmark level.

- Scenario 4 – Emissions at Benchmark Levels for Secondary Abatement

Emissions have been modelled at the value of 450 mg/Nm$^3$ which lies within the benchmark range provided in the recently adopted BREF note, in order to determine the reduction in environmental impact from the installation's emissions, were they to be reduced to the benchmark values through secondary abatement techniques.

In the case of $NO_x$, secondary abatement has been assumed to be SCR, and therefore an additional emission of ammonia, caused by "ammonia slip", has been modelled. Emissions of ammonia have been assumed to be at the benchmark level associated with the use of SCR of 30mg/m$^3$.

As the levels for PM would remain at the levels assessed in scenario 3, these emissions have not been reassessed for this scenario.

**Table 5-3: Modelled stack emission parameters**

| Scenario | Source Ref. | Source Description | Grid Ref (x, y) | Volume Flux (Nm$^3$/s) | Release Height (m) | Stack Diameter (m) | Temp (°C) | Substance | Peak Release rate (g/s) | Normal Release rate (g/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A1 | B1 & B3 | 437212<br>408467 | 15.8 | 73 | 1.600 | 350 | NOx | 42.66 | 17.76 |
| | | | | | | | | SO2 | 12.64 | 7.86 |
| | | | | | | | | PM | 0.47 | 0.32 |
| | A2 | B4 & B6 | 437168<br>408570 | 11.0 | 73 | 2.186 | 328 | NOx | 29.57 | 15.41 |
| | | | | | | | | SO2 | 8.76 | 6.02 |
| | | | | | | | | PM | 0.33 | 0.02 |
| 2 | A1 | B1 & B3 | 437212<br>408467 | 15.8 | 73 | 1.600 | 350 | NOx | 42.66 | 17.76 |
| | | | | | | | | SO2 | 12.64 | 7.86 |

| Scenario | Source Ref. | Source Description | Grid Ref (x, y) | Volume Flux ($Nm^3/s$) | Release Height (m) | Stack Diameter (m) | Temp (°C) | Substance | Peak Release rate (g/s) | Normal Release rate (g/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | PM | 0.47 | 0.32 |
| | A2 | B4 & B6 | 437168<br>408570 | 11.0 | 73 | 2.186 | 328 | NOx | 29.57 | 15.41 |
| | | | | | | | | SO2 | 8.76 | 6.02 |
| | | | | | | | | PM | 0.33 | 0.02 |
| | A3 | B7 | 437171<br>408620 | 10.3 | 73 | 1.44 | 377 | NOx | 8.76 | 7.66 |
| | | | | | | | | SO2 | 8.76 | 5.60 |
| | | | | | | | | PM | 0.19 | 0.19 |
| 3 | A1 | B1 & B3 | 437212<br>408467 | 15.8 | 73 | 1.600 | 350 | NOx | 12.64 | 12.64 |
| | | | | | | | | SO2 | 7.90 | 7.90 |
| | | | | | | | | PM | 0.32 | 0.32 |
| | A2 | B4 & B6 | 437168<br>408570 | 11.0 | 73 | 2.186 | 328 | NOx | 8.76 | 8.76 |
| | | | | | | | | SO2 | 5.48 | 5.48 |
| | | | | | | | | PM | 0.22 | 0.02 |
| | A3 | B7 | 437171<br>408620 | 10.3 | 73 | 1.44 | 377 | NOx | 7.66 | 7.66 |
| | | | | | | | | SO2 | 4.79 | 4.79 |
| | | | | | | | | PM | 0.19 | 0.19 |
| 4 | A1 | B1 & B3 | 437212<br>408467 | 15.8 | 73 | 1.600 | 350 | NOx | 7.90 | 7.11 |
| | | | | | | | | $NH_3$ | 0.47 | 0.32 |
| | A2 | B4 & B6 | 437168<br>408570 | 11.0 | 73 | 2.186 | 328 | NOx | 5.48 | 4.93 |
| | | | | | | | | $NH_3$ | 0.33 | 0.22 |
| | A3 | B7 | 437171<br>408620 | 10.3 | 73 | 1.44 | 377 | NOx | 4.79 | 4.31 |
| | | | | | | | | $NH_3$ | 0.29 | 0.19 |

### Modelled Domain and Sensitive Receptors

The dispersion modelling has been carried out using a grid extending 10km from the installation, in order to obtain concentrations at the location of the nearest sensitive receptors as identified in Table 5-4 below. Worst case results are quoted at the most affected Habitat sites (Carlton Main Brickworks SSSI or Stairfoot Brickworks SSSI), and also for AQMA5.

**Table 5-4: Identified Receptors in the Installation Vicinity**

| Name | Receptor Type | Grid Reference (approx) | Distance from installation (km) |
|---|---|---|---|
| Seckar Wood | SSSI | 433080, 414020 | 6.25km Northwest |
| Stairfoot Brickworks | SSSI | 438120, 404900 | 4km South |
| Carlton Main Brickworks | SSSI | 440970, 408090 | 3.25km East |
| Nostell Brickyard Quarry | SSSI | 440400, 416860 | 9.5km Northeast |
| AQMA5 | AQMA | 436130, 407320 | 2.3km Southwest |

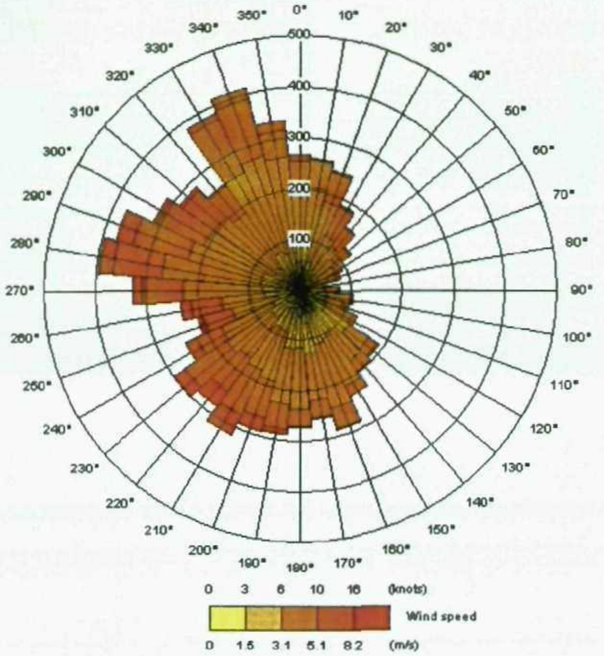
### Meteorology

The dispersion of emissions from a point source is largely dependent on atmospheric stability and turbulent mixing in the atmosphere, which in turn are dependent on wind speed and direction, ambient temperature, cloud cover and the friction created by buildings and local terrain.

Actual measured hourly-sequential meteorological data is available for input into dispersion models, and it is important to select data as representative as possible for the site that is modelled. This is usually achieved by selecting a meteorological station as close to the site as possible, although other stations may be used if the local terrain and conditions vary considerably or if the station does not provide sufficient data. There are several met stations within the vicinity of the installation; Finningley, which is 30km east, of the installation, Leeds, which is 30km north, and Bingley which is further north. It is believed that the meteorological conditions at the Finningley station are the most representative of the conditions at the Ardagh Barnsley installation as both are located on the edge of built up urban areas. Whereas the Leeds met station is located in the centre of the city and is considered the least representative. Data from Bingley has been used in sensitivity testing of the dispersion model. The results reported below are those obtained when using the met data for Finningley.

Guidance on hourly modelling recommends using at least four years of meteorological data, in order to account for yearly variations in weather patterns. In addition, it is recommended that the most recent meteorological data be used, as this is likely to be most representative of current climate conditions. Data for the Finningley met stations are available for the years 2007 to 2011. Initial simulations of the model has shown that met data for different years provides the worst-case results at different receptors (i.e. AQMA5, the habitat sites and nearby residential properties), and therefore the results from different met years have been reported in the assessment below, in order to provide a worst case assessment in each case. The wind-rose for the Finningley met data for 2010 is shown below as an example.

**Wind-rose, Finningley Meteorological Station, 2010**



## Building and Terrain Effects

As discussed above, another variable that can have a significant effect on the dispersion of emissions from sources is the presence of buildings or structures near to the emissions points. In accordance with the modelling guidance for ADMS4.2, building effects are typically considered where a structure of height greater than 40% of the stack height is situated within 8-10 stack heights of the emissions source. This approach is more conservative than that set out in the regulatory D1 assessments often used by local authorities and the Environment Agency.

Site plans were reviewed and it is believed that there are no buildings on site that meet the criteria outlined above for effecting the dispersion of the site's emissions, and therefore no buildings have been included in the model simulation.

