Report

Emission factors programme Task 4(b) – Review of cement sector Pollution Inventory

Report to the Department for Environment, Food and Rural Affairs; the National Assembly of Wales: the Scottish Executive; and the Department of Environment in Northern Ireland

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Executive Summary

This report has been prepared for the Department for the Environment, Food and Rural Affairs; the National Assembly of Wales: the Scottish Executive; and the Department of Environment in Northern Ireland by **netcen** (an operating division of AEA Technology plc) under the contract EPG 1/3/195 - Emission factors for air pollutants.

The Department for Environment Food and Rural Affairs (DEFRA) Air and Environment Quality (AEQ) Division is responsible for maintaining the UK National Atmospheric Emissions Inventory (NAEI). The NAEI is maintained by **netcen** on behalf of DEFRA. As part of the ongoing quality control of the NAEI the quantitative uncertainty in the national emission total of each component pollutant in NAEI is reviewed annually. Based on the findings of this review, project EPG 1/3/195 aims to characterise and minimise uncertainty in the emission factors used in the compilation of the NAEI and by association that of other UK inventories. The project has objectives (Tasks) that are set and reviewed annually; these comprise data collection and evaluation via literature review, personal contact with industrial representatives, direct source measurement and other means as appropriate.

This report provides a summary of work undertaken to assess the NAEI estimates for emissions from the UK cement industry. The NAEI data for UK industry are largely drawn from annual emission reports provided by site operators in England and Wales to the Environment Agency Pollution Inventory (PI). The accuracy of the PI reports is key to the uncertainty of the NAEI. This report provides a review of the PI data for the cement industry sector.

The report highlights potential issues in the PI annual summaries and the industry view. Conclusions are provided on the use of PI data within the NAEI for the cement sector and recommendations for further investigation are provided.

In addition, default emission factors have been derived which may be used in the NAEI (and other inventories) to assess the data provided for certain key pollutants released to the atmosphere from cement installations. Default factors also allow provision of data where source specific data are not available.

Contents

Appendices

1 Introduction

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The report highlights potential issues in the PI annual summaries and the industry view. Recommendations for further investigation are provided. In addition, default emission factors are derived which may be used in the NAEI (and other inventories) for certain key pollutants released to the atmosphere from cement installations where source specific data are not available. The following sections summarise the methodology applied to assess emission factors currently used; key findings; and recommendations. Further details are provided in an Appendix 1, in the form of a summary which was used to present the issues to inventory users and Industry.

2 Methodology

The cement sector was chosen to examine the use of PI data in the NAEI because it contributes significantly to total UK emissions of several air pollutants in the NAEI (Table 2.1).

Table 2.1 – Cement sector contribution to NAEI in 2000

Pollutant	*Contribution to NAEI total*
Particulate	10.3 %
NO_x	2.2%
Carbon	1.7 %
SO_2	1.7 %
Dioxins	1.3 %
PM_{10}	1.2 %
Benzene	1.1 %
HF	1.0 %
Metals	Cd – 1.3 % Cu – 2.1 % Hg – 2.1 %
Other NAEI pollutants	Less than 1 %

Furthermore, the Environment Agency Pollution Inventory returns for 2001 indicate that Padeswood cement plant is the largest source of Polycyclic Aromatic Hydrocarbons (PAH) in that inventory, and the largest dioxin source outside the iron & steel sector.

Not all the pollutants shown in Table 2.1 have been examined – this study has considered particulates & PM_{10}; NOx; CO_2; dioxins; benzene; mercury; and PAH.

In developing emission estimates for the cement sector, the NAEI draws on emissions reported by cement companies to the Environment Agency's PI. The PI returns have been extracted from the Agency's "What's In Your Backyard" web site http://216.31.193.171/asp/1_search_input.asp?dataset=polinv and in some cases checked also against the PI database dated 10 September 2002.

Analyses of NAEI data have been based on a spreadsheet output from the NAEI database, provided by the NAEI team on 24th September 2002. A spreadsheet used to generate the NAEI data for the cement sector was provided on 19th December 2002.

Some company data are also available for comparison from published environmental reports and web sites, these are referenced below at first mention.

The approach followed in this study has been to scrutinise the PI data to assess the spread of data, identify any outliers or inconsistencies, then to approach cement companies for their comments. Based on the combined analysis, recommendations are made in Section 4 for default emission factors. The uncertainty of the emission factors are also estimated.

Further details are given in Appendix 1.

3 Results

3.1 CEMENT PRODUCTION SITES

This report considers only cement production, and excludes post production blending/grinding activities where they are carried out at other sites.

There are about 35 sites reporting to the PI under source code 3.1 “Cement/Lime Manufacture and associated Processes”. These include not only cement production processes, but also sites for lime production, either for sale as a product or for internal use. Examples of the latter include several British Sugar sites (where lime is used in a sugar purification stage) and Brunner Mond (who produce lime as part of a process which principally manufactures sodium carbonate).

There are in addition several sites which have ceased production during the period 1998 to 2002. The “New Rugby” kiln commenced production during 2000. At the time of writing Lafarge Cement UK are constructing a new kiln on their Medway site; when the new plant comes online it is anticipated that the Northfleet site will cease cement production. A new cement kiln has been ordered for Tunstead Quarry.

The NAEI emission estimates for the cement sector are based on a subset of the PI sites, where cement kilns are operated. There were 15 such sites active during 2000, operated by five companies. Sites in Scotland (Lafarge Cement UK – Dunbar) and Northern Ireland (Lafarge Cement UK - Cookstown) are also included in the NAEI estimate but are excluded from the present study as they are not located within the Environment Agency regulatory area and consequently do not provide input to the Agency’s PI.

Although it is recognised that Dunbar and Cookstown do not report to the PI operated by the Environment Agency, both sites have been the subject of emission monitoring by the operator and regulatory authorities. It is recommended that the NAEI should use source specific data where available rather than extrapolated data from the remaining sites.

One of the PI sites, Tunstead Quarry, currently operates one cement kiln and several lime kilns. Analysis of the PI data showed Tunstead to have high emissions of particulate and carbon dioxide. Discussion with the operators, Buxton Lime Industries[1], revealed that their PI returns for authorisation AH9847 includes not only the cement kiln, but also all the lime kilns, aggregated together. It appears therefore that emissions of particulate from cement production are overestimated by the NAEI by approximately 25% (in 2000), while the corresponding emissions from lime production are underestimated by about 60%. Likewise the other NAEI pollutants are likely to show a distorted allocation between cement and lime, though the effect appears to be greatest for particulate.

The accurate mapping of PI sites into the appropriate part of the NAEI contributes to the completeness and transparency of the NAEI; this review suggests that industry sectors used by the PI and NAEI are not consistent and indicates that there is a need to review either the NAEI categories and/or the mapping between PI (and other inventories) and the NAEI.

[1] A subsidiary of Tarmac Central Ltd, part of the Tarmac Group, itself a subsidiary of Anglo Industrial Minerals, a division of Anglo American plc.

3.2 COMPLETENESS OF PI SITE REPORTS

There are a number of gaps in the data available from the PI. Most notably, there are no data for the Tunstead site for any of the pollutants for 1998, nor for some pollutants for 1999. Discussion with the operator has revealed that the data have been withheld on the grounds of commercial confidentiality.

Some other gaps in the data available from the PI have been noted, particularly in the emissions data for benzene.

Two techniques were found to be helpful in identifying outliers, anomalies and gaps:

- tabulating data by year;
- Pareto plots of the range of estimates for each site.

Example of both types of analysis are contained in Appendix 1. The number of gaps in the PI is likely to diminish as operators develop robust reporting procedures and can probably be addressed by the NAEI in an 'ad hoc' fashion, as required. However development of mechanisms for assessing anomalies in the PI data is recommended

3.3 PARTICULATE AND PM_{10}

3.3.1 Particulate emissions

The PI particulate emissions correlate fairly well with the NAEI team's estimates of clinker production (based on capacities). A default particulate emission factor of 0.26 kg particulate per tonne of clinker production has been estimated for the UK cement sector (see Appendix 1). Evaluation of the default factor by comparison with the site emission factors indicates a range of about –30 to +50%. This is an empirical measure of whether the default factor is 'fit for purpose' – it does not represent the uncertainty of the PI emissions.

Where a kiln is fitted with a fabric filter (currently only the Hope works of Lafarge Cement UK), an emission factor of 0.053 kg particulate per tonne of clinker production is indicated. Lafarge Cement UK indicated that both Aberthaw and Cauldon would shortly be fitted with fabric filters.

Lafarge Cement UK reported that their sites are generally using continuous emission monitoring systems (CEMS) for particulate emissions with estimated accuracy of ±10%; where spot samples are used, the estimated uncertainties are ±40% (using BS3405) and ±10% (using BS6069).

The uncertainty associated with CEMS and manual spot samples are dependent on a variety of factors; not least being the adequacy of the sampling facilities. Calibration of CEMS in the UK is not well understood by industry and **netcen** considers that a verifiable uncertainty of ±10% is unlikely for particulate CEMS. A fully compliant BS3405 measurement has a stated uncertainty of ±25% on the emission rate but has a comparatively low collection efficiency for fine particulate. Similarly, a fully compliant BS6069 (ISO 9096) particulate measurement has an uncertainty of ±10% on the measured concentration (but this does not include the measurement uncertainty in determining flow which is needed for calculation of the emission rate).

3.3.2 PM_{10} emissions

PM_{10} emission estimating is handled differently by each company.

- Castle Cement has assumed that all the particulate is PM_{10}. Discussions with the company have established that they have conducted limited measurements which found a PM_{10} content of 70-80% at all sites. They therefore decided it was simplest to assume a worst case of 100%.
- Buxton Lime has not assessed the PM_{10} content, and does not report PM_{10} releases to the PI.
- Lafarge Cement UK has reported different PM_{10} fractions each year for each site. In discussion, Lafarge Cement UK suggested that the PM_{10} fraction is typically 70-80% of the particulate – each site estimates the fraction based on limited spot sampling for PM_{10}.
- Rugby has applied a PM_{10} fraction of 100% in all cases, except for the Barrington site in 2000 (57%) and 2001 (21%).

Each company has effectively developed its own criteria for PM_{10} reporting and consequently reporting of the PM_{10} emission to the PI is inconsistent. Although source-specific measurement-based data are preferable, the reported data appear to be variable.

Reporting all particulate as PM_{10} is not an unreasonable assumption for modern particulate abatement systems but will overestimate emissions from some cement plant. However, until the PI reports for cement manufacture are reported on a consistent basis, it may be appropriate to adopt a default factor for PM_{10} of 100% of particulate emission.

3.4 NO_X

The NO_x emissions in the PI correlate fairly well with the NAEI team's estimates of clinker production (based on capacities). A default emission factor of 3.3 kg NO_x per tonne of clinker production has been estimated. Comparison of the default factor with the site emission factors indicates a range around the default factor of about –30 to +90%. This is an empirical measure of whether the default factor is 'fit for purpose' – this should not be regarded as the uncertainty of the PI emissions.

Lafarge Cement UK has published emission factors for NO_x from their sites. The average (not weighted by production) is 3.27 kg NO_x per tonne of Portland cement Equivalent. This value cannot be compared directly with the figure given above, since one tonne of clinker does not make one tonne of Portland Cement.

Castle Cement (2001) has also reported emission factors for NO_x per tonne of cement. These range from 2.61 kg NO_x per tonne cement in 1998 to 1.18 kg NO_x per tonne cement in 2001. Discussions with the company indicate a clinker content of about 90-95%, so the Castle Cement emission factors equate to about 2.75-2.90 kg NO_x per clinker in 1998 to 1.24-1.31 kg NO_x per tonne clinker in 2001. The graph shown in Appendix 1 illustrates how Castle Cement's two largest sites have amongst the lowest NO_x emission factors in the sector.

Lafarge Cement UK's Northfleet site stands out as having substantially higher NO_x emissions than any other site. Lafarge Cement UK indicated that this is due to the outmoded technology at this soon to be closed site, where a particularly inefficient wet process is operated.

3.5 CO_2

The NAEI reports two categories of CO_2 emission from cement manufacture :

- decarbonising (calcining)
- fuel combustion

CO_2 emissions correlate particularly well with the NAEI team's estimates of clinker production (based on capacities). A default emission factor of 940 kg CO_2 per tonne of clinker production has been estimated. This may be compared with the range of 800-1040 kg/t clinker given by the BREF note for the cement and lime sector; and with an estimated 966-1033 kg/t clinker which may be derived from emission factors published by Castle Cement. Comparison of the default CO_2 factor with the range of factors from BREF and Castle Cement indicates a range of –20 to +30%. However, this should not be regarded as an estimate of the PI uncertainty.

Lafarge Cement UK reported that CO_2 emissions are calculated using a mass balance approach. A mass balance approach is considered to be the most reliable method for the operator to estimate CO_2 emissions from cement manufacture and is consistent with other estimates for CO_2 within the NAEI. The mechanisms for CO_2 production are understood and the operator will have access to primary clinker production and fuel consumption figures for each plant.

3.6 DIOXINS

PI data for dioxin releases are dominated by relatively high releases from Castle Cement's Padeswood and Ribblesdale sites. Discussion with the operator indicates that this is probably due to the high content of organic matter (up to 30%) in the colliery shale used in the kiln at these sites. Castle Cement makes about four emission measurements per year at each site, using EN 1948 which is currently state of the art for determination of dioxin stack concentrations. The site has observed considerable variability in the measurement results, which may be due in part to the inherent uncertainty in the method, and in part due to fluctuations in process emissions. Castle Cement have estimated an uncertainty in the results reported to the PI of ±100%.

This uncertainty is not unreasonable - the EN 1948 Standard reports uncertainty data for measured concentrations from two site trials equivalent to about 150% (Plant A) and 50% (Plant B) for the filter/condenser test procedure (the most commonly applied dioxins emission test procedure in the UK). These uncertainties apply only to the measurement procedure to determine concentration, do not include uncertainty for developing an emission rate and do not include process variability.

Lafarge Cement UK also use EN 1948. The test frequency varies between sites, typically two to four times a year with additional campaigns associated with alternative fuel trials. There is variability between sites in the way in which the measured values are averaged and aggregated to estimate annual emissions.

It has to be concluded that the uncertainty in the NAEI aggregated cement sector estimate is unlikely to be better than ±100%.

3.7 BENZENE

The data to be found in the PI for benzene appear to be of rather varied quality. Two problems may be noted:

- gaps in reporting, e.g. no data for Northfleet in 1999, 2000 or 2001;

- large swings in emissions, e.g. Cauldon reports 14.98 t in 1999; below reporting threshold (100 kg) in 2000; then back up to 30.361 t in 2001.

Castle Cement has indicated that they make one measurement per year at each of their sites, and base the PI returns on these measurements. If this is typical across the sector, then it is likely that the PI returns will have a high level of uncertainty. Castle Cement has estimated uncertainty of ±100%. In the author's opinion, this is an underestimate of the uncertainty for any given plant.

Lafarge Cement UK supported Castle Cement's view. They have observed variability of three orders of magnitude in samples taken within a few days of each other.

Comparison of reported emissions against estimated production suggests a default emission factor of 0.012 kg benzene per tonne clinker, with an estimated uncertainty of ±100%. However, Padeswood and Cauldon have relatively high emissions and indicate the need for improved source specific data.

3.8 MERCURY

The PI data for mercury look particularly variable. In discussion with Castle Cement, they reported that the concentrations are so low that they are very difficult to measure, with most results being below the limit of detection.

Most Lafarge Cement UK sites take four spot samples per year, with an estimated uncertainty of ±50%.

It is recommended that further work is undertaken with the cement companies to assess more thoroughly the metal emissions, especially mercury, cadmium and copper.

3.9 PAH

The data contained in the PI for PAHs appear to be generally of low quality. Three problems may be noted:

- gaps in reporting, e.g. no data for Northfleet in any year;
- inconsistent reporting (two sites have reported more benzo[a]pyrene than total PAH as benzo[a]pyrene);
- where PAHs are reported above the reporting threshold, there are large ranges in the data for a given site.

Relatively high emissions have been reported for Padeswood; in discussions, Castle Cement felt that this was due to the high organic content of the raw materials used at the site.

Lafarge Cement UK commented that this group of pollutants is relatively newly under consideration by the cement sector, and improvements in measurement accuracy may be expected as experience is gained. Currently some sites take one extractive sample per year, others estimate PAH releases by calculation. Estimated uncertainties are ±100%.

The analysis presented in Appendix 1 suggests a possible empirical relationship between benzene emissions and PAH emissions, which could indicate that substantial emissions of PAHs may be being overlooked. It is recommended that this issue is discussed further with those sites who either do not report, or report releases below reporting threshold.

