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EU Emissions Trading Scheme – further approaches to benchmarking in steel and cement sectors

Science Report – SC070011

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Steve Killeen

Head of Science

Executive Summary

The European Commission published a proposal[1] on 23 January 2008 to amend the EU Emissions Trading Scheme, which allows for *"transitional free allocation to installations … through harmonised Community-wide rules ('benchmarks') in order to minimise distortions of competition with the Community. These rules should take account of the most greenhouse gas and energy-efficient techniques, substitutes, alternative production processes, use of biomass, renewables*". As such, benchmarking is expected to be a suitable allocation method to sectors as long as free allocation is deemed necessary due to international competition pressures.

This project will inform the UK Government and the Environment Agency positions on benchmark-based emissions allocations for Phase III of the EU Emissions Trading Scheme (EU ETS). The aim of the project is to investigate to what extent the benchmarks already developed in the UK for the EU ETS (Phase II benchmarks for new entrants, termed 'NE Ph II BMs') are suitable for incumbents in Phase III. The report also looks at potential alternatives to the NE Ph II BMs and considers the key issues that could arise from applying a UK-centred benchmark at the EU level. It is not within the scope of this study, however, to recommend any particular benchmark method(s) for Phase III incumbents. The main research and analysis was undertaken in autumn/winter 2007.

Benchmarks can be applied in a variety of ways, with this study focussing on the use of benchmarks to set allowance distributions within an externally determined sectoral cap for the UK. This is a form of 'top-down' benchmarking. Only limited consideration has been given to 'bottom-up' benchmarking in the report. No consideration has been given to the impacts of bottom-up benchmarking in the absence of sectoral caps and to cross-sectoral implications. Findings presented in this summary relate only to 'top-down' benchmarking.

The issues have been explored by analysing two sectors (cement and iron/steel), selected due to their carbon intensity and vulnerability to international competition. As such, most findings are sector-specific, although we have sought to draw out more general findings where possible. The suitability of different benchmarking formulae is assessed against feasibility, environmental effectiveness and economic criteria.

Findings

Cement sector

The NE Ph II BM for cement is standardised, with no differentiation for raw materials, fuels or technologies, and applies a specific energy consumption (SEC) factor applicable to the best performing examples of the most energy efficient technology type. There are no feasibility issues in applying this to Phase III incumbents and it encourages clean technology through its standardised approach. Within the study's assumptions, cost impacts by installation, company and kiln type compared to NAP II allocations are not considered significant (less than the cost of transporting clinker for 100 km on land) in the context of the company's ability to pass on costs and compete with each other. However, this method standardises factors that incumbents have

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[1] Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC to improve and extend the greenhouse gas emission trading system of the Community. COM (2008)

limited control over (raw material moisture and non-carbonate carbon) and leads to slightly more extreme cost impacts (positive and negative) at installation level versus NAP II allocations compared to methods that take account of site-specific factors. Using the NE Ph II BM at an EU-wide level may, in general, lead to a more stringent allocation for UK kilns relative to their current emissions in comparison to kilns in other Member States.

Of all the methods considered (including the NE Ph II BM), the standardised method with differentiation for site-specific moisture and non-carbonate carbon (referred to as 'A1-0T' in this study) performs best against the criteria, as this also has an SEC based on the best performing examples of the most energy efficient technology. This formula allows for differentiation on basis of raw material moisture over which operators have limited control. At an EU level, failure to differentiate by raw material characteristics (especially moisture) would lead to a relative deficit in allocations to UK installations (and others in North West EU), given the high moisture content geology in this region.

Other options include more differentiation, including technology differentiation (3 and 4 types) and allowance for site-specific kiln bypass. Compared to the rest of the EU, the UK has a larger than average proportion of less energy-efficient kilns and lower than average use of renewable fuels. However, differentiation by technology or fuel at an EU level would not help to encourage clean technology.

The above conclusions are highly sensitive to the policy context assumptions, e.g. the illustrative sectoral caps applied. The choice of formulae as well as parameter values (e.g. SEC) would have to be revisited under specific Phase III assumptions.

Integrated iron and steel sector

The NE Ph II BM for integrated steel is broken down into individual benchmarks for each main process stage, based on best performance of currently operating plants in the UK, and using natural gas as the benchmark fuel for on-site boilers. The design of this method was heavily influenced by its role in benchmarking new entrants (mainly modifications to existing plants) and also government steers to benchmark only direct emissions from equipment covered by the scheme.

This method could be feasible for Phase III incumbents. For each process stage, the method is standardised so should encourage clean technology. Added costs compared to the NAP II allocations are below transportation costs, are in line with other input cost fluctuations and are not thought to have significant distributional impacts.

However, at an installation level, the NE Ph II BM method leads to more extreme cost impacts (positive and negative) versus NAP II allocations compared to the alternative method. The alternative method is based on a more aggregated approach whereby all upstream processes are covered by a single benchmark (avoiding the need to calculate complex energy balances between individual processes and including boilers), separate from the less carbon-intensive downstream processes. The other key difference is that boiler plants are benchmarked by actual fuel type rather than natural gas.

Overall, the alternative method performs slightly better against the criteria than the NE Ph II BM, although its design would require further consideration of imports/exports of key materials such as coke, sinter, pellets and directly reduced iron in order to reduce risk of carbon leakage through intermediate products. This report does not consider 'bottom-up' benchmarking, which is where the advantages of the alternative method would be more apparent, particularly in terms of economic impacts.

At an EU level, differences in raw material flows, fuel types, process boundaries, and other factors would need to be considered to understand the impacts of a UK-based benchmark on the EU or an EU-based benchmark on the UK. However, whilst there are many causes of differences in emissions at an installation level, overall emission factors for integrated steelmaking are expected to be broadly similar across the EU.

Electric arc steelmaking sector

The NE Ph II BM for electric arc furnace (EAF) steelmaking is differentiated across seven main types of steel product, and is based on best current performance of EAF plants in the UK. The method could be feasible for Phase III incumbents and it is standardised for each product type, so should encourage clean technology. Added costs compared to NAP II allocations do not appear to lead to significant distributional impacts at a plant level, although modelling of economic impacts is quite uncertain due to data limitations (such as exact product mix by each installation).

The alternative method mainly seeks to achieve certain incremental refinements to the NE Ph II BM, including accommodation of specific product mixes at each site; allowance for additional emission sources for stainless steel; additional differentiation for large product types; and integration of boiler plants within the overall benchmark.

This is expected to perform well compared to the NE Ph II BM, although data limitations have restricted the extent of analysis possible.

At an EU level, similarities in process technologies, fuels (mainly natural gas) and products provide a good basis for EU-wide benchmarks, although additional product differentiation may be required. Due to data limitations, it is not currently possible to estimate the impacts of a UK-based benchmark on the EU or vice versa.

Wider findings

The applicability of the Phase II New Entrant Benchmarks to Phase III incumbents will vary from sector to sector. Specifically:

- The criteria used to develop NE Ph II BM included feasibility, incentivising clean production and competitiveness impacts, with an overriding steer to develop standardised benchmarks to ensure transparency, simplicity and incentivisation of clean technology. These benchmarks would generally score well against the feasibility and environmental effectiveness criteria used in assessing Phase III incumbent benchmarks. Differentiation was only generally applied for different products (such as types of lime).
- The main potential trade-off is with competitiveness, and the extent of this impact under an EU-wide benchmark will depend on how the UK sector compares with the rest of the EU in terms of raw material, fuel and technology.
- For sectors where NE Ph II BM were broken down into different process units, particularly to allow for allocation for modification of existing plants, more aggregated benchmarks might be more suitable to incumbents, for example, to allow for the variation in energy flows among different processes. The integrated steel sector considered in this report is a good example of this.
- The fundamentally different application of benchmarks to incumbents (generally with historic data) versus new entrants (without historic data) would be expected to lead to minor modifications to the NE Ph II BM so that they were based on actual production, activity levels, product mixes and so on rather than the standardised assumptions for new entrants.
- Developed within a tight timescale though with extensive stakeholder consultation and peer review, the NE Ph II BM may need further refinement.

If benchmarks are applied across EU sectors, the chosen formula will affect the implicit sectoral cap for a country, and how it compares to the NAP II allocation or

2005-2007 emissions. Therefore, variations in installation performance at an EU level are important. Ongoing data collection by EU sectoral associations should allow accurate assessment of proposed benchmarking formula in the near future.

The economic impacts of applying different benchmarking formulae are softened by their combination within an overall sectoral cap. Due to cost pass through thresholds, the effects of switching from one potential formula to another must be assessed in the context of the actual sectoral cap and ratio of auctioned allowances.

A transitional phase benchmark is only relevant where the balancing of economic impacts and environmental effectiveness requires short-term differentiation on the basis of technology or other aspects that the operators have a choice over in the medium to long term. Under the assumptions applied to this analysis, transitional benchmarks do not appear to be relevant for the cement and iron/steel sectors.

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Contents

1 Introduction

1.1 Purpose

This report will help to inform the UK Government and Environment Agency positions on benchmarking as an allocation method during Phase III of the EU Emissions Trading Scheme (EU ETS). Project findings aim to assist the UK's participation in the European Commission's review of the EU ETS.

1.2 Background

Benchmarked allocations in Phase III of EU ETS

Auctioning is considered the most efficient method of allocation from an economic point of view. Due to concerns about competitiveness in the absence of a global carbon market, benchmarking is discussed as a possible allocation method to sectors vulnerable to international competition. Benchmarking, as an alternative to grandfathering, should provide greater incentive for investing in low carbon technology. It should prove a suitable allocation method to such sectors until a global carbon market emerges.

This project focuses on two sectors which combine carbon intensity and exposure to international competition: cement and iron/steel.

This study was commissioned in August 2007 and was undertaken mostly before the European Commission climate and energy package of January 2008 was published.

Phase II new entrant reserve (NER) benchmarks

Under a research project for the Department for Business, Enterprise and Regulatory Reform (BERR) in 2006, benchmarks were developed to generate free allocations for Phase II new entrants and other incumbent installations lacking appropriate historical emissions data. The work involved reviewing and validating the benchmarks used to determine the allocation of emissions allowances to new entrants and other installations for Phase I of the EU ETS, and to determine whether any changes to these benchmarking approaches should be considered for Phase II.

BERR commissioned a number of separate contracts within this overall project, with each contract focussing on a specific sector covered under Phase II.

The choice of benchmarks for Phase II was based on the following agreed evaluation criteria, together with government steers on the use and weighting of these criteria.

- *Feasibility*: Can the input data to the benchmark be verified? Are benchmarks based on 'best practice' for new entrants? Can factors be replicated by a third party? Are benchmarks based on readily available data?
- *Incentives for clean technology for new entrants*: Are benchmarks standardised, avoiding differentiation of raw materials, technologies and fuels?

- *Competitiveness and impact on investment*: Is the proposed benchmark likely to meet needs for a future new entrant? If not, what is the potential impact in emissions and monetary terms?
- *Consistency with incumbent allocations*: How would an allocation using the proposed Phase II benchmark compare against Phase I allocations and relevant emissions?

Furthermore, for Phase II, Government moved away from the integrated approach[2] which applied to a few sectors in Phase I, and focussed on developing benchmarks corresponding only to direct emissions from equipment covered by the scheme.

The work, undertaken within tight timescales, involved the extensive collection and analysis of information including contacts with key stakeholders for the sectors. Draft reports were consulted on as part of BERR's consultation on Phase II new entrants' benchmarks in March and April 2006. Furthermore, the work was subject to peer review by sector experts appointed by BERR.

The outcome of the work was a spreadsheet for the calculation of benchmarked allocations, with a series of separate supporting reports covering each sector. These are available at www.berr.gov.uk.

1.3 Scope of project

This study focuses on the use of benchmarks as a method for distributing sector caps in the UK[3] and aimed to answer the following questions, as set out in the project specification:

- To what extent are Phase II NER BAT benchmarks[4] suitable for incumbents?
- Is there a need to update Phase II benchmarks for the NER and incumbents?
- What is the feasibility and cost to the sector of having a BAT benchmarks?
- What would be the competitive/distributional effects of using BAT benchmarks in the sector?
- Is there a need for a transitional phase which may take into account certain site-specific factors for incumbents?
- If so, what should that benchmark look like and what would be the competitive and distributional effects of this benchmark?
- What would be the effect on intra-UK/intra-EU/extra-EU competition for UK sectors?

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[2] Under the integrated approach, the benchmark corresponded not only to the direct emissions from the new/modified equipment, but also to emissions arising elsewhere at an affected site as a result of the new/modified equipment, for example due to an increase in capacity of existing equipment.

[3] There are several bottom-up allocation illustrations on the basis of benchmarks without the use of an externally determined sectoral cap. These are used primarily to illustrate differences among the different benchmarking formulae considered, which are reduced by the application of a sectoral cap.

[4] Here BAT is defined as best available techniques and technologies commercially available to operators and does not correspond to the meaning adopted under the IPPC Directive.

- What would be the implications for monitoring, reporting and verification (MRV)?
- How would a UK incumbent benchmark affect the distribution of allowances EU-wide across the sector?
- What would be the key issues for other Member States in using UK-developed benchmarks?

The project is not intended to develop actual benchmarks for Phase III, nor is it aimed at determining allowance caps for the focus sectors.

This report relies on desk-top research and industry consultation to provide answers to these questions.

1.4 Report structure

This report is structured as follows:

Section 2: Approach

Section 3: Cement sector analysis

Section 4: Integrated steelworks analysis

Section 5: Electric arc furnace analysis

Appendix A: List of options for cement, integrated steelworks and electric arc furnace

Appendix B: Effects of bottom-up allocation to the cement sector – Added costs

2 Approach

This section sets out the evaluation criteria used to assess the benchmark formulae, parameters and parameter values. The general approach to developing benchmarking formulae is then discussed.

2.1 Criteria for this study

A full multi-criteria analysis would require four steps for the evaluation criteria: (i) establish criteria, (ii) operationalise criteria (quantify where possible), (iii) weigh criteria (prioritise by giving numerical weight) and (iv) assess options on basis of criteria. Quantification at the second stage allows for a quantified weighting and ranking at the assessment stage. Difficulties in quantification at this stage can lead to inaccuracies and to an overall false precision of the assessment. As a result, we use a ‘performance matrix’ which emphasises the trade-offs between the different criteria without converting them to a ‘single currency’ or applying quantified weights.

The criteria considered for the cement and iron/steel benchmarks (BM) include the following three themes:

- Feasibility - Can a benchmark be derived and applied?
- Environmental effectiveness - Does the BM achieve environmental benefits?
- Economic impacts - Does the BM have a negative economic impact?

The cement, and particularly the iron and steel sectors are extremely complex. It is important to ensure that the benchmark method is feasible at design as well as at implementation. The assessment of different benchmarking options requires the type of data needed both for the design and the implementation of actual benchmarks. The availability of data allows us to assess the feasibility of options to some extent; this is aided by a section where monitoring, reporting, and verification are considered.

Environmental effectiveness can be assessed with regards to overall emission reductions and the incentivisation of clean production. In the context of this report − benchmarking options under a ‘top down’ cap defined separately − the only relevant aspect for this criterion is incentivisation of clean production. The less differentiation by fuel, raw material, technology etc., the more environmentally effective the benchmark.

Setting a sectoral cap is outside the scope of this project; the main focus of the economic analysis is the distributional equity of options and balancing incentivisation of clean technology with economic impacts related to the ‘stranded assets’[5] of operators.

The specific criteria and proposed methods for ‘operationalisation’ are presented in Table 2.1. These criteria are solely for the purpose of this project and do not represent a government view on the actual criteria for benchmarks in Phase III of EU ETS.

[5] ‘Stranded asset’ is defined as an asset that is worth less on the market than it is on a balance sheet due to the fact that it has become obsolete in advance of complete depreciation. Source: www.investorwords.com

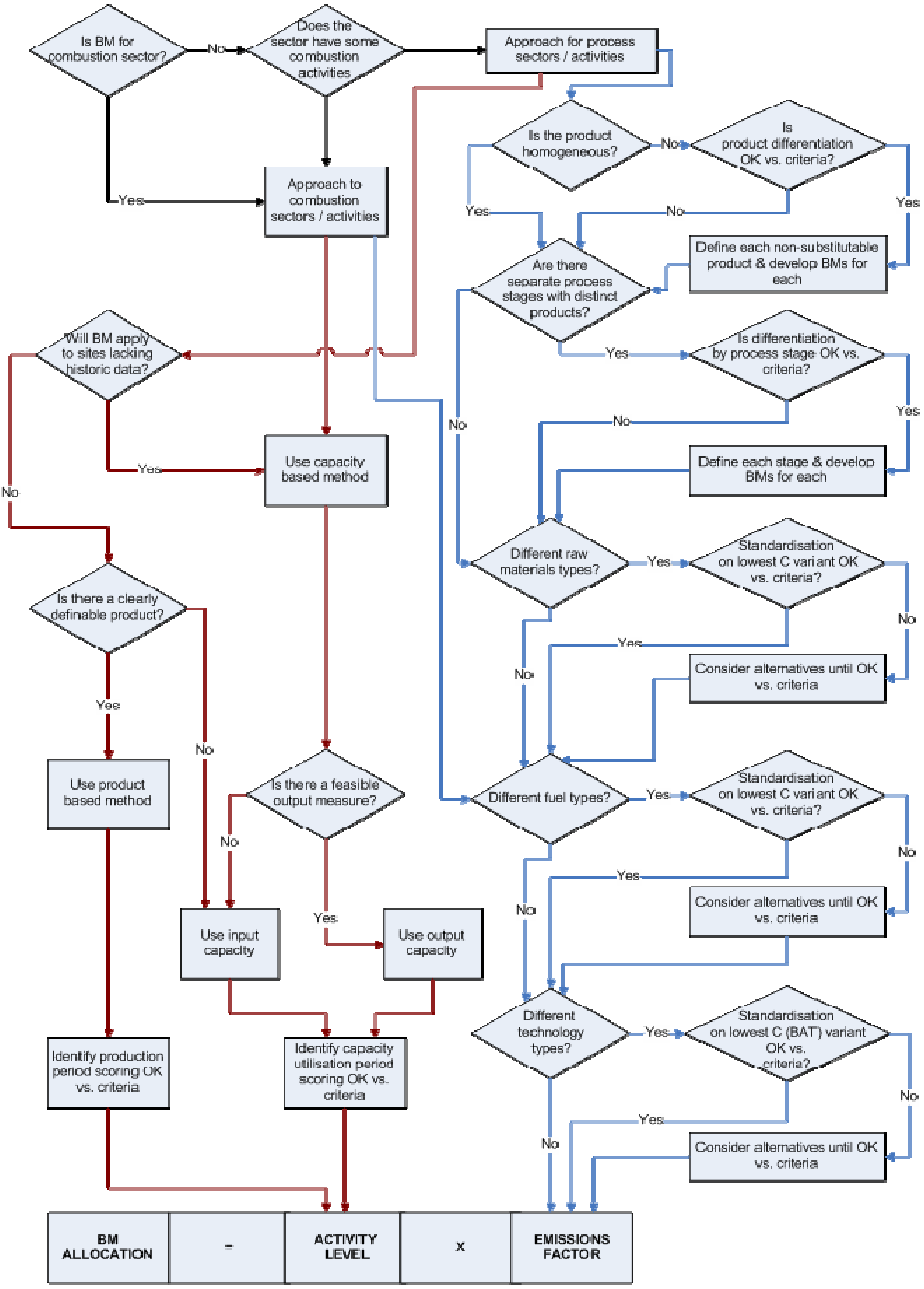
Table 2.1: Criteria for developing benchmarks

Criteria
1. Feasibility
A. How resource intensive is it expected to be to fully *develop* and *maintain* the benchmark method? B. Can the benchmark factors be replicated by a third party? C. Can the input data for the benchmark method be verified?
2. Environmental effectiveness
A. Are benchmarks standardised, avoiding differentiation for raw materials, technologies and fuels?
B. Is the benchmark based on using natural gas as a fuel? (only refers to iron and steel)
3. Economic impacts
A. What is likely impact on distributional equity at installation level?
B. What is likely impact on distributional equity at company level?

2.2 Approach to developing BM options

The Phase II new entrant reserve (NER) benchmarks are taken as a starting point for this study, in accordance with the project specification. However, in order to address the range of questions posed, various options need to be considered. These include any other published options (such as those developed by other Member States or industry) and any new options generated by the project team.

A generic method was prepared for deriving new options, taking into account differences in product homogeneity, availability of production data, and variability in production processes among the plant population considered. The diagram below presents separate benchmarking decision trees for combustion (boiler) and process activities, both divided into activity level and emission factor paths (also see accompanying explanatory Tables 3.1 to 3.3).



—activity level path

—emissions level path

Figure 2.1: Benchmarking method

Table 2.2: Bottom-up benchmarking decisions - Combustion

Activity level	Emissions
Use capacity-based method	Are there different fuel types?
Is there a feasible output measure?	If yes, is standardisation on lowest C OK versus the criteria? Consider alternatives until OK vs. the criteria
If yes, use output capacity	Are there different technology types?
If no, use input capacity	If yes, is standardisation on lowest C OK versus the criteria? Consider alternatives until OK vs. the criteria
Identify capacity utilisation period scoring OK versus the criteria	Derive emissions factor
Derive activity level	

Table 2.3: Bottom-up benchmarking decisions - Processes

Activity level	Emissions
If BM will apply to sites lacking historic data, use capacity-based method, as for combustion	If product is not homogenous and if differentiation is required under criteria, define each non-substitutable product and develop BMs for each
If historic data is available, but there is no definable product use input capacity	If there are separate process stages with distinct products, test differentiation against criteria and if required develop BMs for each
If historic data is available and there is a definable product, use product-based method	Are there different raw material types?
Identify production period/capacity utilisation period scoring OK versus the criteria	If yes, is standardisation on lowest C OK versus the criteria? Consider alternatives until OK vs. the criteria
Derive activity level	Are there different fuel types?
	If yes, is standardisation on lowest C OK versus the criteria? Consider alternatives until OK vs. the criteria
	Are there different technology types?
	If yes, is standardisation on lowest C OK versus the criteria? Consider alternatives until OK vs. the criteria
	Derive emissions factor

3 Cement sector analysis

3.1 Sector description and factors for consideration in benchmarks

This section describes a number of elements in the development and implementation of benchmarks for the cement sector.