The installation is situated on the edge of the urban area of Barnsley, with a mixture of built up housing areas and agriculture, adjacent to the site. A surface roughness of 0.5m has therefore been selected to represent the local area.

The presence of elevated or complex terrain in the vicinity of the source can also affect the flow pattern of the wind field. The Ardagh Barnsley installation is located in an area of gradient approximately equal to a 1 in 4 slope, and is surrounded by similar terrain; therefore the use of terrain data is considered to be appropriate in the modelling assessment. Terrain data have been obtained from Ordnance Survey in the form of Landform Profile tiles SE20, SE21, SE30, SE31, SE40, SE41, SK29, SK39 and SK49. The terrain file applied to the model supported the modelling of receptor points within a 2km by 2 km grid centred on the site. Terrain data was not applied when modelling the impact at more distant receptors.

## 5.3 Predicted Results

The results of the dispersion modelling of proposed total emissions from the installation are shown in Tables 5-5 to 5-8. The predicted maximum ground level concentrations (PCs) of pollutants at off-site locations have been taken directly from the model output. Contour plots have also been produced to illustrate the predicted long term and short term concentrations of NOx for each of the four scenarios (see Appendix A).

NOx emissions at source from combustion activities including glass furnaces are primarily as NO, with NOx typically in the ratio of 9:1 NO: $NO_2$. However, in the ambient air, the emitted NO is oxidised to $NO_2$, primarily through the reaction with ozone. The rate of oxidation depends on several factors including the concentration of ozone and the amount of sunlight.

As the NAQS objectives are set for $NO_2$, due to its potential health impacts, an estimate of the rate of oxidation of NO to $NO_2$ needs to be made for both short term and long term averaging periods. A conservative approach is to assume a 100% conversion rate in the long term (for determining the annual average) and 50% for short-term impacts and this approach has been used in this assessment. In reality, studies have shown that long term/ short term NOx conversion is more likely to be around 70%/ 30% respectively or less, particularly in urban areas where the ozone concentration tends to be suppressed. The assumptions used in this assessment therefore represent a worst case estimate of $NO_2$ impacts arising from the process emissions.

In each scenario, the PC has been added to the ambient concentration (AC), to determine the likely predicted environmental concentration (PEC). The predicted concentrations have been compared with National Air Quality Strategy (NAQS) objectives and the National Objectives for the Protection of Vegetation and Ecosystems.

### Predicted Results – Scenario 1

#### Nitrogen Dioxide

At the current ELV, maximum predicted off-site short-term PC for $NO_2$ was 68.9 $\mu g/m^3$ (as the 99.79th percentile of hourly averages), representing 34% of the relevant NAQS objective for $NO_2$. When combined with the background concentration of 51.8 $\mu g/m^3$ (double the annual average background, in accordance with the H1 Guidance) it forms a PEC of 121 $\mu g/m^3$, representing 60% of the NAQS objective.

This assessment represents a worst-case scenario in terms of the emissions levels, which are assessed at the ELV concentration (currently twice the recently monitored emission levels), the choice of meteorological dataset and the doubling of the worst-case ambient concentration (monitored at Faith Street) for short term impacts, which will already include a contribution from the adjacent Ardagh installation. While these worst-case assumptions are in accordance with modelling guidance, it is considered that it is unlikely that so many worst-case assumptions would occur simultaneously, and therefore impacts associated with $NO_2$ releases from the installation are likely to be lower than indicated by this assessment.

The maximum predicted off-site long-term PC for $NO_2$ (based upon average monitored emissions) was 3.1 $\mu g/m^3$, which represents 8% of the relevant NAQS objective. When combined with the background concentration of 25.9 $\mu g/m^3$ it forms a PEC of 29 $\mu g/m^3$, representing 73% of the NAQS objective.

At the Stairfoot Brickworks SSSI, the long-term PC for $NO_2$ was 0.6 µg/m$^3$, which represents 2% of the relevant NOPVE. When combined with the background concentration of 17.8 µg/m$^3$ for the grid square containing Stairfoot Brickworks, it forms a PEC of 18.5 µg/m$^3$, representing 62% of the NOPVE. Impacts at the slightly nearer Carlton Main Brickworks where similar to those described above for Stairfoot Brickworks SSSI.

At the nearest AQMA (AQMA5), the long-term PC for $NO_2$ was 0.6 µg/m$^3$, which represents 1.5% of the NAQS objective and is marginally over the insignificance level. When combined with the background concentration of 37.9 µg/m$^3$ derived from diffusion tube monitoring within the AQMA, it forms a PEC of 38.5 µg/m$^3$, representing 96% of the NAQS, 94.5% of which is provided by the background concentration. Short-term process contributions are 25.9 µg/m$^3$, or 13% of the short-term NAQS objective.

**Sulphur Dioxide**

The maximum predicted short-term PCs for $SO_2$ during gas firing of the furnaces were:

- 51.4 µg/m$^3$ as the 99.9$^{th}$ percentile of 15-minute averages;
- 38.6 µg/m$^3$ as the 99.73$^{th}$ percentile of hourly averages; and
- 12.9 µg/m$^3$ as the 99.18$^{th}$ percentile of 24-hour averages.

These represent 19%, 11% and 10% of the respective NAQS objectives for $SO_2$. When combined with the ambient concentrations (assumed to be 7.2 µg/m$^3$ for short-term impacts), this leads to PECs representing 22%, 13% and 16% of the respective NAQS objectives.

At the Stairfoot Brickworks Habitats receptor, the long-term PC for $SO_2$ was 0.3 µg/m$^3$, which represents 1% of the relevant NOPVE. When combined with the background concentration of 3.6 µg/m$^3$ it forms a PEC of 3.9µg/m$^3$, representing 19% of the NOPVE.

**Particulate Matter**

At the current ELV, the maximum predicted off-site short-term PC for PM was 0.25 µg/m$^3$ (as the 90.41th percentile of hourly averages), representing 0.5% of the relevant NAQS objective for $PM_{10}$ (PM has been conservatively assessed against air quality objectives for $PM_{10}$). When combined with the background concentration of 33.1 µg/m$^3$ (double the annual average background, in accordance with the H1 Guidance) it forms a PEC of 33.3 µg/m$^3$, representing 67% of the NAQS objective.

The maximum predicted off-site long-term PC for PM was <0.1 µg/m$^3$, which represents < 1% of the relevant NAQS objective. When combined with the background concentration of 16.5 µg/m$^3$ it forms a PEC of 16.5 µg/m$^3$, representing 41% of the NAQS objective.

**Table 5-5: Predicted off-site maximum ground level concentrations – Scenario 1**

| Pollutant | Measured as | AQS(1) ($\mu g/m^3$) | PC ($\mu g/m^3$) | PC/AQS | AC(2) ($\mu g/m^3$) | PEC ($\mu g/m^3$) | PEC/AQS |
|---|---|---|---|---|---|---|---|
| $NO_x$ (as $NO_2$) | Annual mean | 40 | 3.1 | 8% | 25.9 | 29 | 73% |
| | 1-hour mean (99.8th %ile) | 200 | 68.9 | 34% | 51.8 | 121 | 60% |
| | Annual mean (Carlton Main Brickworks SSSI) | 30 (3) | 0.6 | 2% | 17.8 | 18.5 | 62% |
| | Annual Mean (AQMA5) | 40 | 0.6 | 1.5% | 37.9 | 38.5 | 96% |
| | 1-hour mean (99.8th %ile) (AQMA5) | 200 | 25.9 | 13% | 75.8 | 101.7 | 51% |
| $SO_2$ | 24-hour mean (99.2nd %ile) | 125 | 12.9 | 10% | 7.2 | 20.1 | 16% |
| | 1-hour mean (99.7th %ile) | 350 | 38.6 | 11% | 7.2 | 45.8 | 13% |
| | 15-minute mean (99.9th %ile) | 266 | 51.4 | 19% | 7.2 | 58.6 | 22% |
| | Annual mean (Stairfoot Brickworks SSSI)(4) | 20 (3) | 0.3 | 1% | 3.6 | 3.9 | 19% |
| $PM_{10}$ | Annual mean | 40 | <0.1 | <1% | 16.5 | 16.5 | 41% |
| | 24-hour mean (90.4th %ile) | 50 | 0.25 | <1% | 33.3 | 33.3 | 67% |

Notes:

(1) **AQS** = Air Quality Standard (NAQS objective or NOPVE)

(2) AC for short term calculations assumed to be twice annual AC, as per Guidance methodology.

(3) National Objective for Vegetation and Ecosystems (NOPVE)

(4) In this scenario Stairfoot Brickworks SSSI was the most impacted upon habitat receptor, even though it is slightly further from the site than Carlton Main Brickworks SSSI.