4 Summary of recommended default emission factors

Default emission factors can be used to verify source data or provide emission data in the absence of source data. The following default emission factors are recommended:

Pollutant	Emission factor	Range of plant estimates
Particulate, PM_{10}	0.26 kg / t clinker 0.053 kg /t clinker (bag filter)	-30% to +50%
NO_x	3.3 kg / t clinker	-30% to +90%
CO_2	940 kg / t clinker	-20% to +30%
		Estimated uncertainty
Dioxins	0.08 mg TEQ / t clinker	>±100%
Benzene	0.012 kg / t clinker	>±100%
Mercury	Can't be estimated at this time	
PAHs	Can't be estimated at this time	

The uncertainties for particulate, NO_x and CO_2 are estimated based on the spread of reported emissions about the predicted value. The estimated uncertainties for dioxins and benzene are empirical based on the uncertainties reported by the operators and (for dioxins) EN 1948. Sites with particularly high or low emissions need to be handled individually. The Tunstead site needs to be examined again in order to distinguish between cement and lime production.

5 Conclusions

The NAEI uses the England & Wales PI to incorporate site–specific emission estimates for industrial and other processes regulated by the Environment Agency. The following conclusions arise from a review of the emissions reported in the PI for cement manufacture.

1. The accurate mapping of PI sites into the appropriate part of the NAEI contributes to the completeness and transparency of the NAEI. This review suggests that industry sectors used by the PI and NAEI are not consistent and indicates that there is a need for the NAEI project to review either the NAEI categories and/or the mapping between PI (and other inventories) and the NAEI.

2. Although it is recognised that Dunbar and Cookstown do not report to the PI operated by the Environment Agency, it is recommended that the operator and regulatory authorities should be contacted through a task in the emission factor project to obtain source specific data for these sites for incorporation into the NAEI.

3. The number of incidences of missing data in the PI is likely to diminish as operators develop robust reporting procedures and can probably be addressed by the NAEI in an 'ad hoc' fashion, as required.

4. Reporting of the PM_{10} emission to the PI is inconsistent and, until the PI reports for cement manufacture are reported on a consistent basis, it may be appropriate for the NAEI to adopt a default emission factor for PM_{10} of 100% of particulate emission.

5. A mass balance approach is considered to be the most reliable method for the operator to estimate CO_2 emissions from cement manufacture and is consistent with the approach adopted for other estimates for CO_2 within the NAEI.

6. Dioxins emission returns appear to be largely based on measured data however, the results have a high uncertainty. The test frequency varies between sites, typically two to four times a year with additional campaigns associated with alternative fuel trials. Consequently, there will be some inconsistency between sites in the way dioxins data are aggregated to estimate annual emissions.

7. Comparison of reported benzene emissions against estimated production suggests a default emission factor of 0.012 kg benzene per tonne clinker, with an estimated uncertainty of ±100%. However, some sites have relatively high emissions and the need for improved source specific data is indicated.

8. It is recommended that further work is undertaken under this programme with the cement companies to assess more thoroughly the metal emission data, especially mercury, cadmium and copper.

9. The reporting of PAH emissions is a relatively new requirement for the cement sector and some of the PI inconsistencies are believed to be temporary. Currently some sites take one extractive sample per year, others estimate PAH releases by

calculation. Consequently there is some inconsistency at present in PI reporting. It is recommended that further work is undertaken under this programme to assess the available measured data and derive a default PAH emission factor.

10. Empirical analysis indicates some relationship between benzene emissions and PAH emissions, which could indicate that emissions of PAHs may be being overlooked. It is recommended that this issue is discussed further with those sites which either do not report, or report releases below the reporting threshold.

6 References

A full bibliography is detailed in Appendix 1 at the end of the summary presentation.

Appendix 1
Detailed analyses

Assessing uncertainties in the NAEI

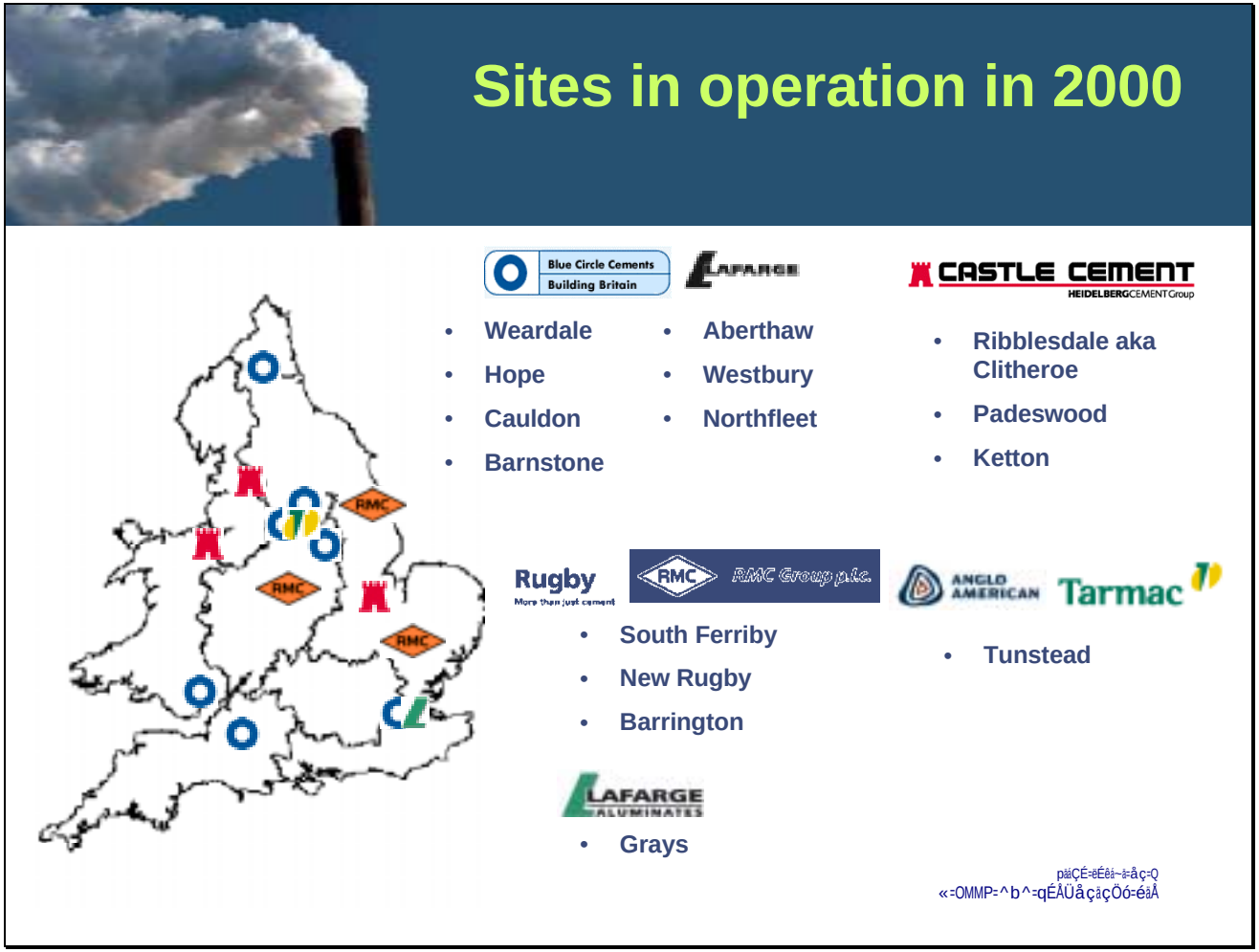
Cement sector

Scope

- England & Wales
- Cement manufacturing
- All air pollutants

Methodology

- Identify relevant sites, activities and authorised processes, reconcile with PI returns and NAEI source categories.
- Interrogate PI, NAEI, and public register to assess coverage of emission sources, to identify key assumptions and to evaluate uncertainties.
- Develop an independent view on appropriate emission factors and associated uncertainties; and make recommendations to update the NAEI.


Sites in operation in 2000
Blue Circle Cements
Building Britain
LAFARGE
CASTLE CEMENT
HEIDELBERGCEMENT Group
• Weardale
• Hope
• Cauldon
• Barnstone
• Aberthaw
• Westbury
• Northfleet
• Ribblesdale aka Clitheroe
• Padeswood
• Ketton
RMC
Rugby
More than just cement
RMC Group p.l.c.
ANGLO AMERICAN
Tarmac
• South Ferriby
• New Rugby
• Barrington
• Tunstead
LAFARGE ALUMINATES
• Grays

Closed sites

Blue Circle Cements Building Britain

LAFARGE

- Masons
- Plymstock
- Weardale – clinker production ceased in August 2002

Rugby More than just cement

RMC RMC Group p.l.c.

- Southam
- Chinnor
- Rochester
- Rugby

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«=OMMP=^b^=qÉÅÜåçâçÖó=éåÅ


New sites
Blue Circle Cements
Building Britain
LAFARGE
Medway
ANGLO AMERICAN
Tarmac
Tunstead
(new kiln
ordered)

The process chain

This report considers cement manufacture only

Quarrying, transportation, cement use in concrete and other products are not considered here

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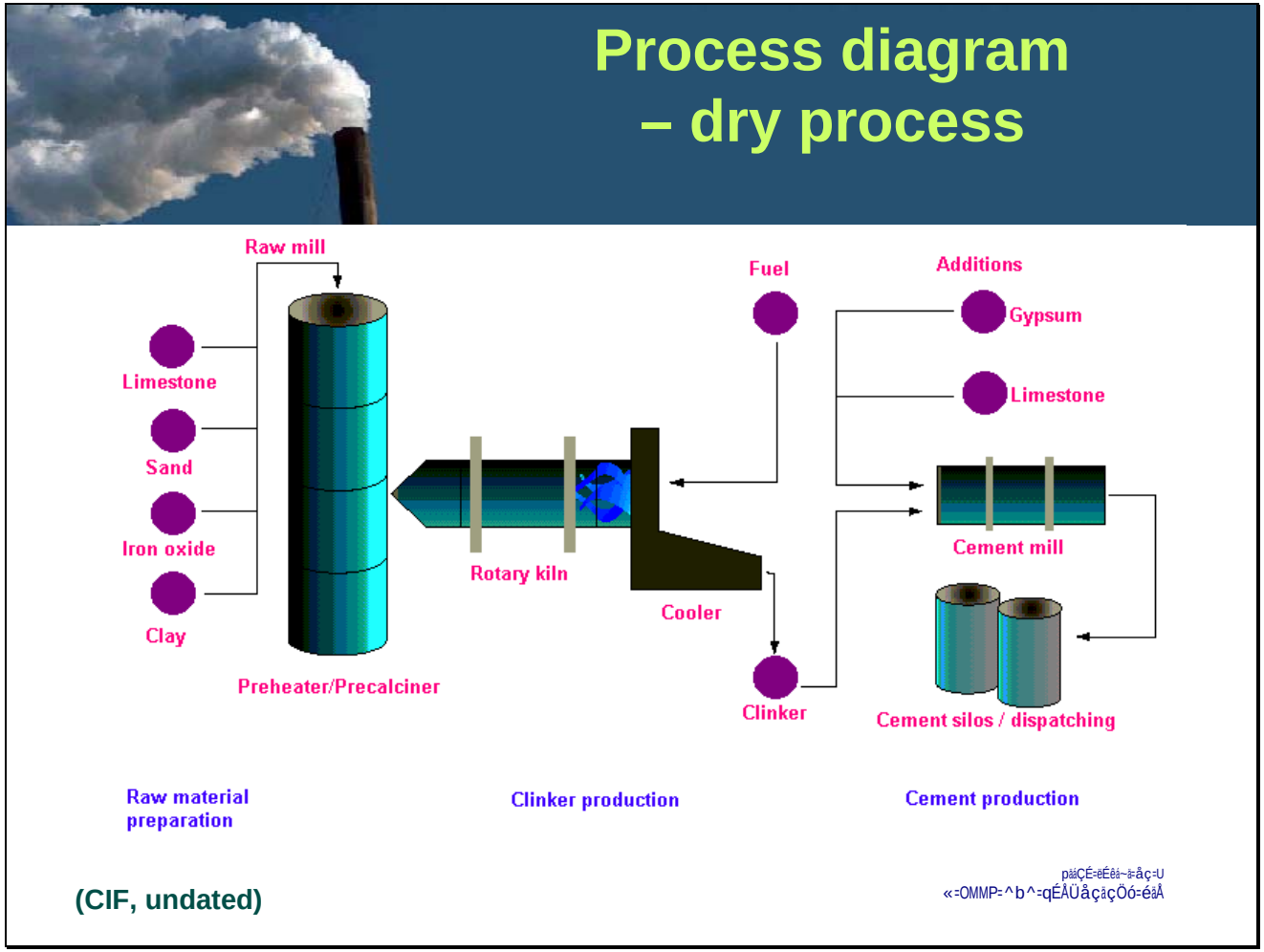
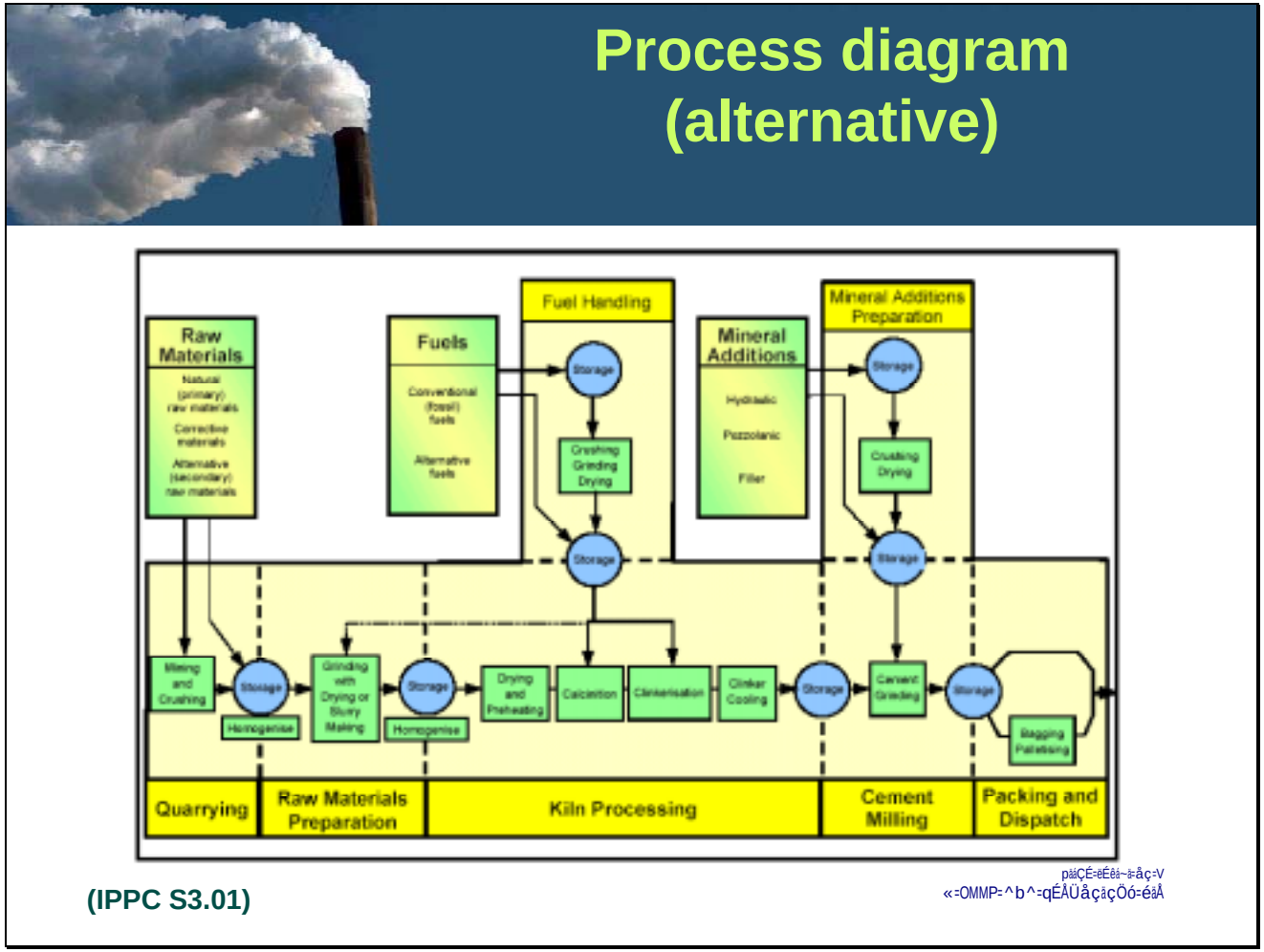
«=OMMP=^b^=qÉÅÜåç¤çÖó=éåÅ


