AEA

EU Emissions Trading System: Benchmarking as an allocation methodology for heat from 2013
(Final Report)

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AEA group
329 Harwell
Didcot
Oxfordshire
OX11 0QJ

t: 0870 190 6148
f: 0870 190 6334

AEA is a business name of AEA Technology plc

AEA is certificated to ISO9001 and ISO14001

Author	Name	Richard Hodges
Approved by	Name	Mahmoud Abu Ebid
	Signature	
	Date	16th June 2010

Executive summary

Background

AEA has been commissioned by the Environment Agency to undertake a project on benchmarking as an Allocation Methodology for Heat from 2013.

This project has its origins in the revised EU Emissions Trading System Directive (2009/29/EC), which was adopted in December 2008. Among other things, the Directive sets out the principles to be followed regarding the allocation of emissions allowances to installations in the EU ETS from 2013. It has made some significant changes to the methods of allowance allocation adopted in earlier phases of the EU ETS with the intention of enabling it to make a greater contribution to tackling climate change.

One key change is the application of activity based benchmarks, based upon the performance of the top 10% performing installations in a sector or sub-sector, and the requirement, where feasible, for these benchmarks to be based upon products.

The European Commission's consultants (Ecofys) have been tasked with establishing the extent to which product benchmarks can be established and applied across Annex I activities and at what level they should be set. Where product benchmarks are not possible or practical, Ecofys have been asked to propose alternative allocation methodologies.

One identified alternative for installations which are only included in the EU ETS due to their combustion activities and installations carrying out other Annex I activities for which product benchmarking is not practical, is a benchmark based on heat generation and consumption.

In response to this, the Environment Agency and DECC have asked AEA to look at a number of aspects related to the feasibility of the establishment and application of heat benchmark(s). These aspects were examined under six separate tasks.

Key Findings

Tasks 1 and 2 –The feasibility of having one benchmark for heat for all activities not covered by an Annex I definition (except combustion) and whether this could also be used as a component of other Annex I activity benchmarks. At what level should the heat benchmark(s) be set at, taking into account the principles set out in the Directive for the derivation of benchmarks

Separate benchmarks have been derived for boiler and Combined Heat and Power (CHP) heat using the principles set out in the revised Directive.

Benchmarking curves for both UK boiler and CHP heat have been combined. Using the principles set out in the revised Directive a benchmark for heat of 98.3kgCO_2/MWh has been derived. When the same is done, but renewable fuels are excluded from the analysis, the derived benchmark for heat is 223.1 kgCO_2/MWhth, which are the emissions from a boiler burning natural gas operating with an efficiency of 90.5% (NCV). This is within 3% of the value proposed by the European Commission's consultants, which is based on the same boiler operating with an efficiency of 93% (NCV) (see Section 3.6-3.7).

The information received and examined from UK industry indicates that in virtually all cases where heat is generated in the form of hot air (direct firing) there is no metering of the quantity of heat generated. Benchmarking for such activities would have to be based upon a fuel input benchmark. In this report we propose a means of using conversion factors, typical of the direct firing application under consideration, to convert fuel inputs to useful heat outputs, against which one universal benchmark for heat is applied, in order to derive an allocation for a direct firing application. In this way the application of one benchmark for heat becomes feasible in all cases where, at a minimum, the quantity of fuel input to the heat generating process is known.

Task3 –The feasibility of using a heat benchmark with a generic improvement factor as a fallback option for Annex I activities (excluding combustion) where a product based benchmark cannot be developed

Two case studies, both in the paper industry, have been undertaken to explore the relative differences between using a product benchmark and a heat benchmark to determine the allocation for the same product at the same installation, thereby putting into relief the need (or otherwise) for a generic improvement factor. This limited study has highlighted the complexity of this question. Although the principle of the application of a generic improvement factor is sound in the pursuit of equitable outcomes resulting from the application of heat and product benchmarks in respect of the same activity, we believe that the question requires further work to understand the range of heat end use efficiencies across the affected sectors.