### Predicted Results – Scenario 2

### Nitrogen Dioxide

At the current ELV, maximum predicted off-site short-term PC for $NO_2$ was 78.6 $\mu g/m^3$ (as the 99.8th percentile of hourly averages), representing 39 % of the relevant NAQS objective for $NO_2$. When combined with the background concentration of 51.8 $\mu g/m^3$ (double the annual average background, in accordance with the H1 Guidance) it forms a PEC of 130 $\mu g/m^3$, representing 65% of the NAQS objective.

This assessment represents a worst-case scenario in terms of the emissions levels, which are assessed at the ELV concentration (currently twice the recently monitored emission levels), the choice of meteorological dataset and the doubling of the worst-case ambient concentration (monitored at Faith Street) for short term impacts, which will already include a contribution from the adjacent Ardagh installation. While these worst-case assumptions are in accordance with modelling guidance, it is considered that it is unlikely that so many worst-case assumptions would occur simultaneously, and therefore impacts associated with $NO_2$ releases from the installation are likely to be lower than indicated by this assessment.

The maximum predicted off-site long-term PC for $NO_2$ (based upon average monitored emissions) was 3.9 μg/m$^3$, which represents 10% of the relevant NAQS objective. When combined with the background concentration of 25.9 μg/m$^3$ it forms a PEC of 29.8 μg/m$^3$, representing 75% of the NAQS objective.

At the Carlton Main Brickworks SSSI, the long-term PC for $NO_2$ was 0.8μg/m$^3$, which represents 3% of the relevant NOPVE. When combined with the background concentration of 17.8 μg/m$^3$ for the grid square containing Carlton Main Brickworks it forms a PEC of 18.6 μg/m$^3$, representing 62% of the NOPVE. Short-term levels are 10% of the Daily Critical Value, and therefore under the H1 assessment criteria would be considered insignificant when assessed.

At AQMA5, the long-term PC for $NO_2$ was 0.7 μg/m$^3$, which represents 1.75% of the NAQS objective and is marginally over the insignificance level. When combined with the background concentration of 37.9 μg/m$^3$ derived from diffusion tube monitoring within the AQMA, it forms a PEC of 38.6 μg/m$^3$, representing 96.5% of the NAQS, 94.5% of which is provided by the background concentration. Short-term process contributions are 15% of the 1-hour NAQS objective, and when combined with twice the background remain at just 52% of the objective.

**Sulphur Dioxide**

The maximum predicted short-term PCs for $SO_2$ during gas firing of the furnaces were:

- 75.4 μg/m$^3$ as the 99.9$^{th}$ percentile of 15-minute averages;
- 56.9 μg/m$^3$ as the 99.73$^{th}$ percentile of hourly averages; and
- 18.8 μg/m$^3$ as the 99.18$^{th}$ percentile of 24-hour averages.

These represent 28%, 16% and 15% of the respective NAQS objectives for $SO_2$. When combined with the ambient concentrations (assumed to be 7.2 μg/m$^3$ for short-term impacts), this leads to PECs representing 31%, 18% and 21% of the respective NAQS objectives.

At the Carlton Main Brickworks Habitats receptor, the long-term PC for $SO_2$ was 0.4 μg/m$^3$, which represents 2% of the relevant NOPVE. When combined with the background concentration of 3.6 μg/m$^3$ it forms a PEC of 4.0 μg/m$^3$, representing 20% of the NOPVE.

**Particulate Matter**

At the current ELV, the maximum predicted off-site short-term PC for PM was 0.3 μg/m$^3$ (as the 90.41th percentile of hourly averages), representing <1% of the relevant NAQS objective for $PM_{10}$ (PM has been conservatively assessed against air quality objectives for $PM_{10}$). When combined with the background concentration of 33.1 μg/m$^3$ (double the annual average background, in accordance with the H1 Guidance) it forms a PEC of 33.4 μg/m$^3$, representing 67% of the NAQS objective.

The maximum predicted off-site long-term PC for PM was < 0.1 μg/m$^3$, which represents less than 1% of the relevant NAQS objective. When combined with the background concentration of 16.5 μg/m$^3$ it forms a PEC of 16.6 μg/m$^3$, representing 41% of the NAQS objective.

**Table 5-6: Predicted off-site maximum ground level concentrations – Scenario 2**

| Pollutant | Measured as | AQS[1] ($\mu g/m^3$) | PC ($\mu g/m^3$) | PC/AQS | AC[2] ($\mu g/m^3$) | PEC ($\mu g/m^3$) | PEC/AQS |
|---|---|---|---|---|---|---|---|
| $NO_x$ (as $NO_2$) | Annual mean | 40 | 3.9 | 10% | 25.9 | 29.8 | 75% |
| | 1-hour mean (99.8th %ile) | 200 | 78.6 | 39% | 51.8 | 130 | 65% |
| | Annual mean (Carlton Main Brickworks SSSI) | 30 [3] | 0.8 | 2% | 17.8 | 18.6 | 62% |
| | Daily mean NOx as $NO_2$ (SSSI) | 75 | 7.5 | 10% | 35.6 | 43.1 | 57% |
| | Annual Mean (AQMA5) | 40 | 0.7 | 2% | 37.9 | 38.6 | 97% |
| | 1-hour mean (99.8th %ile) (AQMA5) | 200 | 29.1 | 15% | 75.8 | 104.9 | 52% |
| $SO_2$ | 24-hour mean (99.2nd %ile) | 125 | 18.8 | 15% | 7.2 | 26 | 21% |
| | 1-hour mean (99.7th %ile) | 350 | 56.9 | 16% | 7.2 | 64.1 | 18% |
| | 15-minute mean (99.9th %ile) | 266 | 75.4 | 28% | 7.2 | 82.6 | 31% |
| | Annual mean (Carlton Main Brickworks SSSI) | 20 [3] | 0.4 | 2% | 3.6 | 4 | 20% |
| $PM_{10}$ | Annual mean | 40 | <0.1 | <1% | 16.5 | 16.6 | 41% |
| | 24-hour mean (90.4th %ile) | 50 | 0.3 | < 1% | 33.1 | 33.4 | 67% |

Notes:

1. **AQS** = Air Quality Standard (NAQS objective or NOPVE)
2. AC for short term calculations assumed to be twice annual AC, as per Guidance methodology.
3. National Objective for Vegetation and Ecosystems (NOPVE)

### Predicted Results – Scenario 3

### Nitrogen Dioxide

Where $NO_2$ emissions are reduced to the levels indicated in the BAT conclusions to be achievable through the use of primary measures only, the maximum predicted off-site short-term PC for $NO_2$ is 29.1 $\mu g/m^3$ (as the 99.8th percentile of hourly averages), representing 15% of the relevant NAQS objective for $NO_2$. When this contribution is assessed against the headroom (NAQS minus twice the annual average background), at 17.4% it is below the 20% threshold applied in the Environment Agency's H1 methodology.

When combined with the background concentration of 51.8 $\mu g/m^3$ (double the annual average background at Faith Street, in accordance with the H1 Guidance) the short-term impacts form a PEC of 80.9 $\mu g/m^3$, representing 40% of the NAQS objective. This represents a reduction of 25% in the short-term $NO_2$ impacts from the installation. This scenario results in short-term impacts which are only 6% greater than those associated with $NO_2$ where secondary abatement is employed.

The maximum predicted off-site long-term PC for $NO_2$, when released at the Sector benchmark is 2.7 μg/m$^3$, which represents 8.8% of the relevant NAQS objective. When combined with the background concentration of 25.9 μg/m$^3$ it forms a PEC of 28.6 μg/m$^3$, representing 72% of the NAQS objective. This scenario results in long-term impacts that are only 3% greater than those associated with $NO_2$ where secondary abatement is employed.

At the Carlton Main Brickworks Habitats receptor, the long-term PC for $NO_2$ was 0.6 μg/m$^3$, which represents 2% of the relevant NOPVE. When combined with the background concentration of 17.8 μg/m$^3$ it forms a PEC of 18.4 μg/m$^3$, representing 61% of the NOPVE. This represents a reduction of 1% in the long-term $NO_2$ impacts from the installation at the Habitats site relative to current levels, and is equivalent to the secondary abatement scenario.

At AQMA5, the long-term PC for $NO_2$ was 0.5 μg/m$^3$, which represents 1.25% of the NAQS objective and is marginally over the insignificance level. When combined with the background concentration of 37.9 μg/m$^3$ derived from diffusion tube monitoring within the AQMA, it forms a PEC of 38.4 μg/m$^3$, representing 96% of the NAQS, 94.5% of which is provided by the background concentration. Short-term process contributions are 5% of the 1-hour NAQS objective, which is within the 10% insignificance threshold.