Process diagram
– dry process
Raw mill
Limestone
Sand
Iron oxide
Clay
Preheater/Precalciner
Rotary kiln
Fuel
Cooler
Clinker
Additions
Gypsum
Limestone
Cement mill
Cement silos / dispatching
Raw material preparation
Clinker production
Cement production
(CIF, undated)


Process diagram (alternative)
Raw Materials
Natural (primary) raw materials
Corrective materials
Alternative (secondary) raw materials
Fuels
Conventional (fossil) fuels
Alternative fuels
Fuel Handling
Storage
Crushing Grinding Drying
Mineral Additions
Hydraulic
Pozzolanic
Filler
Mineral Additions Preparation
Crushing Drying
Mixing and Crushing
Homogenise
Grinding with Drying or Slurry Making
Drying and Preheating
Calcination
Clinkerisation
Clinker Cooling
Cement Grinding
Bagging Palletising
Quarrying
Raw Materials Preparation
Kiln Processing
Cement Milling
Packing and Dispatch

(IPPC S3.01)

NAEI source categories

- Cement_(decarbonising)
  - used for carbon only
- Cement_(Non-decarbonising)
  - used for metals, butadiene, benzene, dioxins, CO, HCl, ammonia, NO_x, SO_2, particulates, VOC
- Cement_(Fuel_Combustion)
  - used for PAHs, black smoke, carbon, methane, Ca, Na, HF, N_2O, PCBs, pentachlorophenol
- Cement_and_concrete_batching
  - used for Ca, K, Mg, Na, PM_{10}

Prioritising analyses

Cement sector contribution to NAEI totals in 2000:

Particulates – 10.3 %

Dioxins – 1.3 %

NO_x – 2.2 %

PM_{10} – 1.2 %

Carbon – 1.7 %

Benzene – 1.1 %

SO_2 – 1.7%

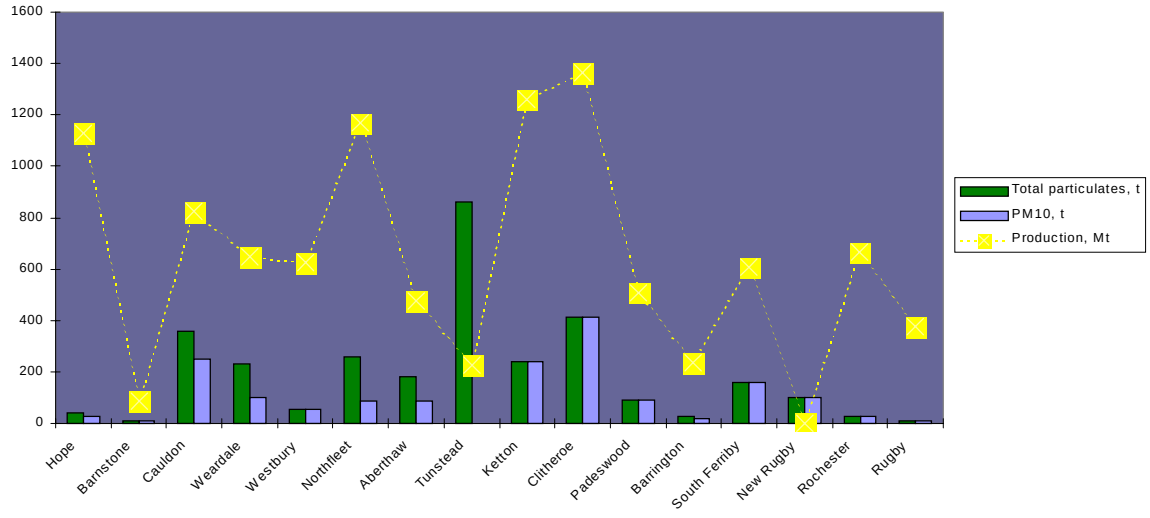
HF – 1.0 %

and of metals, Cd, Cu & Hg all over 1 %

…and PAHs

- Recent ENDS article showed that
  - Castle Cement, Padeswood, is the top industrial source of PAHs (16.9 t in 2001)
  - and is the largest dioxin source outside the steel industry

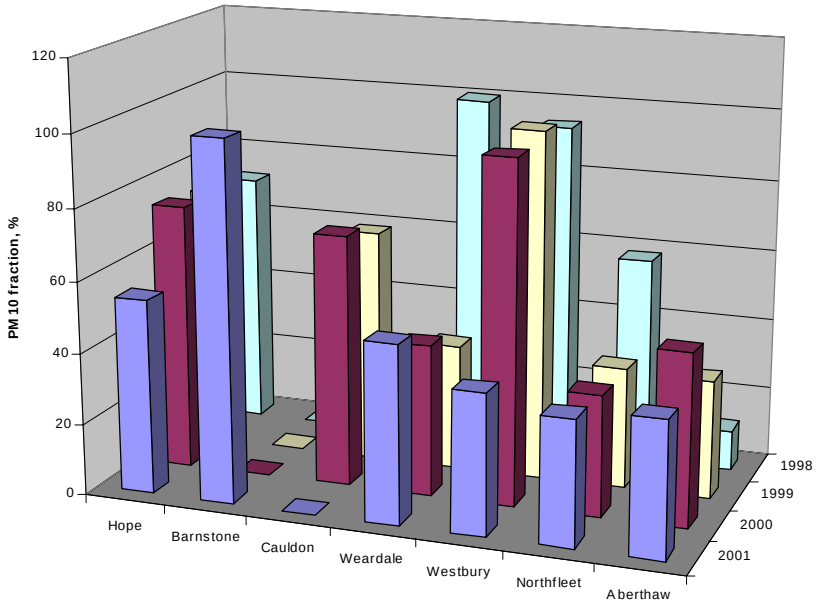
Particulates – PI data



(PI 2000)

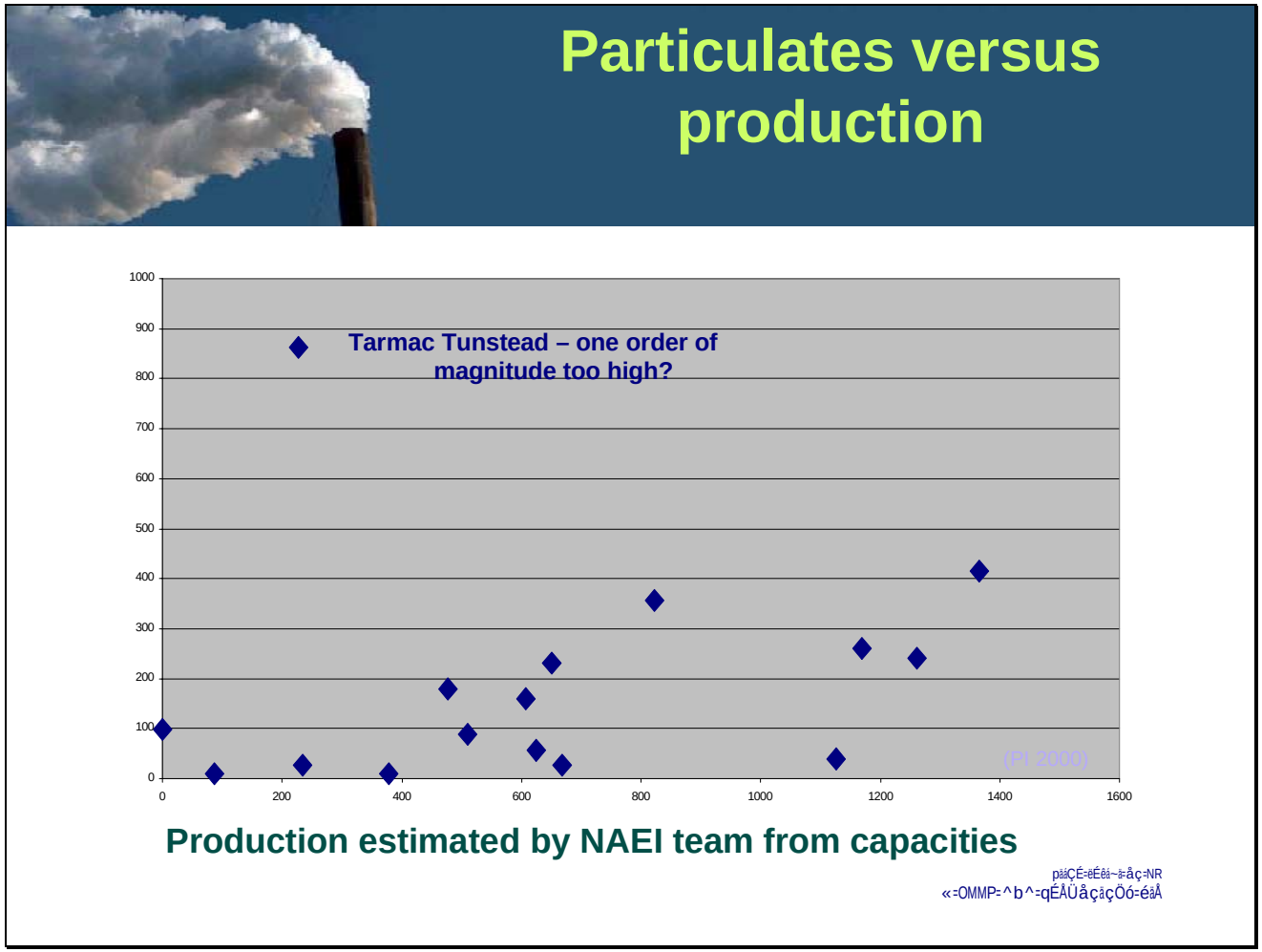
- **Emissions show some correlation with production**
- **Imperfect speciation**