Fuel type

A number of fuel types are used in cement kilns. Historically, the cement industry in the EU has used coal and petroleum coke (petcoke) and these are standard fuels for the sector. However, the industry has the technical ability to make use of a wide range of substitute fuels including tires, fuel derived from municipal and industrial waste, waste liquid solvents and biomass. One way that the cement sector (like many other sectors) may choose to reduce its net emissions of CO_2 is through the use of biofuels.

The level of substitute fuels burnt in cement kilns is expected to continue to rise across the EU due to economic pressures and legislative developments (such as the Landfill Directive). Cement operators sometimes charge a gate fee to accept waste[6] and at the same time reduce their costs for purchasing fossil fuels.

Use of kiln bypass

A kiln bypass is used in some kilns, particularly where substitute fuels are used. Some types of substitute fuels contain impurities and if these need to be removed, this can be done in a bypass unit. Operation of a bypass consumes energy and entails a greater need for fuel. A bypass unit can be adjusted to achieve varying levels of bypass, which could make verification difficult. Furthermore, current bypass usage is not indicative of future use, as an increase in the use of substitute fuels is expected.

Technology type

Kiln technology may be the principal deciding factor in energy efficiency and emissions of CO_2 from fuel combustion, but the choice of technology is partly based on the moisture content and geology of the aggregate used as raw feedstock. This in turn is affected by the location of the plant and the proximity to market.

Four different types of technologies are used: wet (least energy efficient), Lepol, preheater, and precalciner (most energy efficient).

To reduce the specific energy consumption of the process, exhaust gases can be used to heat the feed material in a preheater so that partial calcination occurs outside the kiln, which allows the kiln calcination to be shorter and more energy efficient. A Lepol preheater is used in a semi-wet process, whereas in a dry process a suspension or cyclone preheater is applied. A further measure to increase efficiency of either a wet or dry process is the addition of a precalciner. Heat input is divided between the kiln burner and this stationary chamber, between the kiln and the preheater, which further increases calcination before the mix enters the kiln.

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[6] Entec survey of UK paper producers suggests, for example, that paper producers were quoted a gate fee rate of £20 per tonne dried paper sludge. Current landfill tax levels of £32 supports the potential for waste utilisation.

The cement industry states that all four types of technology are likely to be in use in the UK by incumbents in Phase III. Presently, the UK cement sector is made up of 20 operational kilns across 15 sites, around half of which are wet or semi-wet kilns. A large proportion of these kilns were built in the 1970s. The lifetime of the kiln ranges between 35 and 55 years. According to cement specialists[7], older kilns are refurbished every year, which prolongs their lifetime. The refurbishment requires continuous expenditure, which makes it difficult to determine at first glance whether the capital invested in older plants has or has not been written off. Therefore, while many of the kilns may be approaching initial capital investment recovery, additional investments have been made to keep them going and they would not necessarily be closed down in the near future. Factors that may affect their closure would include continued high fuel prices and the commissioning of new efficient, large capacity plants by the parent company, which would compensate for the old plant closures.

New kilns are most likely to be built on existing sites due to planning constraints. The best commercially available technology for new developments is considered to be the precalciner kiln, although the exact design can vary depending on the level of moisture in raw materials (four- or five-stage preheaters can be used for dry materials, whilst only two-stage preheaters may be used for wet materials).

Raw material moisture

The feedstock used by companies in the different member states (MS) (and within MS) is known to vary in type, quality and moisture content. Limestone (dry) and chalk (wet) materials can be used.

The moisture content is an important consideration for kiln fuel consumption and emissions, as the energy required to drive off moisture is in the region of 2,450 million Joules per tonne (MJ/t) of moisture. This can represent significant additional energy consumption. Traditionally, wet kilns were used for wet raw materials, which are common in the UK, Netherlands, Northern France and the North of Belgium. Modern kiln and pretreatment technology is better able to deal with relatively high moisture content; this approach is used in new plants.

Non-carbonate carbon

Non-carbonate carbon is also a consideration for emissions. This is carbon within the raw materials (such as from a coal seam in the limestone) rather than fuels. Levels of non-carbonate carbon can vary significantly from site to site, although the industry is not aware of any evidence that would indicate any significant differences across MS. If this carbon contributes to the input of energy in the kiln, then the CO_2 from non-carbonate carbon should count towards fuel-related CO_2. However, it is thought by the industry that the carbon is generally oxidised before entering the kiln and hence would not contribute to kiln energy. In practice, this depends on where in the process the raw materials are added.

Process emissions

Standardisation is possible at UK level and is applied for NE Ph II BM.

Phase I new entrant benchmarks allow for installation-specific differentiation. The British Cement Association (BCA) suggests that process emissions can be standardised at the UK level without significant cost compromises.

[7] Meeting with BCA representatives October 2007 and personal communication with Environment Agency cement industry specialist Jon Isherwood, February 2008.

Standardisation is recommended for all options considered, with the exception of process non-carbonate carbon; three of the proposed formulae include installation-specific non-carbonate carbon differentiation.

Cement versus clinker

The basic process of cement-making is the thermal conversion in a kiln of calcium and magnesium carbonate aggregate into the oxide form, which then reacts with silica, alumina and ferrous oxides to form a material called clinker. This is a very energy-intensive process. The clinker is then blended with other substances, such as gypsum and blast furnace slag, to make cement.

Adding blending into the benchmark, by setting the emissions factors in terms of tCO_2 per tonne of cement produced rather than per tonne of clinker produced, would encourage producers to increase energy efficiency and decrease the clinker ratio per tonne of cement. This could bring lower compliance costs or more ambitious targets. The difficulty in implementing this proposal would be that companies have high quality data on clinker production, but more limited information on blending and tonnes of cement equivalent production (including cement quality and conversion factors), partly because in some cases the blending occurs on the site of customers.

Another problem is that clinker could be imported from abroad, which could lead to 'carbon leakage.'

While including cement production in the EU ETS would be difficult given the current and envisaged installation boundaries, it is strongly recommended that methods of encouraging clinker replacement in cement with other materials are looked into.

Use of renewable fuels

Preprocessing emissions (such as from drying biomass residues) may need to be taken into consideration in order to encourage the use of renewable fuels.

3.2 Benchmarking options considered

3.2.1 Short-listed formulae

NE Phase II BM

The reference formula for all sectors is the new entrant Phase II benchmark (further referred to as NE Ph II BM). For the cement sector, this entails a standardised process emission factor/tonne of clinker as well as a standardised combustion emission factor. The benchmark for new entrants was based on capacity data multiplied by a standard utilisation factor to derive production data. For incumbent installations, the formula can be modified to use the production parameter directly.

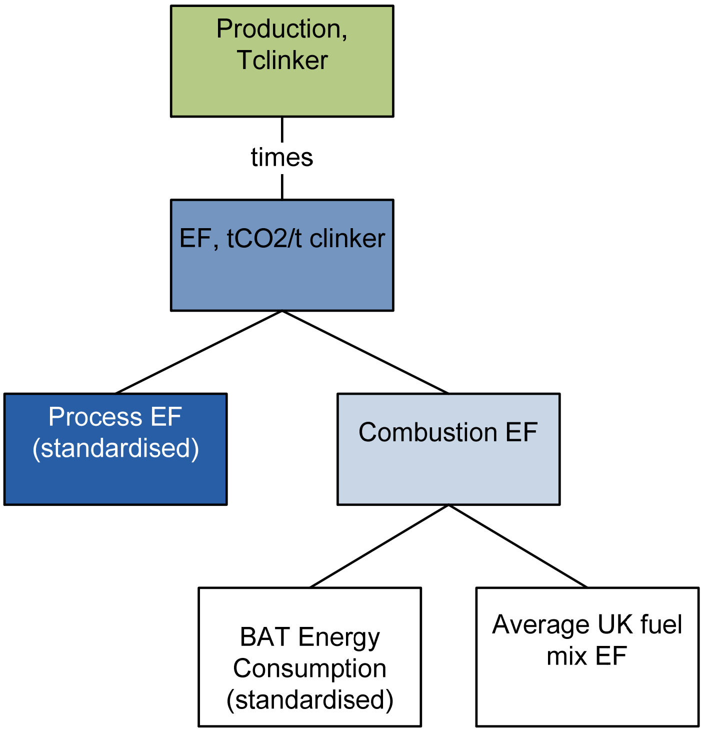


Figure 3.1: Cement Formula 1: NE Ph II BM

Here the emission factor EF is multiplied by the production metric.

While the NE Ph II BM is simple to use and is based on best practice for new plants in terms of energy consumption, it also allows for further improvement by operators, for example by changing the fuel mix.

Alternative 1: No technology differentiation

The first alternative to the NE PhII BM is a formula that allows for the differentiation of moisture content and non-carbonate carbon, factors that operators have little control over. This option is further referred to as A1-0T.

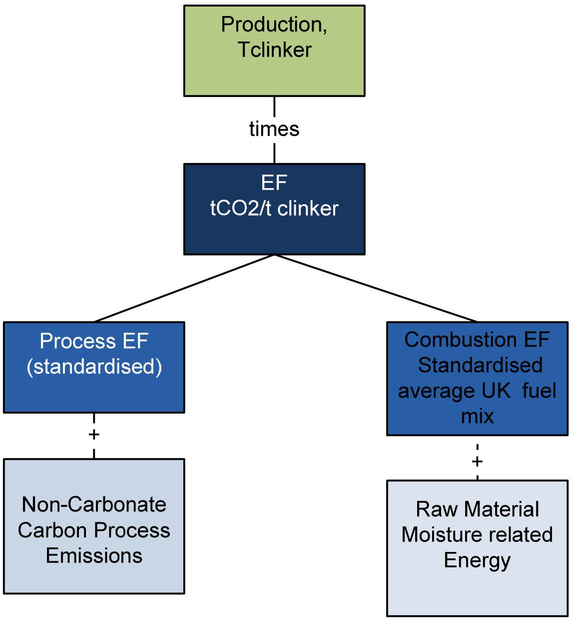


Figure 3.2: Cement Formula 2: Alternative 1– No technology differentiation

Alternative 2: Three-technology differentiation

Under Alternative 2 (A2-3T), suggested by the British Cement Association (BCA), non-carbonate carbon and raw material moisture differentials are accounted for as above. In addition, an installation-specific allowance for kiln bypass is added as well as differentiation by technology type: wet kiln, Lepol, preheater and precalciner kilns. Under this option wet kilns are treated as Lepol kilns, which results in a three-technology differentiation.

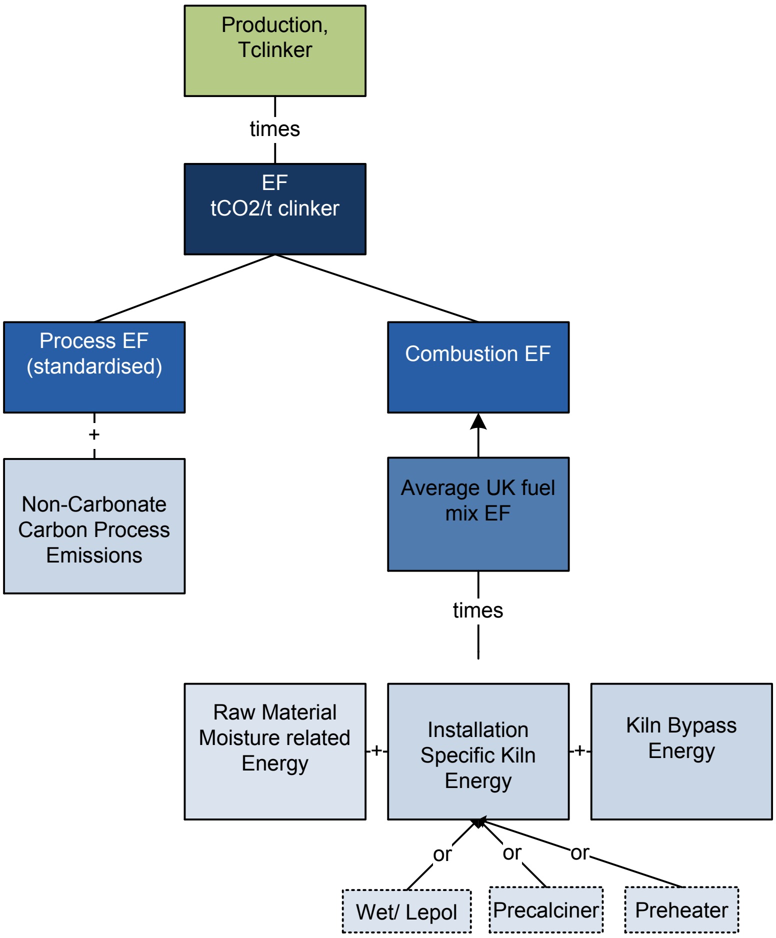


Figure 3.3: Cement Formula 3: Alternative 2 – Three-technology differentiation

Alternative 3: Four-technology differentiation

The last alternative formula (A3-4T), also suggested by BCA, is exactly the same as the above, but wet kilns are assigned a separate specific energy consumption parameter, rather than being assigned the more efficient Lepol kiln parameter. This formula entails the highest level of differentiation among the short-listed formulae.

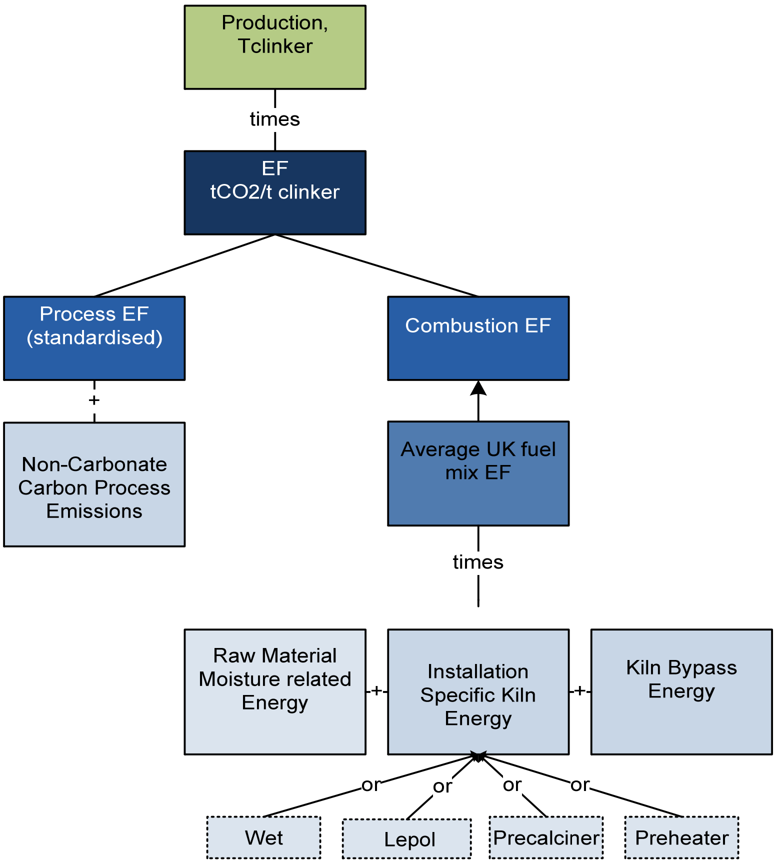


Figure 3.4: Cement Formula 3: Alternative 3 – Four-technology differentiation

For all of these alternatives, the specific energy consumption figure will need to be developed to avoid double counting with any elements that give additional allowances, such as moisture, non-carbonate carbon and kiln bypass.

3.2.2 Parameter values

Activity levels

Clinker production data by installation is available and would be useful for determining the activity level of incumbents. The alternative is capacity data; however, 'capacity' is difficult to define for a cement kiln as actual capacity is often different to the stated capacity and can vary according to the extent of process optimisation[8].

Determining a suitable historic time period for an average level of production for a Phase III benchmark is outside the scope of this study. This would require consideration of economic cycles within the sector, the length of the allocation period in Phase III, and ultimately, the impacts of different options against the evaluation criteria.

[8] Furthermore, a cement kiln would typically operate above its stated capacity due to such optimisation.

Emission factors

Specific energy consumption (SEC)

The four main types of kilns used in the UK (wet, Lepol, precalciner and preheater) have different efficiencies and require different levels of energy to operate. The four BM formulae considered use the following parameters for specific energy consumption,

For NE Ph II BM, the SEC of the top decile (10 per cent) clinker kilns worldwide was taken from Whitehopleman Ltd, based on their 2005 global database for dry process four- or five-stage preheater/calciner kilns, built in the previous 10 years (Entec 2006a on basis of email and mail communication with Whitehopleman Ltd). The parameter is set at **2,902 MJ/t clinker** (net) for all kiln types; there is no technology differentiation.

For the purposes of this report, the specific energy consumption for A1-0T was based on the most efficient decile clinker kilns worldwide taken from Whitehopleman (see above for details). This parameter is set at **2,902 MJ/t clinker** for all kiln types and, as the name of the formula suggests, there is no technology differentiation.

In practice for Phase III, there are clearly alternative options for the level at which this benchmark is set, such as top decile or top quartile. Determining a suitable level would require consideration of the impacts of different options against the evaluation criteria.

Option A2-3T uses the most efficient quartile (25 per cent) energy consumption figure calculated on the basis of data points for each technology type for the last three years (2004 to 2006) with available data (Source: BCA). The parameters are then applied to each technology on the basis of its own category, but wet kilns are assigned the lower 'Lepol' emission factor: wet and Lepol **3,569 MJ/t clinker**, preheater **3,600 MJ/t clinker**, precalciner **3,209 MJ/t clinker**. These values are for illustration and would need to be considered in detail for the design of a Phase III benchmark; for example, in the data above the top quartile produces an SEC for preheater kilns that is above the SEC for Lepol kilns, which is against what is expected by BCA on average.

For the A3-4T option, the parameters are determined as above (for A2-3T), except for the wet kiln which is **5,264 MJ/t clinker**.

The variation in SEC values for the different kiln types is affected by the efficiency of the kiln. In addition, there is a high correlation between kiln type and raw material moisture. The clear delineation of these effects may require additional research.

Raw material moisture

The average UK raw material moisture (13 per cent) is used for NE Ph II BM (Entec 2006a). All alternative formulae use site-specific raw material moisture. In development of a Phase III benchmark, care must be taken to avoid double counting so that any additional allowance for moisture is not already incorporated within the SEC.

Kiln bypass

No provision is made for kiln bypass energy under NE Ph II BM and A1-0T. The other two alternatives allow for site-specific kiln bypass. This may lead to double counting if this energy requirement is already included in the SEC parameter.

Non-carbonate carbon

NE Ph II BM assumes uniform non-carbonate carbon content for all installations (0.64 per cent), based on a UK average (Entec 2006a). Installation-specific non-carbonate carbon contents are used for all alternative formulae.

Fuel mix

The average UK fuel mix is used for all formulae. The actual NE Ph II BM uses fuel mix data for 2004 based on BCA data (Entec 2006a). However, to ensure consistency in the modelling for this study, this and alternative options all have the same fuel mix data, which is updated compared to NE Ph II BM, being applicable to 2006. This is also sourced by BCA (for confidentiality reasons, this cannot be presented in this report).

Process emissions

The process emissions factor is standardised (0.532 tCO_2/t clinker) based on the figure in the NE Ph II BM (Entec 2006a), which is itself based on the figure in the NE Ph I BM.

3.3 Results of UK-level modelling

3.3.1 Modelling assumptions

A summary of data sources and assumptions in the analysis are given in Table 3.1: Data sources, assumptions and key details for modelling.

Table 3.1: Data sources, assumptions and key details for modelling

Aspect		Details
Installations considered in modelling		Estimated emissions allocations for the various BM options in this study (compared to Phase II NAP) are calculated for each of the 15 currently operating cement kilns in the UK, except for two where a full set of data was not available. Phase II NAP data for these installations is also used.
		For the main analysis, the data is weighted by clinker production and presented for four stylised plants (representing each of the four different kiln types: wet, Lepol, preheater, precalciner), with each stylised plant being normalised to a capacity of 1,000 tpd clinker at 85% usage rate.
		Data on relative distributional impacts is presented for each of the 14 (anonymised) installations where data was available.
Installation-level parameters	Clinker production	The data made available by industry for use in this assessment is the maximum annual clinker production for each installation, taken from a period of 2000 to 2007, for currently operating kilns. Source: BCA.
	Raw material moisture	2005/2006 data. Source: BCA
	Non-carbonate carbon	2005/2006 data. Source: BCA
	Kiln bypass	2005/2006 data. Source: BCA
UK parameters	Fuel mix	See above. 2006 data. Source: BCA.

Cont'd

Aspect	Details
Economic analysis	A price of €30/t CO_2 was used for illustration purposes. Allowance price predictions are uncertain; in addition, allowance prices are expected to vary during Phase III. Therefore, this is a source of uncertainty. 100 per cent purchase on the market to cover deficit allowances was assumed. In-house abatement options and intra-company exchanges would affect the actual economic impact for each installation type.

3.3.2 Feasibility

Overall, there are no feasibility problems with NE Ph II BM or A1-0T. According to BCA, all the parameters under A2-3T and A3-4T will be verified under Monitoring and Reporting Guidelines 2007. The consultants have concerns regarding the verification of justification for kiln bypass utilisation under these options due to the large number of factors that may affect kiln bypass utilisation and potential for double-counting.