**Sulphur Dioxide**

Applying the BAT conclusions emission levels, the maximum predicted short-term PCs for $SO_2$ during gas firing of the furnaces were:

- 45.1 μg/m$^3$ as the 99.9th percentile of 15-minute averages;
- 34.3 μg/m$^3$ as the 99.73th percentile of hourly averages; and
- 11.3 μg/m$^3$ as the 99.18th percentile of 24-hour averages.

These represent 17%, 10% and 9% of the respective NAQS objectives for $SO_2$. When combined with the ambient concentrations (assumed to be 7.2 μg/m$^3$ for short-term impacts), this leads to PECs representing 20%, 12% and 15% of the respective NAQS objectives.

At the Carlton Main Brickworks Habitats receptor, the long-term PC for $SO_2$ was 0.4 μg/m$^3$, which represents 2% of the relevant NOPVE. When combined with the background concentration of 3.6 μg/m$^3$ it forms a PEC of 4μg/m$^3$, representing 20% of the NOPVE.

**Table 5-7: Predicted off-site maximum ground level concentrations – Scenario 3**

| Pollutant | Measured as | AQS(1) ($\mu g/m^3$) | PC ($\mu g/m^3$) | PC/AQS | AC(2) ($\mu g/m^3$) | PEC ($\mu g/m^3$) | PEC/AQS |
|---|---|---|---|---|---|---|---|
| $NO_x$ (as $NO_2$) | Annual mean | 40 | 2.7 | 7% | 25.9 | 28.6 | 72% |
| | 1-hour mean (99.8th %ile) | 200 | 29.1 | 15% | 51.8 | 80.9 | 40% |
| | Annual mean (Carlton Main Brickworks SSSI) | 30 (3) | 0.6 | 2% | 17.8 | 18.4 | 61% |
| | Annual mean (AQMA5) | 40 | 0.5 | 1% | 37.9 | 38.4 | 96% |
| | 1-hour mean (99.8th %ile) (AQMA5) | 200 | 10.5 | 5% | 75.8 | 86.3 | 43% |
| $SO_2$ | 24-hour mean (99.2nd %ile) | 125 | 11.3 | 9% | 7.2 | 18.4 | 15% |
| | 1-hour mean (99.7th %ile) | 350 | 34.3 | 10% | 7.2 | 20.7 | 12% |
| | 15-minute mean (99.9th %ile) | 266 | 45.1 | 17% | 7.2 | 18.5 | 20% |
| | Annual mean (Carlton Main Brickworks SSSI) | 20 (3) | 0.4 | 2% | 3.6 | 41.5 | 20% |
| $PM_{10}$ | Annual mean | 40 | 0.07 | <1% | 16.5 | 16.6 | 42% |
| | 24-hour mean (90.4th %ile) | 50 | 0.24 | <1% | 33.1 | 33.3 | 67% |

Notes:

(1) **AQS** = Air Quality Standard (NAQS objective or NOPVE)

(2) AC for short term calculations assumed to be twice annual AC, as per Guidance methodology.

(3) National Objective for Vegetation and Ecosystems (NOPVE)

### Predicted Results – Scenario 4

### Nitrogen Dioxide

Reducing the $NO_2$ emissions to the BAT conclusion benchmark values for secondary abatement reduces the maximum predicted off-site short-term PC for $NO_2$ to 18.2 $\mu g/m^3$ (as the 99.8th percentile of hourly averages), representing 9% of the relevant NAQS objective for $NO_2$. When combined with the background concentration of 51.8 $\mu g/m^3$ (double the annual average background at Faith Street, in accordance with the H1 Guidance) it forms a PEC of 70 $\mu g/m^3$, representing 35% of the NAQS objective. This represents a reduction of 30% in the short-term $NO_2$ impacts from the installation modelled for Scenario 2.

The maximum predicted off-site long-term PC for $NO_2$, when released at the Sector benchmark is 1.5 $\mu g/m^3$, which represents 4% of the relevant NAQS objective. When combined with the background concentration of 25.9 $\mu g/m^3$ it forms a PEC of 27.4 $\mu g/m^3$, representing 69% of the NAQS objective. This represents a reduction of 5% in the long-term $NO_2$ impacts from the installation.

At the Carlton Main Brickworks Habitats receptor, the long-term PC for $NO_2$ was 0.3 µg/m$^3$, which represents 1% of the relevant NOPVE. When combined with the background concentration of 17.8 µg/m$^3$ it forms a PEC of 18.2 µg/m$^3$, representing 61% of the NOPVE. This represents a reduction of 1% in the long-term $NO_2$ impacts from the installation at the Habitats site.

At AQMA5, the long-term PC for $NO_2$ was 0.3 µg/m$^3$, which represents 0.75% of the NAQS objective and the contribution would be considered insignificant. When combined with the background concentration of 37.9 µg/m$^3$ derived from diffusion tube monitoring within the AQMA, it forms a PEC of 38.2 µg/m$^3$, representing 95.5% of the NAQS, 94.5% of which is provided by the background concentration. Short-term process contributions are 3% of the 1-hour NAQS objective, which is within the 10% insignificance threshold.

### Ammonia

Assuming that ammonia emissions associated with the use of SCR are at the benchmark level the maximum off-site process contributions of ammonia is below the threshold for insignificance in both the short-term (<10%) and long-term (<1%) when compared against the appropriate EAL.

Process contributions of ammonia at the nearest human receptors and Carlton Main Brickworks are below the thresholds for insignificance when compared against the appropriate human health and CLPVE criteria across all averaging periods. Furthermore, since the ground level concentration is less than 1% of the CLPVE defined for sensitive communities, in accordance with H1 methodology it can be concluded that the process contribution to deposited ammonia at the SSSI is unlikely to result in significant impact.

### Sulphur Dioxide

The impacts of sulphur dioxide are considered to be the same as set out in Scenario 3, which is set at the BAT conclusions benchmark value.

### Particulate Matter

The impacts of particulates are considered to be the same as set out in Scenario 3, which is set at the BAT conclusions benchmark value.

**Table 5-8: Predicted off-site maximum ground level concentrations – Scenario 4**

| Pollutant | Measured as | AQS(1) ($\mu g/m^3$) | PC ($\mu g/m^3$) | PC/AQS | AC(2) ($\mu g/m^3$) | PEC ($\mu g/m^3$) | PEC/AQS |
|---|---|---|---|---|---|---|---|
| $NO_x$ (as $NO_2$) | Annual mean | 40 | 1.5 | 4% | 25.9 | 27.4 | 69% |
| | 1-hour mean (99.8th %ile) | 200 | 18.2 | 9% | 51.8 | 70 | 35% |
| | Annual mean (Carlton Main Brickworks SSSI) | 30 (3) | 0.3 | 1% | 17.8 | 18.2 | 61% |
| | Annual mean (AQMA5) | 40 | 0.3 | 1% | 37.9 | 38.2 | 95.5% |
| | 1-hour mean (99.8th %ile) (AQMA5) | 200 | 6.6 | 3% | 75.8 | 82.4 | 41% |
| $NH_3$ | Hourly Average | 2500 | 3.8 | <1% | 3.4 | 7.2 | <1% |
| | Annual mean | 180 | 0.069 | <1% | 1.7 | 1.8 | 1% |
| | Annual mean (Carlton Main Brickworks SSSI) | 3 | 0.01 | <1% | 1.7 | 1.7 | 57% |

Notes:

(1) **AQS** = Air Quality Standard (NAQS objective or NOPVE)

(2) AC for short term calculations assumed to be twice annual AC, as per Guidance methodology.

(3) National Objective for Vegetation and Ecosystems (NOPVE)

## 6 EVALUATION OF OPTIONS FOR $NO_X$ CONTROL

Each option has been considered for the following aspects:

- Emissions, incorporating the assessment of impact outlined in Section 5;
- Feasibility, in terms of the technical and geographical specifics of the Barnsley installation;
- Cost (based on capital cost plus estimated annual operating costs annualised in accordance with the H1 methodology, using Ardagh Glass data and publicly available data, as appropriate).

These factors have been used to propose an initial high level recommendation as to whether an option could be considered to represent BAT for the installation.

### 6.1 Baseline (Do Nothing)

**Costs**

There are no extra costs associated with this option.

**Emissions**

The emission levels are over the benchmark limits of 500 - 800mg/m$^3$. Current release is approximately 3.3kg $NO_x$/t melted glass for furnaces B1, B2, B4 and B6 and up to 1,500mg/m$^3$. $NO_x$ releases would continue to contribute 8% of annual NAQS and 35% of short-term NAQS (excluding background) off site. When background concentrations are taken into account, the predicted environmental concentration would be 60% of the short-term NAQS.