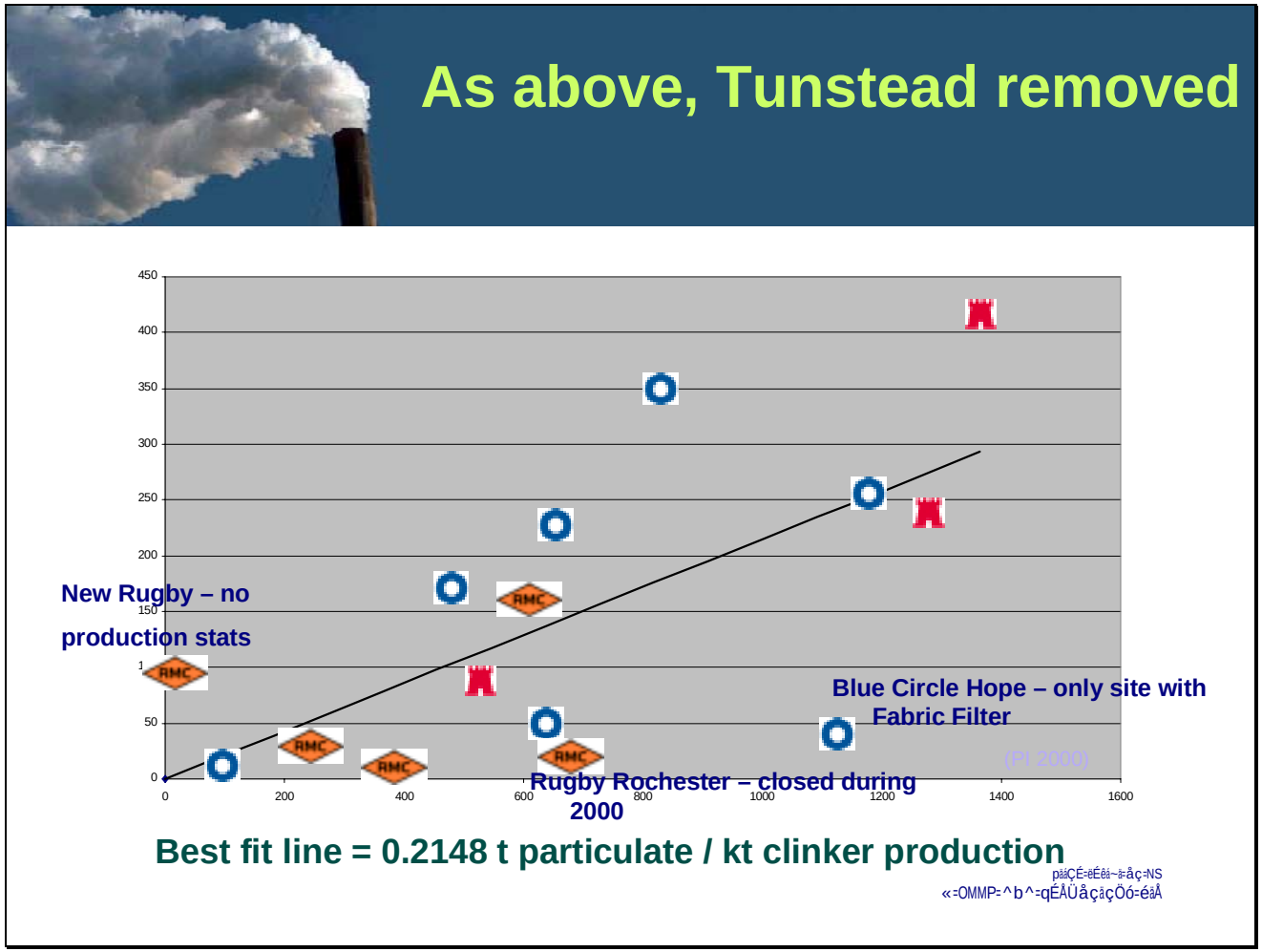
Blue Circle speciation

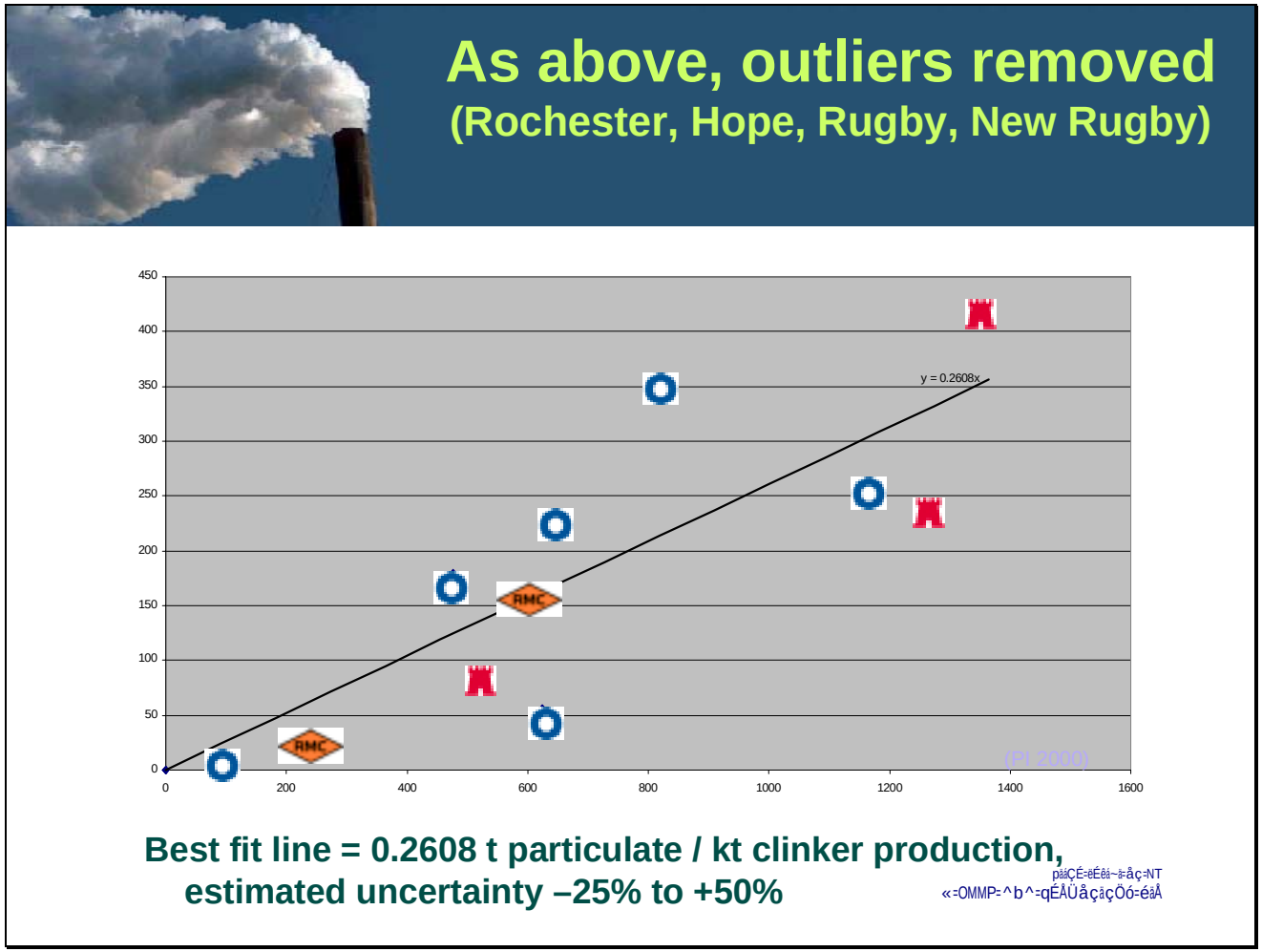


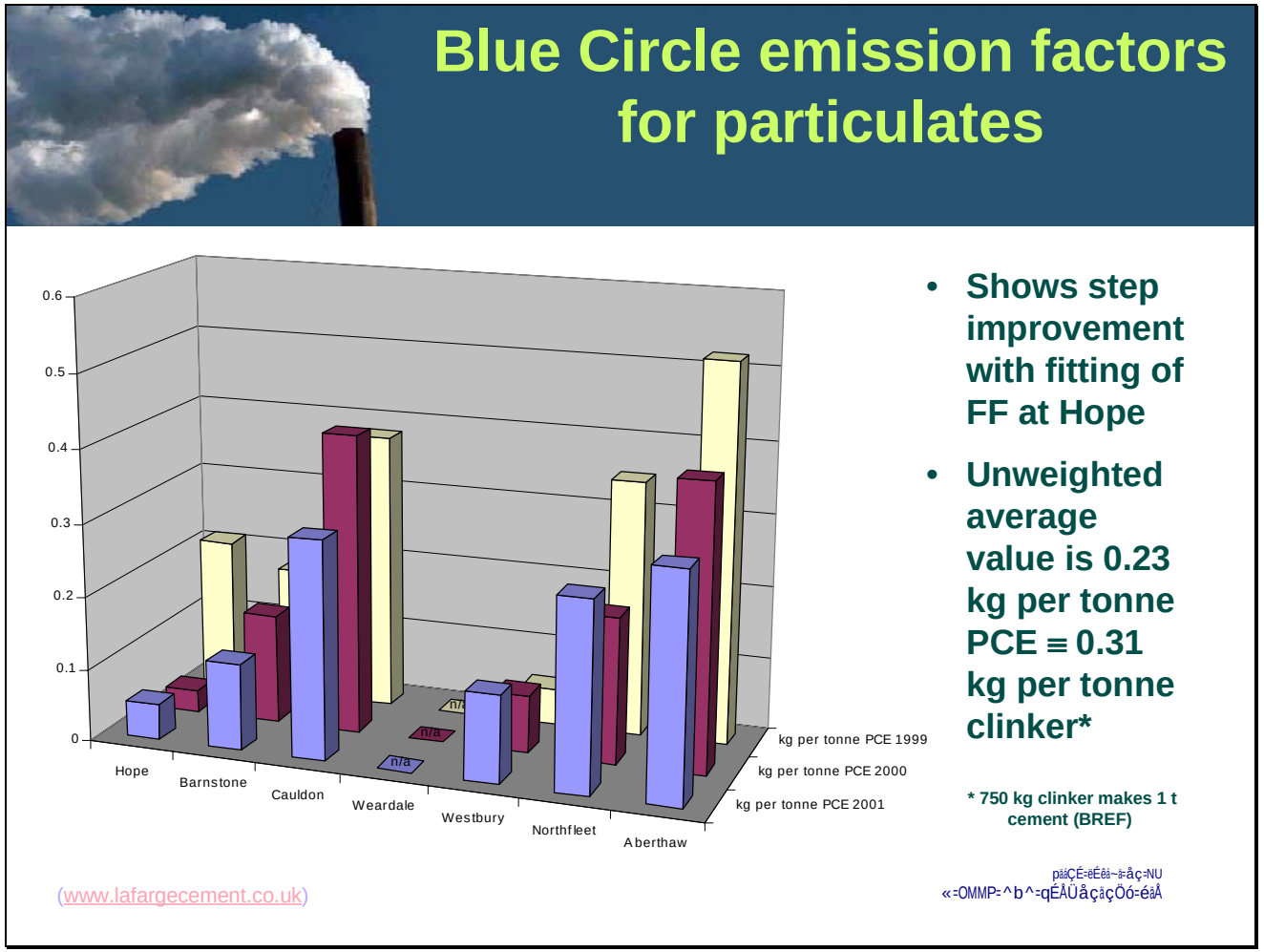
(PI 2000)

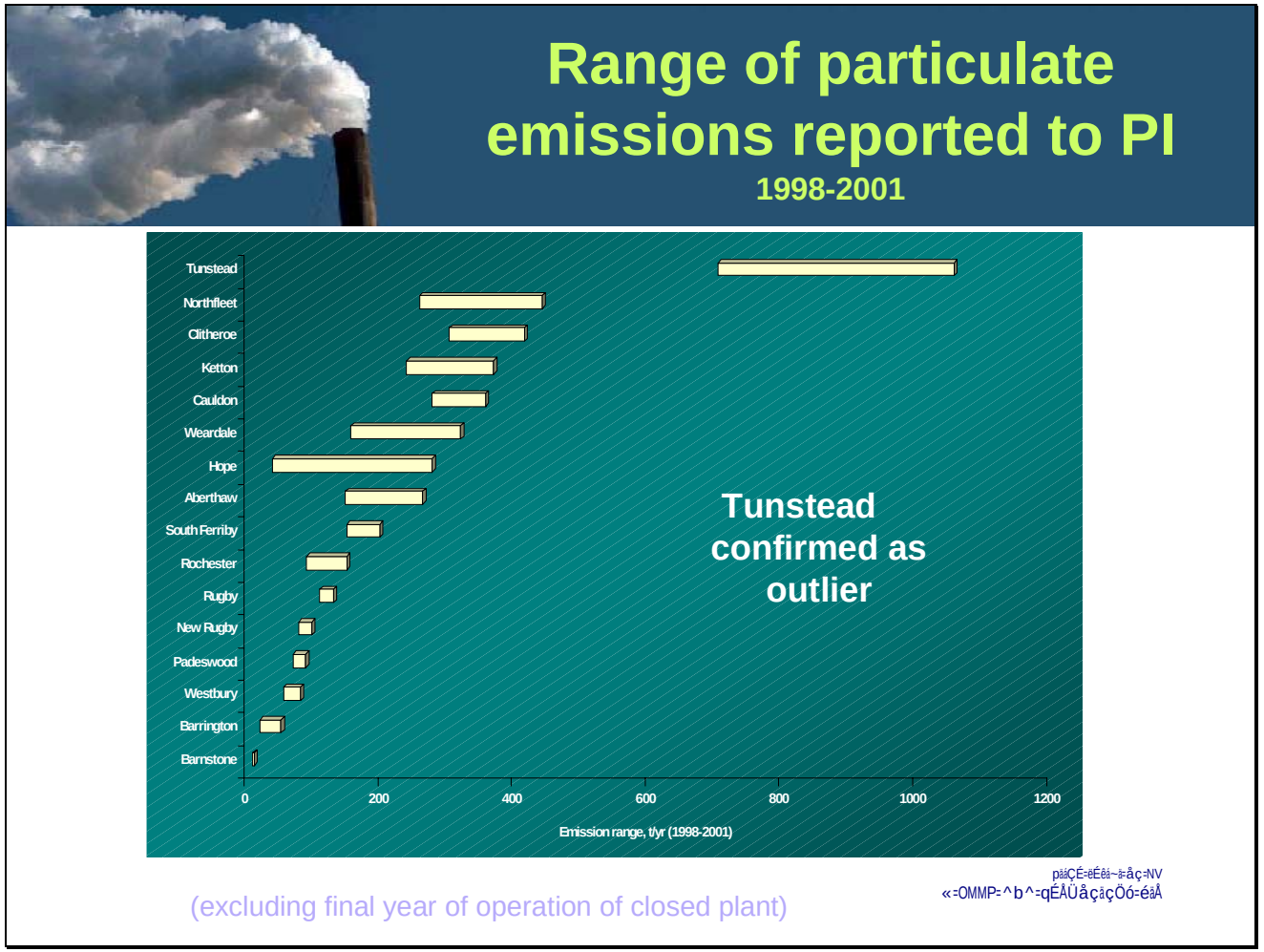
- No PM_{10} data for Cauldon, 2001
- Why such variations at a given site?
- Basis of speciation? Confidence in data?


Particulates versus production
Tarmac Tunstead – one order of magnitude too high?
(PI 2000)
1000
900
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
1200
1400
1600
Production estimated by NAEI team from capacities


As above, Tunstead removed
450
400
350
300
250
200
150
1
50
0
0
200
400
600
800
1000
1200
1400
1600
RMC
New Rugby – no production stats
Blue Circle Hope – only site with Fabric Filter
(PI 2000)
Rugby Rochester – closed during 2000
Best fit line = 0.2148 t particulate / kt clinker production


As above, outliers removed
(Rochester, Hope, Rugby, New Rugby)
y = 0.2608x
RMC
RMC
(PI 2000)
0
50
100
150
200
250
300
350
400
450
0
200
400
600
800
1000
1200
1400
1600
Best fit line = 0.2608 t particulate / kt clinker production,
estimated uncertainty –25% to +50%


Blue Circle emission factors for particulates
0.6
0.5
0.4
0.3
0.2
0.1
0
Hope
Barnstone
Cauldon
Weardale
Westbury
Northfleet
Aberthaw
n/a
n/a
n/a
kg per tonne PCE 1999
kg per tonne PCE 2000
kg per tonne PCE 2001
• Shows step improvement with fitting of FF at Hope
• Unweighted average value is 0.23 kg per tonne PCE ≡ 0.31 kg per tonne clinker*
* 750 kg clinker makes 1 t cement (BREF)
(www.lafargecement.co.uk)

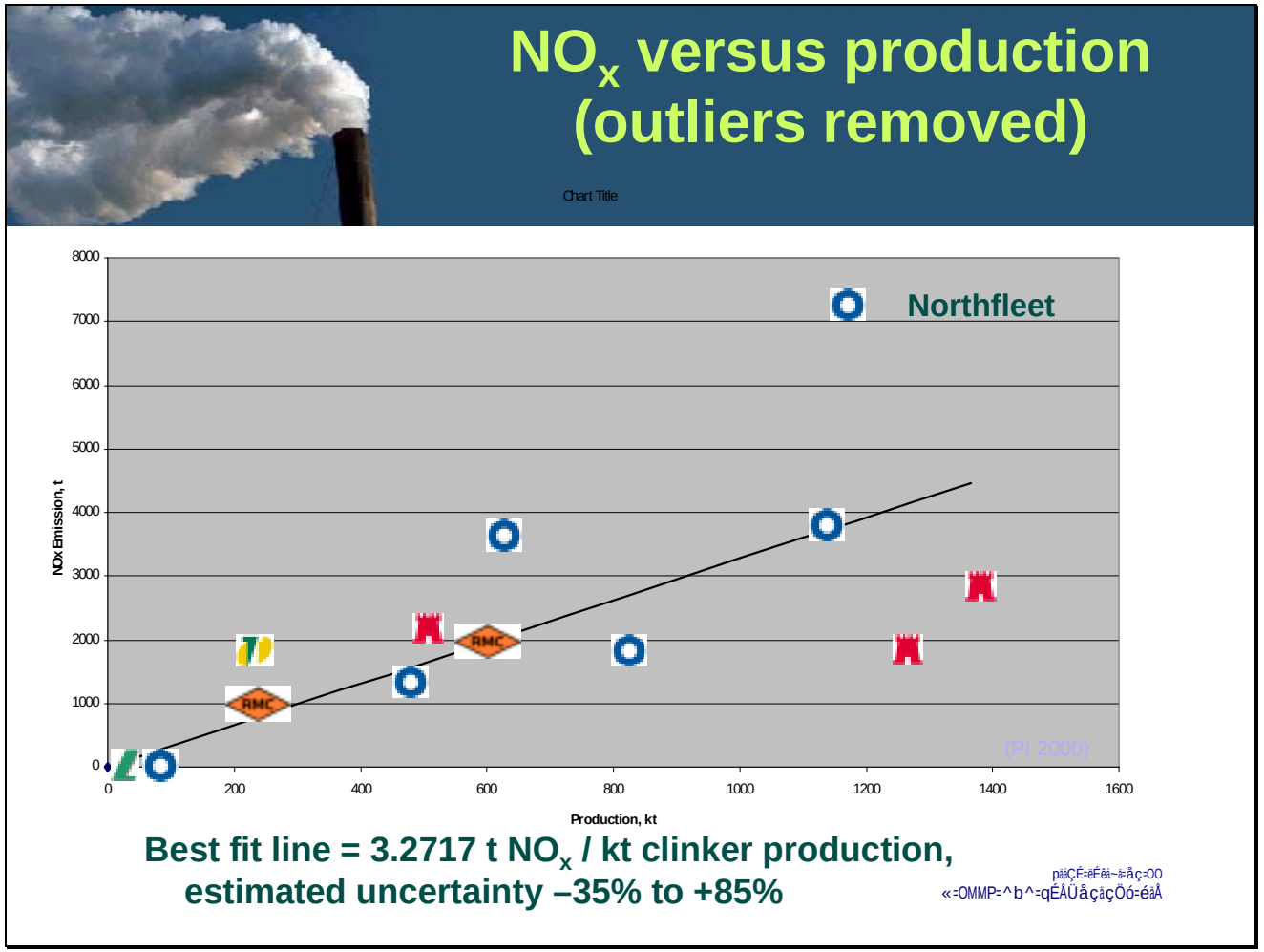

Range of particulate emissions reported to PI
1998-2001
Tunstead
Northfleet
Clitheroe
Ketton
Cauldon
Weardale
Hope
Aberthaw
South Ferriby
Rochester
Rugby
New Rugby
Padeswood
Westbury
Barrington
Barnstone
0
200
400
600
800
1000
1200
Emission range, t/yr (1998-2001)
Tunstead confirmed as outlier
(excluding final year of operation of closed plant)

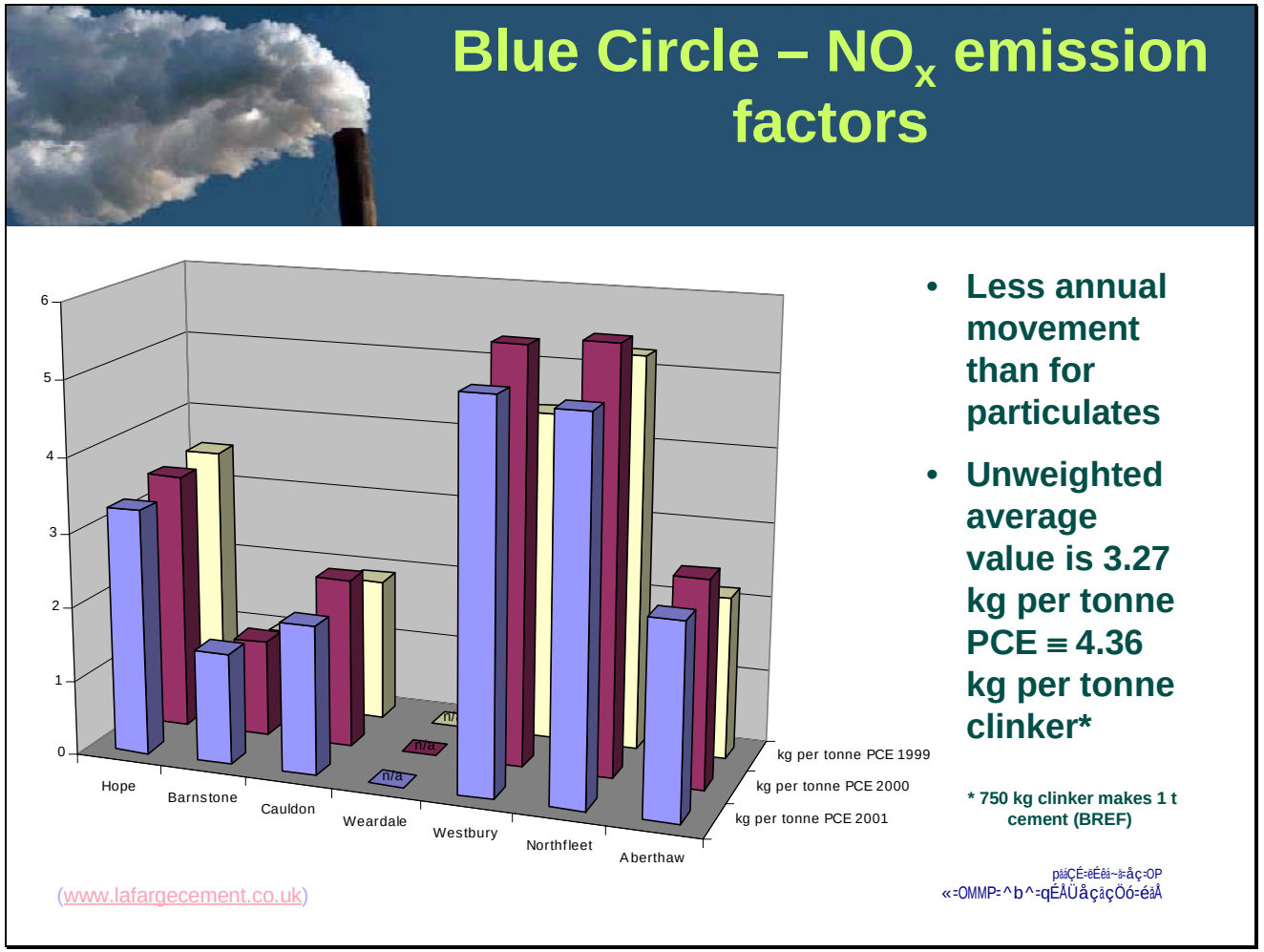
Feedback from Tarmac Central: Tunstead

- Tunstead site includes one cement kiln and several lime kilns
- The data they report to the Pollution Inventory aggregates emissions from all the kilns
- Therefore NAEI overestimates particulate emissions from the Cement sector, and underestimates emissions from the Lime sector