The tables below present data required for the development of benchmarking options.

Table 3.2: Cement: Data requirements for development of benchmark

Factor	NE Ph II BM	A1-0T	A2-3T	A3-4T
Specific energy consumption	Single value required. Available from Whitehopleman Ltd or BCA.	Single value required. Available from Whitehopleman Ltd or BCA.	Three values required (by kiln type). Available from Whitehopleman Ltd or BCA.	Four values required (by kiln type). Available from Whitehopleman Ltd or BCA.
Bypass	Not required.	Not required.	Not required.	Not required.
Fuel type	Single value required (UK average). Available from BCA.	Single value required (UK average). Available from BCA.	Single value required (UK average). Available from BCA.	Single value required (UK average). Available from BCA.
Moisture content	Single value required (UK average). Available from BCA.	Not required.	Not required.	Not required.
Non-carbonate carbon content	Single value required (UK average). Available from BCA.	Not required.	Not required.	Not required.
Process EF	Single value required. Available from BCA.	Single value required. Available from BCA.	Single value required. Available from BCA.	Single value required. Available from BCA.
Clinker production	Not required.	Not required.	Not required.	Not required.
Number of data sets	5	3	5	6

Table 3.3: Cement: Data requirements for benchmark implementation

Factor	NE Ph II BM	A1-0T	A2-3T	A3-4T
Clinker production	Operator to provide	Operator to provide	Operator to provide	Operator to provide
Moisture content	Not required	Operator to provide	Operator to provide	Operator to provide
Non-carbonate carbon content	Not required	Operator to provide	Operator to provide	Operator to provide
Bypass	Not required	Not required	Operator to provide	Operator to provide
Technology	Not required	Not required	Three categories	Four categories
Number of data sets	1	3	5	5

3.3.3 Environmental effectiveness

Reduction of emissions from the sector

Because of commercial confidentiality, the impacts on each UK installation from the four benchmarking formulae cannot be published. Instead, the effects of the different formulae were applied to four stylised plants corresponding to the four technology types in the UK fleet. The impacts of applying the four benchmarking formulae were averaged for each type of plant in the form of tCO_2/t clinker, weighted by production data for 2006. These averages were then normalised to a stylised plant with a capacity of 2,000 tonnes per day and an assumed load factor of 85 per cent. The results of applying the benchmarks alone, as well as those of combining a benchmarking distribution with a sectoral cap (here 2006 emissions are chosen as an example[9]), are presented in the figure below.

[9] Using NAPII allocation data produces similar results

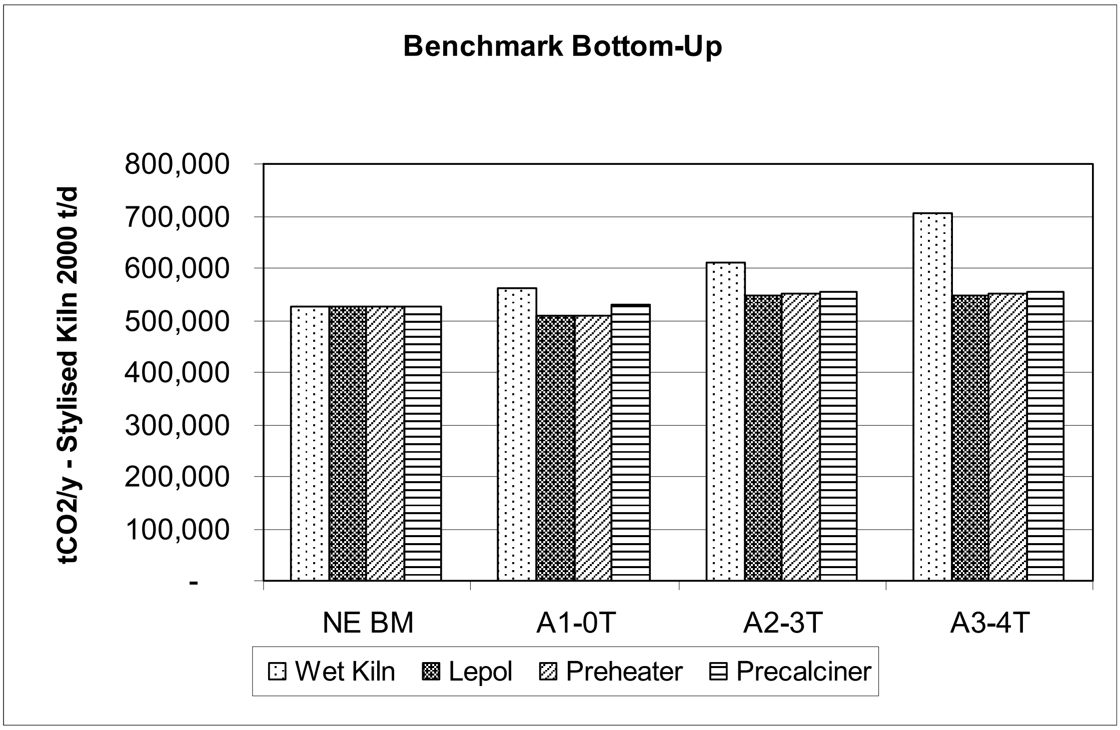


Figure 3.5 Allocation variants (BM only)

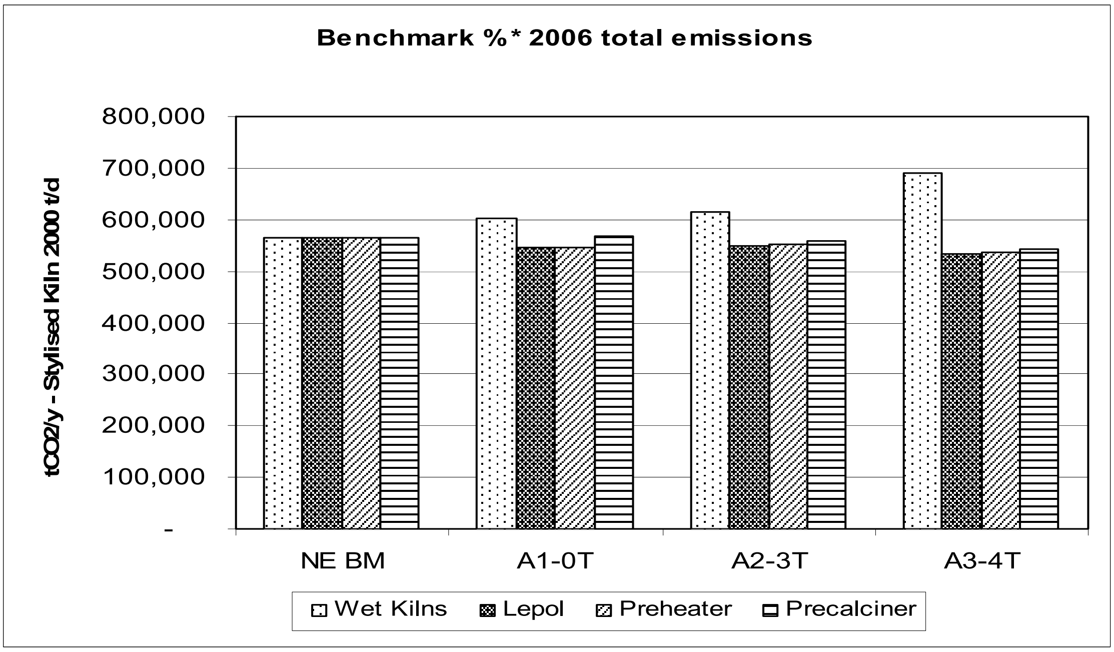


Figure 3.6 Allocation variants (BM plus sectoral cap)

The calculation in Figure 3.5 applies the benchmark directly. The calculation for Figure 3.6 followed the formula below:

$[(\sum A_{BMi} / A_{BMsector} * AE_{2006} / \sum P_i)_* P_{st}$

where

A_{BMi} bottom-up allocation under the selected benchmarking formula to each installation in the group, in tCO_2.

$A_{BMsector}$ sum of bottom-up allocation under the selected benchmarking formula for all the installations in the sector (includes all kiln types), in tCO_2.

AE_{2006} sum of 2006 emissions of all installations in the sector (includes all kiln types), in tCO_2.

P_i production metric, here represented by 2006 production, in t clinker.

P_{st} activity level of stylised plant; for illustration this was chosen at 2,000 tonnes per day, 85 per cent load factor, that is 620,500 t clinker per year).

Despite the large difference in combustion-related parameters used for the four formulae, the difference in allocation is limited due to the high proportion of process emissions, which are standardised. A clear impact, however, is the significant increase in allocation for wet kilns, going from NE BM to A3-4T. This is mainly due to the high Specific Energy Consumption (SEC) figures for A2-3T and A3-4T, but also to the high moisture content for A1-0T, where moisture is a site-specific variable (though SEC is constant across kiln types).

Table 3.4 shows the difference between bottom-up allocations, 2006 emissions, and the Phase II NAP. Figures in this table are sensitive to the base year chosen. This may tend to overstate the allocations in relation to the comparator figures.

Table 3.4: Difference between a bottom-up BM allocation and 2006 emissions

	Difference bottom-up allocation and 2006 emissions		**Difference bottom-up allocation and Phase II NAP**	
	tCO_2/y	%	tCO_2/y	%
NE Ph II BM	-678713	-6.84%	-556577	-5.68%
A1-0T	-670271	-6.76%	-548135	-5.60%
A2-3T	-30762	0%	91373	1%
A3-4T	256373	3%	378508	4%

Encouraging clean technology

The lowest level of differentiation will favour the cleanest production methods; therefore, the ranking of the considered formulae is as follows: one, NE Ph II BM; two, A1-0T; three, A2-3T; four, A3-4T.

In addition, a review of the data suggests that all kiln types would be encouraged to invest in alternative fuels (especially biomass) in order to comply with tighter allocations. All formulae allow for gains resulting from the **use of alternative fuels**.

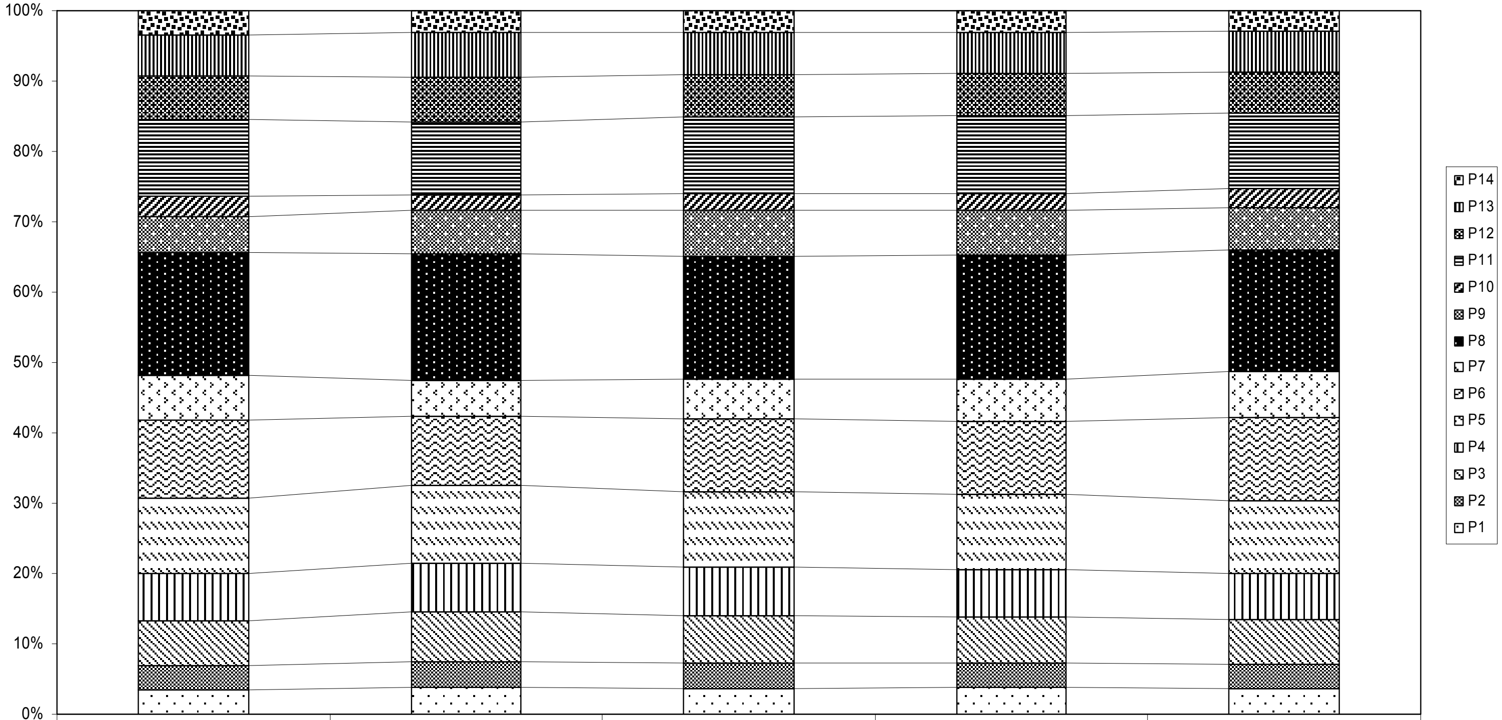
3.3.4 Economic impacts

General competitiveness impacts issues

A number of reports have been written on how the EU ETS may affect the competitiveness of the cement sector. These include reports by the Carbon Trust, McKinsey Ecofys, International Energy Agency and Climate Strategies. These reports are mainly focused on intra-EU and extra-EU competitiveness and have limited relevance to the distributional impacts considered in this study. Some of the data used in these reports were used here for the assessment of intra-UK competition and distributional impacts, such as average UK prices and transportation costs.

Distributional impacts from applying benchmarking formulae

The percentage distribution of allowances does not vary significantly from NAP II or 2006 emissions to the four formulae. No major variation among the different BM formulae is observed, with the exception of the favouring of wet kilns as part of A3-4T. Similarly to Figures 3.5 and 3.6 above, the softened effect is caused by the large proportion of process emissions.



	NAP II	NE Ph II	A1-0T	A2-3T	A3-4T
P14	3.4%	3.2%	3.0%	3.0%	3.0%
P13	5.9%	6.4%	6.1%	5.9%	5.7%
P12	6.2%	6.2%	6.0%	6.1%	5.9%
P11	10.9%	10.4%	10.9%	11.0%	10.7%
P10	2.9%	2.2%	2.3%	2.4%	2.7%
P9	5.1%	6.1%	6.5%	6.3%	6.1%
P8	17.4%	18.0%	17.4%	17.7%	17.2%
P7	6.5%	5.2%	5.6%	5.9%	6.6%
P6	11.1%	9.8%	10.5%	10.5%	11.8%
P5	10.7%	11.0%	10.7%	10.8%	10.4%
P4	6.7%	6.9%	6.9%	6.6%	6.5%
P3	6.4%	7.1%	6.8%	6.6%	6.4%
P2	3.5%	3.6%	3.5%	3.5%	3.4%
P1	3.4%	3.8%	3.7%	3.7%	3.6%

Figure 3.7: Distributional impacts: Cement

The economic impacts of applying the four benchmarking formulae considered were measured in the form of added cost/benefit per tonne of clinker for each installation and for each kiln type. Again, for confidentiality reasons the installation results cannot be presented. Similarly to Figure 3.6 Allocation, these were normalised to a stylised plant with a capacity of 2,000 tonnes per day and an assumed load factor of 85 per cent.

The formula assessed separately each group of plants under each kiln type:

$$[(\sum A_{BMi} / A_{BMsector} * AE_{2006sector} / \sum P_i) * P_{st} - (\sum AE_{2006} / \sum P_i) * P_{st}] * CPrice$$

where:

$\mathbf{A}_{BMi}$	bottom-up allocation under the selected benchmarking formula to each installation in the group, in tCO_2.
$\mathbf{A}_{BMsector}$	sum of bottom-up allocation under the selected benchmarking formula for all the installations in the sector (includes all kiln types), in tCO_2.
AE_{2006}	2006 emissions of each installation in the group, in tCO_2.
$AE_{2006sector}$	2006 emissions of all installations in the sector (includes all kiln types), in tCO_2.
$\mathbf{P}_i$	production metric, here represented by 2006 production, in t clinker.
$\mathbf{P}_{st}$	activity level of stylised plant; for illustration, this was chosen at 1,000 tonnes per day, 85 per cent load factor, that is 620,500 t clinker per year
CPrice	allowance price, for illustration set at €30 per tCO_2e.

The illustration below shows the selection of a benchmarking formula from a given range. The effect of the different formulae is considered against an illustrative sectoral cap and 100 per cent free allocation (given that the sectoral cap was unknown at the time of writing, 2006 actual emissions was selected from the range of possible examples due to the completeness of data available). All the results would be affected by the choice of sectoral cap or proportion of free allocation.

The effects are compared to the 2006 emissions as an example. An impact on the 'zero line' would equate to an allocation per tonne of product equivalent to 2006 emissions; an impact below the line is a cost and an impact above the line is a benefit.

The added cost impacts per tonne of clinker for the four stylised plants are considered by assuming that 100 per cent of deficit allowances are purchased on the market[10].

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[10] In-house abatement potential may allow for cheaper abatement options; similarly, lack of such in-house abatement and higher allowance prices would render higher impacts.

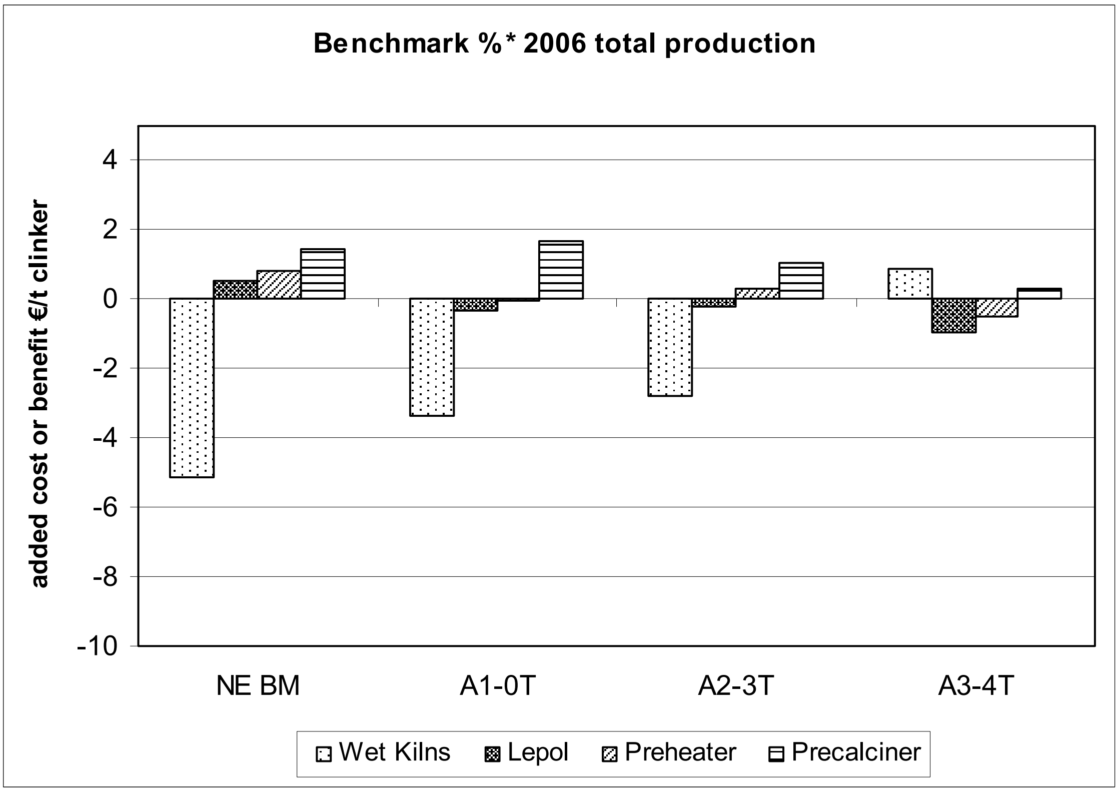


Figure 3.8: Economic impacts: Stylised plants cement

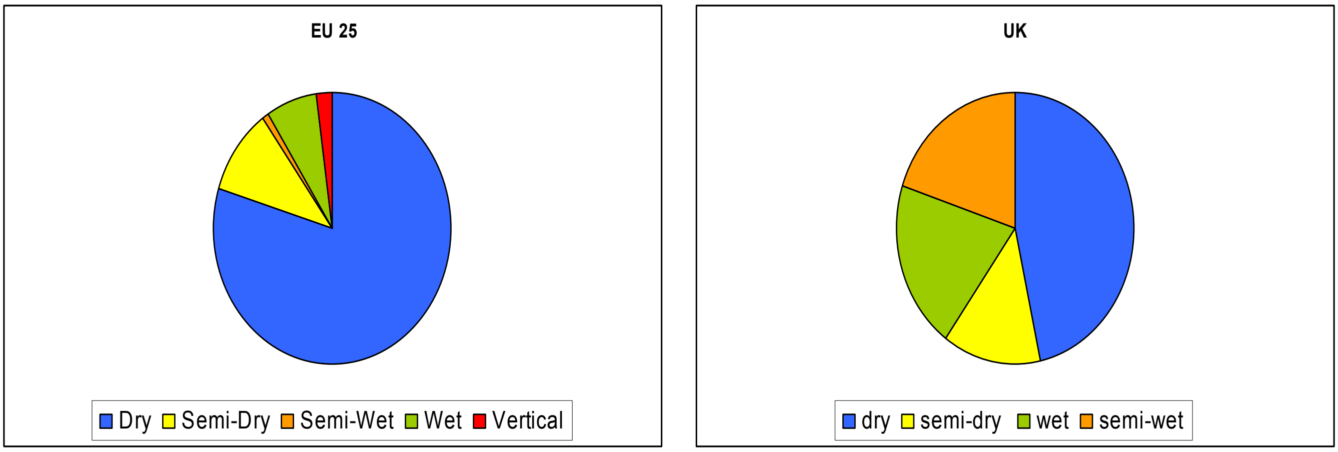
Further to comments from the industry, the effects of applying bottom-up benchmarking without an illustrative sectoral cap are presented in Appendix B.