Task 4 – Determining a methodology for allocating allowances to those installations that consume the heat rather than those who produce it, where the two are different

An analysis has been undertaken of the operation and relative advantages and disadvantages of three cross-boundary heat flow allocation methodologies (described as ‘Method 1’; ‘Method 2b’ and ‘Method 2c’in the Ecofys report[1]). Each have points to recommend them and each have the potential to return undesirable outcomes.

We believe that there is a potential negative economic impact on CHP should Method 1 be adopted and we are therefore recommending that Method 2 should be adopted.

We believe that it is important to get a more detailed picture of the flexibility of contracts existing between heat producers and heat consumers in order to know whether this risk with Method 1 can be mitigated. In addition to avoiding the potential negative impact on CHP associated with Method 1, Method 2 has the advantages of maintaining the link between emissions and allocation and incentivising both the carbon efficient generation of heat and the efficient consumption of heat.

Within Method 2, Methods 2b and 2c would appear to have a relatively even balance of advantages and disadvantages associated with them, and this makes it difficult to positively recommend one over the other at this stage.

Task 5 – To assess different methodologies by which individual heat flows within installations may be determined

For reasons of minimising metering complexity and to allow the application of one heat benchmark for all heat, we are recommending not to distinguish between heat flows in the form of boiler steam, boiler hot water or hot oil. For the same reason, we are also recommending not to distinguish between heat from boilers, CHP or any other sources. We are not presently aware of any perverse outcomes associated with this approach. However, in the case of steam heat, we recommend that account is taken of the energy content of condensate return, using the actual temperature of this return, when determining the quantity of heat used in working out the allocation. The actual temperature of condensate return should be routinely known as this is a parameter that needs to be known in order for the boiler to be controlled.

Task 6 – To assess the impacts of varying levels of free allocation for heat including full auctioning in scenarios where there is a reduction in the cap consistent with 20% and 30% emissions reductions by 2020

Modelling of the effect of a number of allocation reduction and carbon price scenarios on the costs to heat generators has been undertaken. In the case of heat generators using boilers we have determined that the cost of carbon, averaged over the period 2013-2027, and expressed as a percentage of cost of fuel and carbon together, could constitute between 31% and 47% of this cost, under the EU’s 20% cap and 30% cap scenarios, respectively.

The carbon costs experienced by CHP, and how these compare against the conventional alternative of separate generation of heat in boilers and import of electricity from the grid, have been modelled for three separate CHP schemes. Where the CHP schemes have a carbon cost advantage in 2013, this

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[1] Methodology for the free allocation of emission allowances in the EU ETS post 2012.
http://ec.europa.eu/environment/climat/emission/pdf/bm/BM%20study%20-%20%20Project%20Approach%20and%20general%20issues.pdf

advantage continues throughout Phase III, grows with time and reaches a maximum when full auctioning starts.

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1 Introduction

1.1 Revisions to the EU ETS Directive and the Allocation of Emissions Allowances from 2013

In December 2008 the revised European Union Emissions Trading System (EU ETS) Directive (2009/28/EC) was agreed. The revisions contained therein reflect the desire for the EU ETS to make a much greater contribution to tackling climate change. The revisions will take effect for Phase III of the EU ETS, starting in 2013.

The important revisions to the Directive in relation to this project are those concerned with the transitional free allocation rules. The key revisions from the point of view of understanding the rationale for this project are as follows:

- From 2013, with a few exceptions, there will be no free allocation of allowances for electricity generation or production, including that associated with cogeneration (CHP).
- Where allowances continue to be awarded for free, their allocation will be based upon harmonised benchmarks.
- These benchmarks will be based upon the average performance of the 10% most greenhouse gas efficient installations in a sector or sub-sector in the EU in 2007-2008.
- Where possible, the benchmarks will be product based and will be based upon the greenhouse gas emissions per unit activity (e.g. tonnes CO_2 per tonne of product produced).
- The allocation of allowances to a particular installation in 2013 will be 80% of the amount determined. The level of allocation will decline linearly from 80% in 2013 to 30% in 2020. After 2020 the level of allocation will decline linearly to 0% by 2027.
- Sectors deemed at significant risk of carbon leakage will receive 100% of the amount determined.
- This rate of decrease of the allocation level is subject to change following future international climate change agreements.