Conclusions for particulates

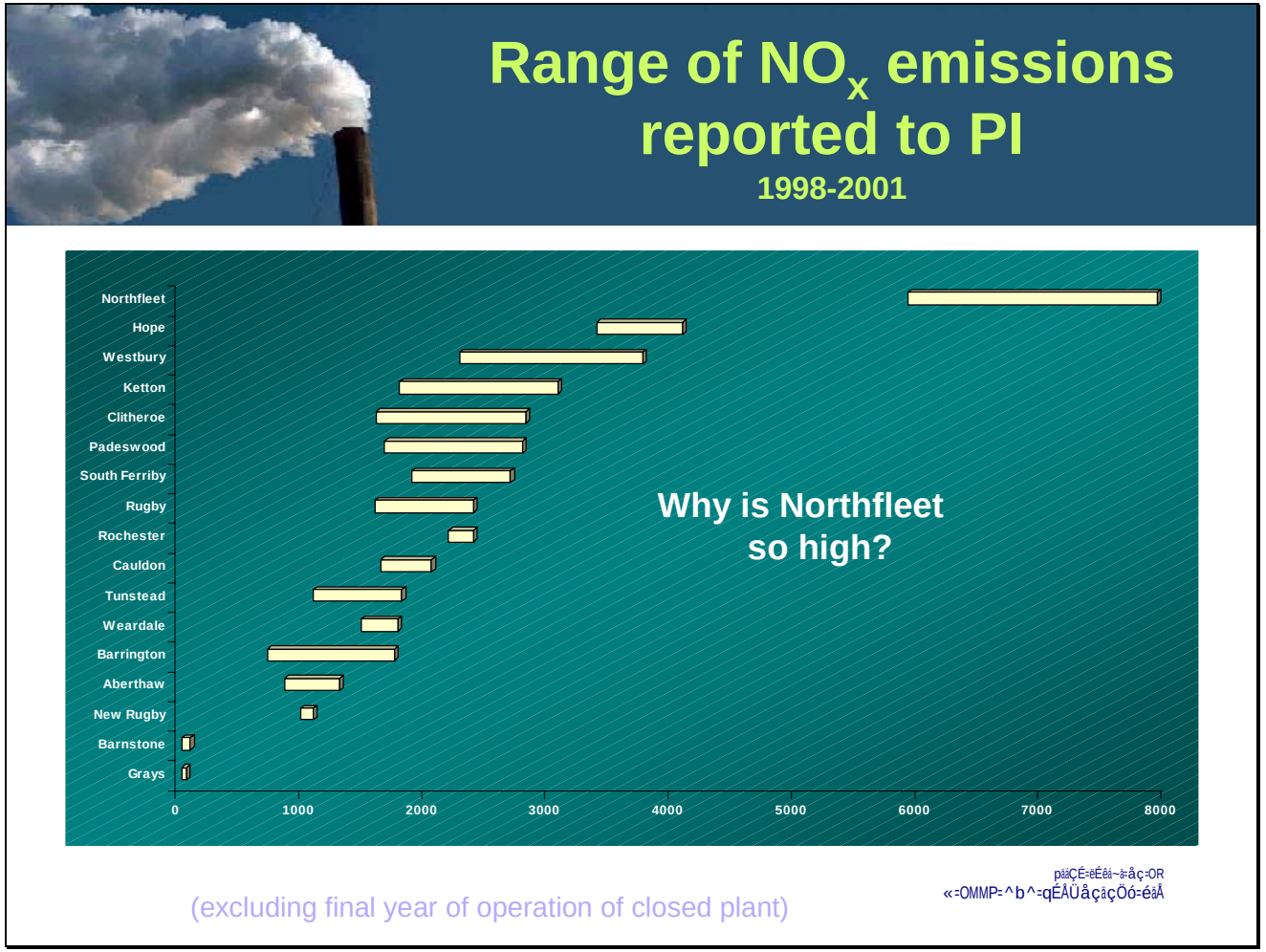
- Speciation needs improvement
- Tunstead appears to be over-reporting emissions, therefore NAEI overestimating source
  - (Tunstead represented 28% of particulate emissions from cement works in England & Wales in 2000)
- Comparison of emissions versus production is a valuable metric to help identify outliers
- Pareto ranking of reported emission ranges also highlights irregularities
- Recommend emission factor of 0.26 kg particulate per tonne clinker, except where Fabric Filter is fitted
- Recommend emission factor of 0.053 kg particulate per tonne clinker where Fabric Filter is fitted
  - (average of reported factors for Hope in 2000 and 2001)


NOx versus production (outliers removed)
Chart Title
Northfleet
NOx Emission, t
Production, kt
0
1000
2000
3000
4000
5000
6000
7000
8000
0
200
400
600
800
1000
1200
1400
1600
RMC
RMC
(PI 2000)
Best fit line = 3.2717 t NOx / kt clinker production,
estimated uncertainty –35% to +85%


Blue Circle – NO_x emission factors
6
5
4
3
2
1
0
n/a
n/a
n/a
Hope
Barnstone
Cauldon
Weardale
Westbury
Northfleet
Aberthaw
kg per tonne PCE 1999
kg per tonne PCE 2000
kg per tonne PCE 2001
(www.lafargecement.co.uk)
• Less annual movement than for particulates
• Unweighted average value is 3.27 kg per tonne PCE ≡ 4.36 kg per tonne clinker*
* 750 kg clinker makes 1 t cement (BREF)

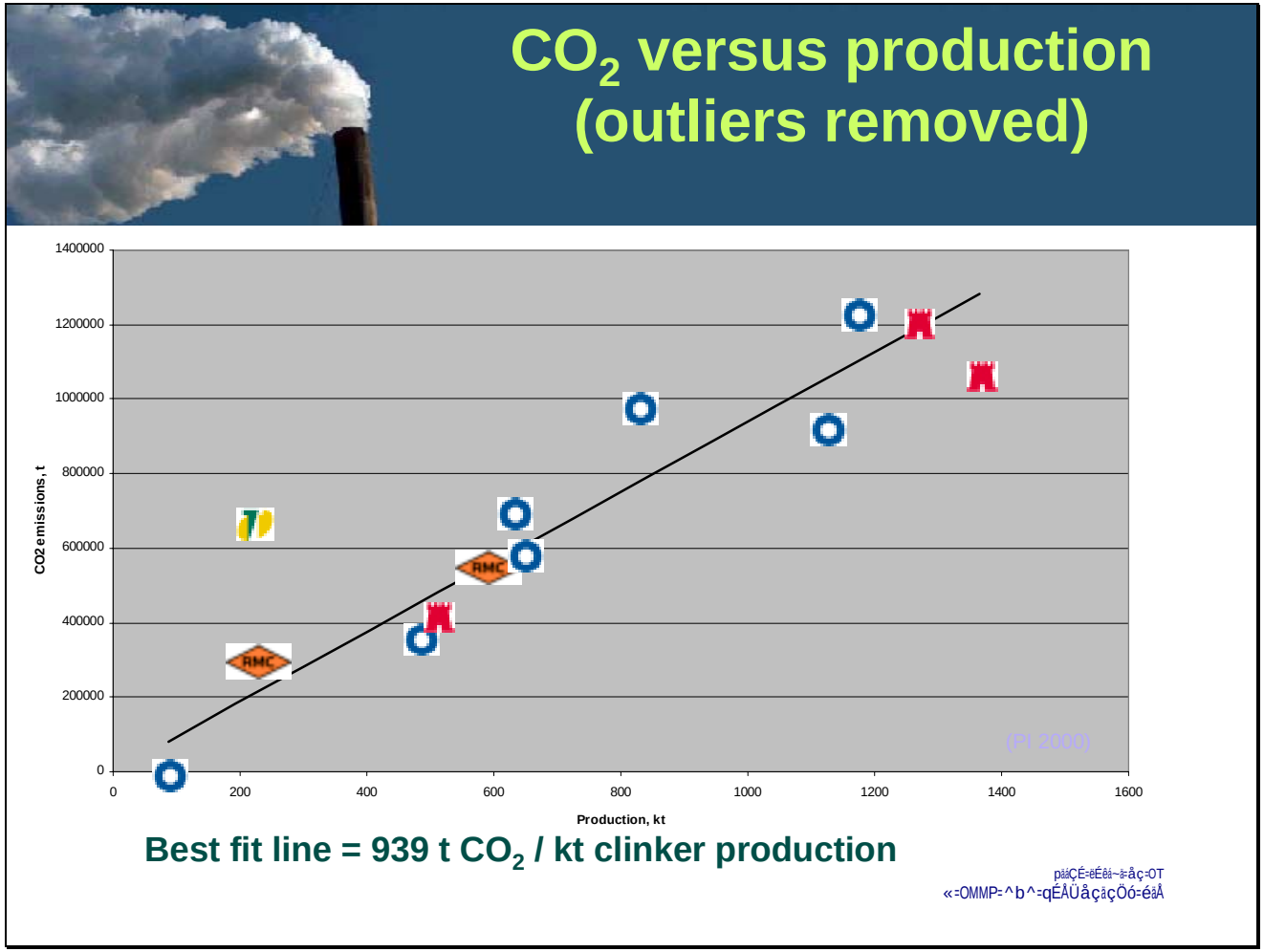
NO_x – some gaps in What's In Your Backyard

- No data found for:
  - Blue Circle Northfleet, 2001
  - Blue Circle Weardale, 2000
  - Tarmac Tunstead, 1998 (not open???)
  - Lafarge Aluminates Grays, 1999
- Data ARE however in the PI Database (except Tunstead 1998)


Range of NOx emissions reported to PI
1998-2001
Northfleet
Hope
Westbury
Ketton
Clitheroe
Padeswood
South Ferriby
Rugby
Rochester
Cauldon
Tunstead
Weardale
Barrington
Aberthaw
New Rugby
Barnstone
Grays
0
1000
2000
3000
4000
5000
6000
7000
8000
Why is Northfleet so high?
(excluding final year of operation of closed plant)

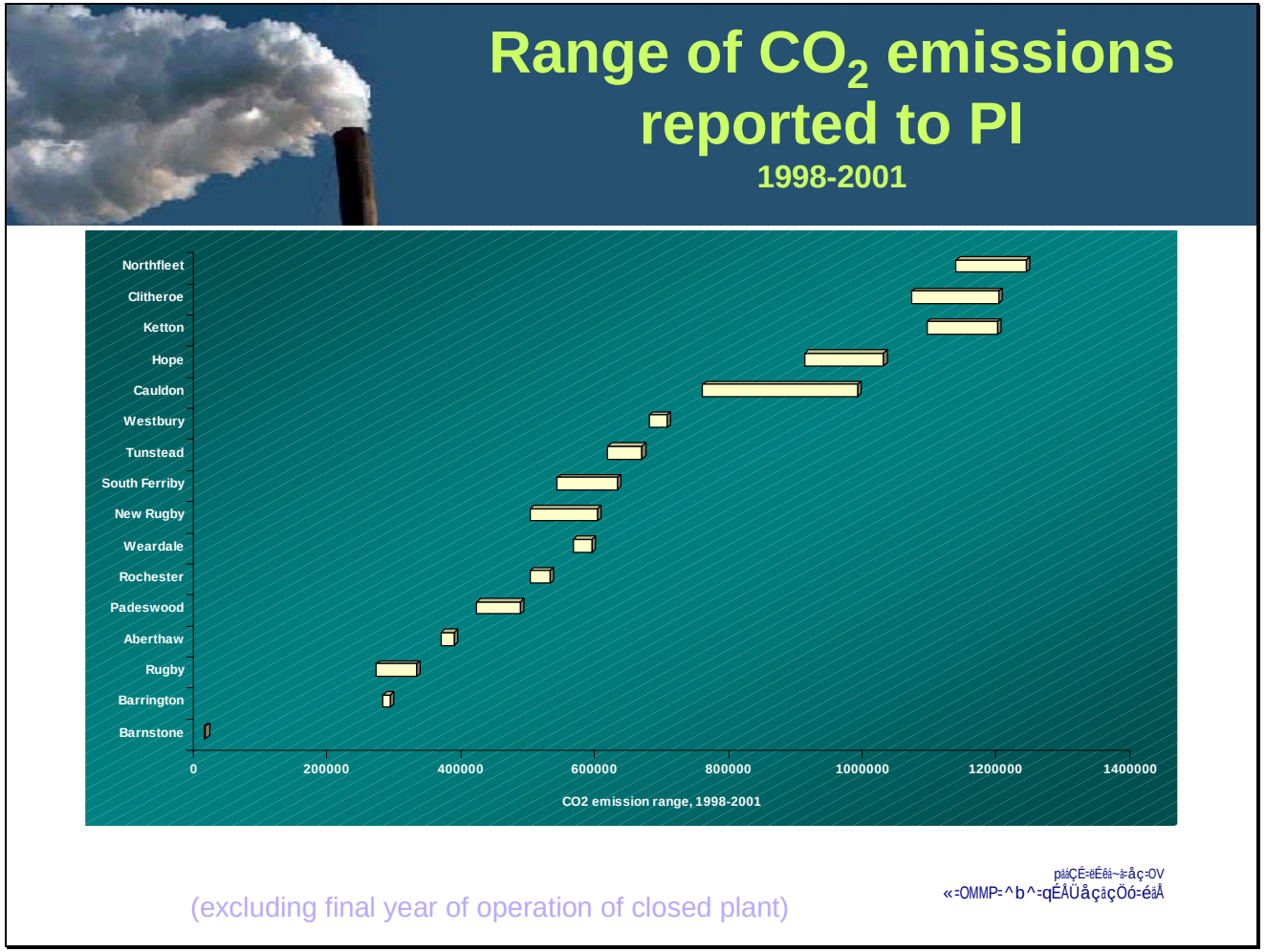
Conclusions for NO_x

- Northfleet stands out as having particularly high emissions
  - → Requires further investigation
- Recommend emission factor of 3.27 kg NO_x per tonne clinker


CO_2 versus production (outliers removed)
CO2 emissions, t
1400000
1200000
1000000
800000
600000
400000
200000
0
0
200
400
600
800
1000
1200
1400
1600
Production, kt
RMC
RMC
(PI 2000)
Best fit line = 939 t CO_2 / kt clinker production