The results of the economic impact assessment suggest that:

- Incremental changes from one formula to the next lead to small differences in added cost for the same type of kiln, for example between €1 and €2/t clinker for the wet kiln.
- The maximum difference between added costs and benefits (e.g. between the costs to the wet kiln and the benefits to the precalciner) under the sectoral cap and allowance price assumption are within the range of transport costs per ton of clinker (€10/t clinker/100 km on land) and are therefore likely to have limited effects on intra-UK competitiveness (this conclusion may be sensitive to changes in sectoral cap or proportion of free allocation and should be reassessed once parameters are fixed).
- A sensitivity on the carbon price of €40/tCO_2e still keeps the maximum difference between the added cost and added benefit impact under €10/t clinker for the combined BM with the 2006 emissions for all installations.
- The more differentiated formulae may lead to an inequitable distribution of added cost/benefits between the wet kiln and the precalciner (under the combination of 2006 emissions and BM distribution, about €1/t clinker in benefits for the wet kiln and €1/t clinker as added cost for the precalciner for formula A3-4T).
- The plant size selected is that of the typical UK size, around 2,000 t/day. Given that the results are considered as added cost/benefit per tonne of clinker, the choice of size does not affect the conclusions.

3.4 MS-level considerations

Member States (MS) with an incidence of **high raw material moisture** (such as the UK, France, Denmark and Holland) may benefit from differentiation by raw material moisture. MS with a high incidence of inefficient kilns would not oppose differentiation by kiln type, while other MS would profit from a benchmark standardised by technology (see distribution of technology types in the EU 25 and the UK below).



Sources: CEMBUREAU, BCA

Figure 3.9: Kiln technology distribution in the EU 25 and the UK

MS with a higher rate of renewable fuels (such as France and Germany) may require a more stringent benchmark with regards to the fuel mix. For the latter, CEMBUREAU could not provide us with exact data for the EU 25 or 27; instead, we received statistics for groups of five to 10 EU MS. These groups tended to have an average alternative fuel use of 20 per cent compared to the UK's approximate 10 per cent (this excludes use of waste solvent fuels which have a higher requirement for kiln bypass utilisation).

Also, under a central EU allocation, other MS with lower current emissions would have the incentive to support a benchmark standardised against stricter parameter values, as this would allow them a higher proportion of allowances than a highly differentiated benchmark would. In particular, this group may be represented by MS with the highest level of renewables, the lowest raw material moisture, and the greatest proportion of dry precalciner kilns.

Based on discussions with the industry, it is assumed that there is a roughly uniform distribution of non-carbonate carbon content in raw materials among MS. A skewed distribution would affect the impacts of a standardised benchmark with regards to non-carbonate carbon across MS.

Ongoing efforts by other MS (Italy, Germany and the Netherlands) to set a suitable benchmark for Phase III for the cement sector consider a standardised formula similar to the UK NE Ph II BM. This is likely to include parameter values that are more stringent than the UK-centric values used for the NE Ph II BM[11].

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[11] Personal communication with Jan Janssen (Verificatie Bureau, Netherlands), November 2008 and Mariano Morazzo (Ministry for the Environment and Territory, Italy), December 2008.

3.5 MRV implications

According to the operators, all parameters in the formula list considered are expected to be verified under Monitoring and Reporting Guidelines 2007 (MRG, 2007).

However, the consultants' view is that potential verification issues may arise if:

- kiln bypass is an installation-defined parameter, because a bypass unit can be adjusted to varying levels of bypass which may not have been recorded;
- there is technology differentiation, but not all kilns fall within a defined type.

3.6 Conclusions

The table below summarises the performance of BM options against the criteria:

Table 3.5: Performance matrix

Criteria	NE Ph II BM	A1-0T	A2-3T	A3-4T
1. Feasibility				
A. How resource intensive is it expected to be to fully *develop* and *maintain* the benchmark method?	+	+	+	+
B. Can benchmark factors be replicated by a third party?	+	+	+	+
C. Can input data for the benchmark method be verified?	+	+/- with proviso that double counting for raw material moisture can be avoided	+/-- with proviso that double counting for raw material moisture and kiln-bypass can be avoided	+/-- with proviso that double counting for raw material moisture and kiln-bypass can be avoided
Data points required to *design* the benchmark	5	3	5	6
Data points required to *implement* the benchmark	1	3	5	5
2. Environmental effectiveness				
A. Are benchmarks standardised, avoiding differentiation for raw materials, technologies and fuels?	+	+/- differentiate on basis of aspects that operators have limited control over	-	--
3. Economic impacts				
What is the likely impact on distributional equity at installation level?	- (assessed on basis of standard deviation for added cost)	0	0/-	0/--
What is the likely impact on distributional equity at company level?	0	0/-	0/--	0/--

'+' positive score on criterion, '++' strongly positive on criterion, '-' negative score on criterion, '—' strongly negative on criterion, '0' no impact, '+/-' combination of positive and negative impacts.

Answers to key questions

Is Phase II NER BM suitable for incumbents?

The suitability of the Phase II NER BM for incumbents was tested against the three criteria (feasibility, environmental effectiveness and economic impact) and compared to three alternative formulae in the context of combining the benchmark with an externally determined sectoral cap to determine an installation's allocation. In summary, the **Phase II NER BM** performs as follows.

There are no feasibility problems associated with the Phase II NER BM. For existing installations, a more accurate metric of activity levels can be used compared to the Phase II NER BM which uses capacity or historical production. Five data points would be required to design the benchmark and one for its implementation. The input factors can be replicated by a third party and the data externally verified.

Phase II NER BM performs excellently with regards to encouraging clean technology and techniques as it applies no differentiation by technology, fuels or raw materials.

This formula may have distributional implications, especially at an EU level. Among the formulae considered, Phase II NER BM produces the highest variation in economic impacts (measured as added cost/benefit per tonne of clinker compared to the Phase II NAP) both by company and by installation. However, the maximum difference between average added costs and average benefits for the least efficient kiln type compared to the most efficient kiln type does not exceed €10/t clinker, the transport cost of a ton of clinker for 100 km onshore, which would affect distributional impacts in intra-UK competition. If allowance prices were to increase to €40/tCO_2e, this figure would also be below €10/tclinker for the 15 installations considered.

Maximum added costs per installation are between 12 (UK price) and 15 per cent (EU average price) of the average price per tonne of cement compared to the 2006 emissions[12].

This compares to the alternative formula **A1-0T** (which differs from Phase II NER BM through differentiation by raw material moisture and non-carbonate carbon) as follows:

There are no feasibility problems associated with A1-0T. All the data required for the design and implementation of the benchmark are reported and verified under the Monitoring and Reporting Guidelines 2007 (MRG 2007). Four data points would be required to design the benchmark and three for its implementation. The input factors can be replicated by a third party. The data can be verified, with proviso that double counting for raw material moisture is avoided (as part of SEC).

The formula A1-0T performs well with regards to encouraging clean technology, as it does not differentiate on the basis of parameters that operators have a choice over, such as technology or fuel.

This formula has less variability in added costs/benefits impacts (measured in terms of standard deviation) compared to Phase II NER BM and reduced maximum added cost per tonne of clinker by installation. If allowance price were to increase to €40/tCO_2e, the maximum difference between average added costs for the least efficient kiln type and average benefits for the most efficient kilns would be below €10/tclinker.

[12] The price of cement considered is €75 – EU average and €100 – UK average. Source: Climate Strategies 2008.

Maximum added costs by individual installation are between 11 (UK price) and 14 per cent (EU average price) of the average price per tonne of cement.

Alternative formula **A2-3T** differentiates by technology and gives the following results.

There are potential verification issues if kiln bypass is an operator-defined parameter (as the extent of bypass, which can be varied, may not be verifiable), or if not all kilns clearly fall within the defined technology type.

The formula A2-3T performs poorly with regards to encouraging clean production, as it differentiates by technology. This formula leads to only a minor reduction in the variability of economic impacts compared to A1-0T, and results in an increased number of installations incurring added costs compared to A1-0T.

Maximum added costs are between eight (UK price) and 11 per cent (EU average price) of the average price per tonne of cement[13].

Alternative A3-4T has a similar performance compared to A2-3T, with a lower score on environmental effectiveness due to increased differentiation by technology, but also reduced variability of impacts compared to the 2006 emissions.

What would be the competitive/distributional effects of using the Phase II NER BM?

The Phase II NER has the highest variability of impacts compared to NAP II both by installation and company. However, maximum added costs would not exceed the costs of transporting clinker within small distances – a threshold relevant for intra-UK competition and distributional impacts. Average added costs per tonne of clinker by installation appear to be relatively small, at under €1/t clinker. Maximum added costs (including outliers) per individual installation are between 12 per cent (UK price) and 15 per cent (EU price) of the price of cement.

Is there a need for a transitional phase to take into account certain site-specific factors?

The Phase II NER and the alternative formula A1-0T appear to perform best against the criteria, given that the reduction in maximum cost and average added cost incurred under the other two alternatives are minimal and that the environmental effectiveness of those alternatives is significantly reduced. Among the two better performing formulae either could be selected, depending on the weight of the parameters. However, the difference between the two is not on parameters that could change within the near future – raw material moisture and non-carbonate carbon. Therefore, if one of the two formulae is selected, a transition phase would seem to be irrelevant.

What would be the implications for monitoring, reporting and verification (MRV)?

There may be potential verification issues if kiln bypass is an operator-defined parameter (as the extent of bypass, which can be varied, may not be verifiable), or if there is technology differentiation and not all kilns fall within a defined technology type.

How would a UK incumbent BM affect the distribution of allowances EU-wide across the sector?

- Under raw material differentiation, UK and other NW EU states with high raw material moisture would receive a higher proportion of allowances than otherwise.

[13] Both UK and EU prices are considered due to uncertainty of future cement prices.

- Under technology differentiation, the UK would receive a higher proportion of allowances due to greater than average proportion of wet and semi-wet kilns
- Under the standardized approach, the UK would receive a lower proportion of allowances compared to emissions for the above reasons and because the UK fuel mix typically has a smaller proportion of lower emission factor substitute fuels.
- At company level, impacts will depend on the profile of plants by company.

4 Integrated steelworks analysis

4.1 Sector description

The main processes at an integrated steelworks use large quantities of raw material and hot or molten intermediate products and produce large amounts of gases with varying calorific values that are reused in other processes or flared. The operations are very energy intensive, with the energy accounting for approximately 50 per cent of the gross value added of the sector.

The predominant greenhouse gas emitted by the sector is carbon dioxide derived from the combustion of fuels for processes such as coke and iron making, and intermediate fuel gases which are used for other processes such as energy generation and slab re-heating. Carbon dioxide emissions from other sources include the use of limestone in the production of sinter and the use of dolomitic limestone as a flux in the basic oxygen steel (BOS) making process.

The basic process of the integrated iron and steel industry is the chemical reduction of iron ore to form steel products by the blast furnace/basic oxygen steel making route. The three integrated sites in the UK, located at Port Talbot, Scunthorpe and Teesside, each operate the same basic process that consists of five distinct stages. These are:

1. Coke making. The majority of the imported energy into the iron and steel process is in the form of coal, 83 per cent of which is converted into coke prior to use in the blast furnace. It is possible for coke to be imported into the integrated steelworks instead of, or in addition to, being made on site. Surplus coke may be exported to other sites.

2. Sintering, in which the iron ore is roasted in preparation for conversion to iron. It is possible for sintered ore to be imported into the integrated steelworks instead of, or in addition to, being made on site.

3. Iron making, in which the sintered ore, limestone, coke and reductant fuels are chemically reacted to reduce the iron ore to an impure liquid iron referred to as ‘hot metal’, which contains approximately four per cent carbon, in a blast furnace. In certain cases, sintered ore is substituted with pellets. Although not produced in the UK, pellets are imported for use in UK blast furnaces.

4. Steel making and casting, in which the conversion of iron to steel is carried out by the BOS process where the carbon level is typically reduced to 0.1 per cent or less, and after secondary steel making the liquid steel is cast into a solid for further processing or sale. The steel output from this stage is in the form of slabs, blooms and billets. Whilst there are variations in the types of steel produced at this stage across different sites, CO_2 emissions are not considered to be sensitive to the type of steel from this stage and hence product differentiation at this stage is not considered important.

5. Hot rolling, forming, cold rolling and further processing, in which the output from the steel making is reheated, shaped and treated to give a wide range of finished products such as rods, bars, plate, sections, coil and tube. The reheat furnace is the main source of CO_2 at this stage.

The measurements of production are based on the weight of steel produced by the BOS process and are typically measured in tonnes of liquid steel.

Of the above five stages, Stages 1 to 4 give rise to the majority of CO_2, around 90 per cent, although the percentage of emissions from each stage can vary significantly from site to site depending on how process gases are used.

In addition to the main steel making stages, a significant source of CO_2 is the on-site boiler plants which can generate steam, hot water and electricity for use in various processes. The boilers can use a range of fuels including coke oven gas (COG), blast furnace gas (BFG), natural gas and heavy fuel oil. COG and BFG are unavoidable process gases which would be flared to atmosphere if not used on site. It is recognised as good practice to recover the energy value of these gases (which have higher CO_2 emissions than natural gas) as much as possible, and therefore they can make up the majority of the energy input in the boiler plants, as at the UK integrated sites. However, the way in which process gases are used on site can vary significantly across different sites and hence the fuel mix (and CO_2 emissions) of the boilers can vary significantly.

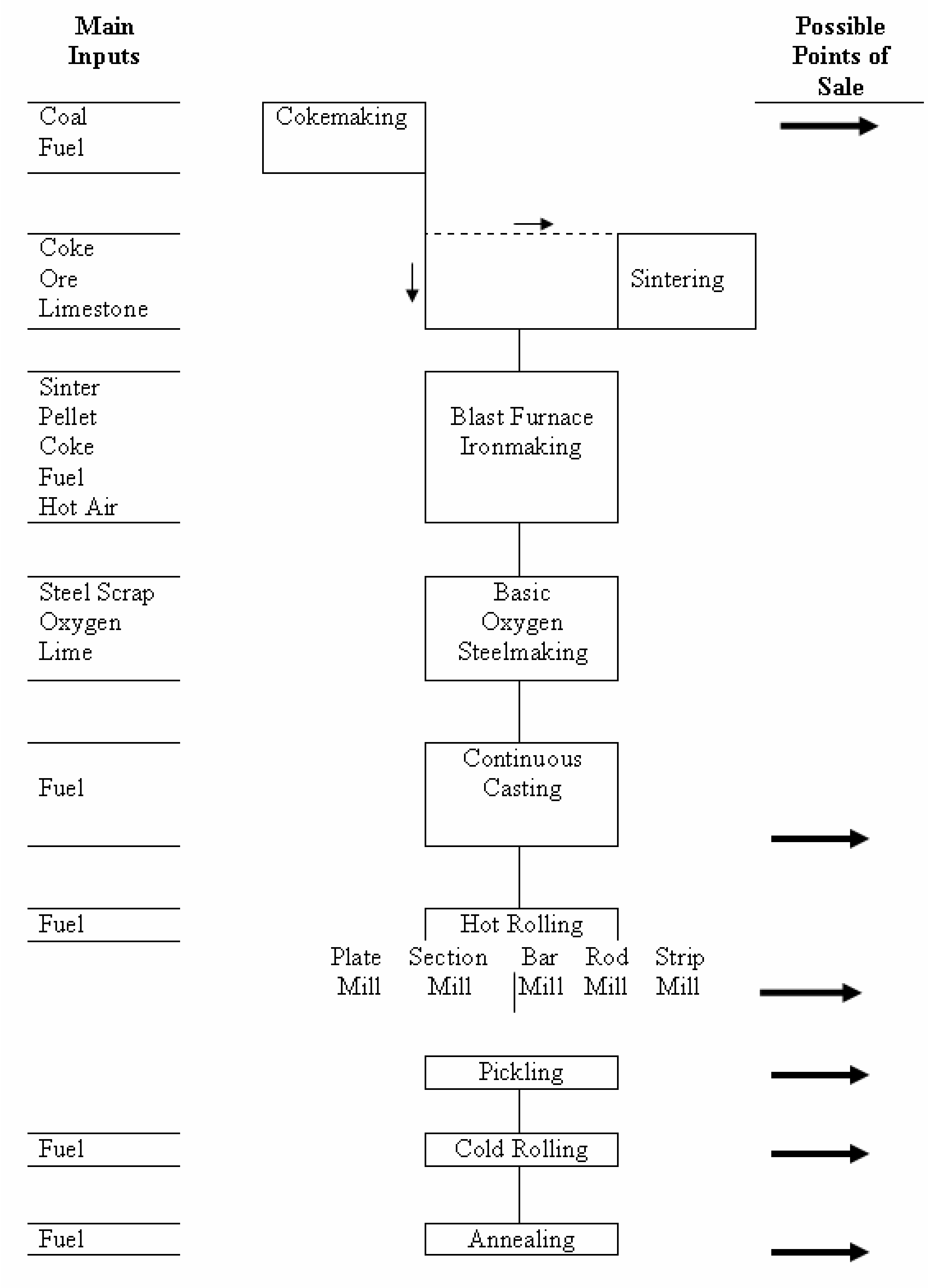

Figure 4.1: Integrated steel process in the UK

Table 4.1: Fuel use and generation of process gases in UK integrated steel plants

Process	Function	Possible fuels	Process gas
Boilers	To generate steam for process use and power generation.	COG BFG BOS gas Natural gas Fuel oil	Exhaust released to atmosphere.
Cokemaking	Purchased coal heated in a coke oven by underfiring with a fuel. Product is coke, a strong clinker-like form of carbon suitable for the blast furnace and COG.	COG BFG	COG of good calorific value – collected. Underfiring gas exhaust released to atmosphere.
Sintering	Crushed ore and fluxes partially melted to form a strong reactive clinker suitable for ironmaking in the blast furnace.	COG Natural gas Coke Coal	Burnt to atmosphere.
Ironmaking	The coke partially combusts in a hot (1150 ^oC) air blast to produce CO and additional heat. CO is a reducing agent which removes the oxygen from iron oxide ore in the sinter to produce CO_2 and iron. The high temperature (above 1500 ^oC) in the BF melts the iron which is then tapped off at regular intervals. Fuel is required to heat the air blast.	(for BF) Coke Injected coal, hydrocarbons (for hot blast) COG BFG Natural gas	BF gas generated in enormous quantities. Collected but has a low calorific value Gas from hot blast stoves released to atmosphere.
BOS	Impure blast furnace iron refined by oxygen and lime-based slag. Carbon removal generates large quantities of CO-rich gas. A small amount of fuel required for preheating equipment for secondary steelmaking and steel transportation.	COG Natural gas	BOS gas has reasonable calorific value. May be collected or flared to atmosphere. Exhaust combustion gases released to atmosphere.
Continuous casting	Converts liquid steel into a simple solid shape suitable for rolling. Fuel required for preheating equipment.	COG Natural gas	Exhaust released to atmosphere.
Hot rolling	Shapes steel by rolling at high (1250^oC) temperature. Fuel need to heat incoming material.	COG BFG Natural gas BOS gas	Exhaust released to atmosphere.

4.2 Benchmarking options considered

4.2.1 Short-listed formulae

NE Phase II BM

Due to the requirements of NE Ph II BM formula to generate allowances for individual process steps which may be new or modified (and which may be the subject of the NER application) and due to government steer for Phase II to develop benchmarks that correspond only to direct emissions from equipment covered by the scheme, the formula differentiates among the large number of process steps, both upstream and downstream, using separate parameters for each step[14].

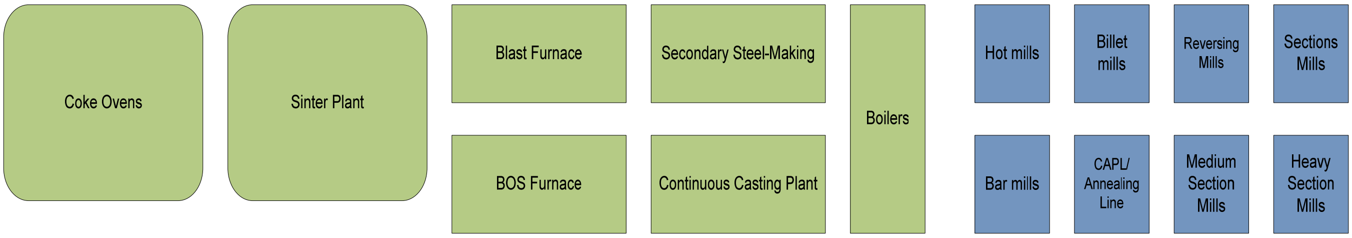

Figure 4.2: Integrated steelworks formula 1: NE Phase II BM

However, by subdividing the overall process into individual steps, the industry was concerned that the NE Ph II BM would not take account of the fact that the use of blast furnace and coke oven gases is inter-related.

An essential feature of fuel economy and CO_2 minimisation in integrated steelplants is the extensive use of process exhaust gases as fuels. The wide variety of fuel types and plants which use fuels is indicated in Table 4.2 together with exhaust gases from the processes. It is not unusual for a site to use mixtures of perhaps three gases for a particular application, where the same application on a different site would probably employ a different fuel mix.