**Feasibility**

This option is feasible as there is no extra cost or change in technique involved. However it would not achieve the BAT-AELs set out within the March 2012 BREF and the associated BAT conclusions.

**Recommendation**

The continued high releases of $NO_x$ mean the site would not comply with regulatory requirements. Therefore this is not a suitable option.

### 6.2 Re-commissioning of B7

**Costs**

The cost of refurbishing furnace B7 is undisclosed. Operation of B7 will require the installation of an electrostatic precipitator (EP) and associated dry scrubbing system and an extension to the current B7 chimney. Cost estimates for particulate and sulphur dioxide abatement installation are approximately £2.5 million. For the purposes of this assessment, these costs are discounted as they are considered essential to the effective re-commissioning of B7.

**Emissions**

Due to the increase in output with the recommissioning of B7, $NO_x$ releases would increase to 10% of annual NAQS and 39% of short-term NAQS (excluding background) off site. When background concentrations are taken into account, the predicted environmental concentration would be 65% of the short-term NAQS. The operation of B7 with the inclusion of primary measures would reduce the overall release rate to approximately 2.9kg $NO_x$/t melted glass.

**Feasibility**

This option is feasible as there is no extra cost or change in technique involved beyond the re-commissioning changes for B7 furnace.

**Recommendation**

Although furnace B7 would be compliant with the BAT-AELs appropriate for the application of primary measures, the continued higher release concentrations of $NO_x$ from the other furnaces would mean the site would not comply with regulatory requirements. Therefore this is not a suitable long-term option, but represents the worst-case 'baseline' scenario prior to the staged implementation of further measures on furnaces B1-B6.

## 6.3 Primary Combustion Modifications

**Costs**

The cost for developing and installing primary measures for each furnace is estimated at £0.4 million, producing an overall capital cost of £1.6 million for the four furnaces requiring modification. These costs are in addition to the necessary costs incurred during the normal completion of a major repair, which are excluded from this assessment, but will run to millions of pounds for each furnace.

The work would be undertaken during the planned repair period for each of the four furnaces.

There are no significant additional annual operational costs predicted for the application of primary measures.

**Emissions**

The installation of primary measures at other Ardagh Group facilities has already demonstrated emission levels of 800mg/$m^3$ (approximately 1.2kg NOx/t melted glass) or below are achievable. The BAT-AEL within the March 2012 BREF states a range of 500-800 mg/$m^3$, which equates to 0.75-1.2kg NOx/t melted glass.

Use of this method could potentially reduce emissions to 7% of LT NAQS and 15% of ST NAQS. This will provide at least 24% improvement on the current short-term situation. The short-term impact is below the Environment Agency H1 screening threshold of 20% of the headroom (NAQS – twice the background) for short-term.

The process contributions at the worst case AQMA are only marginally above the insignificance threshold of 1%, at 1.25% of the long-term NAQS, whilst short-term contributions are considered to be insignificant at 5% of the short-term NAQS.

### Feasibility

As the existing plant can be modified and the work undertaken during the planned major repairs for each furnace, this option is relatively easy to implement, albeit over a timescale of approximately ten to fifteen years.

### Cross-Media Effects

The application of primary measures is unlikely to have significant additional impacts providing the control measures are managed correctly. Carbon monoxide generation can be significant where control of air:fuel ratios is not correctly maintained, however the application of a sophisticated furnace control system will minimise the potential for this (particularly as high levels of CO can damage the refractory lining of the furnace and consequently affect the operational capability of the furnace).

### Recommendation

Primary combustion modifications should provides a large potential reduction in emissions for relatively low cost.

## 6.4 Retrofit of SCR

### Costs

The costs of this option are regarded as high, both in terms of capital and operating costs.

The estimated capital cost for fitting SCR to support all five furnaces is in the region of £3.3 million. Three SCR units would be required to achieve abatement through the three stacks serving the five furnaces.

Overall operating costs, including ammonia purchase (approximately 2,100 tonnes a year of 25% ammonia solution at an estimated cost of £100/t), catalyst replacement (carried out every 5 years) and additional energy requirements, are estimated at £860,000 a year (costs provided by SCR supplier).

### Emissions

SCR should achieve <500mg/m$^3$ for $NO_x$, and would therefore comply with the BAT conclusion benchmark levels. This is equivalent to approximately 0.75kg $NO_x$/t melted glass.

SCR would reduce emissions of $NO_2$ to 4% of LT NAQS and 9% of ST NAQS. This is 3% and 6% less respectively than the long term/ short term process contribution achievable from primary measures.

The process contributions at the worst case AQMA are insignificant for both the long-term and short-term NAQS objectives, at 1% and 3% respectively.

Likely releases of ammonia associated with SCR operation are regarded as insignificant in both the long- and short-term although localised health and safety issues remain for the delivery, off-loading and storage of ammonia solution at the site, which lies within 150 metres of residential housing.

**Feasibility**

The technology and the space on site are available and the emissions performance would meet the sector benchmarks. As the facility operates with electrostatic precipitators, there are no issues with reheating of flue gases.

**Cross-media effects**

The use of ammonia is associated not only with the slippage of unreacted ammonia solution but also with environmental and safety implications from ammonia transport, storage and use.

Estimated use of ammonia reagent, based upon a capacity of 1475tpd glass production for the installation and based upon equivalent consumption of 145l/hr for a 640tpd container glass plant (March 2012 BREF) is 335l/hr. This is equivalent to 2,935$m^3$ annual consumption of 25% ammonia solution, and would require a delivery of 20$m^3$ ammonia at least once a week to the facility, which would have to be transported past the residential areas surrounding the facility. Bulk ammonia storage tanks would also be located adjacent to the SCR plants, within 150m of residential housing.

Production of ammonia for use in the SCR process also generates indirect emissions to air associated with the use of SCR. According to the BREF for the Manufacture of Large Volume Inorganic Chemicals, the generation of ammonia releases carbon dioxide at a rate of approximately 1.15-1.4kg/kg $NH_3$ produced. This is equivalent to an annual release of 844 – 1,027 tonnes of $CO_2$. $NO_x$ is also generated in the ammonia manufacturing process, at levels of around 200-400mg/$m^3$, equivalent to the reduction achieved in applying SCR against primary measures. Ammonia generation also uses approximately 30GJ of energy per tonne produced, equivalent to 23,000GJ to produce the annual ammonia volume required for the potential SCR operation at Barnsley.

**Recommendation**

This method provides the least risk in terms of complying with BAT-AELs as set out in the adopted BREF and BAT conclusions, but has the potential to be the most expensive as well. It also introduces significant health and safety management requirements at the facility for the transport, delivery and safe storage of the ammonia reagent. The use of ammonia also introduces a number of indirect environmental effects, including increased $CO_2$ generation, additional indirect $NO_x$ release and high energy consumption from the production of ammonia.

Based upon the review above, a cost-benefit assessment is undertaken in Section 6 to determine which option is considered to represent BAT for the Barnsley installation.

## 6. 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 use of "primary means" or measures to prevent generation of pollutant emissions within a process, for example through use of alternative, less hazardous materials, 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.

The impact assessment detailed above indicates that the difference in the predicted annual environmental concentrations of $NO_x$ between the use of primary and secondary abatement is only 3%. This difference in off-site impact is not considered to be significant. The economic implications of installing secondary abatement therefore should also be considered to further assist the determination of BAT for the installation.

### 6.1 Risk Appraisal of Options

A simple risk appraisal of the options is demonstrated in Table 6-1 below, based on High, Medium and Low classifications. This suggests that the use of primary combustion techniques represents the lowest level of risk overall, subject to regulatory agreement on a derogation against the BAT-AEL levels during the staged implementation of primary measures.

**Table 6-1: Qualitative risk appraisal of options for NOx control**

| Option | Cost | Emissions | Feasibility | Cross-media effects | Ranking |
|---|---|---|---|---|---|
| **Current Operations with B7** | LOW | HIGH | NO | LOW | 3 |
| **Primary Measures** | MEDIUM | MEDIUM | YES | LOW | 1 |
| **SCR** | HIGH | LOW | YES | HIGH | 2 |

### 6.2 Marginal Costs of Abatement

An assessment of the marginal costs of abatement (also known as a 'BAT curve') is a simplistic way to represent the cost-benefit case of each option assessed.

The Equivalent Annual Costs (EAC) forms the basis of this assessment, and it represents a predicted annual cost for the installation and operation of the technology, spreading the capital cost of the technology across the lifetime of the equipment. The EACs have been calculated using the Environment Agency's H1 Environmental Risk Assessment – Annex K Options Appraisal costing technique, applying Lang factors (estimated conversion factors using the basic equipment cost to calculate the costs for ancillary aspects e.g. pumps, pipework etc) where detailed costs are not available. The EAC is developed using a standard lifetime for a furnace (and associated abatement equipment) of 15 years, with the capital and operating costs being normalised over this 15-year period, using a discount rate of 8%.