CO_2 – some gaps

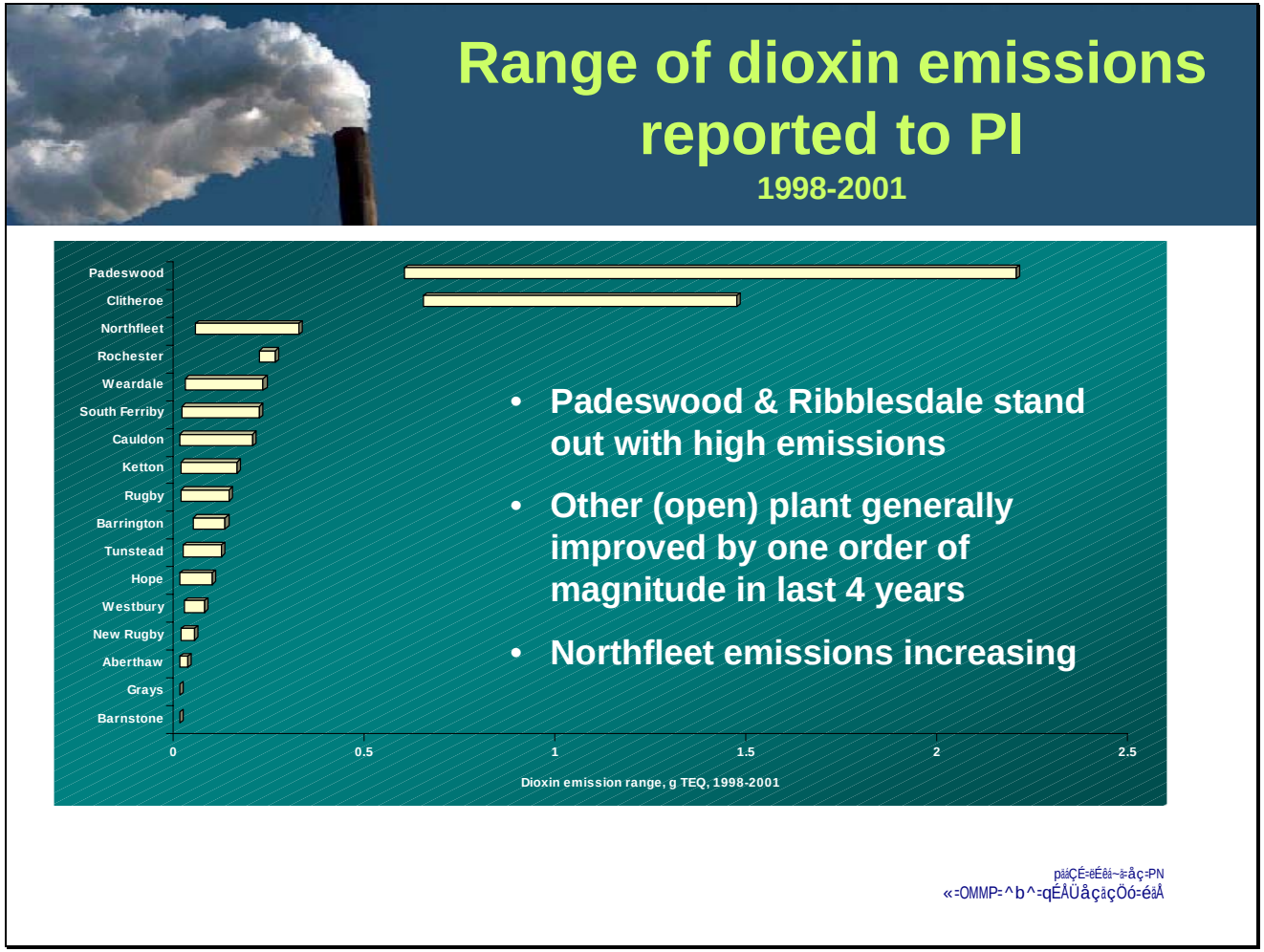
- No data reported for:
  - Tarmac Tunstead, 1998 and 1999

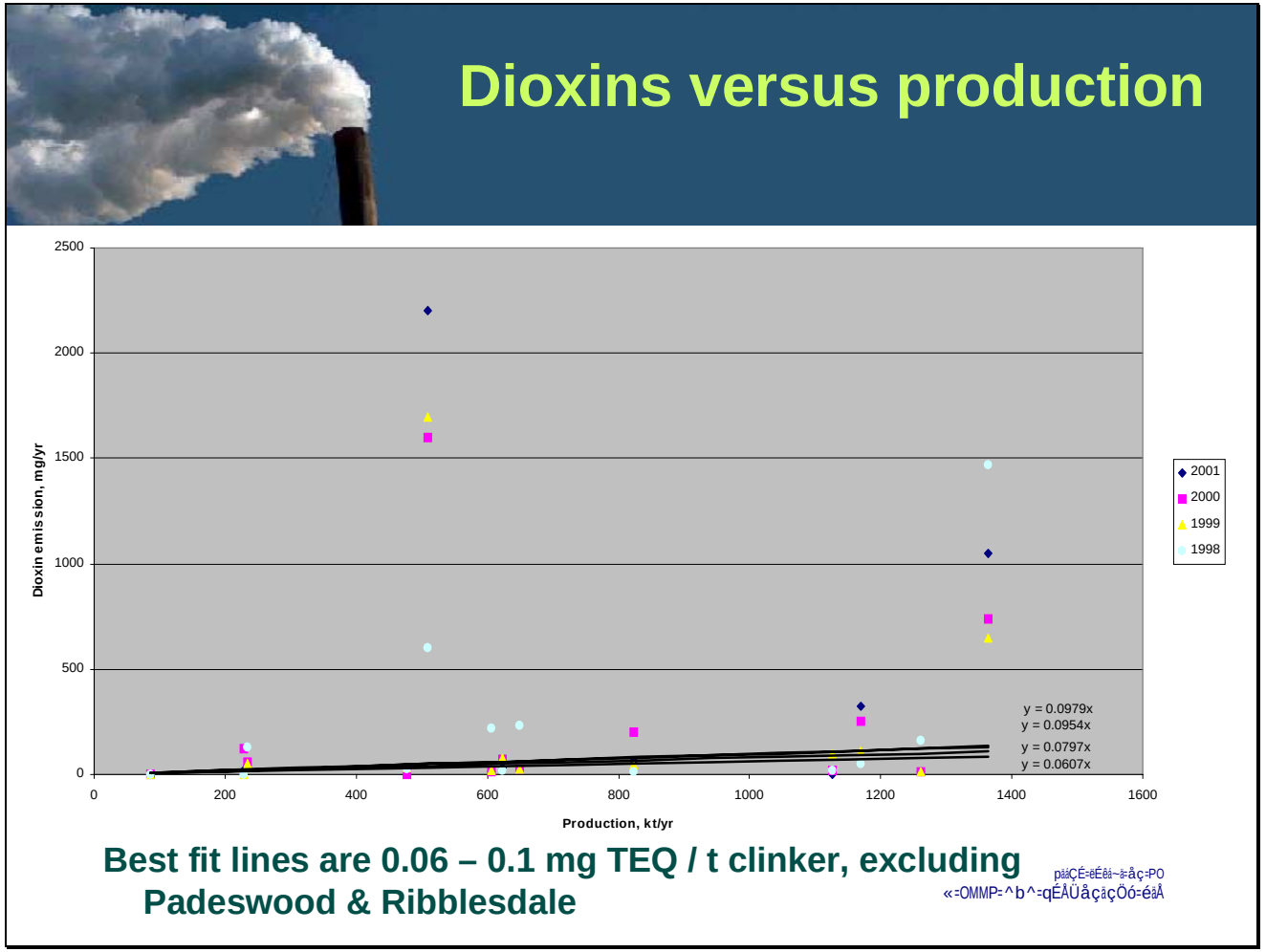

Range of CO_2 emissions reported to PI
1998-2001
Northfleet
Clitheroe
Ketton
Hope
Cauldon
Westbury
Tunstead
South Ferriby
New Rugby
Weardale
Rochester
Padeswood
Aberthaw
Rugby
Barrington
Barnstone
0
200000
400000
600000
800000
1000000
1200000
1400000
CO2 emission range, 1998-2001
(excluding final year of operation of closed plant)

CO_2 – comparison of emission factors

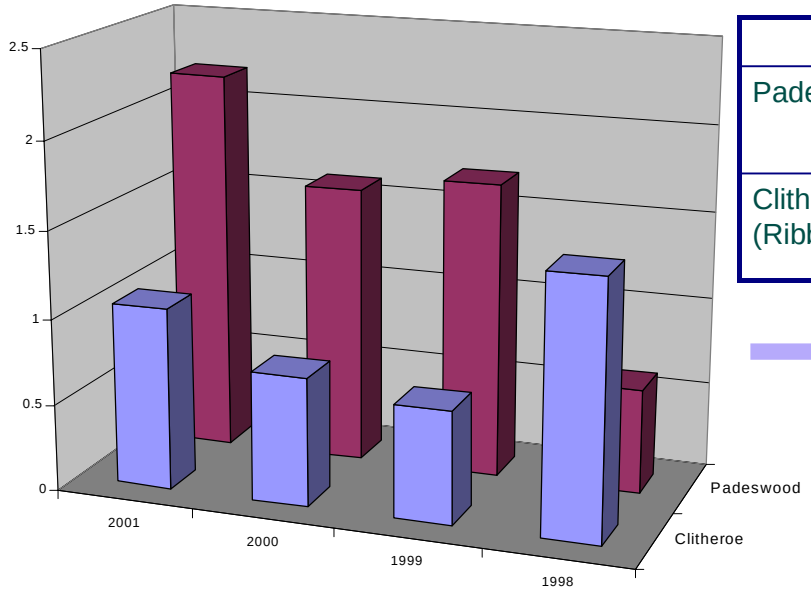
- Regression line above gives 939 kg/t clinker
- BREF gives 800-1040 kg/t clinker
- Blue Circle gives a range of 197-1,056 kg/t PCE, average 768 kg/t PCE which is equivalent to 1,024 kg/t clinker
- Castle Cement data are equivalent to 966-1033 kg/t clinker
- WBCSD (Battelle, 2002) gives a factor of 940 kg/t cement which is equivalent to 1250 kg/t clinker

→ Recommend using an emission factor of 939 kg/t clinker, which has estimated uncertainty of –15% to +33%


Range of dioxin emissions reported to PI
1998-2001
Padeswood
Clitheroe
Northfleet
Rochester
Weardale
South Ferriby
Cauldon
Ketton
Rugby
Barrington
Tunstead
Hope
Westbury
New Rugby
Aberthaw
Grays
Barnstone
0
0.5
1
1.5
2
2.5
Dioxin emission range, g TEQ, 1998-2001
• Padeswood & Ribblesdale stand out with high emissions
• Other (open) plant generally improved by one order of magnitude in last 4 years
• Northfleet emissions increasing


Dioxins versus production
Dioxin emission, mg/yr
Production, kt/yr
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
1600
2001
2000
1999
1998
y = 0.0979x
y = 0.0954x
y = 0.0797x
y = 0.0607x
Best fit lines are 0.06 – 0.1 mg TEQ / t clinker, excluding Padeswood & Ribblesdale

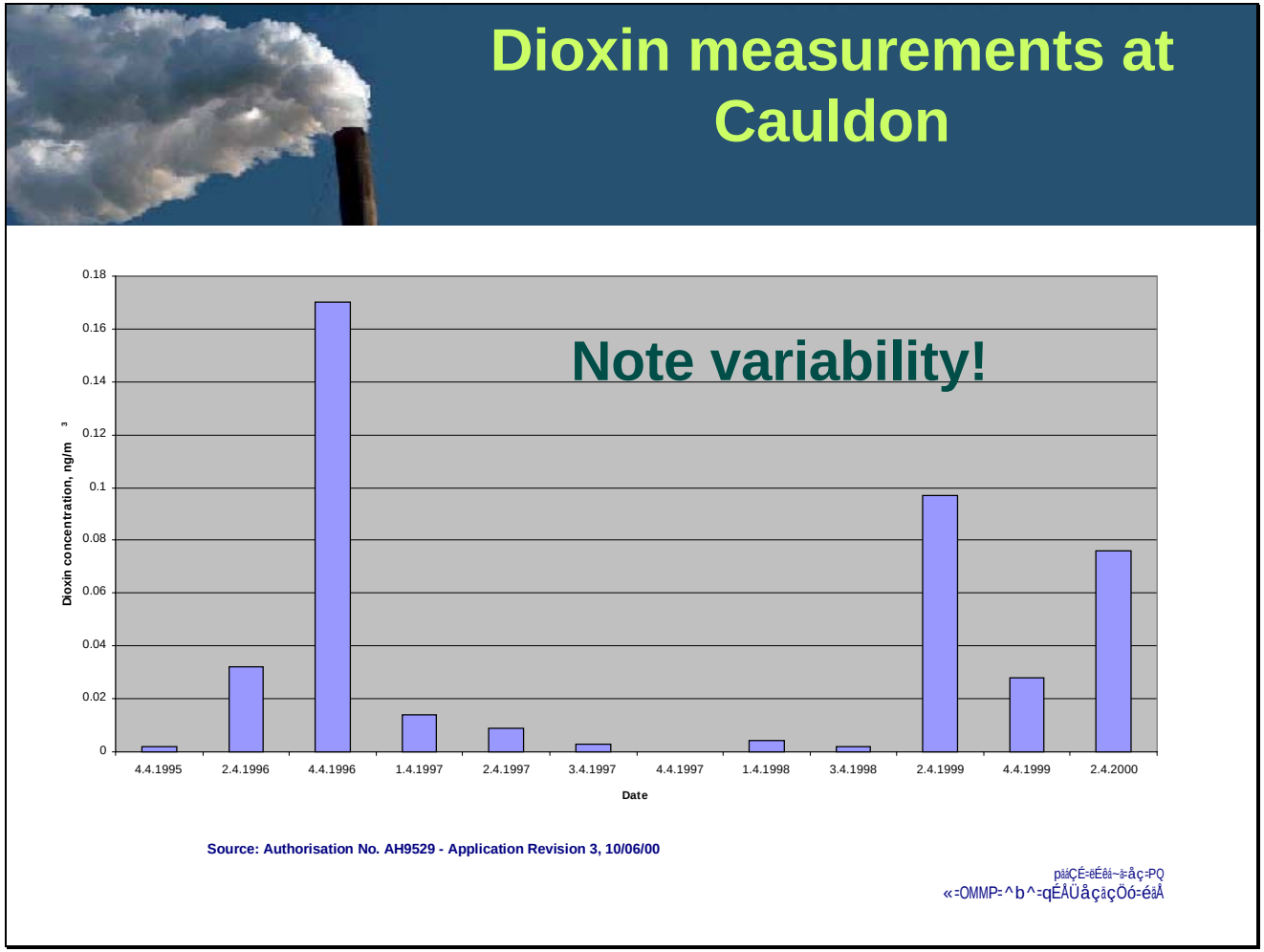
Dioxin trends at top sites

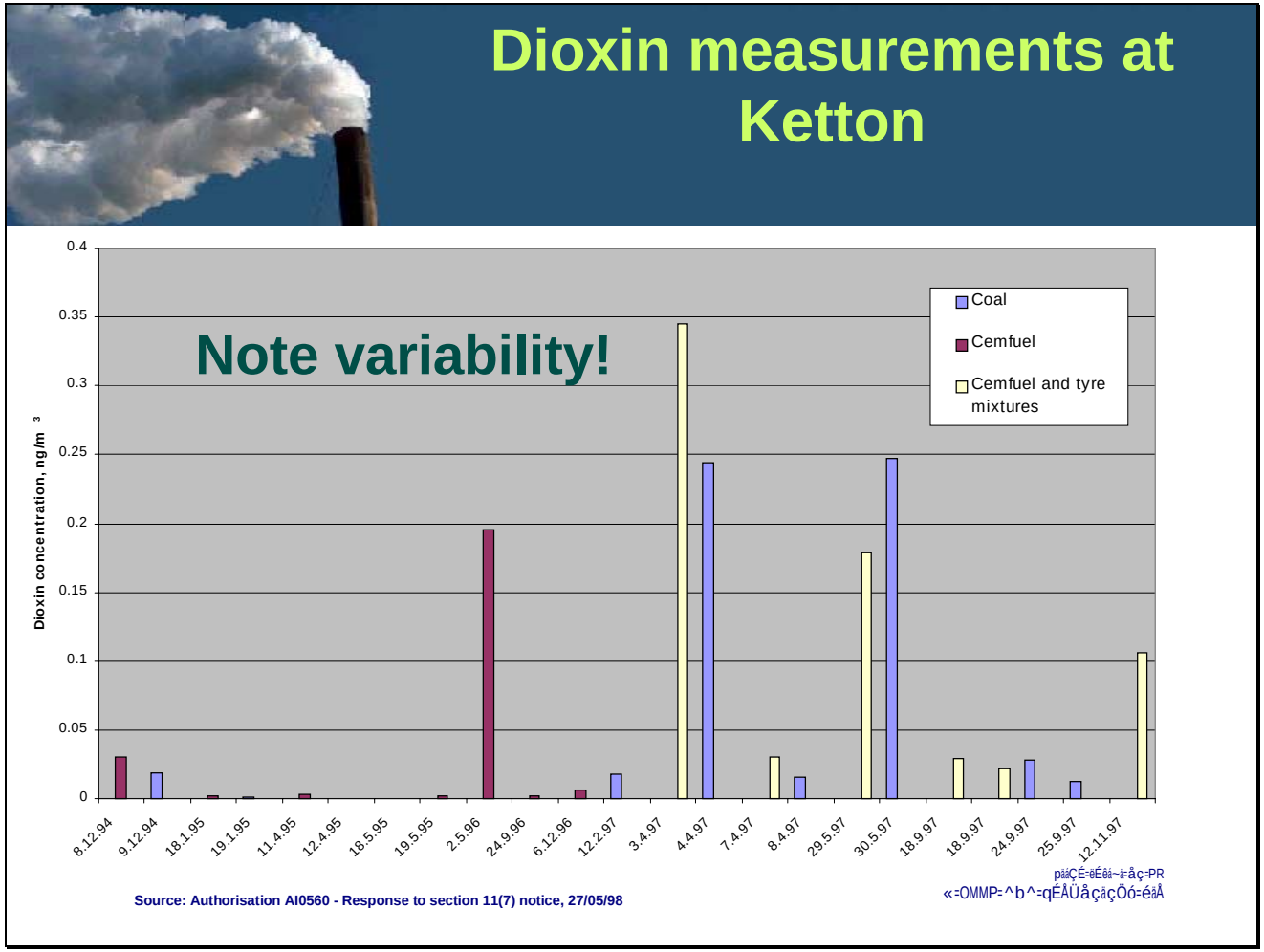


(PI 2000)