Process gases are generally inferior in calorific value compared to conventional fuels and have higher CO_2 emissions per unit of heat delivered. A comparison at the two extremes, natural gas and blast furnace gas, serves to emphasise the difference:

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[14] For Phase II, Government moved away from the 'integrated' approach which applied to a few sectors in Phase I including integrated steelworks. Under this approach, the BM corresponded not only to direct emissions from new and modified equipment, but also to emissions arising elsewhere at a site as a result of the equipment, for example due to an increase in capacity. As such, the agreed focus for Phase II was on potential benchmarks under a 'direct' approach only. For more on direct versus integrated approach, see Entec 2006b (http://www.berr.gov.uk/files/file28603.pdf)

Table 4.2: CO_2 Emissions from natural gas and from BOS gas

	Caloric value MJ/m^3	Emission factor tCO_2/TJ
Natural gas	36	57
Blast furnace gas, BFG	3.4	270

Thus, although it appears that BFG is an unattractive fuel with low calorific value and a much larger CO_2 emission per unit of energy, BFG is used extensively because it is an unavoidable byproduct which would otherwise be flared to atmosphere and replaces other fuels such as natural gas.

Related to this, a further concern of industry with the NE Ph II BM is that the element of the BM allocation applicable to the combustion process is based on natural gas as a fuel, as a result of government steer to achieve consistency across sectors, with a low CO_2 emission factor. However, as indicated in the research for NE Ph II BM, this standardisation on natural gas would lead to allowances significantly below needs for this part of the site, under a bottom-up approach, given that process gases which make up the majority of gases used are generally of a much higher emission factor.

Under a top-down approach and with a fully standardised BM, the actual level of the BM emissions factor does not determine allocations if the benchmark is used simply to apportion a sector cap. However, there could still be distributional issues caused by variations in fuel mixes across installations and Member States.

Alternative 1: Upstream and downstream integration

Further to discussions with the industry, and following the benchmark development process, the alternative formula proposed includes a benchmarking parameter for all of the upstream activities, which represent roughly 90 per cent of CO_2 emissions.

In practice, the formula for benchmarked allocations for the upstream activities would take into account additions/subtractions due to exports/imports of products from individual processes (such as coke, sinter) and alternatives to sinter used in the blast furnace (such as pellets). Furthermore, this should take into account cases where the boiler plants are off site and operated by a different operator.

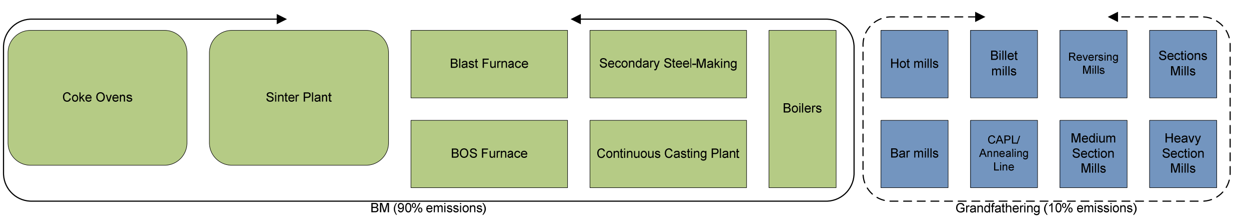

Figure 4.3: Integrated steelworks formula 2: Alternative 1

Downstream activities are quite different in that they represent only a relatively small proportion (about 10 per cent) of total site emissions and there is a significant variation in processes/products from site to site. Benchmarking downstream activities would be possible, although given the variation in process/product types and the fact that emissions at a mill will be highly influenced by the site-specific fuel balances and fuels used at the mill (such as blast furnace gas, natural gas), it might be difficult to identify suitable BM for incumbents. For the purposes of this study, and to simplify the analysis, the allocation for downstream activities has applied a grandfathering approach. In practice, the actual allocation method for these activities would need to be consistent with the requirements of the EU ETS, including any criteria for allocation methods.

Other alternatives

Other alternatives including separate benchmarking parameters for coke ovens, sinter plant, and boilers (Alternative A2) or coke ovens, sinter plant and other upstream activities (Alternative A3) were considered. The rationale for these alternatives was the potential for import/export of products from these individual processes. Whilst there may be merit in considering these further for Phase III, for the purposes of this analysis there could be similarities between Alternative 1 (A1), A2 and A3, depending on how imports/exports are treated in method A1, and how site-wide energy balances are treated. With the limited data and resources available to this study, it was not possible to investigate A2 and A3 separately. However, the general comparison between A1 and NE Ph II BM could also apply to the other alternatives and NE Ph II BM, depending on the detailed aspects of these alternatives.

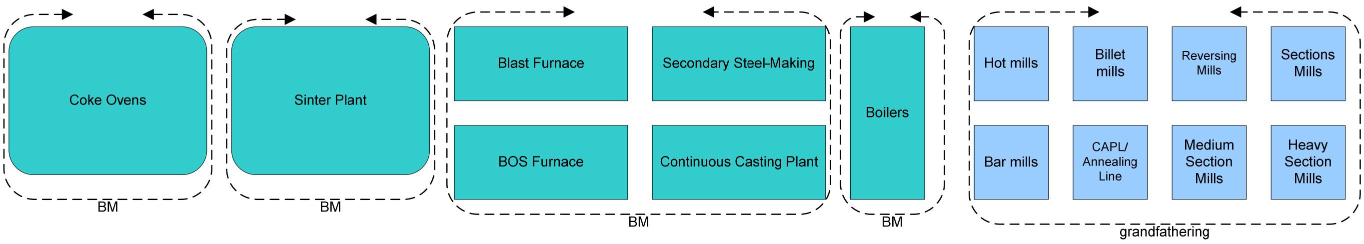

Figure 4.4: Integrated steelworks formula 3: Alternative 2

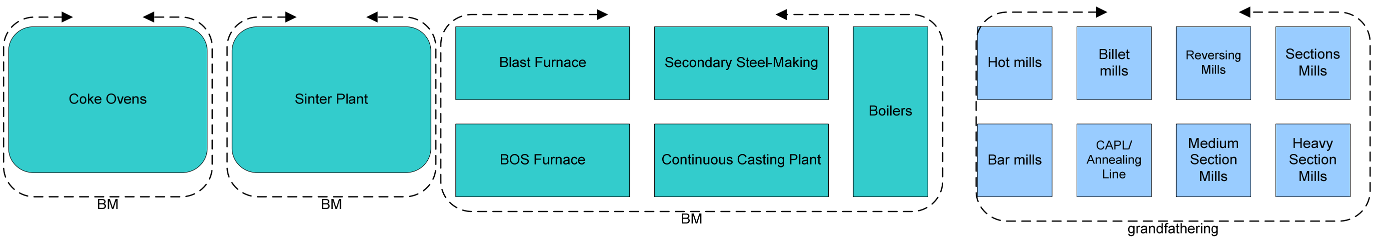

Figure 4.5: Integrated steelworks formula 4: Alternative 3

A further option broached by the industry, which has not been investigated in this study, is an energy-based benchmark. The advantage here is that a universal energy benchmark could be developed for all plants; the disadvantage is that reconciling this BM with a CO_2 constraint would require significant additional work. Whether this would bring overall advantages would need to be determined, and given the complexity of the sector would require a separate endeavour.

4.2.2 Parameter values

Activity levels

The definition of activity can be complex in integrated steelworks, given the ability of operators to import intermediary raw materials such as sinter, coke and pellets or produce them in house, and also to export materials at different stages of production. The production of intermediary materials, in particular, can be highly carbon intensive and as a result fluctuations in imports/own product could affect emissions considerably.

In addition, integrated steel industry representatives believe that historical data is inadequate for forecasting future production trends, as future production also depends on the steel industry cycles and de-bottlenecking activities.

The activity level for the NE Ph II BM was based on the average usage factor of UK plants over a 10-year period up to 2005 (based on assumed maximum capacity equivalent to the highest production over the 10-year period) multiplied by capacity (Entec 2006b).

For incumbent BM, actual production at the individual steelworks site can be used, and for modelling an average over four years (2002 to 2005) was taken for simplicity and for illustrative purposes. In practice, for an ex-ante Ph III BM an average over a longer time period would take into account industry cycles more comprehensively, although further work outside the scope of this study would be required to investigate this, by comparing the impacts of different options against the evaluation criteria.

The alternative to production data, namely capacity data, can be difficult to define at an integrated steelworks. Various definitions may be used including 'design' capacity (identified throughput under current operating conditions); 'unconstrained' capacity (maximum capacity as governed by physical size and engineering characteristics); 'constrained' capacity (amount of production that can be achieved within constraints of adjacent processes); and so on.

Similar to the main steelworks processes, actual activity levels can be used for the boiler plants rather than standardised levels for the NE Ph II BM, as this study is focussed on incumbent benchmarking.

Emission factors

Lowest actual UK emission factors are used for each process element at an integrated steelworks under the NE Ph II BM (Entec 2006b). Furthermore, combustion plants for raising steam and generating electricity at integrated steelworks are covered by generic combustion benchmarks, based on natural gas fuels (in line with government steer to achieve consistency in fuel types across combustion sectors).

Industry representatives expressed concern about the difficulties that such an allocation could create for Phase III incumbents, due to the complex energy balances at each site, and the significantly higher emission factors of actual steelworks combustion plant fuels (such as BFG, coke oven gas) compared to natural gas.

Actual UK emission factors are also used for the alternative formula for upstream processes for the purposes of this study, although, in line with the benchmark formula, they are aggregated over the range of individual process stages[15] and a production

[15] Including combustion plants and flares (flares were not included in PII NE SS)

weighted average, based on 2002-2005 data, is taken across the three integrated sites. Specific variants considered include:

- Alternative 1A parameters based on average historical emissions.
- Alternative 1B parameters based on historical emissions of the top quartile.
- Alternative 1C parameters as for Alternative 1A minus five per cent.

For downstream processes, which are more heterogeneous and give rise to only a minority of emissions, a grandfathering approach is used for the purposes of this study. In practice, a benchmarking approach could also be used, although this would need to consider the large range of product types and potentially significant variations in emissions due to the specific fuels used.

4.3 Results of UK-level modelling

4.3.1 Modelling assumptions

A summary of data sources and assumptions in the analysis are given in Table 4.3.

Table 4.3: Data sources, assumptions and key details for modelling

Aspect		**Details**
Installations considered in modelling		Each of the three integrated steelworks in the UK
Installation-level parameters	Steel production	Data for 2002 to 2005. Source: Corus
	Activity level of boiler plants	Data for 2002 to 2004, in MWh per annum. Source: Corus
	Coke and pellet imports/exports	For simplicity of analysis, these imports/exports are not taken into account in this study, although they would need to be considered when developing a Phase III benchmark
Economic analysis		A price of €30/t CO_2 was used for illustration purposes. Allowance price predictions are uncertain; in addition, allowance prices are expected to vary during Phase III. Therefore, this is a source of uncertainty.
		100 per cent purchase on the market to cover deficit allowances was assumed. In-house abatement options and intra-company exchanges would affect the actual economic impact for each installation type.

4.3.2 Feasibility

The integrated steelworks sector is a particularly complex one and the design of a benchmark for incumbents is expected to require a considerable amount of time from highly specialised staff. The figure below represents the different flows that affect the emissions in both the integrated steelworks and EAF sub-sectors.

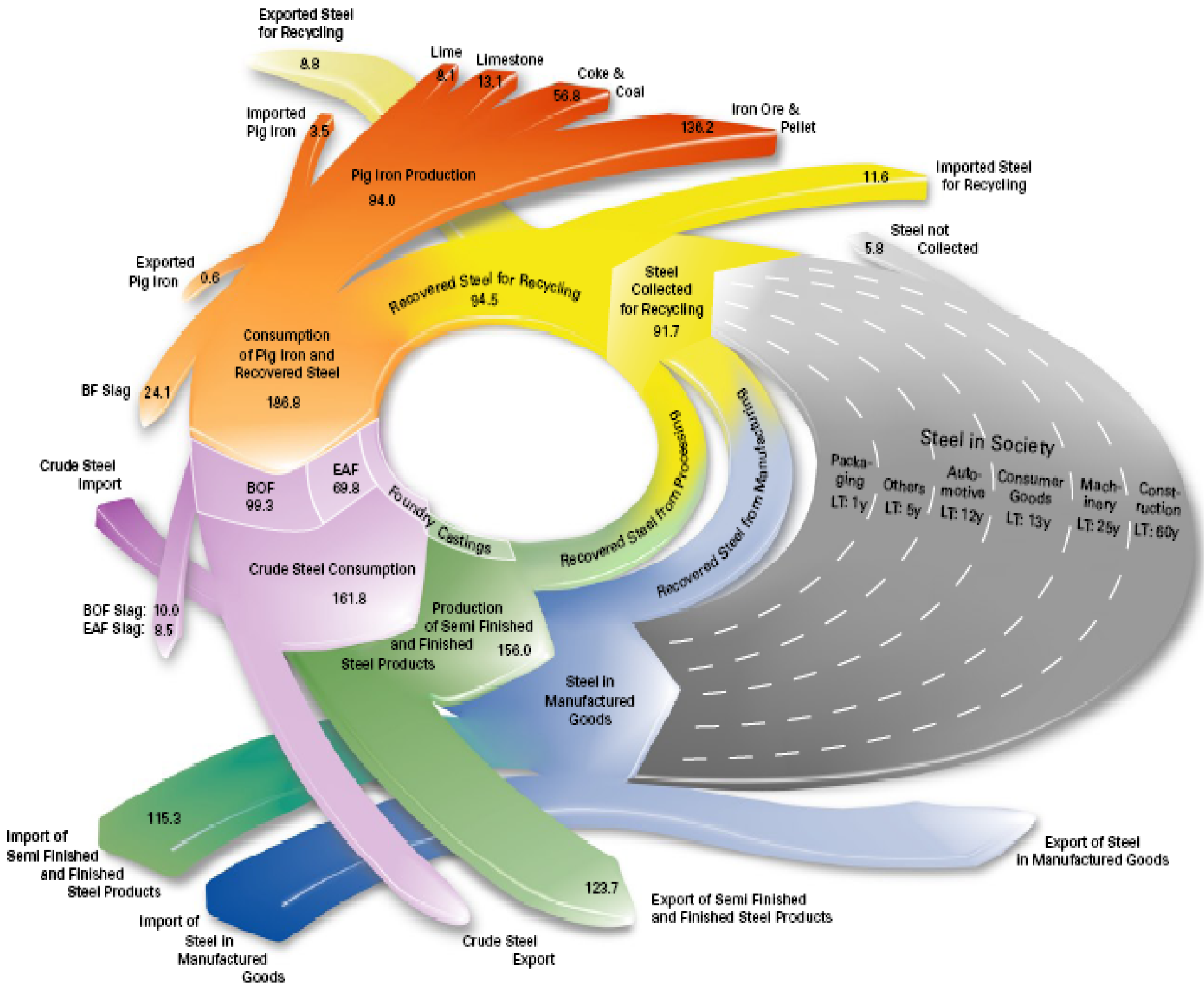

Figure 4.6: Application of BM formulae to integrated steelworks (from EUROFER)

An accurate benchmark would require understanding of the flows affecting scrap utilisation, imports of pellets, sinter and coke. Also, interactions with the electricity sector, which are not shown in the figure above, are likely to affect emissions from operators and leakage within and outside the EU considerably. For example there are plants which use boilers belonging to another entity, creating difficulties for boundary definitions (to place this in a context of scale, a typical proportion of emissions from boilers at UK integrated steelworks is 43 per cent). Given this variability, both the NE Ph II BM and the alternative formula would require additional feasibility consideration before being transposed to the EU context.

The tables below present data required for the development and implementation of benchmarking options.

Table 4.4: Integrated steelworks: Data requirements for development of BM

Factor	NE Ph II BM	Alternative-1
CO_2 emissions - verified emissions (to develop emission factors)	Data for 15 technology types required. Available from Corus for three UK plants.	Single value for upstream processes. Plus values for coke, sinter and pellet production, and boiler plant (for EU-wide BM). Also values for downstream processes if benchmarked. Available from Corus for 3 UK plants.
Steel production (to develop emission factors)	Data for 15 technology types required. Available from Corus for three UK plants.	Single value for upstream processes. Plus values for coke, sinter and pellet production, import and export. Also values for boiler plant. (for EU-wide BM). Also values for downstream processes if benchmarked. Available from Corus for 3 UK plants.
Natural gas EF (to calculate boiler emissions)	Standard value required. Available from Department for Environment, Food and Rural Affairs.	Not required.
Number of data sets	31	At least 10

Table 4.5: Integrated steelworks: Data requirements for implementation of BM

Factor	NE Ph II BM	Alternative-1
Coke production	Operator to provide	Not required
Coke imports/exports (for EU-wide BM)	Not required	Operator to provide
Sinter production	Operator to provide	Not required
Sinter imports/exports (for EU-wide BM)	Not required	Operator to provide
Iron production	Operator to provide	Not required
Pellets imports/exports (for EU-wide BM)	Not required	Operator to provide
Liquid steel production	Operator to provide for BOS furnace and secondary steelmaking process	Not required
Steel production	Operator to provide for continuous casting plant, hot wide strip mills, annealing line, billet mills, reversing mills, medium section mills, heavy section mills, bar mills and section mills (as appropriate for site).	Operator to provide for continuous casting plant and also downstream processes if they are benchmarked
Boiler fuel consumption	Operator to provide	Not required
Boiler imports/exports (for EU-wide BM)	Not required	Operator to provide
Historic emissions for downstream mills	Not required	Operator to provide, unless they are benchmarked
Number of data sets	Maximum of 15	At least 6 (for EU-wide BM)

4.3.3 Environmental effectiveness

The figure below represents total historical emissions, total sectoral emissions under a bottom-up benchmark designed on the basis of Alternative 1. For the latter three parameter value variants were applied:

- Alternative 1A parameters based on average historical emissions.
- Alternative 1B parameters based on historical emissions of the top quartile.
- Alternative 1C parameters as for Alternative 1A minus five per cent.

A bottom-up allocation using the alternative formula under all its variants would produce results similar to grandfathering on the basis of historical emissions; applying the NE Ph II BM formula would lead to a much lower allocation (especially because of standardising boiler plant emission factors on natural gas), but the effects of all the approaches considered are fairly uniform across installations.

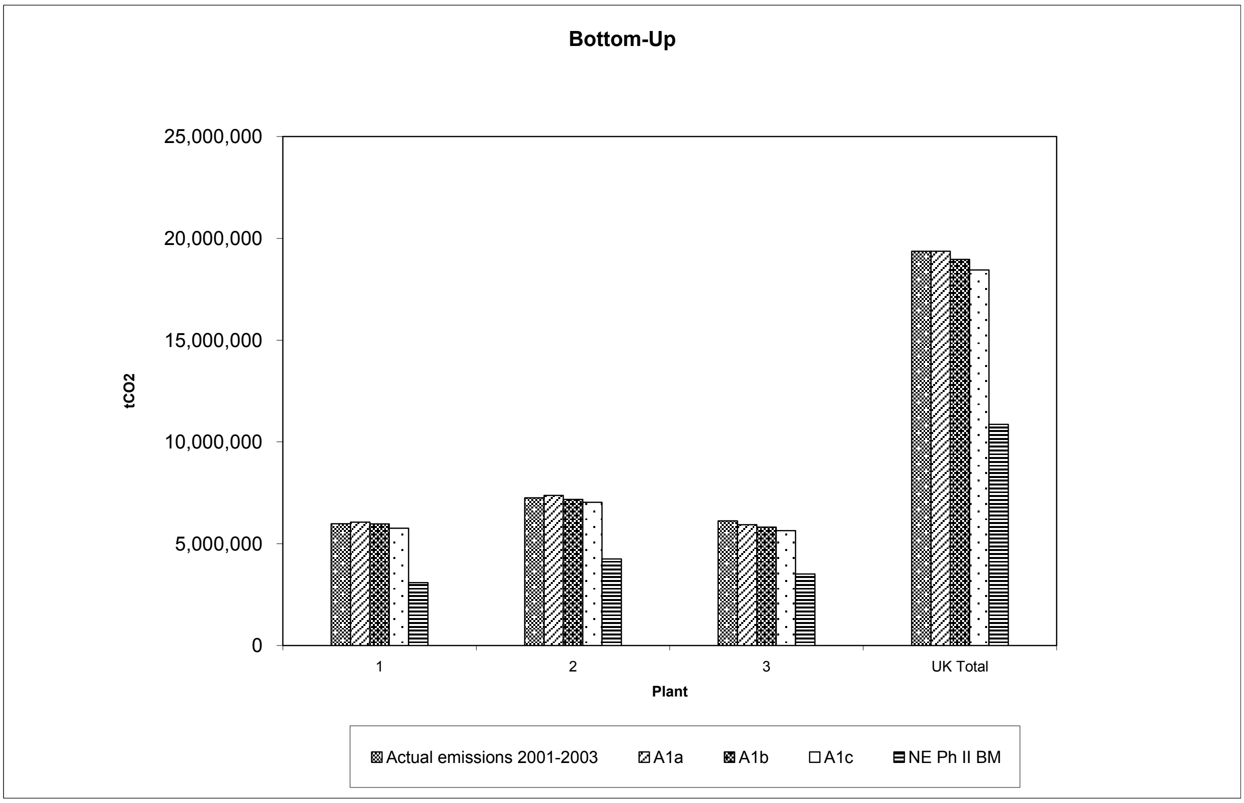

Figure 4.7A: Application of BM formulae to integrated steelworks

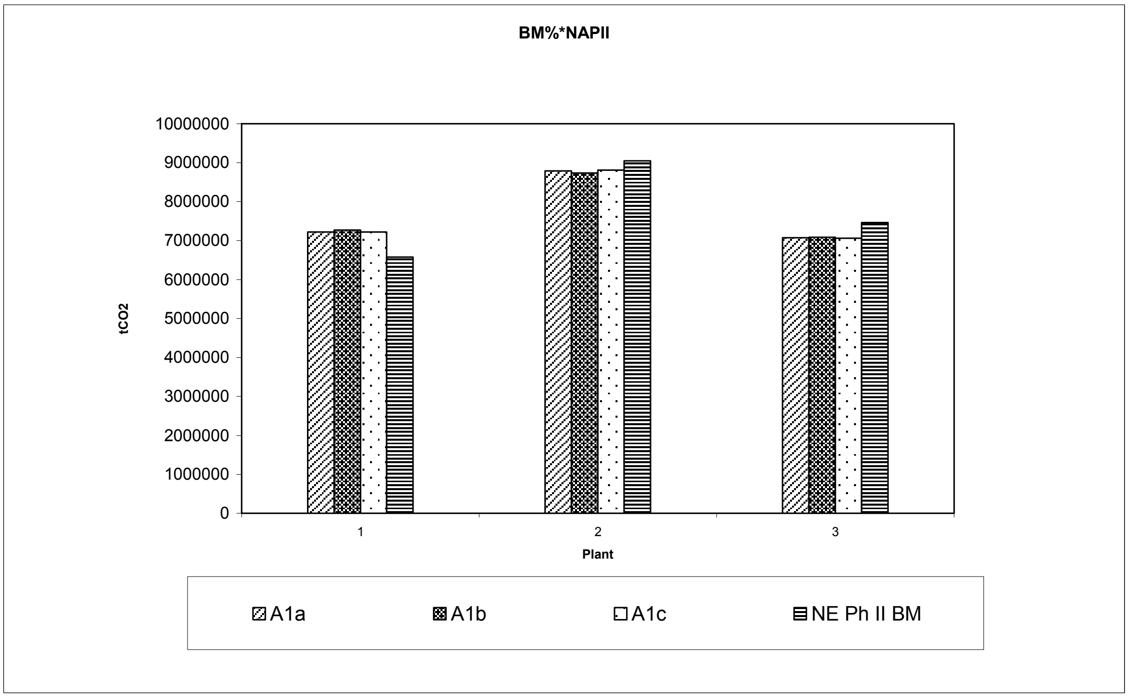

Figure 4.8B: Application of BM and NAP formulae to integrated steelworks

Due to the lack of variability in plant performance, the different benchmarking methods combined with a top-down sectoral cap result in homogenous results. Further to discussions with sectoral experts, it appears that there is limited potential for improvement in the integrated steelworks sub-sector in the short run, in addition to the sector's efforts to reduce energy consumption by approximately one per cent per year. In the longer run, technologies such as carbon capture and storage (CCS) and other options currently in research and development would yield further options.

