Our Ref. BL3838_0791

TATA

Mrs F Devine
National Permitting Service
Environment Agency
Sapphire East
550 Streetsbrook Road
Solihull
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11th August 2014

Sent by email

Dear Fiona

Re: BL3838 Regulation 60 Notice. Justification of derogations from achieving BAT-AELs at Scunthorpe integrated steelworks

On 30th April 2014, Tata Steel submitted its response to the Environment Agency's Regulation 60 Notice. An application was made for the submission to be treated as commercially confidential. Further to recent correspondence, please find enclosed our response to the Regulation 60 Notice for inclusion in the public register.

This document seeks to provide justification of derogations from achieving the Iron and Steel Best Available Techniques – Associated Emission Levels at Scunthorpe steelworks.

Please do not hesitate if you require anything further.

Katherine Haigh
Long Products Environment Manager

cc. Peter Quinn, Neil Haines, Chris Jackson, Stuart Cadzow – Tata Steel
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Justification of derogations from achieving BAT-AELs at Scunthorpe integrated steelworks

1. Introduction

The Environment Agency is currently reviewing the Environmental Permit for Scunthorpe steelworks in order to ensure that the new permits comply with the requirements of the Industrial Emissions Directive (IED). A formal notice served under Regulation 60 of the Environmental Permitting Regulations, requesting information required for this review, was received in June 2013 and Tata Steel submitted a response in September. This response compared the techniques employed at Scunthorpe with those in the BAT conclusions for Iron and Steel Production published in March 2012, and highlighted some areas where the relevant BAT-associated emission levels (BAT-AELs) would not be achieved before the default deadline of March 2016.

Article 15(4) of the IED allows the Environment Agency to set Emission Limit Values (ELVs) that are less strict than the BAT-AELs (after 8th March 2016) only in cases where achieving the BAT-AELs would lead to disproportionately higher costs compared to the environmental benefits due to:

(a) the geographical location or the local environmental conditions of the installation concerned; or
(b) the technical characteristics of the installation concerned.

In February 2013 the Environment Agency issued guidance[1] on the application of the IED and paragraph 4.41 outlines some technical characteristics that may be particularly relevant:

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

In October 2013 the Environment Agency issued draft guidance[2] on the assessment of a case for derogation from BAT-AELs, and further guidance was included in a letter dated 11th February 2014. Although the September 2013 response to the Regulation 60 notice included some justification of derogations from BAT-AELs where required, these justifications did not meet the criteria in the subsequently issued guidance and the letter of 11th February requested further information.

[1] Environment Agency, "Industrial Emissions Directive EPR Guidance on Part A installations", February 2013; www.gov.uk/government/uploads/system/uploads/attachment_data/file/221044/pb13898-epr-guidance-part-a-130222.pdf

[2] Environment Agency, "H1 Annex K - Assessment of a case for derogation from BAT AELs", v 2.1, October 2013; https://consult.environment-agency.gov.uk/file/2681088

2. Relevant technical characteristics of the coke plants

The derogations requested at Scunthorpe steelworks are all associated with the coke plants, and the discussions in this section are applicable to each of the individual derogations.

The principal technical characteristic of the Scunthorpe coke plants that differentiates them from most other coke plants in Europe is the age of the batteries, which impacts on the cost and potential operational lifetime of any retrofitted pollution abatement equipment.

- Batteries 1 and 2 at Appleby were originally built in 1938, and most recently rebuilt from the pad up in 1984 (battery 1) and 1999 (battery 2);
- Batteries 3 and 4 at Appleby were originally built in 1951 and rebuilt in 1991;
- All three batteries at Dawes Lane were built in 1978/9.

Thus six of the seven coke oven batteries at Scunthorpe have been in operation for at least twenty years since the last rebuild, the three Dawes Lane batteries have already operated for over thirty years and parts of the Appleby coke plant are more than sixty years old. In the medium to long term, major capital expenditure will be required to maintain coke production at Scunthorpe and the current configuration cannot be assumed to continue indefinitely.

Any investment in pollution abatement technology at the existing plants may therefore have a more limited operational lifetime than would be the case at a new installation, and hence the benefits of achieving the BAT-AELs (i.e. the remaining years of operation multiplied by the annual pollution abated) will be lower at Scunthorpe than at most other European coke plants.

Furthermore, the age of the Scunthorpe plants means that installation of additional pollution abatement may be more complex (and hence more expensive) than at modern plants. In the case of Appleby coke ovens, there is a further relevant technical characteristic – since batteries 1 and 2 and batteries 3 and 4 were built at different times and are not fully integrated together, some abatement techniques, such as pushing emissions control, would have to be duplicated, whereas in a more typical European coke plant of similar size a single system would serve the whole plant.

The combination of potentially lower benefits and higher costs means that the costs of achieving BAT at Scunthorpe are disproportionately higher than the environmental benefits. Achieving all the BAT-AELs at Scunthorpe would be less cost-effective than at more typical European plants.

3 BAT 48 – coke oven gas desulphurisation

3.1 Best Available Techniques and associated performance

BAT is to reduce the sulphur content of the coke oven gas (COG) by using one of the following techniques:

I. desulphurisation by absorption systems
II. wet oxidative desulphurisation.

The residual hydrogen sulphide (H_2S) concentrations associated with BAT, determined as daily mean averages, are <300 – 1000 mg/Nm³ in the case of using BAT I (the higher values being associated with higher ambient temperature and the lower values being associated with lower ambient temperature) and <10 mg/Nm³ in the case of using BAT II.

3.2 Current techniques and performance

Coke oven gas is not currently desulphurised at either of the Scunthorpe coke plants. The sulphur content of the COG is controlled by the use of low-sulphur coking coals, but the H_2S levels still exceed those associated with the use of BAT.

The mean H_2S concentration in the coke oven gas from Dawes Lane in 2013 was 2.56 g/Nm³ (with a range of 1.17 to 3.98 g/Nm³) and at Appleby the H_2S averaged 4.03 g/Nm³ (with a range of 3.14 to 4.85 g/Nm³). The coal blends at the two plants are the same, but differences in the configuration of the by-products plants, particularly the production of ammonium sulphate at Appleby compared to the production of concentrated ammonia liquor or incineration at Dawes Lane, means that a greater proportion of the input sulphur is retained in the cleaned coke oven gas at Appleby.