	2001	2000	1999	1998
Padeswood	M	E	M	M
Clitheroe (Ribblesdale)	M	M	M	M

→ Castle Cement uses EN 1948, estimates ± 100% uncertainty in the measurements


Dioxin measurements at Cauldon
Note variability!
Dioxin concentration, ng/m3
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
4.4.1995
2.4.1996
4.4.1996
1.4.1997
2.4.1997
3.4.1997
4.4.1997
1.4.1998
3.4.1998
2.4.1999
4.4.1999
2.4.2000
Date
Source: Authorisation No. AH9529 - Application Revision 3, 10/06/00


Dioxin measurements at Ketton
Note variability!
Dioxin concentration, ng/m ³
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Coal
Cemfuel
Cemfuel and tyre mixtures
8.12.94
9.12.94
18.1.95
19.1.95
11.4.95
12.4.95
18.5.95
19.5.95
2.5.96
24.9.96
6.12.96
12.2.97
3.4.97
4.4.97
7.4.97
8.4.97
29.5.97
30.5.97
18.9.97
18.9.97
24.9.97
25.9.97
12.11.97
Source: Authorisation AI0560 - Response to section 11(7) notice, 27/05/98

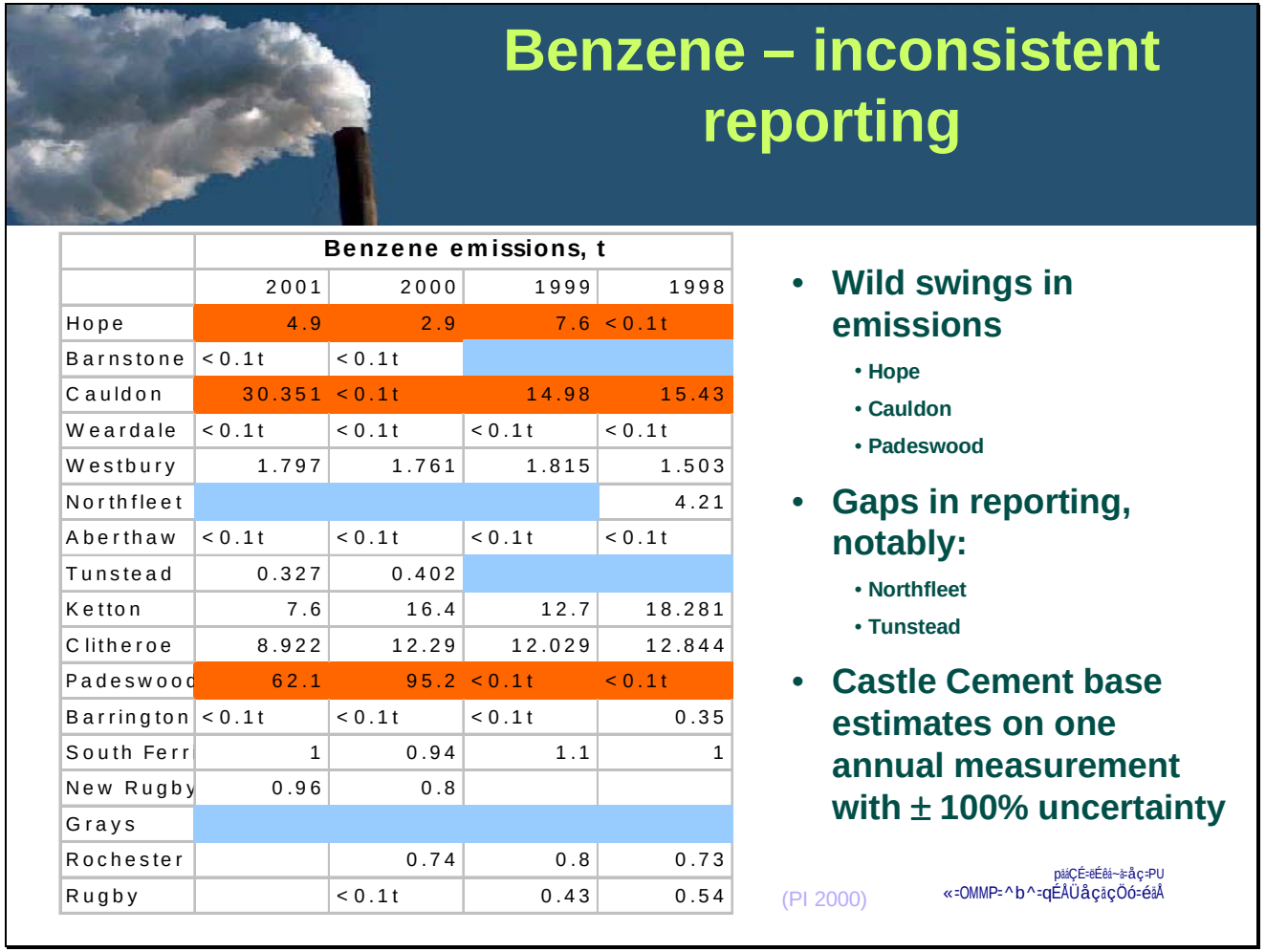
Dioxin measurements at Westbury

	Dioxin concentration, ng/m^3	Uncertainty
Baseline	0.007	± 0.006
25% substitution with alternative fuels	0.011	± 0.007

Source: AEA Technology, Review of Tyre Burning in Cement Kilns, July 2002

Conclusions - dioxins

- Padeswood and Ribblesdale/Clitheroe are major sources within the sector and across the inventory
- Emission returns for these and a number of the sites are based on measurements
- The measurements show large variabilities and uncertainties
- Estimate an emission factor of 0.08 mg TEQ per tonne clinker, with uncertainty range of -100% to +200%.

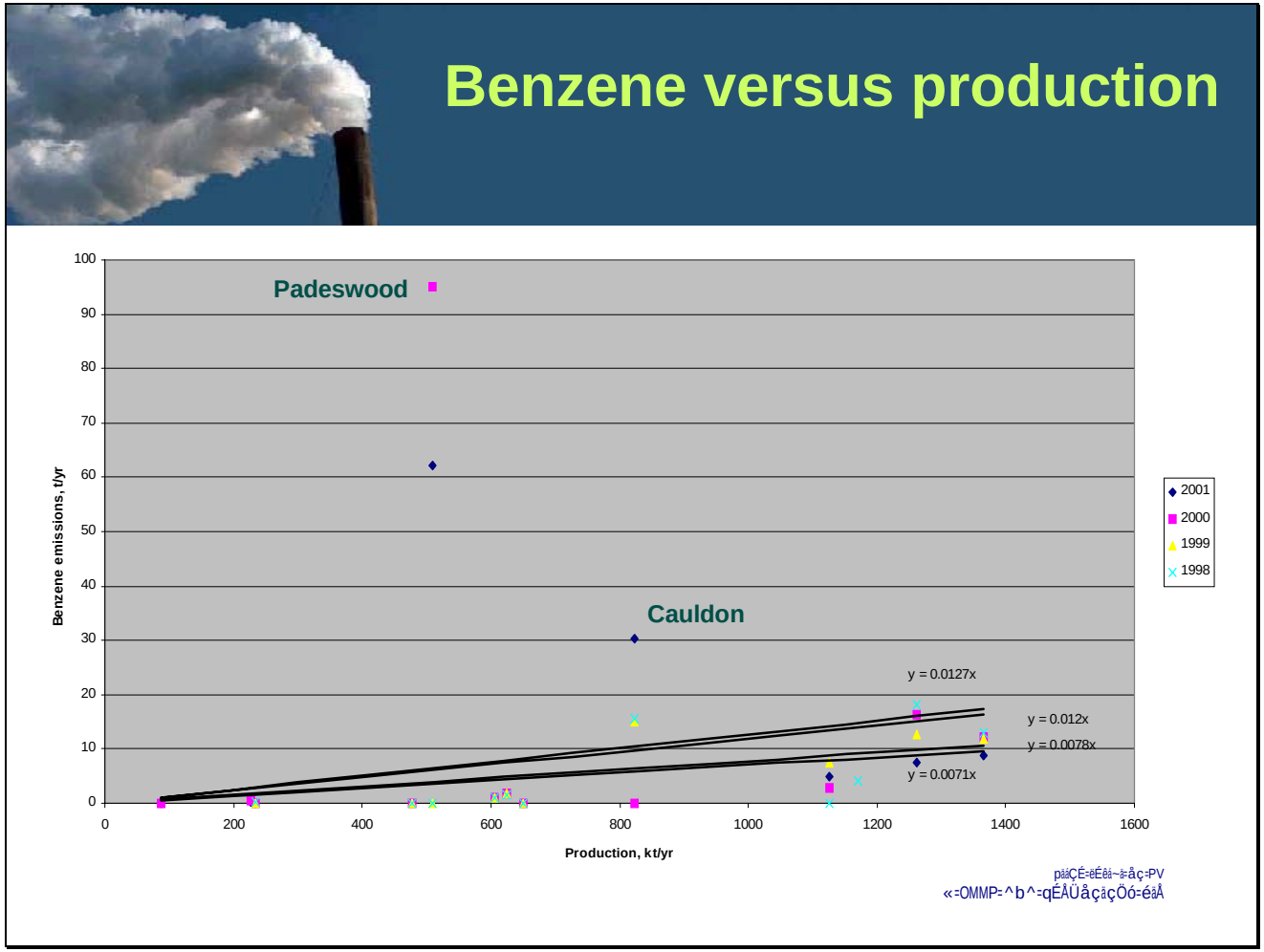


Benzene – inconsistent reporting

	Benzene emissions, t			
	2001	2000	1999	1998
Hope	4.9	2.9	7.6	< 0.1 t
Barnstone	< 0.1 t	< 0.1 t		
Cauldon	30.351	< 0.1 t	14.98	15.43
Weardale	< 0.1 t	< 0.1 t	< 0.1 t	< 0.1 t
Westbury	1.797	1.761	1.815	1.503
Northfleet				4.21
Aberthaw	< 0.1 t	< 0.1 t	< 0.1 t	< 0.1 t
Tunstead	0.327	0.402		
Ketton	7.6	16.4	12.7	18.281
Clitheroe	8.922	12.29	12.029	12.844
Padeswood	62.1	95.2	< 0.1 t	< 0.1 t
Barrington	< 0.1 t	< 0.1 t	< 0.1 t	0.35
South Ferr	1	0.94	1.1	1
New Rugby	0.96	0.8		
Grays				
Rochester		0.74	0.8	0.73
Rugby		< 0.1 t	0.43	0.54

- **Wild swings in emissions**
  - **Hope**
  - **Cauldon**
  - **Padeswood**
- **Gaps in reporting, notably:**
  - **Northfleet**
  - **Tunstead**
- **Castle Cement base estimates on one annual measurement with ± 100% uncertainty**

(PI 2000)


Benzene versus production
Padeswood
Cauldon
Benzene emissions, t/yr
Production, kt/yr
y = 0.0127x
y = 0.012x
y = 0.0078x
y = 0.0071x
2001
2000
1999
1998
0
10
20
30
40
50
60
70
80
90
100
0
200
400
600
800
1000
1200
1400
1600

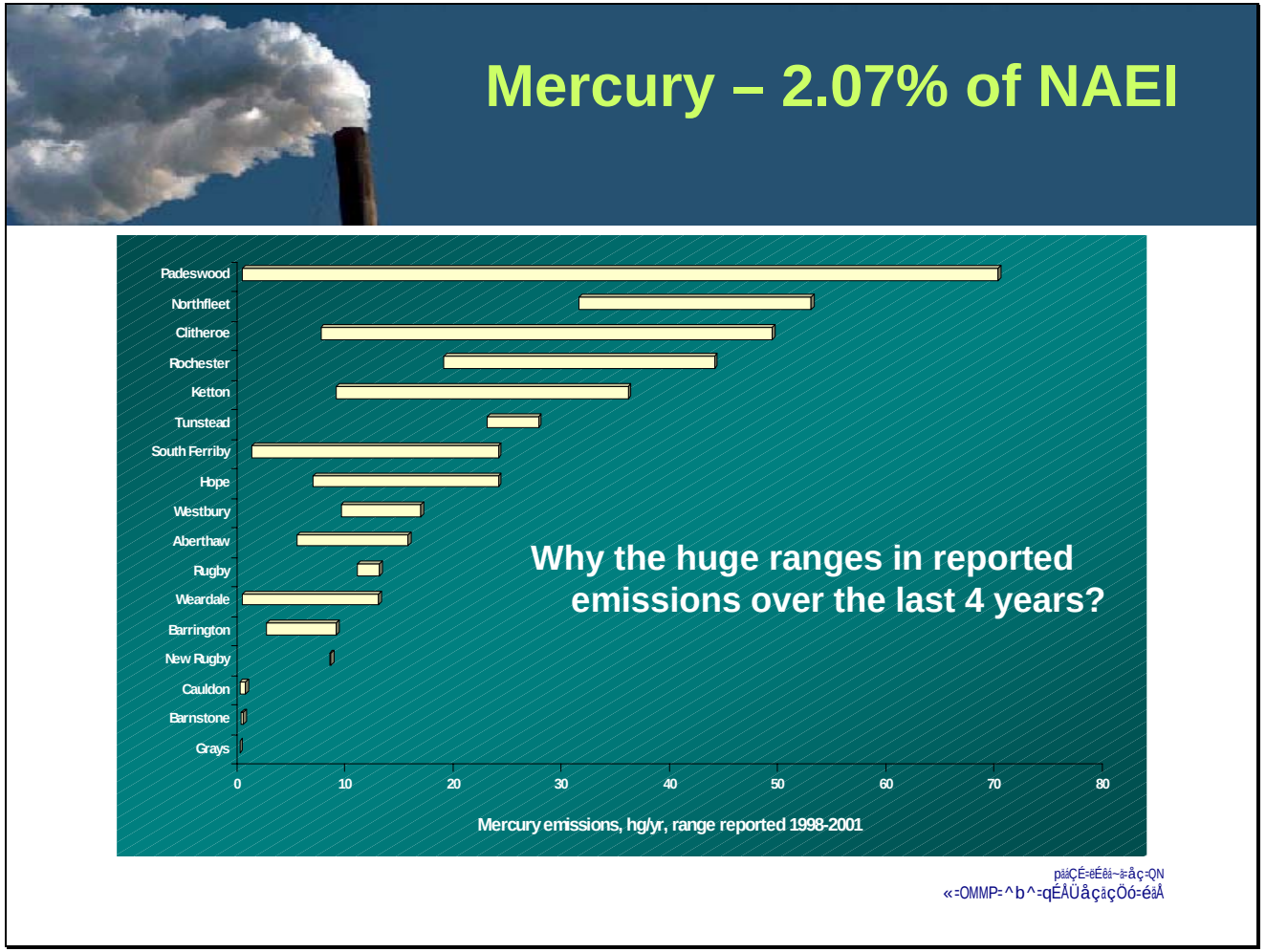
Benzene emission factors

- Including BRT's at reporting threshold value (100 kg) gives range of emission factors of 0.007 to 0.013 kg benzene per tonne clinker
- Excluding BRT's from the calculation gives range of emission factors of 0.008 to 0.016 kg benzene per tonne clinker