Accounting for carbon-intensive product flows and alternative feedstocks to blast furnace

In setting a benchmark per tonne of upstream or downstream product, there is the risk of producing a perverse incentive to import intermediate products such as coke, directly reduced iron, pellets, or sinter. This would reduce emissions from EU ETS-covered installations, but would increase global greenhouse gases through transformation processes abroad and transport. It is therefore suggested that imports and exports of intermediate products are recorded at installation level for the purpose of BM.

The operationalisation of recordkeeping, and the way this information is integrated in the benchmarking/allocation process is expected to require further, potentially extensive consideration. Relevance of historic data and the potential need/demand for ex-post adjustments are likely to cause feasibility problems.

Another aspect that could be addressed as part of this exercise is the transfer of heat energy across ETS installation boundaries (this refers to the off-site boiler issue mentioned above).

4.3.4 Economic impacts

Existing literature on impacts of EU ETS

We have relied on recent literature (Carbon Trust, Climate Strategies, Hatch Beddows, IEA, McKinsey and Ecofys) for product range data.

Distributional impacts from applying benchmarking formulae

Under all variations of Alternative A1, the distribution of allowances is almost the same; hence, variations in the BM formula would not make a difference in allocation under a predetermined sectoral cap. Under the NE Ph II BM, the bottom-up allocation changes visibly to produce a potential deficit and the distribution of allowances changes more markedly among the three considered installations than among the variants of the alternative formula. Overall, however, the effect of the BM formula would be limited.

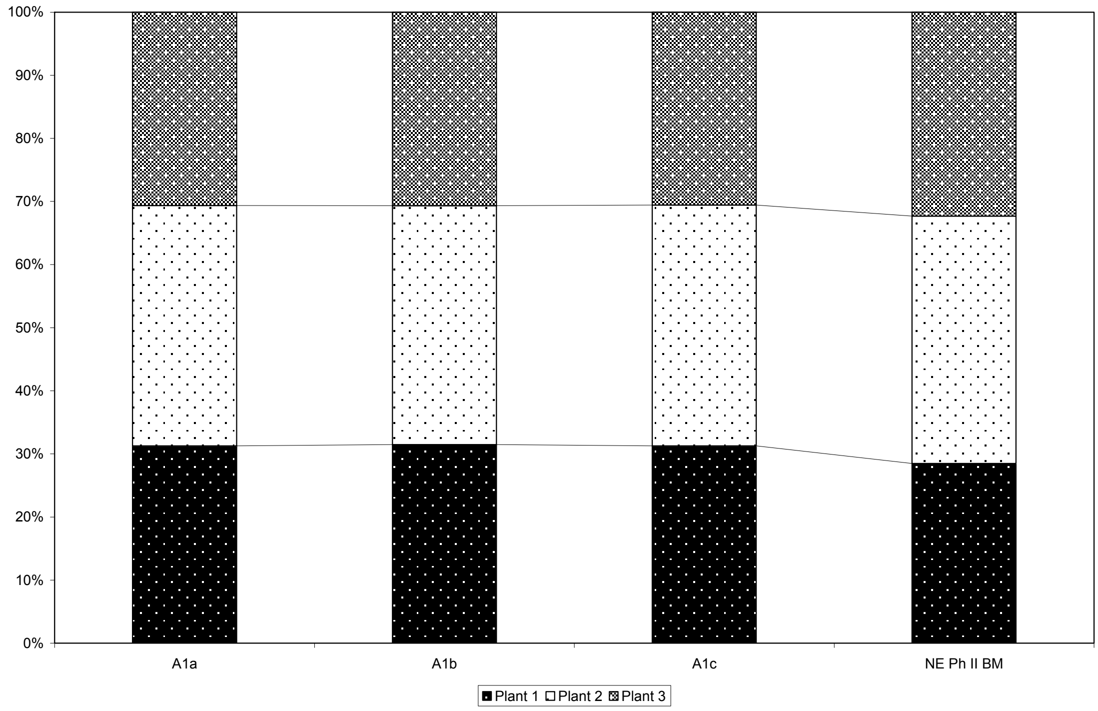

Figure 4.9: Application of BM formulae to the integrated steelwork operators

Added cost/benefit estimation

The illustration below shows the selection of a benchmarking formula from a given range. The effect of the different formulae is considered in the context of an illustrative sectoral cap and 100 per cent free allocation (given that the sectoral cap was unknown at the time of writing, the NAP II allocation was selected from the range of possible examples due to the completeness of data available). All the results would be affected by the choice of sectoral cap or proportion of free allocation.

The effects are compared to the NAP II allocation as an example. An impact on the 'zero line' would equate to an allocation per tonne of product equivalent to NAP II, an impact below the line is a cost and an impact above the line is a benefit.

The average deficit/surplus per tonne of liquid steel (LS) was multiplied by €30, the assumed CO_2 price:

€ impact = (T_{CO2} /T $_{LS}$ BM%$_{installation}$*NAPII$_{sector}$ - T_{CO2} /T $_{LS}$ NAPII$_{installation}$) * €30/T_{CO2}

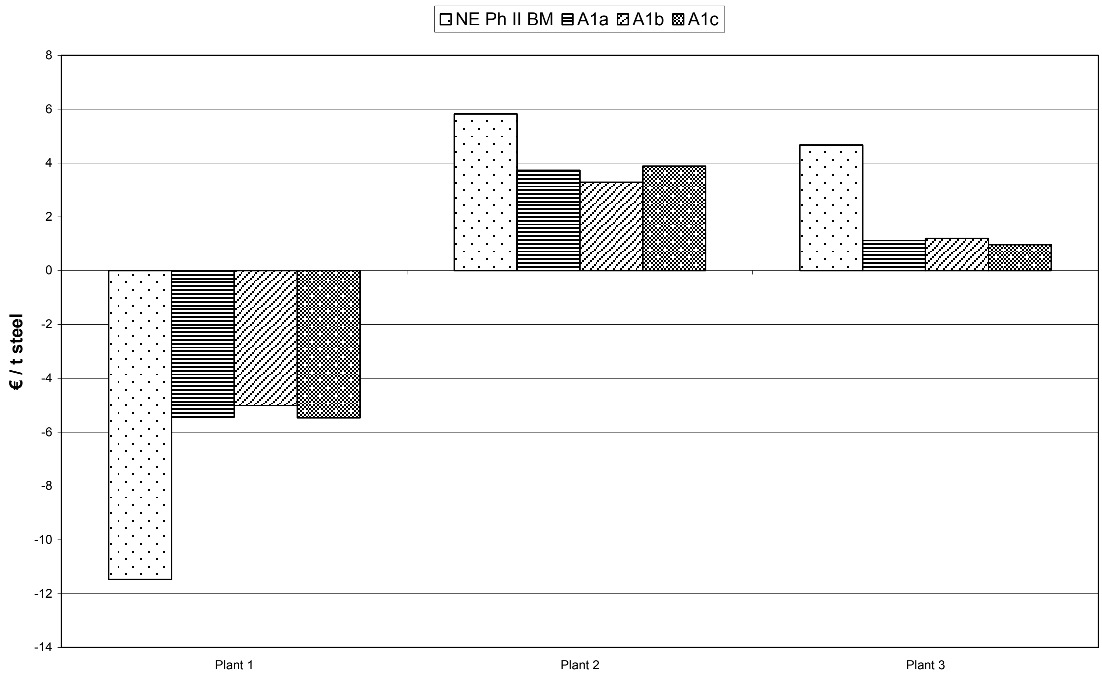

Figure 4.10: Added costs/benefits per tonne liquid steel: integrated steelworks

The results suggest that all formulae considered entail a similar number of winners and losers, although the variability of impacts (measured in terms of standard deviation from average) are considerably lower for the alternative formula variants, at about half the level for the NE Ph II BM.

NE Ph II BM	A1a	A1b	A1c
9.67	4.72	4.31	4.78

According to Hatch Beddows (2007) a steel prices ranged between €500/t (for hot rolled coil) to €700/t (for heavy sections) in 2006. Using the implied cost range, we estimate that:

- Applying the Phase II NER BM together with the NAP II allocation results in a range of added costs of up to two per cent as a percentage of minimum product price or a benefit of one per cent as a percentage of maximum product price.

Added costs are below transportation costs and would therefore not have significant distributional impacts. Furthermore, they are considered to be in line with other input cost fluctuations.

4.4 MS-level considerations

Whilst many integrated steelworks across the EU may have an overall emission factor in the region of 1.6 to 1.8 tonnes of CO_2 per tonne of liquid steel, there can be significant variations at the installation level depending on the extent of:

- imports/exports of coke, sinter, pellets, directly reduced iron;
- export of fuel for off-site power generation;
- variation in fuel types for boiler plants and other process units;
- variation in types of products for off-site sales.

The extent of impact of these and other variables will depend on the type of benchmark chosen. There is a risk that allocation to the UK industry would change significantly under an EU-wide standardised benchmark, but the extent of the risk is highly uncertain and would require further analysis at EU level.

The data required would include at a minimum:

- CO_2 emissions from EAF and integrated steel installations covered by the EU ETS for each member state;
- product range from EAF and integrated steel installations covered by the EU ETS for each member state;
- flows of carbon-intensive intermediate products;
- qualitatively, process irregularities.

4.5 MRV implications

No MRV complications are envisaged for the NE Ph II BM formula, except for potential verification issues regarding definition of plant capacity.

The alternative formula would require additional MRV work for the suggested accounting of carbon-intensive intermediate product flows (such as sinter, coke).

4.6 Conclusions

The table below summarises the performance of BM options against the criteria:

Table 4.6: Performance matrix: Integrated steelworks

Criteria	NE Ph II BM	A1a	A1b	A1c
1. Feasibility				
A. How resource intensive is it expected to be to fully *develop* and *maintain* the benchmark method?	+/-- Already developed for Phase II. For updating, large number of data points required.	+/- A number of data sets needed.		
Data points required to *develop* benchmark	31	6		

Criteria	NE Ph II BM	A1a	A1b	A1c
1. Feasibility				
Data points required to *implement* benchmark	Max. 15		4	
B. Can benchmark factors be replicated by a third party?	+		+	
C. Can input data for the benchmark method be verified?	+		+	
2. Environmental effectiveness				
Are benchmarks standardised, avoiding differentiation for raw materials, technologies and fuels?	++ Standardised to UK top performance	++	++	++
3. Economic impacts				
What is the likely impact on distributional equity at installation level?	--	0	0	0
What is the likely impact on distributional equity at company level?	0	0	0	0

'+' positive score on criterion, '++' strongly positive on criterion, '-' negative score on criterion, '—' strongly negative on criterion, '0' no impact, '+/-' combination of positive and negative impacts.

Answers to key questions

Is Phase II NER BM suitable for incumbents?

The suitability of the Phase II NER BM for incumbents was tested against the three criteria (feasibility, environmental effectiveness and economic impacts) and compared to variants of the alternative formula. The **Phase II NER BM** performs as follows.

The Phase II NER BM required 31 data points for its development and up to 15 data points for its implementation and therefore is relatively labour-intensive, if some of the data points have to be updated. However, the parameters required can be replicated by a third party and can also be verified.

The Phase II NER BM does not differentiate by technology or fuel and therefore scores well on its ability to encourage clean techniques and technology.

The Phase II NER BM was required to apply to new/modified individual steps and hence differentiates among the large number of processes. This approach is less applicable to whole incumbent sites for which more aggregated groupings can be applied and which can take a more integrated approach to variations in process gas usage across a site. Applying the Phase II NER BM together with the NAP II allocation results in a range of added costs of up to two per cent as a percentage of minimum product price or a benefit of one per cent as a percentage of maximum product price[16].

The **alternative formula (variants A1a, A1b, and A1c)** performed as follows.

The alternative formula requires six data points for its design and four data points for implementation. Similarly to the Phase II NER BM, some existing data points would require updating. The added complication of the alternative formula is accounting for

[16] Added cost as % of minimum costs and added benefits as % of maximum product price are selected to provide conservative range of impacts, i.e. presented with a bias towards the cost side.

flows of carbon-intensive inputs and outputs. This would be new with regards to what is currently undertaken under EU ETS reporting and verification in the steel sector. A considerable amount of background work with regards to such flows was undertaken by EUROFER for the development of a benchmarking proposal separate from the EU ETS. It is therefore expected that, with the cooperation of EUROFER and industry representatives, the design and implementation of the proposed formula is feasible.

The alternative formula does not differentiate by technology or fuel and therefore scores well on its ability to encourage clean techniques and technology.

Applying the alternative formulae results in a range of between one per cent added costs and one per cent added benefits (as percent of product price). Variation among the three variants is insignificant.

What would be the competitive/distributional effects of using the Phase II NER BM?

Using the process mapping of Phase II NER BM together with NAPII allocation leads to insignificant added costs compared to overall product prices and is not expected to lead to major distributional impacts within the UK.

Is there a need for a transitional phase to take into account certain site-specific factors?

The need for a transitional phase is set by the magnitude of risk of stranded assets in the sector. In the context of the two considered formulae, technology differentiation is not included and therefore a transitional phase is irrelevant. Provided there is homogeneity of the technology used in the UK integrated steelworks sector, it is unlikely that the need for a transitional phase would emerge further to a more detailed analysis.

What would be the implications for monitoring, reporting and verification (MRV)?

The use of Phase II NER BM would not entail added MRV complications. The design and implementation of alternative formula would require changes to MRG guidelines and implementation to account for the flow of carbon-intensive inputs and outputs.

How would a UK incumbent benchmark affect the distribution of allowances EU-wide across the sector?

Current data scarcity does not allow for a full assessment of the applicability of a UK BM at the EU level. Divergence may arise from different process structures (boilers, coke ovens), blast furnace burden types (sinter, pellets, direct reduced iron (DRI)), scales of operation, fuel types and product ranges.

What would be the key issues for other Member States in using UK-developed BM?

The key issue would be ensuring that all process structures, blast furnace burden types, fuel types and products were considered.

5 Electric arc furnace analysis

5.1 Sector description

This section describes some of the key characteristics of the sector relevant to BM.

The direct smelting of iron-containing materials, mainly scrap, is usually performed in an electric arc furnace (EAF) which needs considerable amounts of electrical energy and can cause substantial emissions to air and solid wastes/byproducts, mainly as filter dust and slags (EIPCCB 2001a). With respect to the end products, a distinction can be made between production of ordinary 'carbon steel' as well as low alloyed steel and high alloyed steels/stainless steels. Each of these product grades involves the use of different quality of scrap metal (higher or lower carbon content), different alloying additions and different final product carbon content.

Molten metal is transferred from the EAF via a 'ladle' and various 'ladle treatments' are used to impart the desired metal properties prior to casting. Vacuum degassing is also carried out in ladles. Often a second furnace called a 'ladle furnace' is used in addition to the main electric arc furnace and ladles. A ladle furnace (which operates like a lower power EAF) is used to melt/blend alloying additions into the liquid steel product from the EAF prior to casting of the metal product. The figure below indicates the main inputs and outputs of the process:

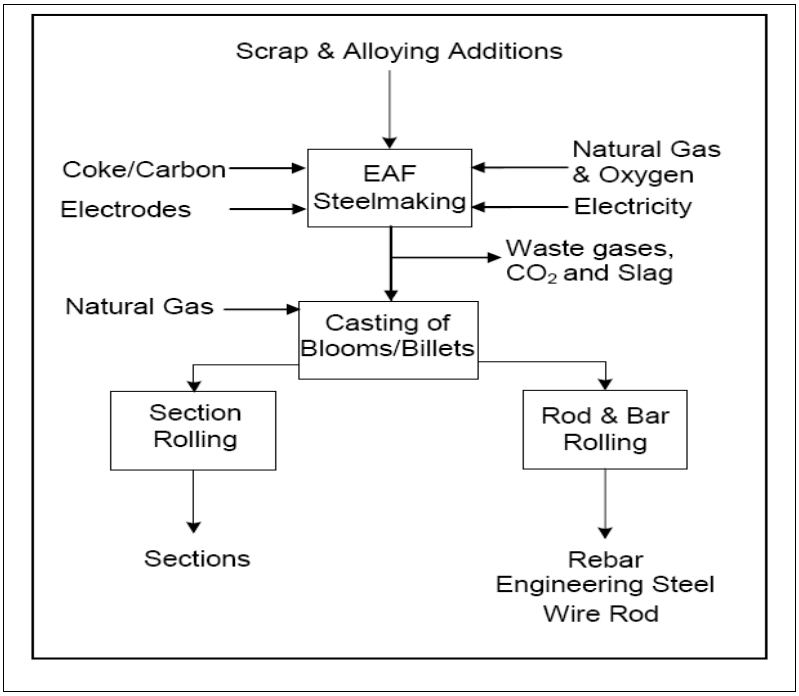

Figure 5.1: EAF process flow overview diagram

CO_2 is emitted from the EAF steelmaking process from a number of sources:

- combustion of natural gas, propane or other fossil fuels fed to the EAF;
- combustion of natural gas or other fossil fuels used to raise steam in boilers;

- combustion of natural gas or other fossil fuels to directly heat ladles, ladle furnaces, casting machine ancillaries and other associated equipment;
- carbon losses from reducing the carbon content of the scrap metal feedstock via oxygen injection at the EAF;
- carbon losses from oxidation of the carbon content of the metallic and non-metallic alloying additions;
- Ooidation of coke/coal and other carbon injected at the EAF and other points in the process;
- consumption of the carbon electrodes at the EAF and ladle furnace;
- heating of AOD vessels (this is an additional process vessel used only in the manufacture of stainless steel).

Interaction between direct and indirect emissions

The main economic impact to EAF plants is the price of electricity (an indirect impact), as EAF plants do not receive allowances for indirect energy inputs. Nearly all CO_2 emissions (85 per cent) from EAF are indirect emissions from electricity consumption (in the production of more complex higher alloy steels, this can fall to 65-70 per cent), compared to only 10 per cent for integrated steelworks. Given measures taken to avoid windfall profits in the electricity sector and tighter GHG reduction targets, the prices of electricity charged to EAF operators are expected to increase. This in turn may lead to increased direct emissions as explained in the text box below.

Box 2: Use of carbon to reduce electricity consumption in EAF

There is now pressure on the industry to use additional carbon/carbon utilisation techniques to augment the use of electricity, because of the significant cost increases that have occurred recently. In the past, it has been used purely to enhance the steel-making chemistry and as such, much of the reaction was suppressed and only CO formed, not CO_2. This releases only about 30 per cent (and in some cases 20 per cent) of the energy if the reaction goes to completion. If the second stage of the combustion can be achieved whilst there is significant scrap in the furnace, some of the energy can be used and so techniques are being developed to do this. Carbon is also added to the slag to make it foam and hence shield the walls and roof of the furnace from much of the direct radiation from the electrodes, directing more of the energy into the melt.

Therefore assessments of benchmarking formulae and parameter values should be considered in the context of the wider EU ETS context.

Following discussion with industry experts, it appears that there is limited potential for improvement in the EAF sub-sector in the short run in addition to the sector's efforts to reduce energy consumption by one per cent per year. In the longer run, other options currently in research and development would yield more abatement options.

5.2 Benchmarking options considered

5.2.1 Short-listed formulae

NE Phase II BM

The NE Ph II BM includes a significant differentiation by process type (Entec 2006c).