The volumes of coke oven gas produced at each plant in 2013 were 172 M Nm³ at Dawes Lane and 257 M Nm³ at Appleby. Assuming that all the H_2S in the gas is oxidised to sulphur dioxide, the SO_2 emissions from coke oven gas combustion across the whole of the Scunthorpe site attributable to the H_2S content of the gas would be:

- Gas from Dawes Lane: 831 tonnes per annum
- Gas from Appleby: 1,951 tonnes per annum

There are other sulphurous species in the coke oven gas, such as carbon disulphide (CS_2), carbon oxysulphide (COS) and mercaptans, but these are present in much lower concentrations than H_2S. COG desulphurisation plants do not generally remove these species with high efficiency anyway and so they have been neglected in this assessment. At Dawes Lane a further 212 tonnes SO_2 were emitted from the ammonia incinerator stack in 2013, which may also be eliminated depending on the configuration of the COG desulphurisation plant.

3.3 Impact of current emissions

SO_2 concentrations have been continuously measured at the Rowland Road monitoring station near Scunthorpe steelworks since 2004 and the table overleaf, derived from data[3] compiled by Defra, shows that overall levels are well within the relevant Air Quality Standards.

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[3] Defra data archive, “Annual and Exceedence Statistics”, http://uk-air.defra.gov.uk/data/exceedence

Averaging period	15 minutes	1 hour	24 hours	1 year
Percentile	99.9	99.7	99	-
2004	N/A - data capture only 56%			
2005	N/A - data capture only 74%			
2006	138	101	45	7
2007	120	85	34	6
2008	144	106	53	7
2009	93	64	30	5
2010	88	69	31	7
2011	N/A - data capture only 71%			
2012	112	77	45	5
2013	103	81	45	6
Air Quality Standard	**266**	**350**	**125**	-

Therefore the current SO_2 emissions from coke oven gas combustion, despite residual hydrogen sulphide (H_2S) concentrations higher than the BAT-associated standard, have not led to any breach of local Air Quality Standards.

3.4 Potential pollution abatement through achieving BAT

If the best available techniques for the reduction of the sulphur content of coke oven gas were to be applied at both Scunthorpe coke plants and the BAT-associated standard were to be achieved, then the mass of SO_2 released from the site and the impact on local air quality would both fall. For the purposes of this assessment, it is assumed that the mean H_2S concentration in the coke oven gas could be reduced to 0.5 g/Nm³ at both coke plants. On this basis, total annual SO_2 emissions attributable to the H_2S content of coke oven gas after desulphurisation would be:

- Gas from Dawes Lane: 162 tonnes per annum
- Gas from Appleby: 242 tonnes per annum

Thus installation of coke oven gas desulphurisation plants to achieve BAT at Scunthorpe could be expected to reduce SO_2 emissions from the site by 2,378 tonnes per year compared to the current situation. If the configuration of the plant treating the gas from Dawes Lane is such as to eliminate emissions from ammonia incineration, then a further reduction of 212 tonnes per annum could be expected.

3.5 Proposed timescales for COG desulphurisation

Conceptually it is planned to install coke oven gas desulphurisation units to treat the gas arising from both of the coke plants at Scunthorpe, subject to the capital planning process within Tata Steel.

The lead time for design, construction and commissioning of coke oven gas desulphurisation plants is such that it is not possible to have a plant in operation at either of the coke ovens before the default deadline of March 2016. Installation of COG desulphurisation is a substantial and complex project involving considerable engineering and technological resource and therefore it will be beneficial to advance the project in two stages. The development of any second unit would be conditional on successful commissioning of the first unit and Tata Steel cannot currently commit to this investment. Another reason for not undertaking both schemes in parallel is that coke production rates will fall at some stages of the installation and if both coke plants were operating at reduced production simultaneously there would be insufficient coke for the needs of the rest of the steelworks, which would have an unacceptable impact on the costs of steelmaking at the site. One option being considered is to build a common sulphur recovery plant at Dawes Lane, where space is less constrained than at Appleby – in this case the sulphur removal stages would still be undertaken at both coke plants separately.

Phasing the implementation of COG desulphurisation represents a technically and financially achievable solution and provides for maximising the benefit of knowledge gained from the first plant in the development of the second one. Coke oven gas desulphurisation is also planned at Tata Steel's Morfa coke ovens, which will further stretch resources. Timescales for the project at Scunthorpe will depend on the final choice of approach, and particularly on whether a common sulphur recovery plant is built, rather than separate units at each coke plant. It is expected that all the coke oven gas from both of the Scunthorpe coke plants will be desulphurised by no later than January 2022, though in practice gas from at least one of the coke plants will be treated earlier than this. For the purposes of the cost-benefit analysis, the extreme case of implementing all the coke oven gas desulphurisation only in January 2022 has been evaluated.

3.6 Costs of coke oven gas desulphurisation at Scunthorpe

3.6.1 Options considered

Because of the long lead times for the design, construction and commissioning of coke oven gas desulphurisation plants, the only means by which coke oven gas with an H_2S content greater than the BAT-associated standard would not be produced at Scunthorpe after March 2016 would be to cease coke production at that date and not restart production until coke oven gas desulphurisation plants have been installed. In the interim, coke would have to be bought from external suppliers and additional natural gas would also have to be purchased as coke oven gas would no longer be available for pilot burners at the power plants and enrichment of blast furnace gas. The revenue from the sale of coke oven by-products would also be lost over that period. As well as the additional costs incurred through buying from external suppliers rather than making coke on site, there is no guarantee that sufficient coke of the required quality would be available to maintain blast furnace production at the site.

Furthermore, coke oven batteries of the type used at Scunthorpe are designed to be gas-tight when carefully heated up from new and held constantly at the high temperatures required for coking. In this way, expansion of the materials of construction seals gaps between bricks to create gas-tight walls, door jambs are sealed to the walls and the structure is held rigidly by the tie bars. Mothballing the coke ovens to allow time for the construction of COG desulphurisation plants would result in the structure cooling and losing its integrity. There are no examples world-wide of a mothballed coke oven battery of this type being brought back into operation. Thus if coke production were to cease in March 2016, the only feasible option for the continuation of cokemaking would be to completely rebuild the ovens, incorporating coke oven gas desulphurisation, at a cost of several hundreds of millions of pounds. These rebuilds would occur earlier than in the normal investment cycle and so would represent an additional cost to the business. It would not be expected that a new coke plant could be operational before March 2019, so for at least three years there would be no cokemaking at Scunthorpe and coke and natural gas would have to be purchased.