The assessment incorporates the Equivalent Annualised Costs (EAC) calculated in Section 5, and the volume of primary pollutant removed (normally expressed in tonnes per year). This provides a cost per tonne of pollutant removed, which can then be used to demonstrate the most cost effective option. Typically the elbow of the BAT curve represents the most appropriate balance of costs against benefits.

To provide a comparable assessment of the options investigated, the cost of installing each form of abatement is converted into Pounds Sterling per tonne of oxides of nitrogen removed per year (£/t/yr). The results of this are set out in Table 6-2 below. This can then be converted to a BAT curve.

**Table 6-2: Cost/Benefit assessment of $NO_x$ removal options at Barnsley**

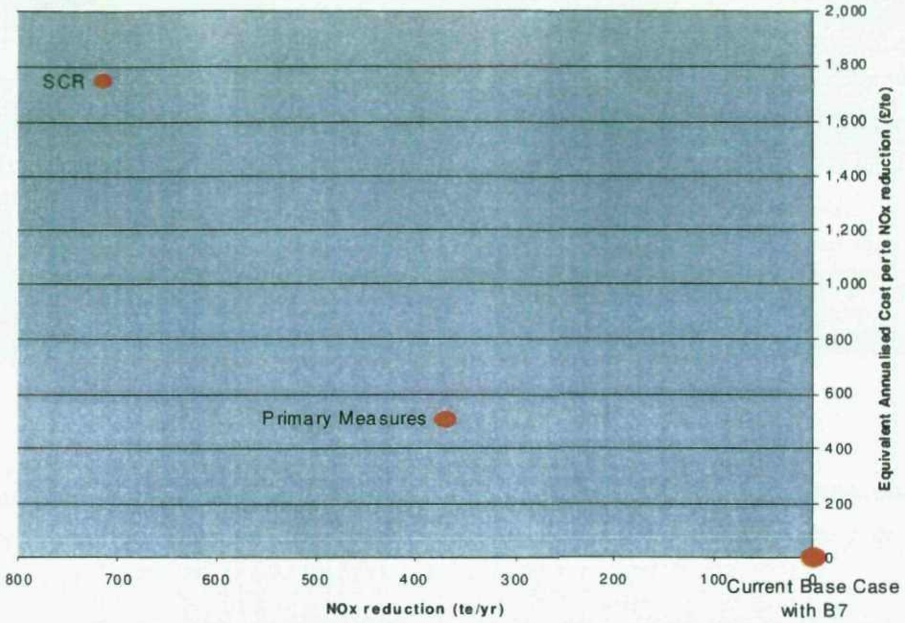
| Option | Max. emission rate (mg/m$^3$) | $NO_x$ release (t/yr) | Capital Costs (£,000) | Annual Operating Costs (£,000) | Equivalent Annual Costs (EAC) (£,000) | £/t $NO_x$ removed/ yr |
|---|---|---|---|---|---|---|
| **Current Operations with B7** | 1,405 | 1,287[1] | - | - | - | - |
| **Primary Measures** | 800 | 918 | 1,600 | 0 | 187 | 507 |
| **SCR** | 500 | 572 | 3,300 | 860 | 1,247 | 1,744 |

Notes 1: Based upon annual average emissions from 2010-11. If the assessment is *based* on reducing emissions from the current ELVs, the cost/ benefit for $NO_x$ removal per year for primary and secondary measures is £114/t and £630/t respectively.

The BAT curve in Figure 6.1 below is simplistic as it is based upon three main options (current operation with B7, primary measures and SCR), however there is a clear distinction between the cost per tonne of NOx removed for primary measures set against the cost for SCR, with SCR requiring around six times the investment cost per tonne NOx removed. There are also complications with the application of this technique due to the increase in hazard profile of the installation through the introduction of bulk ammonia storage.

It is therefore considered that the cost benefit assessment coupled with the predicted level of environmental impact do not support the additional expenditure required for secondary abatement and that the use of primary measures on all furnaces represents BAT at the Barnsley installation.

**Figure 6.1: Marginal Cost of Abatement**



## 6.3 Control of Sulphur Dioxide

A brief assessment of sulphur dioxide control requirements is also provided, as the March 2012 BREF included a revised $SO_2$ BAT-AEL of 500mg/m$^3$. Monitoring results for 2010 and 2011 show an average $SO_2$ concentration of between 500-550mg/m$^3$ being achieved on all operational furnaces at Barnsley with the dry scrubbing process currently applied.

Of the three main sulphur dioxide air quality standards (15 minutes, 1 hour and 24 hour), the current operation with B7 would be compliant with the 20% headroom threshold criteria for all but the 15-minute standard, where a process contribution of 29% against the current headroom is calculated. Additional lime injection to achieve the BAT-AELs would deliver off-site impacts within the 20% headroom thresholds for all three standards. Process contributions at the nearest SSSI (Carlton Main Brickworks, designated for geological features) remain the same for both scenarios, with a 2% long-term contribution – both marginally over the 1% insignificance threshold.

In all cases where the process contributions are assessed against the short-term air quality standards, contributions below 30% are achieved, indicating a low likelihood of the air quality standards for $SO_2$ to be breached.

To achieve a level consistently below 500mg/m$^3$, a reduction in the current emission concentrations by 100mg/m$^3$ may be necessary. This is equivalent to a reduction in the annual tonnage of $SO_2$ released from 628 tonnes to 486 tonnes, a removal rate of 142 tonnes per year. Applying a stoichiometric ratio of 2:1 for reagent: $SO_2$ removed as set out in Table 4.30 of the March 2012 BREF, this would equate to an additional use of 284 tonnes of lime (calcium hydroxide), and would result in approximately 400 tonnes per year of additional filter dust to be removed and recycled. The cost of the additional $SO_2$ abatement is estimated at £46,000 per year, based upon the current price paid for lime by Ardagh. This is equivalent to

£322/t $SO_2$ removed, and would be considered an appropriate benchmark for $SO_2$ abatement at the facility.

The installation uses filter dust recycling (which could result in higher sulphate content in the furnace feed if the $SO_2$ removal rate is increased), and achieves external cullet recycling rates of approximately 40%. The March 2012 BREF states that "Values reported in the table (<200 – 500mg/m$^3$) may be difficult to achieve in combination with filter dust recycling and the rate of recycling of external cullet". As the sulphur balance within the furnaces is carefully managed, it is therefore anticipated that the majority of any additional filter dust generated would need to be removed as waste. If a conservative assumption is made that 75% of the additional filter dust would need to be disposed of, this would result in 300 tonnes per year of filter dust rich in calcium sulphate requiring disposal. Although the filter dust may be suitable for re-use in the fertiliser/agricultural industry, or water treatment applications, the potential presence of trace levels of heavy metals may affect the use within these sectors, so disposal through incineration is considered the most likely option. Disposal through incineration is estimated at £150/t, equivalent to £45,000 per year. The requirement for disposal effectively doubles the cost of abatement from £322/t to £641/t.

It is therefore considered that the existing emissions performance represents BAT for the installation given the degree of recycle undertaken. This is based upon the following considerations:

- minimal change in off-site environmental impact as a result of increase lime injection, *particularly at the nearest SSSI (designated for geological features and therefore less* sensitive to acidification effects), where impacts are at 2% of the EAL for both scenarios;
- generation of excess filter dust (estimated at 300 tonnes a year) which cannot be recycled within the process and will require off-site disposal to land or by incineration;
- possible indirect emissions of $SO_2$ and other pollutants through incineration of excess filter dust;
- indirect impacts associated with lime manufacture, including an additional 900GJ energy use and additional emissions of $NO_x$, $SO_2$ and over 400 tonnes of $CO_2$ annually.

It is proposed that the installation will continue to operate to the current standards, with emissions unlikely to exceed 600mg/m$^3$ as an annual average.

## 7. DEROGATION JUSTIFICATION

Should the application of primary measures for the control of NOx be accepted as BAT for the furnaces at Barnsley, a timetable for the implementation of primary measures would need to be agreed. As primary measures are introduced during a major repair, the appropriate timing for such repairs needs to be considered.

### 7.1 Time Constraints for Scheduled Major Repairs

The timing for major repair works need to be selected prior to any furnace structure failure and to optimise furnace life while providing minimum disruption to glass manufacture and production scheduling. Exact timings for the major repairs are determined by frequent furnace inspections and are prioritised based upon expert evaluation / analysis of the furnace condition and the continued safe operation of the furnace.

The design and procurement phase for a major furnace repair typically takes 10 – 12 months. Furnace refractories need to be ordered 7 months prior to a major repair being carried out, and the design and quoting phase could be 5 months prior to this.