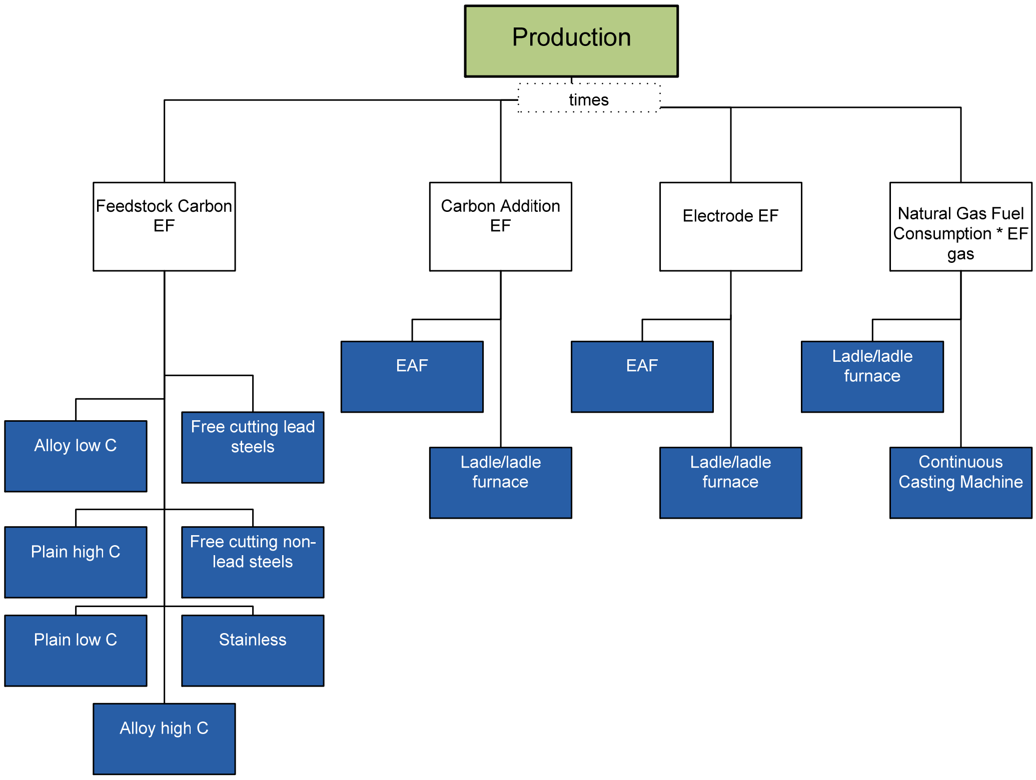

Figure 5.2: Electric arc furnace: NE Phase II BM

Industry representatives were content with the new entrant benchmarking formula, but expressed concerns about the fact that the benchmark requires the operator to select one type of product (which would determine the allocation) and prevents them from selecting the actual mix (in practice, this is driven by the need for verification and is clearly difficult for a new entrant to verify a future product mix); the BM does not take into account all emission sources within a stainless steel plant; and plants making large castings (which require more energy for melting) are not specifically accounted for[17]. Steam-raising boilers and other on-site combustion plants are covered by separate generic benchmark methods for combustion plants.

[17] According to the Entec New Entrant Benchmark Report, "*the operator should provide the verifier with documentation such as production schedules and sales forecasts to support the choice of main steel grade selected*."

Alternative 1

A slightly simplified formula was proposed as an alternative. This formula has five rather than seven steel types; includes additional emission sources for stainless steel; and allows for differentiation by product size. Large castings require more energy and use multiple ladles (in the formula, shown as the added step of multiple ladle casting premium). Under the alternative, incumbents would be allowed to select a mix of products, as compared to a single product under the NE Ph II BM.

This formula accounts for fuel used in combustion plants through separate fuel-based elements of the formula.

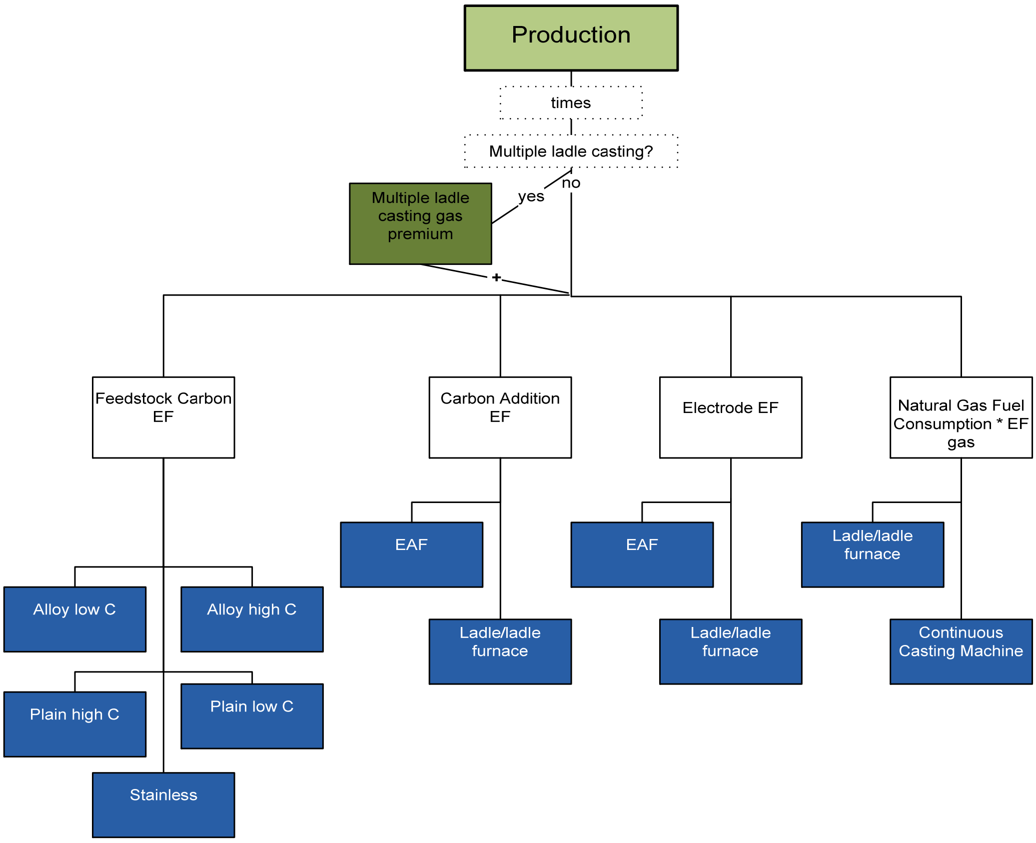

Figure 5.3: Electric arc furnace: Alternative 1

5.2.2 Parameter values

Activity levels

The NE Ph II BM uses two standardised factors to differentiate between plants making only plain low carbon steels and other EAF plants, in accordance with a government steer. This was to more closely reflect the distinctly different levels of utilisation of these types of plants[18], and to more closely meet site needs (Entec 2006c).

[18] For plants making only plain low carbon steels, changeover times between production runs are reduced and hence overall utilisation can be higher than for plants making specialist steel grades or a mixture of steel types.

Industry representatives suggested that differentiated utilisation factors for different steel types multiplied by a verified capacity should be used for Ph III (this assumes that the verified capacity does not already include a utilisation factor; care must be taken to avoid double counting).

Emission Factors

BAT-based emission-level parameters were used for each process element under the NE Ph II BM (Entec 2006c). These were differentiated between the EAF, ladle/ladle furnace, casting machine and boilers, and, for emissions from scrap losses, between seven steel categories, as presented in the following table.

Table 5.1: Details for the NE Phase II BM for the electric arc furnace

$EF_{feedstock}$	$EF_{feedstock}$ (tCO_2/tls) = Standard carbon loss from feedstock (% w/w C)/100 * 44/12	
	Standard carbon loss values are as follows:	
	Plain low carbon steels:	0.152 %w/w C
	Plain high carbon steels:	0.314 %w/w C
	Alloy low carbon steels:	0.152 %w/w C
	Alloy high carbon steels:	0.457 %w/w C
	Free cutting lead steels:	0.152 %w/w C
	Free cutting non-lead steels:	0.152 %w/w C
	Stainless steels:	1.231 %w/w C
	Where 92 per cent of the total carbon loss is attributed to the EAF and eight per cent is attributed to the ladle/ladle furnace	
EF_{carbon}	EAF:	0.0466 tCO_2/tonne of liquid steel
	Ladle/ladle furnace:	0.0018 tCO_2/tonne of liquid steel
$EF_{electrode}$	EAF:	0.0081 tCO_2/tonne of liquid steel
	Ladle/ladle furnace:	0.0014 tCO_2/tonne of liquid steel
SEC_{gas} (gross basis)	EAF:	52 kWh/tonne of liquid steel
	Ladle/ladle furnace:	45 kWh/tonne of liquid steel
	Casting machine:	23 kWh/tonne of liquid steel
EF_{gas}	0.00019 tCO_2/kWh (based on natural gas gross calorific value)	

Industry representatives expressed concerns about the difficulties that such an allocation would create, in particular due to the inability to select the specific product mix (inherently caused by its application to new entrants, for which the product mix is not verifiable); the incomplete coverage of stainless steel emission sources; and the lack of consideration of additional energy use for plants making large castings.

The alternative formula considered in this study covers CO_2 emissions for the full process (including boilers) relevant to the production of steel type (steel type defines the process route, number of stages and so on) with five categories of steel. Sites that undertake multiple ladle casting will have the normal CO_2 emissions for the relevant steel type with a premium for fuel emissions because of increased ladle heating.

Alternative 1A parameters based on average historical emissions for each product type are listed in Figure 4.10. A breakdown of the specific emission factors is given in the following table. These figures have been provided by industry and have not been verified by the authors. As such, they should be regarded as illustrative only, where further work would be required to develop potential benchmarks for incumbents for Ph III of EU ETS.

Table 5.2: Details for the NE Phase II BM for integrated steel, tCO2/t liquid steel

Steel type	Plain low carbon	Plain high carbon	Alloy low carbon	Alloy high carbon	Stainless	Multi-ladle casting premium
External fuel (ladle heating/tundish heating etc)	13.50	13.50	29.60	29.60	40.81	22.60
Internal fuel (oxy/ fuel burners, coal injection etc)	15.30	15.30	9.63	9.63	0.00	
Electrodes	9.48	9.48	11.81	11.81	13.60	
Chemical carbon	28.12	28.12	57.15	57.15	17.78	
Foaming slag carbon	22.05	22.05	17.58	17.58	0.00	
Net carbon loss from scrap	5.57	11.35	5.57	11.35	4.53	
Carbon loss from alloys	0.74	0.74	24.78	24.94	48.86	
Cut-off fuel	0.24	0.24	1.03	1.03	1.56	
Total	95.00	100.78	157.15	163.09	127.14	

Alternative 1B parameters based on the historical emissions minus 10 per cent[19] for each product type listed in Figure 4.10.

5.3 Results of UK-level modelling

5.3.1 Modelling assumptions

The previous sections describe the benchmarking options and parameter values which have been considered in this study. A summary of data sources and assumptions for other aspects of the analysis are given in Table 5.3 below.

[19] In comparison, the NE Ph II BM was estimated to require an overall reduction in CO_2 emission intensity of around eight per cent compared to current EAF performance levels (Entec 2006c).

Table 5.3: Data sources, assumptions and key details for modelling

Aspect		Details
Installations considered in modelling		Six existing EAF installations in the UK.
Installation-level parameters	Steel production	2002 to 2006 data for five installations; 2003 to 2006 data for one installation. The data is not verified. Ladle/ladle furnace output data is not available therefore the output from the EAF has been assumed to apply to both steps, This will result in a small (less than two per cent) over-allocation under the NE Ph II BM.
	Steel types	Information on the steel type product mix has only been made available for two installations. For one other installation, alloy low carbon steel has been assumed on advice of the operator. For the remaining three installations, plain low carbon steel has been assumed. Due to the range of emission factors for different steel types, this assumption introduces a potential error of 58 per cent under allocation in the emissions calculated for these three installations under the alternative benchmark options. The emission factors for the steel categories are indicative only as they are based on a limited data trawl. Figures to establish viable benchmarks will require detailed input from the sector.
	Activity level of boiler plants	Data for 2001 to 2006, in MWh per annum. Source: Installation operators. Actual boiler fuel consumption is not known for Plant 1. Therefore, a standard value of 43 kWh/tonne liquid steel (Entec 2006c) has been applied for that plant. Under the alternative benchmark options, the boiler fuel consumption is incorporated into the steel category emission factor.
Economic analysis		A price of €30/t CO_2 was used for illustration purposes. Allowance price predictions are uncertain; in addition, allowance prices are expected to vary during Phase III. Therefore, this is a source of uncertainty. 100 per cent purchase on the market to cover deficit allowances was assumed. In-house abatement options and intra-company exchanges would affect the actual economic impact for each installation type.

5.3.2 Feasibility

Similar to the integrated steelworks sector, electric arc steel production is very complex. The main problem that could be encountered in designing a BM for phase III is data availability; for example the division between electric arc furnace, ladle furnace and casting machine is commercially sensitive data that the operators can have difficulties in making public. More extensive difficulties can be expected if the benchmark is extended to other MS. The tables below present data required for the development and implementation of benchmarking options.

Table 5.4: Electric arc furnace: Data requirements for development of BM

Factor	NE Ph II BM	Alternative-1
Scrap net carbon loss % w/w C (to calculate feedstock EF)	Required for seven steel categories. Available from industry.	Not required
Emission factor from electrode (to calculate process EF)	Required for electric arc furnace and ladle. Available from industry.	Not required
Emission factor from carbon addition (to calculate process EF)	Required for electric arc furnace and ladle. Available from industry.	Not required
Scrap loss contribution (to calculate process EF)	Required for electric arc furnace and ladle. Available from industry.	Not required
Specific energy consumption (to calculate fuel EF)	Required for electric arc furnace, ladle and continuous casting machine. Available from industry.	Not required
Natural gas EF (to calculate fuel EF)	Standard value required. Available from Defra.	Not required
CO_2 emissions from external fuel (ladle heating/tundish heating etc)* (to calculate specific EF)	Not required	Required for five steel categories. Available from industry.
CO_2 emissions from internal fuel (oxy/fuel burners, coal injection etc)* (to calculate specific EF)	Not required	Required for five steel categories. Available from industry.
CO_2 emissions from electrodes* (to calculate specific EF)	Not required	Required for five steel categories. Available from industry.
CO_2 emissions from chemical carbon* (to calculate specific EF)	Not required	Required for five steel categories. Available from industry.
CO_2 emissions from foaming slag carbon* (to calculate specific EF)	Not required	Required for five steel categories. Available from industry.
CO_2 emissions from net carbon loss from scrap* (to calculate specific EF)	Not required	Required for five steel categories. Available from industry.
CO_2 emissions from carbon loss from alloys* (to calculate specific EF)	Not required	Required for five steel categories. Available from industry.
CO_2 emissions from cut-off fuel* (to calculate specific EF)	Not required	Required for five steel categories. Available from industry.
Tonnes liquid steel produced (to calculate specific EF)	Not required	Required for five steel categories.
CO_2 emissions from multiple ladle casting gas premium (to calculate specific EF)	Not required	Required for multi-ladle castings. Available from industry.
Number of data sets	17	46

Table 5.5: Electric arc furnace: Data requirements for the implementation of BM

Factor	NE Ph II BM	Alternative-1
Steel production	Operator to provide for electric arc furnace, ladle furnace and continuous casting machine	Operator to provide for continuous casting machine for each of five steel types.
Steel type	Operator to provide main steel types produced, from seven categories	Operator to provide list of steel types produced, from five categories
Multiple ladle	Not required	Operator to confirm
Boiler plant capacity	Operator to confirm	Not required
Number of data sets	5	3 to 8

5.3.3 Environmental effectiveness

The figure below represents the difference between historical emissions and a bottom-up allocation for six EAF plants in the UK, should the proposed BM alternative be used.

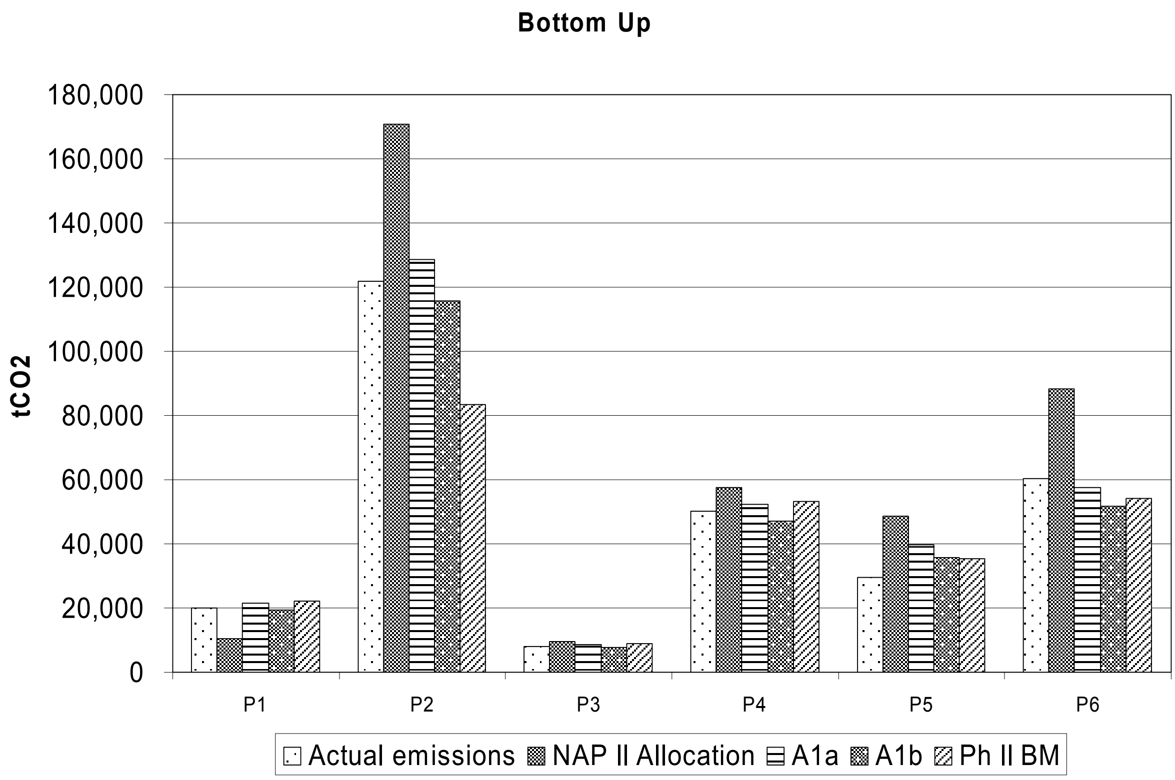

Figure 5.4A: Application of alternative BM formula to EAF operators

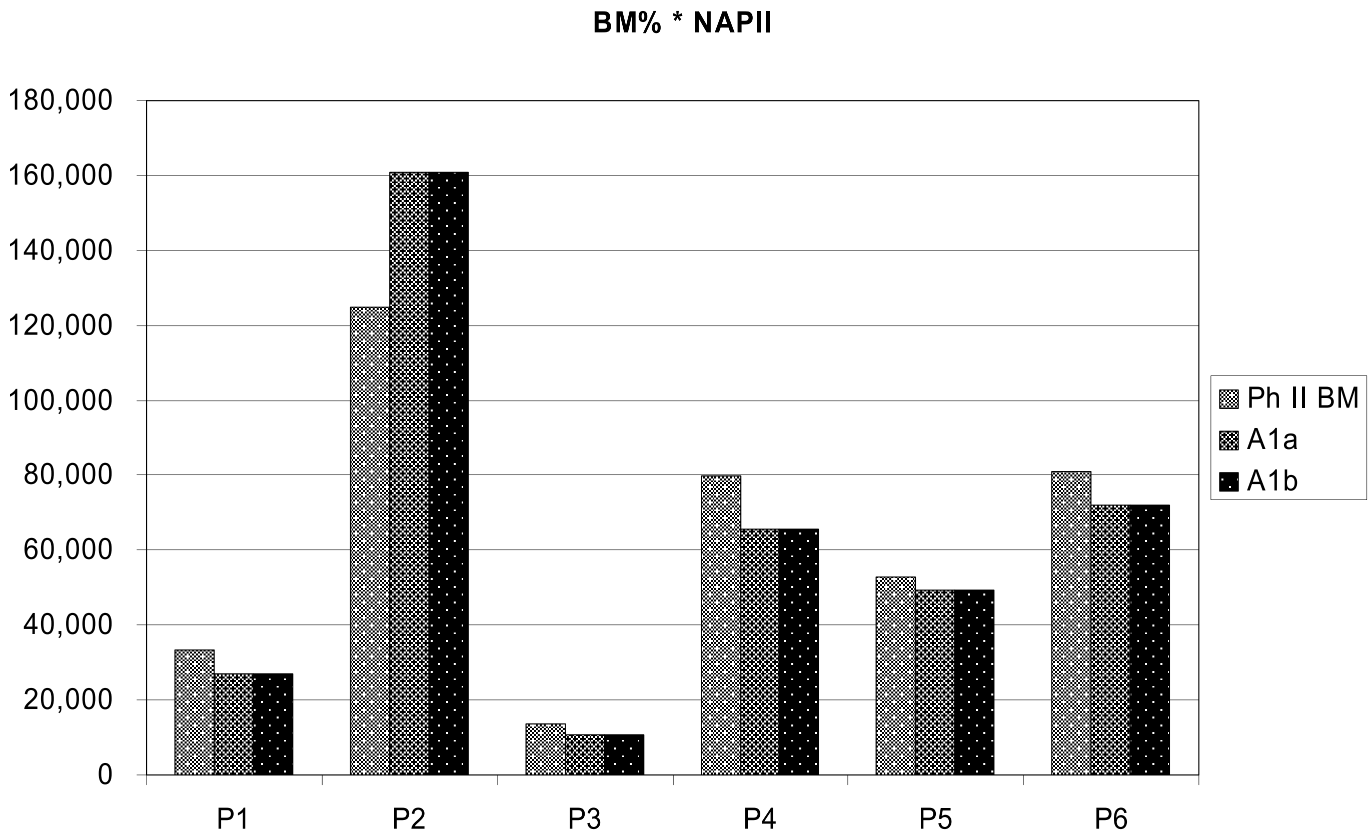

Figure 5.5B: Application of alternative BM and NAP formula to EAF operators

The bottom up allocation shows that all the considered benchmarking variants would provide an allocation below the NAP II for most plants and that there is a limited difference between the A1a allocation and historical emissions with increasing variability for the other variants. The top-down allocation applying the Ph II benchmarking formula and the alternative formula variants suggests that the alternative formula would provide a lower allocation to all plants but one, most likely due to product differentiation issues. There is no difference between the two variants of the alternative formula.