Because of the high cost of achieving BAT as described above, two further scenarios have been considered:

- Continue to operate the existing plants without coke oven gas desulphurisation for a period, but then install coke oven gas desulphurisation units to treat the gas arising from both of the coke plants at Scunthorpe, subject to the capital planning process within Tata Steel. Desulphurisation of the gas from both coke plants would be operational from January 2022 and at a later date, the coke plants would be rebuilt within the normal investment cycle. This alternative would result in greater SO_2 emissions than achieving BAT, but would be less costly.
- Continue to operate the existing plants without coke oven gas desulphurisation until such time as they would need to be rebuilt within the normal investment cycle. The rebuilt plants would incorporate coke oven gas desulphurisation. This alternative would have still greater SO_2 emissions, but would again be less costly.

3.6.2 Net Present Cost calculations

The Net Present Cost (i.e. the cost at 2014 prices, taking into account both capital and operating costs) of the three options considered has been assessed as stipulated in the Environment Agency's letter dated 11th February 2014. For consistency, only the costs up to 2046 have been evaluated for each option, since by that date it is assumed that the three scenarios will have converged to the same situation, namely a new coke oven plant incorporating coke oven gas desulphurisation, and it is only the differences between the options that are relevant here. The Net Present Cost of some of the options depends on the date by which rebuilding within the normal investment cycle would become necessary. There is currently no definite timescale for these rebuilds and for the purposes of this cost-benefit analysis they are assumed to occur in 2036.

The Net Present Cost to 2046 of ceasing coke production at Scunthorpe in March 2016 and rebuilding the coke plants to incorporate coke oven gas desulphurisation would be £833M. This is the only option that avoids producing coke oven gas with an H_2S content greater than the BAT-associated standard after March 2016.

The Net Present Cost of retrofitting coke oven gas desulphurisation to the existing coke plants, followed by rebuilding within the normal investment cycle (assumed to be in 2036), has also been assessed. Outline quotes have been obtained from two manufacturers, considering a number of different potential scenarios for coke oven gas desulphurisation at Scunthorpe, but final selection of the best options depends on further discussions with suppliers, which are currently taking place. "Future-proofing" the investment, bearing in mind the need for major capital expenditure to maintain coke production at Scunthorpe in the medium to long term, will be a significant factor in the final decision. It is expected that the desulphurisation plants will be built in such a way that if there is a change in the current configuration, at least a part of the capital expenditure already made can be offset by reusing as much as possible of the desulphurisation plant and thus reducing the capital cost of a new coke plant at some time in the future. The Net Present Cost of this option would be £428M.

The Net Present Cost of continuing to operate the existing coke plants without coke oven gas desulphurisation until rebuilding within the normal investment cycle (assumed to be 2036) would be £299M.

3.7 Other factors

All the potential desulphurisation options use significant amounts of steam and/or electrical energy. There will be environmental costs (for instance emissions of CO_2, NO_x, SO_2 and dust) associated with the generation of these utilities, but these emissions have not been quantified here.

Assuming that the sulphurous product from the COG desulphurisation plant can be sold as a useful by-product, there will be no significant waste generation from coke oven gas desulphurisation.

3.8 Cost-benefit analysis

The effective SO_2 abatement cost can be calculated by dividing the difference between the Net Present Cost of an option and the base case (namely continuing to operate the existing plants without coke oven gas desulphurisation until such time as they would need to be rebuilt within the normal investment cycle) by the amount of SO_2 that would be abated by earlier installation of coke oven gas desulphurisation.

Assuming that the existing coke plants would need to be rebuilt in 2036, the Net Present Cost of rebuilding to incorporate coke oven gas desulphurisation at that time, but not before, would be £299M (see section 3.2.3 above). If coke oven gas desulphurisation plants were to be retrofitted at Dawes Lane and Appleby before that date, the Net Present Cost would rise to £428M and if the rebuild were brought forward to 2016 so as to achieve BAT, the Net Present Cost would be £833M.

In terms of SO_2 emissions, the base case would mean that for twenty years (2016 to 2036), annual emissions would be 2,590 tonnes per annum greater than could be achieved through implementation of BAT – a total of 51,800 tonnes. For the case of retrofitting coke oven gas desulphurisation at the existing plants, SO_2 emissions in excess of BAT would amount to up to six years' worth – a total of 15,540 tonnes. The effective SO_2 abatement cost of retrofitting COG desulphurisation would therefore be $(428\text{-}299)\text{x}10^6/(51{,}800\text{-}15{,}540)$ = £3,554 per tonne SO_2 abated.

For the case of ceasing coke production in 2016 and rebuilding the coke plants immediately, the effective SO_2 abatement cost would be $(833\text{-}299)\text{x}10^6/(51{,}800\text{-}0)$ = £10,305 per tonne SO_2 abated.

The marginal cost of ceasing coke production in 2016 and rebuilding the coke plants earlier than the normal investment cycle, compared to the proposed option of retrofitting coke oven gas desulphurisation to the existing plants would be $(833\text{-}428)\text{x}10^6/(15{,}540\text{-}0)$ = £26,057 per tonne SO_2 abated.

One means of assessing whether achieving BAT would lead to disproportionately higher costs compared to the environmental benefits is to compare the abatement costs calculated above to the marginal external costs attributable to each additional tonne of pollutant emitted (the damage cost). No definitive set of damage costs exists, but a report[4] by Eunomia consultants undertaken for the Environment Agency in 2012 suggested a value of €8,033 per tonne SO_2 (at 2010 prices). Using an exchange rate of €1=£0.815 and increasing the value

4 "Review of the Mineral Oil and Gas Refining BREF - Proposed Approach to Using CBA to Determine BAT Conclusions and BAT-AELs", Eunomia research and consultants, October 2012

by 2½% per annum to account for inflation and by a further 2% per annum to account for increased willingness to pay, as recommended in a report[5] from the UK Interdepartmental Group on Costs and Benefits, gives an SO_2 damage cost of £7,822 at 2014 prices. On this basis, ceasing coke production in 2016 and rebuilding the coke plants earlier than the normal investment cycle in order to achieve BAT by March 2016 is disproportionately costly compared to the environmental benefits that would be accrued.