One of the Annex I activities of the revised Directive relates to the combustion of fuels at installations with a total rated thermal input exceeding 20 MW. Many installations are included in EU ETS on this criterion alone. Some of these installations exist solely to combust fuels for the generation and on supply of electricity and heat, while others undertake other activities, for example the production of food and drink products. The fact that these installations are included in EU ETS only because of their combustion activities means that they do not undertake the other Annex I activities for which specific product outputs can be defined. This makes the establishment of an activity-based benchmark based on product difficult or impossible. It is therefore necessary to establish an alternative activity based benchmark for such installations.

Other installations are covered by EU ETS because they undertake Annex I activities for which a product output can be readily associated, but the actual specific product is specialised or so few installations produce it that it is impractical and inappropriate to establish a product benchmark along the lines intended in the revised Directive. An alternative allocation approach is required in such cases.

More installations may be engaged in Annex I activities for which a product output can be readily associated, but the individual specific products are numerous. In such cases, a solution may be to apply one benchmark across a number of different products. However, if these different products have very different CO_2 emissions associated with their production it may not be appropriate to do this, and establishing and applying benchmarks for a very large number of individual products may not be practical. This constitutes another situation where an alternative is required.

1.2 The Concept of a Benchmark for Heat and the Objectives of this Project

The European Commission's consultants (Ecofys) have proposed fallback approaches to apply where product based benchmarking is either impossible or impractical. They propose:

1. A heat production benchmark for combustion activities where the generated heat is carried by an intermediate medium such as hot water or steam, which can be measured and monitored
2. A fuel mix benchmark for combustion activities where the heat generated cannot be measured (e.g. furnaces)
3. Historic emissions for non-fuel related process emissions. This is not considered in this report.

In the case of a **heat production benchmark** the amount of allocation in respect of the heat produced will be the heat benchmark multiplied by the amount of heat produced.

In the case of a **fuel mix benchmark** the amount of allocation in respect of this combusted fuel will be the fuel mix benchmark (taking into account fuel combustion efficiencies) multiplied by the quantity of fuel combusted.

This report will concentrate on the feasibility of the application of benchmarking heat output, which incentivises both the choice of low carbon fuels and the efficient generation of heat but will also consider the second approach which only incentivises the choice of low carbon fuels. The second approach (and variations of it) will be discussed in the context of situations where there is insufficient information available for the first approach to be adopted.

In the case of a heat production benchmark, there are a number of issues that must be understood and resolved before it can be applied. These include, but are not limited to:

- At what level should a benchmark for heat be set, given the principles set out in the revised EU ETS Directive
- The use of a range of heat generating technologies with different heat generating efficiencies (boiler, CHP and the recovery of process waste heat), i.e. whether a different benchmark level should be set for different heat generating technologies
- The current extent and reliability of heat metering and their adequacy for establishing and applying heat benchmarks.
- Reconciling the fact that generators and consumers of heat are often at different installations and the need to incentivise both the efficient generation and consumption of heat.
- Whether a heat production benchmark can be made to incentivise the efficient use of the generated heat through the application of a "generic improvement factor" to the heat generation benchmark.
- The impacts upon heat generators and consumers over time of the combination of the application of benchmarks and a declining level of free allocation.
- The possibility that generators and consumers of heat are subject to different levels of risk of carbon leakage

This project sets out to explore and recommend a way forward for the above issues and other issues that have come to light during the course of the study. Pursuant of this, this Final Report considers the above issues, and others, under six separate Tasks. These are:

- Task 1-The feasibility of having one benchmark for heat for all activities not covered by an Annex I definition (except combustion) and whether this could also be used as a component of other Annex I activity benchmarks

- Task 2- At what level should the heat benchmark(s) be set at, taking into account the principles set out in the Directive for the derivation of benchmarks

- Task 3- The feasibility of using a heat benchmark with a generic improvement factor as a fallback option for Annex I activities (excluding combustion) where a product based benchmark cannot be developed

- Task 4- Determining a methodology for allocating allowances to those installations that consume the heat rather than those who produce it, where the two are different
- Task 5- To assess different methodologies by which individual heat flows within installations may be determined
- Task 6- To assess the impacts of varying levels of free allocation for heat including full auctioning in scenarios where there is a 20% and 30% reduction in the cap by 2020.