5.3.4 Economic impacts

Other literature on competitiveness impacts

Previous studies on competitiveness impacts such as Ecofys (2006) and Climate Strategies (2008) were analysed here and relied on for conclusions with regards to profitability in the sector, ability to pass through additional costs and intra-EU trade.

Distributional impacts from applying benchmarking formulae

The distribution of allowances changes from NAP II to NE Phase II BM; the percentage allocation on the basis of alternative variants are similar to the NAP II distribution.

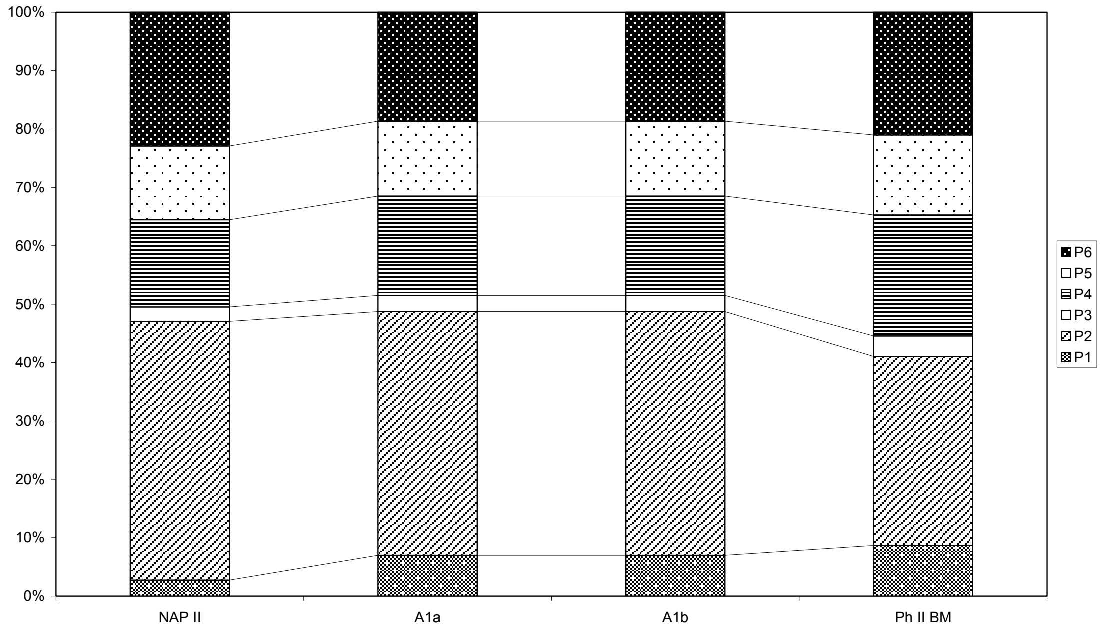

Figure 5.6: Application of the alternative BM formula to EAF operators: Distributional Impacts

Added cost/benefit estimates

The added cost implications are calculated for each plant by combining the bottom-up BM distribution with the overall sectoral cap for NAP II. The latter is used as an illustration and is not expected to correspond to the free allocation in Phase III.

$$\text{€ impact} = (T_{CO2} / T_{LS}\ BM\%_{installation} * NAPII_{sector} - T_{CO2} / T_{LS}\ NAPII_{installation}) * \text{€}30/T_{CO2}$$

The number of 'winners' and 'losers' is distributed evenly, but the allocation using the alternative benchmarking formula leads to a lower standard deviation among results.

Here, the effects are compared to the NAP II allocation. An impact on the 'zero line' would equate to an allocation per tonne of product equivalent to NAP II.

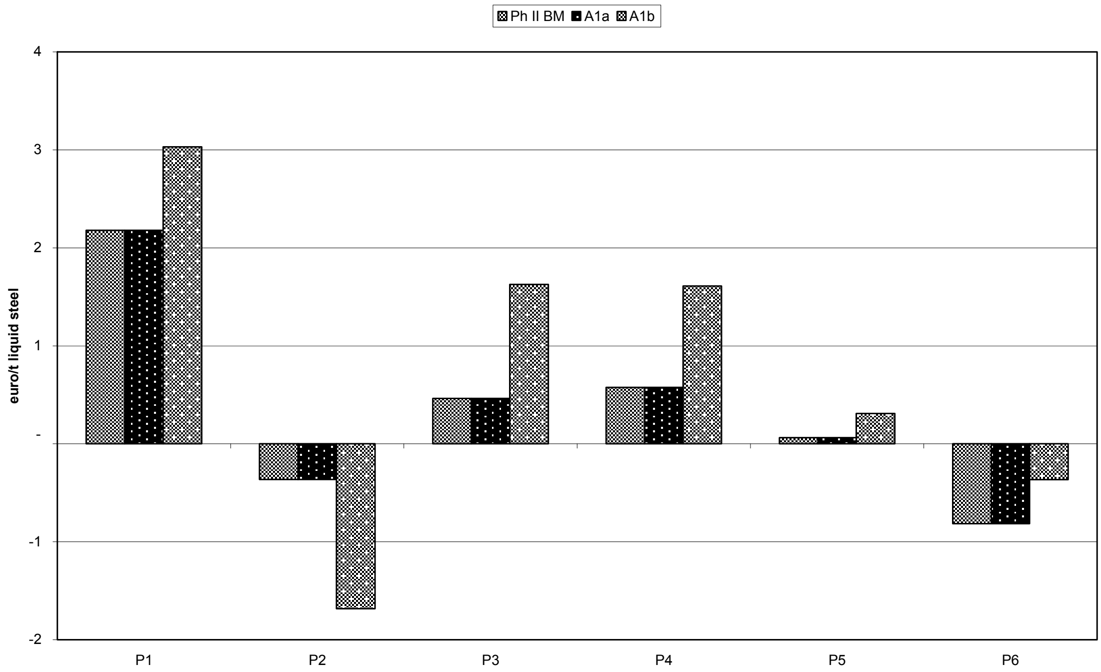

Figure 5.7: Application of the alternative BM formula to EAF operators

It appears from the figure above that the deviation in distribution of impacts from the NAP II allocation is lower for the NE Ph II BM than the proposed alternative variants. The results are subject to uncertainty due to the range of steel types produced by UK operators, given that the analysis is undertaken per average tonne of liquid steel.

As discussed for integrated steel, steel prices range between €500/t and €700/t and therefore the effects presented above are limited (up to one per cent of product price). If Hatch Beddows (2007) cost assumptions are applied to the EAF sector, the added costs are below transportation costs and would therefore not have significant distributional impacts. Furthermore, they are in line with other input cost fluctuations.

5.4 MS-level considerations

Whilst the benchmark options are already differentiated by product, EAF technologies tend to be similar across the EU and fuels tend to be natural gas; there may be some limited impacts in applying these potential benchmarks across the EU. For example, some plants don't have access to natural gas and therefore use LPG or gas oil for furnace heating. Also, there is a ferrochrome process in Finland which is distinctly different to other EAF plants in having a particularly high CO_2 EF.

Overall, at the EU level, ensuring that all process structures and products are considered will be important. For instance, within the UK only one plant produces only stainless steel and therefore there are no problems with regards to a UK BM position, but it is reportedly one of the most complex stainless steel operations in Europe and so could fare badly against a simple average European performance.

Further product differentiation may therefore be required although fuel differentiation would seem less attractive, as it would reduce the incentive for low carbon fuels.

5.5 MRV Implications

No MRV complications are envisaged for the NE Ph II BM formula.

The alternative formula is a simplified version of the NE Ph II BM in terms of processes considered, but adds a new parameter for large castings and emissions from heating multiple ladles.

In addition, it is suggested that operators are allowed to choose the product mix on the basis of historical data rather than a single product type, as for new entrants. Data on the product mix would have to be verified.

This is likely to lead to additional, but not insurmountable, MRV requirements.

5.6 Conclusions

The performance of formulae and variants against criteria is shown in the table below.

Table 5.6: Performance matrix: Electric arc furnace

Criteria	NE Ph II BM	A1a	A1b
1. Feasibility			
A. How resource intensive is it expected to be to fully *develop* and *maintain* the benchmark method?	+/- Already developed, although if updating was necessary a number of data sets would be needed to update emission factors. Production at each stage is required. Product type is required, although product mix details could be used instead for incumbents.	+/- Greater data intensity than NE Ph II BM, although data points should be available. Total production and number of ladles are required. Product mix details are required.	
Data points required to *design* the benchmark	17	46	
Data points required to *implement* the benchmark	5	3 to 8	
B. Can benchmark factors be replicated by a third party?	+ Standardised to UK BAT	+	
C. Can input data for the benchmark method be verified?	+	+	
2. Environmental effectiveness			
A. Are benchmarks standardised, avoiding differentiation for raw materials, technologies and fuels?	+	+	
3. Economic impacts			
A. What is the likely impact on distributional equity at installation level?	-	0	0
B. What is the likely impact on distributional equity at company level?	--	0	0

'+' positive score on criterion, '++' strongly positive on criterion, '-' negative score on criterion, '—' strongly negative on criterion, '0' no impact, '+/-' combination of positive and negative impacts.

Answers to key questions

Is Phase II NER BM suitable for incumbents?

The suitability of Phase II NER BM for incumbents was tested against the three criteria (feasibility, environmental effectiveness and economic impacts) and compared to the variants of alternative formula. In summary, the **Phase II NER BM** performs as follows.

The Phase II NER BM requires five data points for its implementation. The parameters required can be replicated by a third party and can also be verified. In addition, for incumbents it should be feasible to use the actual product mix in the benchmark formula, rather than having to select just one product type, as for new entrants.

The Phase II NER BM does not differentiate by technology or fuel and therefore scores well on its ability to encourage clean techniques and technology.

Applying the Phase II NER BM in combination with the NAP II sectoral cap does not produce marked economic impacts, measured as added costs. Maximum added costs per tonne of steel constitute less than 0.4 per cent of the minimum price of steel.

In comparison, the **alternative formula** suggested by the consultants in consultation with industry experts performs as follows.

The alternative formula requires 46 data points for its development and three to eight data points for its implementation and therefore requires more effort than the Phase II NER BM. Despite the data intensity, most data points should be available. The only potential data availability issue would appear to relate to the product mix. Currently, EAF operators do not report the product mix in the format required under the alternative formula considered[20]. Data for the latest set of representative years would be required as an input in working out the benchmark allocation.

The alternative formula does not differentiate by technology or fuel and therefore scores well on its ability to encourage clean techniques and technology.

Applying the alternative variants in combination with the NAP II sectoral cap leads to limited economic/distributional impacts, even less so than under the Phase II NER BM combination with the NAP II. Added costs per tonne of steel are below 0.1 per cent of the lowest price of steel.

What would be the competitive/distributional effects of using the Phase II NER BM?

As a proportion of product price, the added costs considered here are very low.

The distributional impacts for the alternative formula are considered above.

Is there a need for a transitional phase to take into account certain site-specific factors?

The need for a transitional phase is determined by the magnitude of risk of stranded assets in the sector. In the context of the two formulae, technology differentiation is not included, nor any factor that could change in the medium term, and therefore a transitional phase is irrelevant. Provided there is homogeneity of the technology used in the UK electric arc furnaces, it is unlikely that the need for a transitional phase would emerge from a more detailed analysis. This conclusion may have to be re-assessed if an EU-wide benchmark is envisaged.

What would be the implications for monitoring, reporting and verification (MRV)?

[20] Operators suggest that this is more complex for some plants than others.

For the Phase II NER BM, the most likely MRV complications would arise from verifying the closeness of the actual product mix to the product selected by the operator.

For the alternative formula, information on product types and their production levels would have to be provided and verified if actual product mix were to be considered.

How would a UK incumbent benchmark affect the distribution of allowances EU-wide across the sector?

EAF steel production processes across the EU are relatively uniform and no significant changes in the approach to standardisation are expected from a shift from a UK-centric to an EU-centric benchmark. Some variations may occur, for example where plants do not have access to a natural gas infrastructure, and therefore use LPG or gas oil for furnace heating. Also, there is a ferrochrome process in Finland which is distinctly different to other EAF plants in having a particularly high CO_2 emission factor. At design, the uniformity of process structure and product range at EU level would require verification.

What would be the key issues for other Member States in using UK developed BM?

The key issue would be ensuring that all process structures and products were considered (such as the issues related to the complex UK stainless steel operation).

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List of Abbreviations

BAT	Best Available Techniques
BAU	Business As Usual
BCA	British Cement Association
BF	Blast Furnace
BFG	Blast Furnace Gas
BM	Benchmark
BOS	Basic Oxygen Steel
BREF	Best Available Techniques Reference Document
Btu	British Thermal Unit
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CITL	Community Independent Transaction Log
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COG	Coke Oven Gas
DRI	Directly Reduced Iron
EAF	Electric Arc Furnace
EF	Emission Factor
ETS	Emissions Trading Scheme
EUROFER	European Confederation of Iron and Steel Industries
IPPC	Integrated Pollution Prevention and Control
JI	Joint Implementation
MJ	Mega Joule
MRG	Monitoring and Reporting Guidelines
MRV	Monitoring, Reporting and Verification
MS	Member States
NAP	National Allocation Plan
NER	New Entrant Reserve
Ph II	Phase 2
SEC	Specific Energy Consumption
t	Tonne

T/O	Turnover
TJ	Tera Joule
UNFCCC	United Nations Framework Convention on Climate Change

Appendix A: Benchmarking options considered

Cement: Rejected formulae

Option No	Formula							Source	Assessment
	Allocation	=	Production	*	(Combustion EF	+	Process EF)		
5			Installation specific		Installation-specific input parameters for: (1) energy to drive off raw material moisture; (2) energy lost in kiln bypass; (3) CO_2 due to non-carbonate carbon in raw material No differentiation of SEC by technology		Installation specific	Phase I NER spreadsheet	
6			Capacity* Utilisation (Installation specific production can be used for incumbents)		Standardised at BAT		Standardised at BAT	Germany Phase II New Entrant Benchmark	Same as UK NE Benchmark for Phase II
7			Production growth factor		Emissions from combustion averaged for 2001-2002 * world best available technology energy consumption/SEC of installation in 1999* allocation factor		Not included	The Netherlands Phase II New Entrant Benchmark	Rejected on basis of feasibility; approach requires actual specific energy consumption of installation, which is confidential and difficult to verify.
8			Projected output		Benchmark emission factor/installation BAT			Sweden Phase II New Entrant Benchmark	

Option No	Formula							Source	Assessment
9			Annual production		Benchmark (t CO_2/t clinker) differentiated by: Precalciner 3-stage Precalciner 4-stage Precalciner 5-stage Benchmark only applicable to new plants		Standardised at BAT	Research Institute of Cement Industry Germany	Rejected on basis of unjustified feasibility difficulties related to high differentiation versus limited improvements with regards to distributional equity among incumbent UK plants

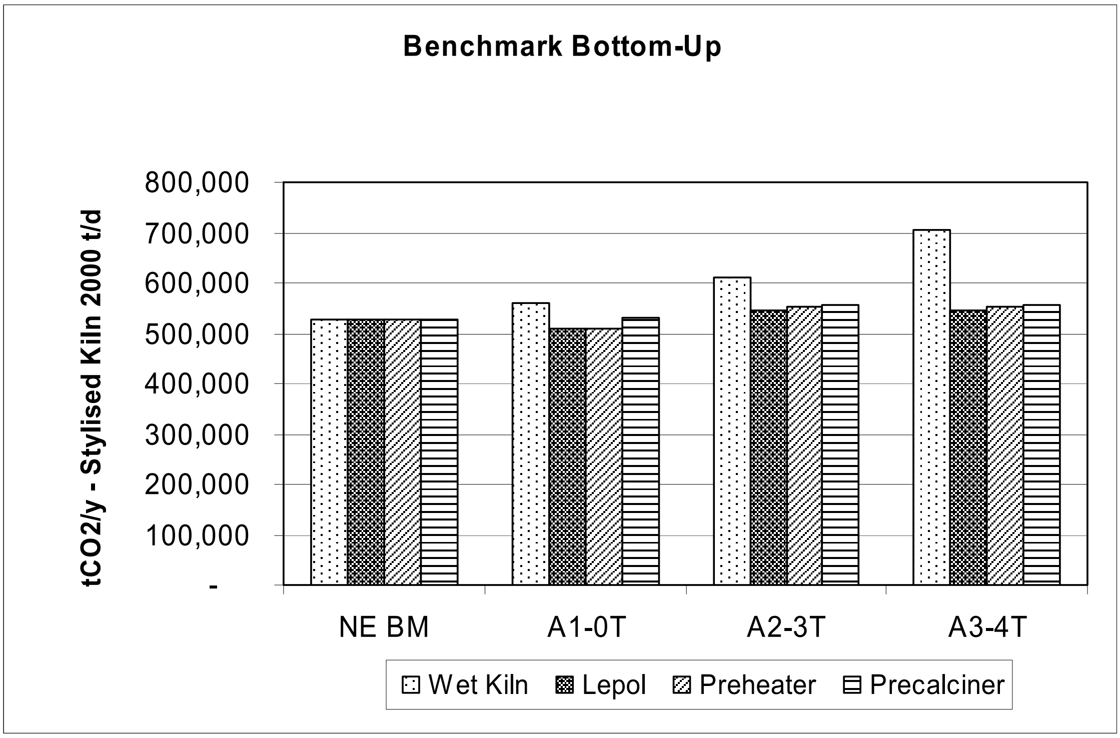
Integrated steelworks: Rejected formulae

Option No	**Formula**					**Source**	
	Allocation	=	Production for process S	*	EF for process S		
3			Capacity* Utilisation (Could be replaced with installation specific production for incumbents)		Standardised best available technology (BAT) benchmark per MW capacity	Greece NE Benchmark Phase I	Application is unclear
4			Projected output		Standardised benchmark/installation-specific BAT	Sweden NE Benchmark Phase I	Rejected on basis of limited process differentiation – likely to be inapplicable to incumbents and difficulty in determining installation-specific BAT.
5			Production growth factor		Emissions from combustion averaged for 2001-2002 * world BAT energy consumption/SEC of installation in 1999* allocation factor	Netherlands NE Benchmark Phase I	Rejected on basis of feasibility; approach requires actual specific energy consumption of installation, which is confidential and difficult to verify.
6			Capacity* Utilisation (Could be replaced with installation specific production for incumbents)		Standardised at BAT	Germany NE Benchmark Phase I	Rejected on basis of likely adverse economic impact on basis of limited process differentiation.

EAF: Rejected formulae

Option Number						Source	Assessment
3			Capacity* Utilisation (Could be replaced with installation specific production for incumbents)		Standardised BAT benchmark per MW capacity	Greece NE Benchmark Phase I	Application is unclear
4			Projected output		Standardised benchmark/installation-specific BAT	Sweden NE Benchmark Phase I	Rejected on basis of limited process differentiation – likely to be inapplicable to incumbents and difficulty in determining installation-specific BAT.
5			Production growth factor		Emissions from combustion averaged for 2001-2002 * world BAT energy consumption/SEC of installation in 1999* allocation factor	Netherlands NE Benchmark Phase I	Rejected on basis of feasibility; approach requires actual specific energy consumption of installation, which is confidential and difficult to verify.
6			Capacity* Utilisation (Could be replaced with installation specific production for incumbents)		Standardised at BAT	Germany NE Benchmark Phase I	Rejected on basis of likely adverse economic impact on basis of limited process differentiation.

Appendix B: Effects of bottom-up benchmarking for cement sector



Further to requests from the cement sector stakeholder, a bottom up analysis was included here for information.

The added cost impacts per tonne of clinker for these four stylised plants are considered by assuming that 100 per cent of deficit allowances are purchased on the market at the price of €30/t CO_2.

Formula, separately for each group of plants designated under each kiln type:

$$[(\sum A_{BMi} / \sum P_i) * P_{st} - (\sum AE_{2006} / \sum P_i) * P_{st}] * CPrice$$

where:

A_{BMi} bottom-up allocation under the selected benchmarking formula to each installation in the group, in tCO_2.

AE_{2006} NAP II allocation to each installation in the group, in tCO_2.

P_i production metric, here represented by the maximum clinker output in tonnes between 2000 and 2007, in T clinker.

P_{st} activity level of stylised plant; for illustration this was chosen at 1,000 tonnes per day, 85 per cent load factor, that is 310,250 tonnes per year.

CPrice allowance price, illustration set at €30/tCO_2e.

The plant size selected is about half the typical UK size (around 2,000 t/d). Given that the results are considered as added cost/benefit per tonne of clinker, the choice of size does not affect the conclusions. However, if conclusions were to be drawn on an installation basis, this would need to be taken into consideration.

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