Thus achieving BAT by ceasing coke production in 2016 is not cost-effective compared to the proposed option of retrofitting coke oven gas desulphurisation to the existing plants, even allowing for the fact that the latter option results in the emission of up to 15,540 tonnes SO_2 more than achieving BAT by March 2016.

3.9 Conclusions

The implementation of BAT for desulphurisation of coke oven gas is less cost-effective at Scunthorpe than at more typical European coke plants due to:

- the technical characteristics, namely the age of the existing plants, meaning that retrofitted pollution abatement equipment would have a more limited operational life than would be the case at a new installation – this significantly increases the overall abatement cost
- the technical characteristics, namely the general investment cycle for this type of installation, meaning that bringing forward a rebuild of the plant to incorporate coke oven gas desulphurisation would significantly increase the Net Present Cost of the rebuild

The effective abatement cost to achieve BAT (by ceasing coke production in 2016 and rebuilding the coke plants earlier than the normal investment cycle) is £10,305 per tonne SO_2 abated, which exceeds the damage cost for SO_2, and hence is disproportionately costly compared to the environmental benefits that would be accrued.

The effective abatement cost of Tata Steel's proposed alternative (retrofitting coke oven gas desulphurisation at the existing plants, though not by March 2016) is £3,554 per tonne SO_2 abated. The marginal cost of achieving BAT compared to the proposed alternative is £26,057 per tonne SO_2 abated.

Furthermore, current SO_2 emissions from coke oven gas combustion, despite residual hydrogen sulphide (H_2S) concentrations higher than the BAT-associated standard, have not led to any breach of local Air Quality Standards.

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5 "Air Quality Appraisal – Damage Cost Methodology", February 2011, www.gov.uk/government/uploads/system/uploads/attachment_data/file/182391/air-quality-damage-cost-methodology-110211.pdf

4. BAT 49 – coke oven underfiring

4.1 Best Available Techniques and associated emission levels

BAT for coke oven underfiring is to reduce the emissions by using the following techniques:

I. preventing leakage between the oven chamber and the heating chamber by means of regular coke oven operation
II. repairing leakage between the oven chamber and the heating chamber (only applicable to existing plants)
III. incorporating low-nitrogen oxides (NO_X) techniques in the construction of new batteries, such as staged combustion and the use of thinner bricks and refractory with a better thermal conductivity (only applicable to new plants)
IV. using desulphurised coke oven gas (COG) process gases

The BAT-associated emission levels, determined as daily mean values and relating to an oxygen content of 5 % are:

- sulphur oxides (SO_X), expressed as sulphur dioxide (SO_2) <200 – 500 mg/Nm^3
- dust <1 – 20 mg/Nm^3
- nitrogen oxides (NO_X), expressed as nitrogen dioxide (NO_2) <350 – 500 mg/Nm^3 for new or substantially revamped plants (less than 10 years old) and 500 – 650 mg/Nm^3 for older plants with well maintained batteries and incorporated low- nitrogen oxides (NO_X) techniques.

4.2 Current techniques and emission levels

4.2.1 SO_2

As discussed under BAT 48, coke oven gas is not currently desulphurised at either of the Scunthorpe coke plants. SO_2 is instead controlled by the use of low-sulphur coking coals, but this does not achieve the same degree of environmental protection as the use of desulphurised coke oven gas (BAT IV).

SO_2 emissions from underfiring stacks are not currently monitored as mass emissions are instead calculated from the sulphur content of the coke oven gas used. The expected SO_2 concentrations can be estimated as shown below:

- Dry waste gas volume from combustion of coke oven gas = 5.01 m^3/m^3 COG, related to an oxygen content of 5%
- Organic sulphur content of COG assumed to be 0.2 g/Nm^3
- H_2S content of Dawes Lane COG = 2.56 g/Nm^3 (2013 average)
- Corresponding SO_2 concentration in underfiring waste gases =

  $$2 * (2.56*32/34 + 0.2) / 5.01 * 1000 = 1,043 \text{ mg/Nm}^3$$
- At Appleby, average COG H_2S content = 4.03 g/Nm^3, giving 1,594 mg SO_2/Nm^3

Emissions from underfiring are thus expected to exceed the BAT-AEL.

Mass emissions of SO_2 from underfiring can be estimated from the expected concentrations and the volume of coke oven gas burned at each plant:

- Dawes Lane: 107 M Nm^3 COG burned, giving 558 tonnes SO_2 per annum
- Appleby: 130 M Nm^3 COG burned, giving 1,039 tonnes SO_2 per annum

4.2.2 Dust

Although the techniques described in BAT I and BAT II are implemented at Scunthorpe, dust emissions still exceed the BAT-AEL. Regular coke oven operation (BAT I) to protect the fabric of the batteries and ensure consistent coke quality is a key aim of the battery control systems and if through-wall leakage is detected, maintenance is scheduled (BAT II) to repair the leakage as soon as possible. Repairs may take the form of ceramic welding of limited areas or completely rebuilding badly cracked walls. Due to the age of the batteries, the condition of the walls separating the heating chambers from the ovens themselves has deteriorated and performance will fall short of that expected from new plants. This has been exacerbated by the enforced sub-optimal operating conditions during the recent economic crisis, when coking times were increased to match coke output to demand for steel.

Dust emissions from underfiring are monitored using obscuration meters, but these have not yet been calibrated due to the difficulties in obtaining representative spot samples from the waste gas ducts. Dust concentrations at Appleby coke ovens, based on annual spot samples since 2008, have ranged from 58 to 167 mg/Nm³ when converted to 5% oxygen, though it should be noted that the sampling arrangements do not meet the requirements of the Environment Agency's Technical Guidance Note[6] (M1). Spot sampling at Dawes Lane has only been required since the start of 2014 – the mean dust concentration from the first sampling exercise was 219 mg/Nm³ when converted to 5% oxygen, but until further measurements have been completed it cannot be determined whether this is a typical value or not. Although the measurements are not daily means, it is clear that emissions currently exceed the BAT-AEL.