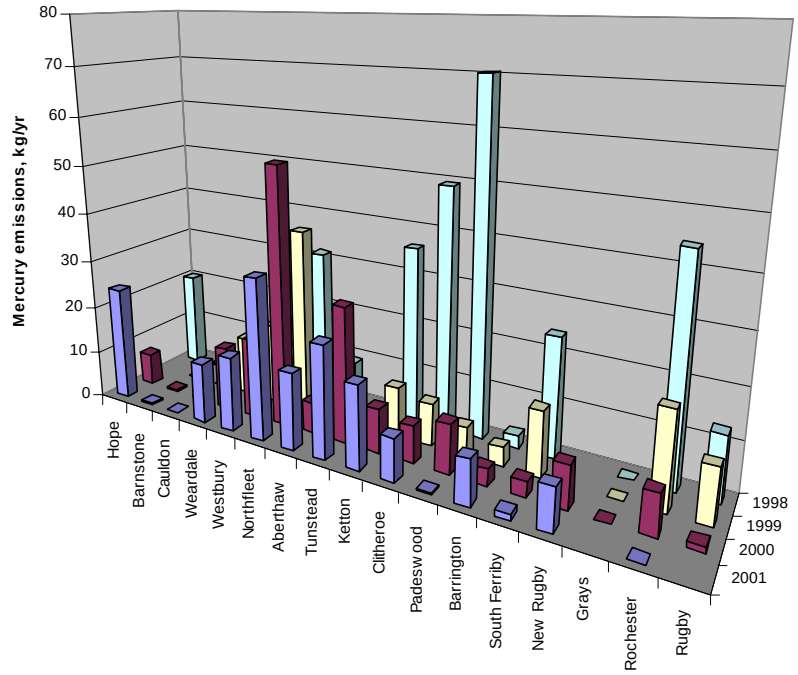
→ Recommend a default emission factor of

0.012 kg benzene per tonne clinker, with uncertainy of ±100%

BUT note high emissions from Padeswood and Cauldon


Mercury – 2.07% of NAEI
Padeswood
Northfleet
Clitheroe
Rochester
Ketton
Tunstead
South Ferriby
Hope
Westbury
Aberthaw
Rugby
Weardale
Barrington
New Rugby
Cauldon
Barnstone
Grays
0
10
20
30
40
50
60
70
80
Why the huge ranges in reported emissions over the last 4 years?
Mercury emissions, hg/yr, range reported 1998-2001

Mercury trends

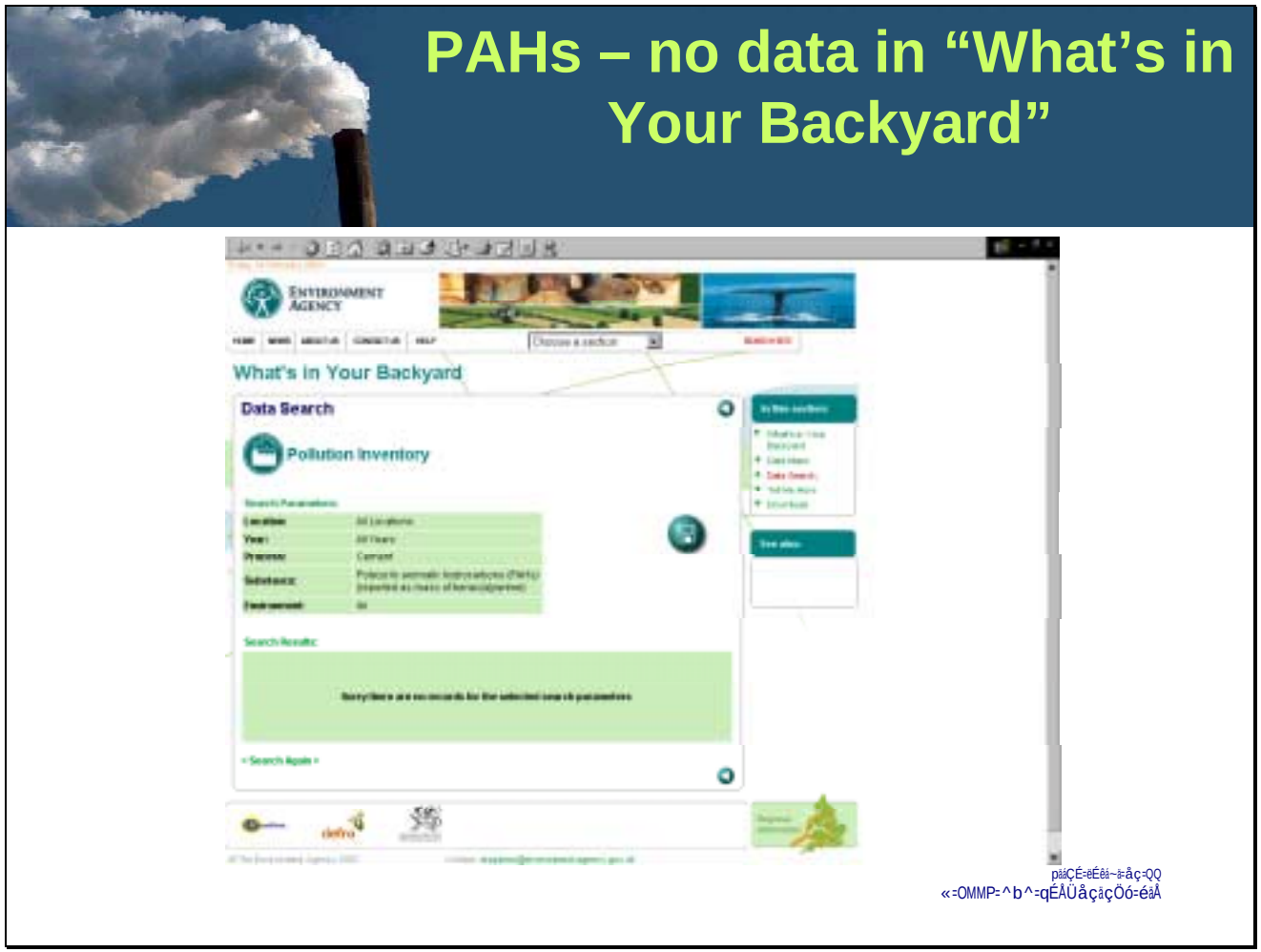


(PI 2000)

- **Several sites showing major emission reductions, recommend confirming this with the sites**
- **Cauldon seems particularly low for its capacity**

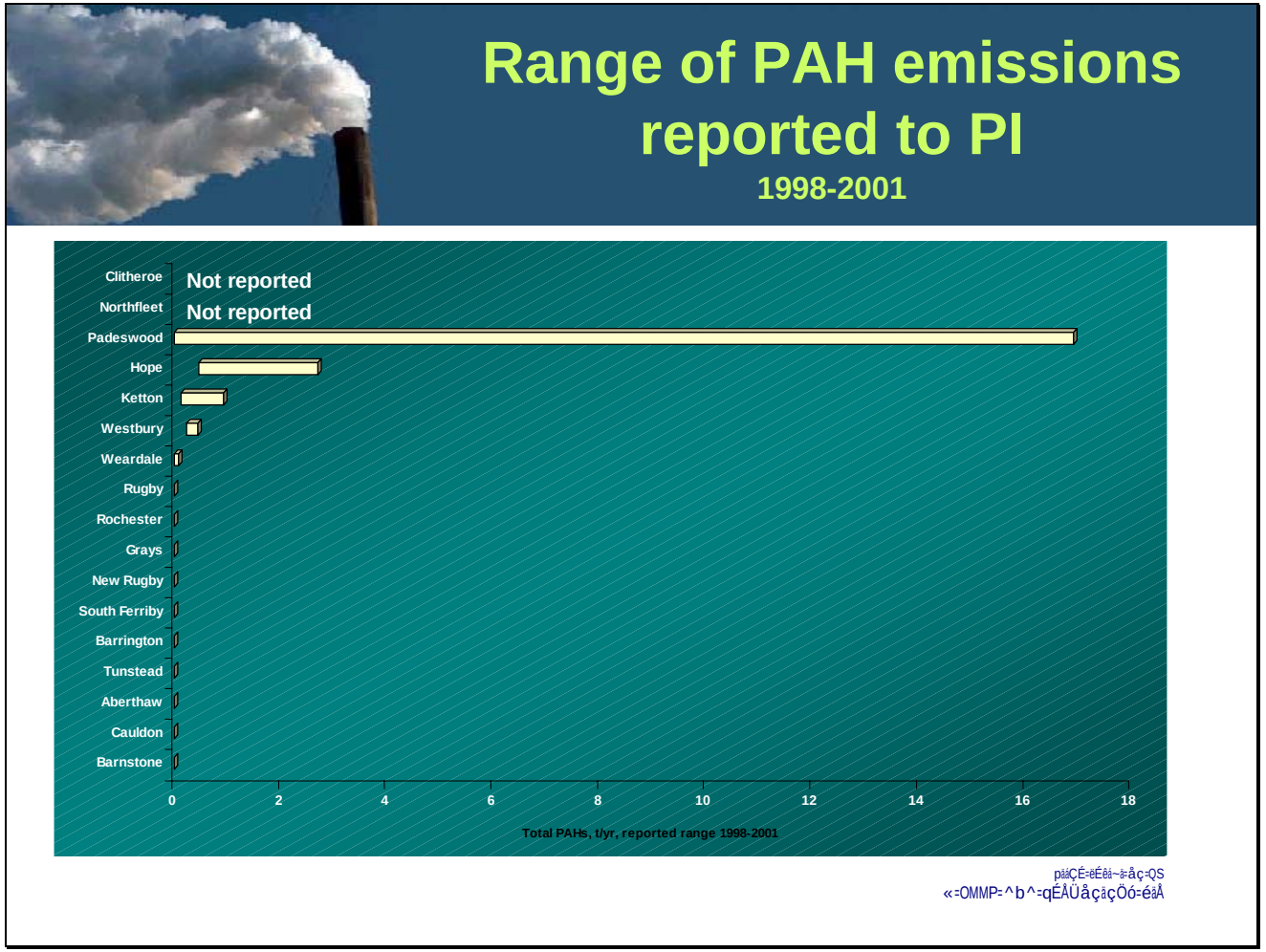
Mercury – some gaps

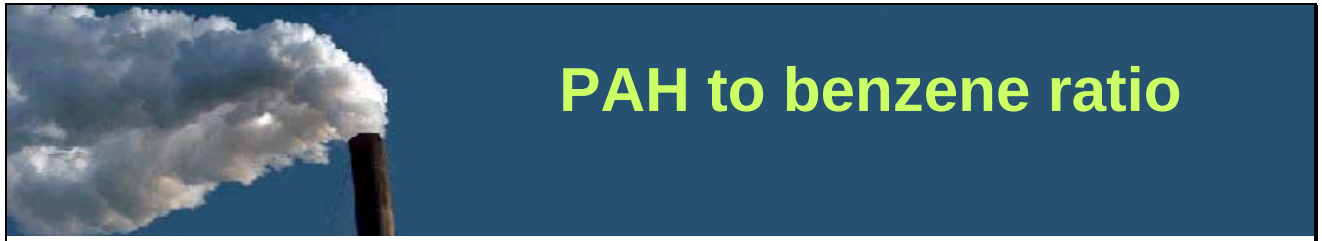
- No data reported for:
  - Tarmac Tunstead, 1998 and 1999
  - Blue Circle Hope, 1999


PAHs – no data in “What’s in Your Backyard”
ENVIRONMENT AGENCY
What's in Your Backyard
Data Search
Pollution Inventory
Search Results
« Search Again »
pâáÇÉ÷ëÉêä~ä÷åç÷QQ
«÷OMMP÷^b^÷qÉÅÜåçâçÖó÷éäÅ

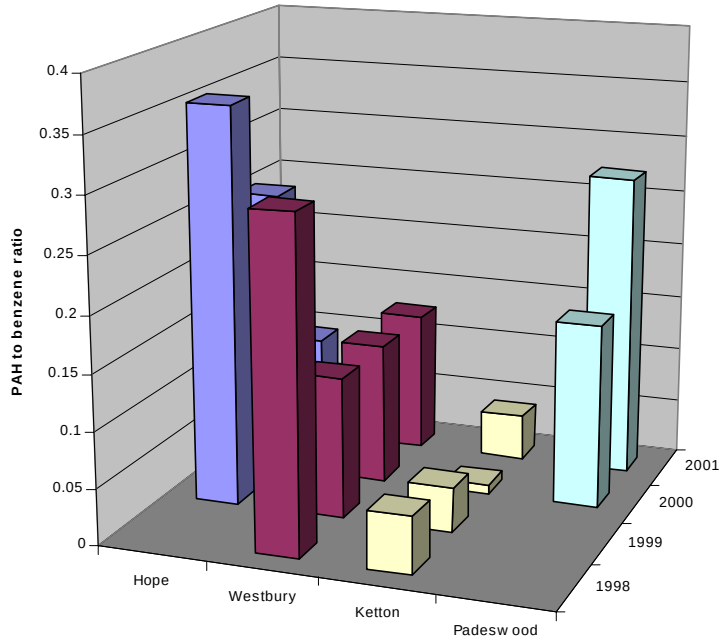
PAHs – data gaps

- No data reported for:
  - Northfleet (all years)
  - Tunstead (1998)
  - Ribblesdale/Clitheroe (all years)
  - Grays (1998 & 2000)
  - Rochester (1999)
- No total PAH but benzo[a]pyrene (BRT) for:
  - Barnstone (2001)
  - Aberthaw (1999-2001)
- No benzo[a]pyrene but total PAH (BRT) for:
  - Barnstone (1998, 1999)
  - Grays (1999, 2001)


Range of PAH emissions reported to PI
1998-2001
Clitheroe
Northfleet
Padeswood
Hope
Ketton
Westbury
Weardale
Rugby
Rochester
Grays
New Rugby
South Ferriby
Barrington
Tunstead
Aberthaw
Cauldon
Barnstone
Not reported
Not reported
0
2
4
6
8
10
12
14
16
18
Total PAHs, t/yr, reported range 1998-2001



PAH to benzene ratio



- There appears to be an empirical relationship between PAHs and benzene
- Range in PAH:benzene ratio between 0.04 to 0.3 (excluding top and bottom extremes)

Missing PAH sources?

- Applying same factors to other large benzene emitters suggests potential PAH emissions from:
  - Cauldon (1 to 9 t/yr estimated for 2001)
  - Northfleet (0.2 to 1.3 t/yr in 1998 – benzene not reported in subsequent years)
  - Tunstead (0.01 to 0.1 t/yr in 2001)
  - Ribblesdale/Clitheroe (0.4 to 2.7 t/yr in 2001, and higher in earlier years)
  - New Rugby (0.04 to 0.3 in 2001)

PAHs – contradictory reporting

- Cauldon:
  - reports <100g of PAH every year
  - reports <100g of benzo[a]pyrene every year EXCEPT 2001: 2.938 kg
- → If this is correct, supports view on previous slide that substantial total PAH emissions may occur
- Hope:
  - reports 0.46 t of total PAH in 2001
  - yet also reports 0.6 t of benzo[a]pyrene in same year

Conclusions I

- Particulates
  - speciation needs improvement
  - source possibly 25% over-estimated due to over-reporting by Tunstead
  - recommend emission factors of 0.053 and 0.26 kg particulate / t clinker for plant with and without fabric filters
- NO_x
  - potential over-estimation of source due to high reporting by Northfleet (requires investigation)
  - some data gaps due to non-reporting by some plant in some years
  - recommend emission factor of 3.27 kg NO_x / t clinker

päÇÉ=èÉê~ã=âç=RM
«=OMMP=^b^=qÉÅÜåçäçÖó=éäÅ

Conclusions II

- CO_2
  - Recommend an emission factor of 939 kg/t clinker, which has estimated uncertainty of –15% to +33%
- Dioxins
  - NAEI estimate strongly influenced by top two emitters Padeswood and Ribblesdale/Clitheroe
  - Recommend scrutiny of basis of emission estimates (measurement data) for these sites
- Benzene
  - Inconsistent reporting suggests large uncertainty, further assessment recommended for Hope, Cauldon, Padeswood, Northfleet, Tunstead

Conclusions III

- Mercury
  - Very varied emissions may be due to substantial emission reductions in recent years… but could simply be large uncertainties; recommend testing with the sites
  - Cauldon is reporting particularly low emissions for its capacity, recommend testing this
  - Recommend also checking Cd, Cu
- PAHs
  - Data look unreliable – many gaps, evidence of inconsistencies, suspected under-reporting: recommend exploring basis of estimates and null returns with sites

Bibliography I

- CIF (Australian Cement Industry Federation), 'Cement Industry Environment Report', http://www.cement.org.au/environment.htm (undated).
- IPPC S3.01, Guidance for the Cement and Lime Sector, Version 1, April 2001.
- ENDS Report 336, 'Pollution inventory shows standstill on dioxin and PAH emissions', January 2003, pp. 10-11.

Bibliography II

- European IPPC Bureau, Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries (BREF Note), December 2001.
- Battelle, 'Toward a Sustainable Cement Industry', 2002.