It is anticipated that carrying out the major repair itself would take up to 4 months for each furnace, from draining the glass and cooling down the furnace, to completion of the repair and commissioning of the repaired furnace. This results in an overall project time of up to 18 months, which gives sufficient time to develop and implement plans to ensure that the workforce can be redeployed during the furnace downtime to keep the number of redundancies to a minimum.

The Ardagh Group have 20 manufacturing sites across Europe and a further 9 in the USA, and all furnace maintenance work is carried out by their Central Technical Services Group, and therefore planning for maintenance and major repair work across the group is complex. The Ardagh furnace repair schedule is commercially confidential, however in order to demonstrate Ardagh Glass' commitment to carrying out the P4 major repair and installation of primary measures to reduce $NO_x$ emissions to BREF ELV benchmark values, a copy of the major milestones within the repair schedule will be made available to the local authority if required; this will be reported under separate cover. The repair schedule shows that the four furnaces are due to undergo major repairs over the next 10-15 years, on a staged schedule to limit impact on production at Ardagh Barnsley. Recent rebuilds in the UK at Knottingley and Wheatley have already been undertaken, with two planned for 2013 at Portland and Barnsley. Where these rebuilds have been undertaken with primary measure improvements, these have successfully reduced $NO_x$ levels.

The budgeted costs for the inclusion of primary measures within the B1/B3/B4/B6 major repairs are some £1.6 million. This is in addition to the necessary costs for a major repair which is usually in a range of £5 million - £15million dependant upon the size of the furnace.

### 7.2 Implications of Carrying Out an Unscheduled Major Repair

Should Ardagh be required to implement the proposed primary measures improvements as soon as possible, there are many consequences of carrying out an unscheduled major repair. These include loss of manufacturing capacity, reduction in plant efficiency, potential loss of business and additional costs. Further details on each of these are provided below.

### 7.2.1 Loss of Manufacturing Capacity

As described above, a scheduled major repair enables time for new furnace designs to be completed, contracts for supply and installation to be finalised and the production and fabrication of the required materials.

It also enables glass manufacture to be located to other facilities within the group in order to fulfil contracts and maintain market share. The main cost implications of an unplanned major repair therefore, are primarily associated with lost production, estimated to be approximately £20,000 - 40,000/day dependent upon furnace size.

The unplanned furnace downtime would include the design and procurement phase of the project, which during a scheduled repair is carried out whilst the furnace is operational. As stated above, this normally takes between 10 and 12 months depending on the complexity of the project, and therefore if an unscheduled major repair was carried out, lost production during this planning period alone would cost the company £10-12 million.

During a scheduled major repair, production capacity can be relocated across the Ardagh Group, however it is generally not possible to do this at short notice. Capacity to manufacture products at other plants within the Ardagh Group is available but limited. It is considered likely that loss of manufacturing capacity at short notice could lead to work being lost to competitors either on a short term or permanent basis, which could have large economic implications for the company.

### 7.2.2 Additional Costs

In the event of an unscheduled major repair being required, in order that the impacts of production downtime are minimised, all possible options to minimise the 10 – 12 month design and procurement timeframe would be utilised. It is considered that the costs of an unscheduled major repair could therefore be considerably more than a scheduled major repair due to the following factors:

- Premium rates would be incurred for design work to ensure a faster turnaround, likely to be up to 25% greater than normal design costs;
- Premium rates for production and fabrication works, likely to be 5% greater than normal costs.
- The unscheduled major repair would need to run concurrently with other scheduled repairs for the Ardagh Group. The Central Technical Services arm of the company only has limited staff and resources for a finite number of refurbishments per year (up to 4 cold repairs and 7 hot repairs per year). An unscheduled event would mean the need to import additional contract staff and resources, such that the Ardagh Group engineering and consultancy costs would be significantly increased, potentially doubled (normally costed at 5% total of the major repair budget).
- Contracts for the supply of materials would be awarded to suppliers with shortest lead times, rather than being based on best value or quality of materials. This could lead to additional costs of 10 - 15% above normal costs.
- Contracts for installation would be based on contractor availability rather than skill, cost or best value. This would lead to additional costs in the region of up to 25% more for the refractory demolition / build.

Given that the cost of the major repairs has been estimated as being between £5 million – £15 million, these additional costs could add at least a further £1 million onto the costs of the major repair. As stated above, the cost implications from production losses during the unscheduled major repair could be up to £12 million, and therefore this unanticipated level of spend would have a huge impact on the company finances.

## 7.3 Socio-Economic Factors

In addition to the cost implications detailed above, if an unscheduled major repair is to be carried out, it is likely to result in a layoff of up to 30% of the site workforce because there would not have been time to plan so that those staff could be redeployed whilst works were being carried out. When scheduled major repairs are carried out it is possible to avoid large scale redundancies by making alternative arrangements for the workforce, ensuring they remain busy.

## 8. CONCLUSION

Based upon the above assessment, it is recommended that primary control measures be considered to represent BAT for the control of nitrogen oxide emissions from the Barnsley installation and should be implemented during the next scheduled repairs for furnaces B1, B3, B4 and B6. This recommendation takes into account the level of $NO_x$ reduction achieved when compared against SCR along with the excessive cost of installing and running secondary abatement and the associated health and safety risks of transporting and storing the ammonia reagent required.

SCR would be considered the most technically appropriate option for a new build glass container site to ensure sector guidance BAT emissions levels for $NO_x$ are achieved. However, there are significant issues surrounding the implementation of SCR at Barnsley, including the increased safety risk from storage and transport of bulk ammonia reagent, increased indirect emissions from the manufacture and use of ammonia and high operational costs. Section 4.4.2.7 of the Glass BREF also states that for applications where unabated emissions are below 2,500 mg/m$^3$, SCR is not generally considered by the Glass Industry to be the most cost-effective technique available, although recent increases in energy prices have made SCR more attractive compared to high-energy primary measures such as chemical reduction by fuel or oxy-firing. Emissions from the four furnaces currently operating at Barnsley are currently well below this level and range between 1,100 – 1,500 mg/m$^3$ as a long-term average.

The implementation of primary control measures on all the furnaces at Barnsley would achieve NOx levels equivalent to the BAT AEL emission levels, and can be delivered at a much-reduced cost, with none of the issues associated with the introduction of SCR. The off-site impact of NOx from the application of primary measures is just 6% higher in the short term and 3% higher in the long term than that achieved by the use of SCR, and remains within the short-term screening threshold applied by the H1 methodology. The insignificant long-term impact on the nearest Air Quality Management Area from the release of $NO_x$ from Barnsley should also be regarded as a strong argument for the application of primary measures as BAT at the Barnsley installation.

Modelling of the introduction of the B7 furnace emissions prior to implementation of primary measures on the remaining furnaces (Scenario 2) demonstrates that the additional furnace will not lead to breaches of NAQS objectives around the installation, with long-term process contributions at a maximum of 10% of the NAQS and just 2% of the NAQS at the nearest AQMA and ecological receptor. Short-term process contributions are also limited to a maximum of 39% of the NAQS (and just 15% at the nearest designated AQMA), and these levels are considered to be very conservative due to the assessment criteria applied.

Based upon the minimal change in off-site environmental impact, the increased generation of filter dust requiring off-site disposal and subsequent potential impact on process operations, the application of the <200-500mg/m$^3$ BAT-AEL for $SO_2$ is considered inappropriate for the installation. It is considered that the existing sulphur dioxide emissions performance represents BAT for the installation given the degree of recycle undertaken. It is therefore proposed that the installation will continue to operate to the current standards, with emissions unlikely to exceed 600mg/m$^3$ as an annual average.