One factor contributing to high dust levels at Appleby is that benzol levels in the coke oven gas are relatively high, giving rise to a more sooty flame and hence higher particulate emissions than would otherwise be the case. It is planned to replace the benzol plant at Appleby before 2016, which would be expected to reduce particulate emissions, though not to the level of the BAT-AEL.

Mass emissions of dust from underfiring can be estimated from the mean concentration and the volume of coke oven gas burned. The annual release from Appleby is estimated to be 73 tonnes per annum, but there are not sufficient measurements of dust concentration to reliably estimate emissions of particulate matter from Dawes Lane. It would be expected that most of the dust from underfiring would be fine particles and for the purposes of this assessment it is assumed that it is all PM_{10} and $PM_{2.5}$.

4.2.3 NO_x

The relevant BAT-AELs for NO_x from coke oven underfiring are already achieved. Batteries 2, 3 and 4 at Appleby coke ovens (all of which were rebuilt during the 1990s) incorporate staged combustion (BAT III) to reduce NO_x formation and measured NO_x concentrations in the past three years (2011 to 2013, based on quarterly spot samples) ranged from 200 to 361 mg/Nm³ when converted to 5% oxygen, which is lower than the relevant BAT-AEL (500 – 650 mg/Nm³ for plants over 10 years old incorporating low-NO_x techniques). Although the

[6] Environment Agency, "Technical Guidance Note M1 - Sampling requirements for stack emission monitoring", v 6, January 2010; www.gov.uk/government/uploads/system/uploads/attachment_data/file/296772/ geho0110brro-e-e.pdf

measurements are hourly average spot samples, the consistently low results give confidence that the daily mean values would also be in compliance with the BAT-AEL.

Battery 1 at Appleby and all the batteries at Dawes Lane are older and do not incorporate low-NO_x techniques. It is not possible to retro-fit integrated low-NO_x techniques to existing coke plants without a full rebuild of the batteries. Since Dawes Lane does not incorporate low-NO_x techniques, there is no relevant BAT-AEL for this plant.

Thus derogation is required from the BAT-AELs for SO_2 and dust, but not for NO_x.

4.3 Impact of current emissions

Dispersion modelling has been undertaken to assess the impact of estimated SO_2, PM_{10} and $PM_{2.5}$ emissions from coke oven underfiring at the two Scunthorpe coke plants. Ground level concentrations have been predicted at the local authority monitoring station at Rowland Road and the results, along with the relevant Air Quality Standards, are:

- SO_2 (99.9th percentile of 15 minute means): peak = 25.8 µg/m³, AQS = 266 µg/m³
- SO_2 (99.7th percentile of hourly means): peak = 22.3 µg/m³, AQS = 350 µg/m³
- SO_2 (99.2nd percentile of daily means): peak = 6.7 µg/m³, AQS = 125 µg/m³
- SO_2 (annual mean): peak = 0.6 µg/m³, µg/m³, AQS = 20 µg/m³
- PM_{10} (90.4th percentile of daily means): peak = 0.1 µg/m³, AQS = 50 µg/m³
- PM_{10} (annual mean): peak = 0.03 µg/m³, AQS = 40 µg/m³
- $PM_{2.5}$ (annual mean): peak = 0.03 µg/m³, AQS = 25 µg/m³

Therefore the current emissions from coke oven underfiring, despite not achieving the BAT-AELs for SO_2 and dust, contribute less than 1% of the long-term Air Quality Standards for SO_2, PM_{10} and $PM_{2.5}$ and less than 10% of the short-term AQSs. Based on the methodology included in the Environment Agency's H1 guidance note[7], this means that the Process Contribution attributable to these dust emissions would be assessed as having an insignificant environmental impact.

4.4 Potential pollution abatement through achieving BAT

4.4.1 SO_2

BAT IV states that the use of desulphurised coke oven gas is the best technique to achieve the BAT-AEL for SO_2 from underfiring and after installation of coke oven gas desulphurisation plants as described under BAT 48, it is assumed that the mean H_2S concentration in the gas could be reduced to 0.5 g/Nm³. On this basis, total annual SO_2 emissions from coke oven underfiring would be:

- Dawes Lane: 143 tonnes per annum
- Appleby: 174 tonnes per annum

Thus the use of desulphurised coke oven gas for underfiring at Scunthorpe to achieve BAT could be expected to reduce SO_2 emissions from this source by 1,279 tonnes per year compared to the current situation.

An alternative means of achieving the BAT-AEL for SO_2 from underfiring would be to convert the ovens to fire a different, low-sulphur fuel gas such as blast furnace gas or a synthetic

[7] Environment Agency, "H1 Annex F – Air Emissions", Issue 2.2, December 2011, page 18

coke oven gas (natural gas plus blast furnace gas). Although this could achieve the BAT-AEL for underfiring, the displaced coke oven gas would simply be burned elsewhere on the integrated steelworks, or else flared. Thus the total SO_2 emissions from the site would remain at the current levels and this option has not been considered further as it does not achieve the same degree of environmental protection as coke oven gas desulphurisation.

4.4.2 Dust

If the BAT-AEL for dust of 20 mg/Nm³ were to be achieved at Appleby coke ovens, the annual mass emissions would fall to 13 tonnes per annum, a reduction of 60 tonnes. There are not sufficient measurements of dust concentration to reliably estimate emissions of particulate matter from Dawes Lane.

4.5 Costs of achieving BAT at Scunthorpe

4.5.1 SO_2

The costs of a number of different options for coke oven gas desulphurisation are detailed under BAT 48.

4.5.2 Dust

Since the techniques described in BAT I and BAT II are implemented at Scunthorpe, but are not adequate to bring dust emissions below the BAT-AEL, it is considered that BAT will not be achieved until the ovens are rebuilt. The magnitude of the potential pollution reduction (60 tonnes per annum at Appleby) is not sufficient to justify bringing forward the rebuild ahead of the normal investment cycle

4.6 Cost-benefit analysis

The cost-benefit analysis of coke oven gas desulphurisation is detailed under BAT 48.

4.7 Conclusions

The implementation of BAT for reduction of emissions from coke oven underfiring is less cost-effective at Scunthorpe than at more typical European coke plants due to:

- the technical characteristics, namely the age of the existing plants, meaning that retrofitted coke oven gas desulphurisation equipment would have a more limited operational life than would be the case at a new installation – this significantly increases the overall abatement cost
- the technical characteristics, namely the general investment cycle for this type of installation, meaning that bringing forward a rebuild of the plant to incorporate coke oven gas desulphurisation or to prevent through-wall leakage would significantly increase the Net Present Cost of the rebuild

Further details are included under BAT 48.

5. BAT 50 – coke oven pushing emissions

5.1 Best Available Techniques and associated emission levels

BAT for coke pushing is to reduce dust emissions by using the following techniques:

I. extraction by means of an integrated coke transfer machine equipped with a hood
II. using land-based extraction gas treatment with a bag filter or other abatement systems
III. using a one point or a mobile quenching car.

The BAT-associated emission level for dust from coke pushing is <10 mg/Nm³ in the case of bag filters and <20 mg/Nm³ in other cases, determined as the average over the sampling period (discontinuous measurement, spot samples for at least half an hour).

At existing plants, lack of space may constrain the applicability.

5.2 Current techniques and emission levels

Extraction systems for the capture of pushing emissions are not installed at either of the Scunthorpe coke plants. Pushing emissions are instead limited by careful control of coal blend quality and coking times and homogenous heating to ensure complete coking of the charge before pushing, but this does not achieve the same degree of environmental protection as the use of the best available techniques.

Pushing emissions are monitored through the use of a Pushing Emissions Factor (PEF); the current Environmental Permit sets limits of no more than 0.6 for the weekly average PEF and no more than 0.2 for the quarterly average and actual values are typically less than these limits. The PEF is a qualitative measure and no quantitative measurements of the dust concentrations or mass emission rates from pushing have been undertaken at Scunthorpe – the only estimates come from the use of emission factors derived from other plants.

Studies to assess the effectiveness of the PECAR pushing emissions abatement system at Redcar coke ovens included some measurements of unabated emissions; a total mass emission of 10.2 kg dust per push was calculated, equivalent to about 500 g dust per tonne of coke. At Llanwern, unabated emissions were reported as 520 to 600 g/tonne and the European Commission's BREF notes (page 266) quote total particulate emissions without abatement as about 500 g/tonne.

Particle size distribution data for the unabated emissions were also obtained from the trials at Redcar coke ovens and are shown below:

Particle size (µm)	1.25	2	2.95	4.3	5.25	>5.25
Cumulative percentage	0.5	1.1	1.4	1.9	2.2	100

The majority of the particulate matter emitted during pushing of coke ovens is coarse dust and grit and will be deposited within the integrated steelworks, rather than directly contributing to dust concentrations in ambient air beyond the site boundary. From the limited particle size data available, it is estimated that less than 5% of the total dust from pushing is PM_{10} and less than 1.5% is $PM_{2.5}$.

Annual coke production at Scunthorpe in 2013 was 417,229 tonnes at Dawes Lane coke ovens and 623,014 tonnes at Appleby. A factor of 550 g total dust and grit per tonne coke has been used at Scunthorpe for reporting to the Environment Agency's Pollution Inventory so emissions for calendar year 2013 are estimated to be:

- Dawes Lane: 229 tonnes total dust and grit, 11.5 tonnes PM_{10} and 3.4 tonnes $PM_{2.5}$
- Appleby: 343 tonnes total dust and grit, 17.1 tonnes PM_{10} and 5.1 tonnes $PM_{2.5}$

5.3 Impact of current emissions

Dispersion modelling has been undertaken to assess the impact of estimated PM_{10} and $PM_{2.5}$ emissions from coke pushing at the two Scunthorpe coke plants. Ground level concentrations have been predicted at the local authority monitoring station at Rowland Road and the results, along with the relevant Air Quality Standards, are:

- PM_{10} (90.4th percentile of daily means): peak = 0.42 µg/m³, AQS = 50 µg/m³
- PM_{10} (annual mean): peak = 0.1 µg/m³, AQS = 40 µg/m³
- $PM_{2.5}$ (annual mean): peak = 0.03 µg/m³, AQS = 25 µg/m³

Therefore the current emissions from coke oven pushing, despite not achieving the BAT-AEL for dust, contribute less than 1% of the long-term Air Quality Standards for PM_{10} and $PM_{2.5}$ and less than 10% of the daily mean PM_{10} AQS. Based on the methodology included in the Environment Agency's H1 guidance note, this means that the Process Contribution attributable to these dust emissions would be assessed as having an insignificant environmental impact.

5.4 Potential pollution abatement through achieving BAT

The European Commission's BREF notes (page 266) state that a capture efficiency of at least 99% is achievable by the application of BAT and an extracted gas volume of 200,000 to 400,000 Nm³/hour is quoted. For the purposes of this assessment, it is assumed that installations at Dawes Lane and Appleby coke ovens would achieve 99.5% capture and the volume flow would be at the bottom end of the quoted range as the plants are relatively small. Although the BAT-AEL for coke pushing emissions abatement using a bag filter is 10 mg/Nm³, actual performance is likely to be significantly better than this and a figure of 2 mg/Nm³ as a long-term average has been assumed. It would be expected that any dust emitted from the bag filter would be mostly in the smaller size fractions and it is assumed that 80% will be PM_{10} and 50% $PM_{2.5}$. On this basis, total annual emissions after installation of pushing emissions abatement can be estimated as:

- Residual pushing emissions at Dawes Lane (0.5% of unabated levels): 1.15 tonnes total dust and grit, 0.057 tonnes PM_{10} and 0.017 tonnes $PM_{2.5}$
- Residual pushing emissions at Appleby (0.5% of unabated levels): 1.71 tonnes total dust and grit, 0.086 tonnes PM_{10} and 0.026 tonnes $PM_{2.5}$
- Emissions from bag filters: 3.5 tonnes total dust, 2.8 tonnes PM_{10} and 1.75 tonnes $PM_{2.5}$ for each plant

Thus installation of pushing emissions abatement equipment to achieve BAT at Scunthorpe could be expected to reduce direct PM_{10} emissions by 23 tonnes per year and $PM_{2.5}$ emissions by 5 tonnes per year compared to the current situation (8.6 tonnes PM_{10} and 1.7 tonnes $PM_{2.5}$ at Dawes Lane and 14.2 and 3.4 tonnes at Appleby).