## APPENDIX A FIGURES

NOTES

— Annual Mean $NO_2$ ($\mu g/m^3$)

● Sources

● AQ Selected Receptors

▭ Model Domain

Copyright
*Contains Ordnance Survey Data*
© Crown Copyright and database right 2012

| Revision Details | By | Check | Date | Suffix |
|---|---|---|---|---|

Purpose of Issue
Draft

Client
Ardagh Glass Ltd

Project Title
Ardargh Glass BAT Assessment - Barnsley Installation

Drawing Title
Scenario 1: Current Operations Nitrogen Dioxide Long Term

| Drawn | Checked | Approved | Date |
|---|---|---|---|
| EW | GG | GG | 10/08/12 |

URS Internal Project No.
47063542

Scale @ A3
1:22,000

This document has been prepared in accordance with the scope of URS' appointment with its client and is subject to the terms of that appointment. URS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided. Only written dimensions shall be used.
© URS Infrastructure & Environment UK Limited

URS Infrastructure & Environment UK Limited
Scott House
Alencon Link Basingstoke
Hampshire RG21 7PP
Telephone (01256) 310200
Fax (01256) 310201
www.ursglobal.com

URS

Drawing Number
Figure 4.1

Rev
01

NOTES

| | |
|---|---|
| — | 99.79$^{th}$ %$^{ile}$ NO$_2$ (µg/m$^3$) |
| ● | AQ Selected Receptors |
| ● | Sources |
| ┌ ┐ | Model Domain |

Copyright
*Contains Ordnance Survey Data*
© Crown Copyright and database right 2012

| Revision Details | By | Check | Date | Suffix |
|---|---|---|---|---|

Purpose of Issue
Draft

Client
Ardagh Glass Ltd

Project Title
Ardargh Glass BAT Assessment - Barnsley Installation

Drawing Title
Scenario 1: Current Operations Nitrogen Dioxide Short Term

| Drawn | Checked | Approved | Date |
|---|---|---|---|
| EW | GG | GG | 10/08/12 |

URS Internal Project No.
47063542

Scale @ A3
1:22,000

This document has been prepared in accordance with the scope of URS' appointment with its client and is subject to the terms of that appointment. URS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided. Only written dimensions shall be used.
© URS Infrastructure & Environment UK Limited

URS Infrastructure & Environment UK Limited
Scott House
Alencon Link, Basingstoke
Hampshire RG21 7PP
Telephone (01256) 310200
Fax (01256) 310201
www.ursglobal.com

Drawing Number
Figure 4.2

Rev
01

NOTES

| | |
|---|---|
| — | Annual Mean NO2 (µg/m$^3$) |
| ● | Sources |
| ● | AQ Selected Receptors |
| ⬚ | Model Domain |

Copyright
Contains Ordnance Survey Data
© Crown Copyright and database right 2012

| Revision Details | By / Check | Check Date | Suffix |
|---|---|---|---|

Purpose of Issue
Draft

Client
Ardagh Glass Ltd

Project Title
Ardargh Glass BAT Assessment - Barnsley Installation

Drawing Title
Scenario 2: Current Operations with B7 Furnace Nitrogen Dioxide Long Term

| Drawn | Checked | Approved | Date |
|---|---|---|---|
| EW | GG | GG | 10/08/12 |

| URS Internal Project No. | Scale @ A3 |
|---|---|
| 47063542 | 1:22,000 |

This document has been prepared in accordance with the scope of URS' appointment with its client and is subject to the terms of that appointment. URS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided. Only written dimensions shall be used
© URS Infrastructure & Environment UK Limited

URS Infrastructure & Environment UK Limited
Scott House
Alençon Link, Basingstoke
Hampshire RG21 7PP
Telephone (01256) 310200
Fax (01256) 310201
www.ursglobal.com

| Drawing Number | Rev |
|---|---|
| Figure 4.3 | 01 |

Copyright
Contains Ordnance Survey Data
© Crown Copyright and database right 2012

| Revision Details | By / Check | Check Date | Suffix |
|---|---|---|---|

Purpose of Issue
Draft

Client
Ardagh Glass Ltd

Project Title
Ardargh Glass BAT Assessment - Barnsley Installation

Drawing Title
Scenario 2: Current Operations with B7 Furnace Nitrogen Dioxide Short Term

| Drawn | Checked | Approved | Date |
|---|---|---|---|
| EW | GG | GG | 10/08/12 |

| URS Internal Project No. | Scale @ A3 |
|---|---|
| 47063542 | 1:22,000 |

This document has been prepared in accordance with the scope of URS' appointment with its client and is subject to the terms of that appointment. URS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided. Only written dimensions shall be used.
© URS Infrastructure & Environment UK Limited

URS Infrastructure & Environment UK Limited
Scott House
Alencon Link Basingstoke
Hampshire RG21 7PP
Telephone (01256) 310200
Fax (01256) 310201
www.ursglobal.com

Drawing Number
Figure 4.4

Rev
01

NOTES

- ——— Annual Mean NO2 (µg/m$^4$)
- ● Sources
- ● AQ Selected Receptors
- ┌┄┐ Model Domain

Copyright
Contains Ordnance Survey Data
© Crown Copyright and database right 2012

| Revision Details | By / Check | Check Date | Suffix |
|---|---|---|---|

Purpose of Issue
Draft

Client
Ardagh Glass Ltd

Project Title
Ardargh Glass BAT Assessment - Barnsley Installation

Drawing Title
Scenario 3: Proposed Operations with Primary Measures Nitrogen Dioxide Long Term

| Drawn | Checked | Approved | Date |
|---|---|---|---|
| EW | GG | GG | 10/08/12 |

URS Internal Project No.
47063542

Scale @ A3
1:22,000

This document has been prepared in accordance with the scope of URS' appointment with its client and is subject to the terms of that appointment. URS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided. Only written dimensions shall be used
© URS Infrastructure & Environment UK Limited

URS Infrastructure & Environment UK Limited
Scott House
Alençon Link, Basingstoke
Hampshire, RG21 7PP
Telephone (01256) 310200
Fax (01256) 310201
www.ursglobal.com

Drawing Number
**Figure 4.5**

Rev
01

NOTES

— 99.79th %ile NO2 (µg/m³)

● Sources

● AQ Selected Receptors

┆ Model Domain

Copyright
Contains Ordnance Survey Data
© Crown Copyright and database right 2012

| Revision Details | By / Check | Check Date | Suffix |
|---|---|---|---|
| | | | |

Purpose of Issue
Draft

Client
Ardagh Glass Ltd

Project Title
Ardargh Glass BAT Assessment - Barnsley Installation

Drawing Title
Scenario 3: Proposed Operations with Primary Measures Nitrogen Dioxide Short Term

| Drawn | Checked | Approved | Date |
|---|---|---|---|
| EW | GG | GG | 10/08/12 |

| URS Internal Project No. | Scale @ A3 |
|---|---|
| 47063542 | 1:22,000 |

This document has been prepared in accordance with the scope of URS' appointment with its client and is subject to the terms of that appointment. URS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided. Only written dimensions shall be used.
© URS Infrastructure & Environment UK Limited

URS Infrastructure & Environment UK Limited
Scott House
Alençon Link Basingstoke
Hampshire RG21 7PP
Telephone (01256) 310200
Fax (01256) 310201
www.ursglobal.com

| Drawing Number | Rev |
|---|---|
| Figure 4.6 | 01 |

NOTES

— Annual Mean NO2 (µg/m$^3$)

● AQ Selected Receptors

● Sources

┌ ┐ Model Domain

Copyright
Contains Ordnance Survey Data
© Crown Copyright and database right 2012

| Revision Details | By | Check | Date | Suffix |
|---|---|---|---|---|

Purpose of Issue
Draft

Client
Ardagh Glass Ltd

Project Title
Ardargh Glass BAT Assessment - Barnsley Installation

Drawing Title
Scenario 4: Proposed Operations with SCR Applied Nitrogen Dioxide Long Term

| Drawn | Checked | Approved | Date |
|---|---|---|---|
| EW | GG | GG | 10/08/12 |

URS Internal Project No.
47063542

Scale @ A3
1:22,000

This document has been prepared in accordance with the scope of URS' appointment with its client and is subject to the terms of that appointment. URS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided. Only written dimensions shall be used.
© URS Infrastructure & Environment UK Limited

URS Infrastructure & Environment UK Limited
Scott House
Alençon Link, Basingstoke
Hampshire RG21 7PP
Telephone (01256) 310200
Fax (01256) 310201
www.ursglobal.com

Drawing Number
Figure 4.7

Rev
01

NOTES

— 99.79th %ile NO2 (µg/m3)

● AQ Selected Receptors

● Sources

┆ Model Domain

Copyright
Contains Ordnance Survey Data
© Crown Copyright and database right 2012

Revision Details | By / Check | Check Date | Suffix

Purpose of Issue
Draft

Client
Ardagh Glass Ltd

Project Title
Ardargh Glass BAT Assessment - Barnsley Installation

Drawing Title
Scenario 4: Proposed Operations with SCR Applied Nitrogen Dioxide Short Term

| Drawn | Checked | Approved | Date |
|---|---|---|---|
| EW | GG | GG | 10/08/12 |

URS Internal Project No.
47063542

Scale @ A3
1:22,000

This document has been prepared in accordance with the scope of URS' appointment with its client and is subject to the terms of that appointment. URS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided. Only written dimensions shall be used
© URS Infrastructure & Environment UK Limited

URS Infrastructure & Environment UK Limited
Scott House
Alençon Link, Basingstoke
Hampshire, RG21 7PP
Telephone (01256) 310200
Fax (01256) 310201
www.ursglobal.com

Drawing Number
**Figure 4.8**

Rev
01