5.5 Costs of achieving BAT at Scunthorpe

The Net Present Cost (i.e. the cost at 2014 prices, taking into account both capital and operating costs) of installing coke pushing emissions abatement has been assessed as stipulated in the Environment Agency's letter dated 11th February 2014. It should be noted that schemes to implement coke oven pushing abatement are not currently being pursued, and there is no guarantee that BAT could actually be achieved by March 2016. But if such schemes were implemented at both coke plants by 2016, the Net Present Cost over a thirty year operational lifetime would be £152M.

5.6 Other factors

In addition to the financial costs, generation of the additional electrical energy required to run the fans (around 2 GWh per year) will result in emissions of CO_2, NO_x, SO_2 and dust at power stations connected to the national grid. Using a typical factor for the UK of 480 tonnes CO_2/GWh electricity consumed[8] means that an additional 30,000 tonnes CO_2 could be emitted over the 30 year operating life of the abatement plant (though it would be expected that changes in the electricity mix over this period would reduce this total). NO_x, SO_2 and dust emissions from power generation have not been quantified here.

5.7 Cost-benefit analysis

Abatement costs can be calculated by dividing the Net Present Cost of the potential pushing emissions abatement schemes by the mass of pollutants abated over the lifetime of the equipment. Overall, the estimated abatement costs over a thirty year operating life would be:

- Total dust and grit: £9,001 per tonne abated
- PM_{10}: £221,416 per tonne abated
- $PM_{2.5}$: £1,005,136 per tonne abated

These figures can then be compared to damage costs for particulate matter to assess the cost-effectiveness of achieving BAT. No definitive set of damage costs exists, but a report by Eunomia consultants undertaken for the Environment Agency in 2012 suggested values of €16,443 per tonne PM_{10} and €25,322 per tonne $PM_{2.5}$ – equivalent to £16,012 and £24,658 at 2014 prices. On this basis, installation of coke oven pushing abatement in order to achieve BAT by March 2016 is disproportionately costly compared to the environmental benefits that would be accrued.

Moreover, the age of the existing plants means that the operational life of any retrofitted pushing emissions abatement equipment is likely to be less than thirty years, which will further increase the abatement costs, as the mass of pollutants abated would fall, but the capital cost of the schemes would remain the same.

5.8 Conclusions

The implementation of BAT for coke pushing is less cost-effective at Scunthorpe than at more typical European coke plants due to:

- the technical characteristics, namely the age of the existing plants, meaning that retrofitted pollution abatement equipment would have a more limited operational life

[8] Defra, "2013 Government GHG Conversion Factors for Company Reporting", July 2013, www.gov.uk/government/uploads/system/uploads/attachment_data/file/224437/pb13988-emission-factor-methodology-130719.pdf, Table 7: Base electricity generation emissions factors (including imported electricity)

than would be the case at a new installation – this significantly increases the overall abatement cost

- the technical characteristics, namely the configuration of Appleby coke ovens, making it more technically difficult and costly to comply as at least some elements of a coke oven pushing abatement scheme would have to be duplicated

The effective abatement cost to achieve BAT is over £200,000 per tonne PM_{10} abated and over £1,000,000 per tonne $PM_{2.5}$. These figures exceed the relevant damage costs by more than a factor of ten, and hence coke pushing emissions abatement is disproportionately costly compared to the environmental benefits that would be accrued.

6. BAT 51 – coke quenching

6.1 Best Available Techniques and associated emission levels

BAT for coke quenching is to reduce dust emissions by using one of the following techniques:

I. coke dry quenching (CDQ) with the recovery of sensible heat and the removal of dust from charging, handling and screening operations by means of a bag filter
II. emission-minimised conventional wet quenching
III. coke stabilisation quenching (CSQ)

The BAT-associated emission levels for dust, determined as the average over the sampling period, are:

- <20 mg/Nm3 in case of coke dry quenching
- <25 g/t coke in case of emission minimised conventional wet quenching (based on the use of the non-isokinetic Mohrhauer method)
- <10 g/t coke in case of coke stabilisation quenching (based on isokinetic sampling)

For BAT II, existing quenching towers can be equipped with emissions reduction baffles, a minimum tower height of at least 30 m is necessary in order to ensure sufficient draught conditions. For BAT III, as the system is larger than that necessary for conventional quenching, lack of space at the plant may be a constraint.

6.2 Current techniques and emission levels

Conventional wet quenching (BAT II) is used at both of the Scunthorpe coke plants – there are two quench towers at Appleby and one at Dawes Lane and all are equipped with baffles to reduce dust emissions. None of the existing quench towers achieves the BAT-AEL of <25 g dust/tonne coke. Mean emission factors, based on the non-isokinetic Mohrhauer method, are 102 g/tonne at Dawes Lane, 271 g/tonne for No. 1 quench tower at Appleby (batteries 1 and 2) and 590 g/tonne for Appleby's No. 2 quench tower (which is only 18.3 m high).

It should be noted that the conventional method of measuring coke quenching emissions, using Mohrhauer probes, captures only coarse particulate material above about 100 µm in diameter. Trials in May 2008 to measure the **total** emissions from quenching using an isokinetic method suggested that finer particles contributed up to a further 60 g/tonne coke at Appleby's No. 2 quench tower, though the difficulty of making such measurements in the turbulent steam plume from coke quenching means that there is necessarily a large uncertainty associated with these estimates.

Particle size distribution data from this trial are shown below:

Particle size (µm)	0.3	0.7	1.4	2.9	5.7	11.1	22.8	100	>100
Cumulative %age	<0.1	0.1	0.3	0.7	1.1	1.8	4.9	10.9	100

This suggests that the majority of the particulate matter emitted during coke quenching is coarse dust and grit and will be deposited within the integrated steelworks, rather than directly contributing to dust concentrations in ambient air beyond the site boundary.

However, measurements undertaken on the new quench tower at Morfa coke ovens and experience in Germany suggest that the ratio of coarse to finer particulate matter is not constant between different quench towers. It has been shown that as emissions of coarse dust and grit (measured by the Mohrhauer method) decrease, emissions of finer particles form a larger proportion of the total. So whilst at Appleby No. 2 quench tower coarse particulate emissions were 590 g/tonne and PM_{10} emissions around 12 g/tonne (2% of the total), at Morfa the coarse dust emissions were 10.5 g/tonne, emissions of dust between 10 µm and 100 µm diameter were 42.1 g/tonne and PM_{10} emissions 3 g/tonne (5.3% of the total or 29% of the amount of coarse dust and grit from the Mohrhauer method).

Hence although the new quench tower at Morfa demonstrated a very significant improvement with respect to coarse particulate material, this was not reflected to the same degree in respect of PM_{10}. This finding is not surprising, since the abatement method of directing the rising steam plume through grit arrestors so that large particles impinge on the baffles and are removed will be less effective for smaller particles which will tend to follow the streamlines around the baffles and hence little abatement will be effected.

For the purposes of this assessment it is assumed that PM_{10} and $PM_{2.5}$ emissions factors are related linearly to the Mohrhauer result:

- Appleby No. 2: Mohrhauer = 590 g/tonne; PM_{10} = 12 g/tonne, $PM_{2.5}$ = 4.7 g/tonne
- Appleby No. 1: Mohrhauer = 271 g/tonne; PM_{10} = 7.1 g/tonne, $PM_{2.5}$ = 3.7 g/tonne
- Dawes Lane: Mohrhauer = 102 g/tonne; PM_{10} = 4.5 g/tonne, $PM_{2.5}$ = 3.2 g/tonne
- *Morfa: Mohrhauer = 10.5 g/tonne; PM_{10} = 3.0 g/tonne, $PM_{2.5}$ = 2.9 g/tonne*

Annual coke production at Scunthorpe in 2013 was 417,229 tonnes at Dawes Lane coke ovens and 623,014 tonnes at Appleby. Using the factors above, and assuming that the two quench towers at Appleby are used equally, emissions for calendar year 2013 are estimated to be:

- Dawes Lane: 43 tonnes dust and grit >100 µm, 1.9 tonnes PM_{10}, 1.3 tonnes $PM_{2.5}$
- Appleby: 268 tonnes total dust and grit>100 µm, 5.9 tonnes PM_{10}, 2.6 tonnes $PM_{2.5}$

6.3 Impact of current emissions

Dispersion modelling has been undertaken to assess the impact of estimated PM_{10} and $PM_{2.5}$ emissions from coke quenching at the two Scunthorpe coke plants. Ground level concentrations have been predicted at the local authority monitoring station at Rowland Road and the results, along with the relevant Air Quality Standards, are:

- PM_{10} (90.4th percentile of daily means): peak = 0.13 µg/m³, AQS = 50 µg/m³
- PM_{10} (annual mean): peak = 0.03 µg/m³, AQS = 40 µg/m³
- $PM_{2.5}$ (annual mean): peak = 0.01 µg/m³, AQS = 25 µg/m³

Therefore the current emissions from coke oven pushing, despite not achieving the BAT-AEL for dust, contribute less than 1% of the long-term Air Quality Standards for PM_{10} and $PM_{2.5}$ and less than 10% of the daily mean PM_{10} AQS. Based on the methodology included in the Environment Agency's H1 guidance note, this means that the Process Contribution attributable to these dust emissions would be assessed as having an insignificant environmental impact.

6.4 Potential pollution abatement through achieving BAT

If BAT for dust from coke quenching were to be achieved at Scunthorpe, then assuming that PM_{10} and $PM_{2.5}$ emissions would then be at the same levels as measured at Morfa coke ovens, the annual mass emissions would fall to:

- Dawes Lane: 4.4 tonnes dust and grit >100 µm, 1.3 tonnes PM_{10}, 1.2 tonnes $PM_{2.5}$
- Appleby: 6.5 tonnes total dust and grit>100 µm, 1.9 tonnes PM_{10}, 1.8 tonnes $PM_{2.5}$

Thus replacing the existing quench towers to achieve BAT at Scunthorpe could be expected to reduce total dust and grit emissions by 300 tonnes per year, direct PM_{10} emissions by 4.6 tonnes per year and $PM_{2.5}$ emissions by less than 1 tonne per year compared to the current situation.

6.5 Costs of achieving BAT at Scunthorpe

The Net Present Cost (i.e. the cost at 2014 prices, taking into account both capital and operating costs) of installing coke pushing emissions abatement has been assessed as stipulated in the Environment Agency's letter dated 11th February 2014. It should be noted that schemes to implement coke oven pushing abatement are not currently being pursued, and there is no guarantee that BAT could actually be achieved by March 2016. But if such schemes were implemented at both coke plants by 2016, the Net Present Cost over a thirty year operational lifetime would be £33.4M.

6.6 Cost-benefit analysis

Abatement costs can be calculated by dividing the Net Present Cost of replacing the existing quench towers by the mass of pollutants abated over the lifetime of the equipment. Overall, the estimated abatement costs over a thirty year operating life would be:

- Total dust and grit: £3,712 per tonne abated
- PM_{10}: £240,243 per tonne abated
- $PM_{2.5}$: £1,199,190 per tonne abated

These figures can then be compared to damage costs for particulate matter to assess the cost-effectiveness of achieving BAT. No definitive set of damage costs exists, but a report by Eunomia consultants undertaken for the Environment Agency in 2012 suggested values of €16,443 per tonne PM_{10} and €25,322 per tonne $PM_{2.5}$ – equivalent to £16,012 and £24,658 at 2014 prices. On this basis, installation of coke oven pushing abatement in order to achieve BAT by March 2016 is disproportionately costly compared to the environmental benefits that would be accrued.

Moreover, the age of the existing plants means that the operational life of any new quench towers may be less than thirty years, which will further increase the abatement costs, as the mass of pollutants abated would fall, but the capital cost of the schemes would remain the same.

6.7 Conclusions

The implementation of BAT for coke quenching is less cost-effective at Scunthorpe than at more typical European coke plants due to:

- the technical characteristics, namely the age of the existing plants, meaning that retrofitted pollution abatement equipment would have a more limited operational life than would be the case at a new installation – this significantly increases the overall abatement cost
- the technical characteristics, namely the configuration of Appleby coke ovens, making it more technically difficult and costly to comply as two quench towers would be required, rather than one at a more typical installation

The effective abatement cost to achieve BAT is over £200,000 per tonne PM_{10} abated and over £1,000,000 per tonne $PM_{2.5}$. These figures exceed the relevant damage costs by more than a factor of ten, and hence coke pushing emissions abatement is disproportionately costly compared to the environmental benefits that would be accrued.