2 Task 1

2.1 The Context of Task 1

The objective of Task 1 is:

“To determine the feasibility of having one heat benchmark for all activities not covered by an Annex I definition apart from combustion and whether this could be used as a component of other Annex I activity benchmarks.”

Article 10a of the revised Directive[2] sets out the principle whereby benchmarks used to determine the amount of free allocation to installations in each sector or sub-sector should be calculated for products rather than for inputs. This principle is expected to maximise the incentive for greenhouse gas emissions reductions and energy efficiency savings throughout each production process.

Products are considered to include physical end products, like paper, or pig iron. They will also include intermediaries that are traded between EU ETS installations, such as pulp that is used to produce paper, coke that is used in blast furnaces in the production of pig iron and clinker used in the production of cement.

2.2 Heat Generating Technologies and Media of Heat Transport

Heat used in industrial processes can be transported via a number of media and these include:
- Steam
- Hot water
- Hot oil
- Hot air

Moreover, there is a range of technologies that can generate this heat, including:
- Boilers
- Combined Heat and Power (CHP)
- Direct firing
- Process waste heat recovery plant

Table 1 maps the different heat generation technologies to the media carrying the heat

Table 1 Heat generating technologies and the media carrying the heat

Technology/Medium	Steam	Hot Water	Hot Oil	Hot Air
Boilers	✓	✓	✓	
CHP	✓	✓	✓	✓
Direct Firing				✓
Process Waste Heat	✓	✓		

2.3 Arriving at a Single Benchmark for Heat

Task 1 sets out to explore the feasibility of the derivation and the eventual application of one benchmark for heat irrespective of its technology of generation and medium of transfer.

Arriving at a reliable benchmark for heat and the satisfactory application of this benchmark requires two things to be known with a good degree of confidence:
- The amount and type of fuel combusted in the generation of heat

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[2] 2009/29/EC

- The quantity of heat released in the combustion of the fuel embodied in the transfer medium AND, depending upon the relationship between the heat generator and consumer, the quantity of this heat reaching the application of end use.

Taken together, these allow a determination of the CO_2 emissions associated with each unit of heat generated and consumed.

Significantly, the second point implies that the determination of a reliable heat benchmark requires either metering the quantity of heat or accurately inferring it from other measurable variables. While metering of the heat contained within steam, hot water and hot oil can be achieved, in practice it is very difficult in the case of hot air, where the associated heat will have to be deduced from knowledge of air mass flows and temperatures into and out of the heat consuming process. This is likely to be difficult to establish and verify, as such information is unlikely to be available.

2.3.1 Heat from Boilers

Information relating to the fuel consumed in the generation of heat and the quantity of heat generated in boilers has been sought from two sources:

UK CHPQA scheme information. The UK CHP Quality Assurance (CHPQA) programme maintains energy input and electricity and heat outputs for all CHP schemes covered by the EU ETS. Some schemes submitting to CHPQA contain stand-alone boilers[3] as well as the CHP prime mover[4]. However, under the EU Cogeneration Directive[5] Member States have to submit data relating to the efficiency of the prime mover only. This necessitates the removal of the fuel consumption and heat generation associated with the stand alone boilers from this analysis. AEA carries out this EU Directive analysis by, where possible, removing actual metered values of boiler fuel and heat. Where metered values are not readily available the boiler fuel and heat is inferred from standard boiler efficiencies, prime mover heat to power ratios and prime mover electricity generating efficiencies. In cases where this analysis was possible due to the availability of metered boiler fuel and heat this was used in the analysis presented in this report. This was the case for 40 schemes covered under CHPQA.

Directly from industry. UK sector associations were asked to supply information on boilers used on industrial sites. The requested information included, inter alia, boiler capacity, fuel inputs and heat outputs from the boiler and whether these inputs and outputs are directly metered, deduced or calculated. The intention was to use information on boilers with metered fuel and heat to supplement that available from CHPQA scheme information. This separate source of information yielded data on 9 separate boiler schemes.

The above two sources of information have yielded 49 separate boiler schemes consisting of 139 separate fired boilers with a combined heat capacity of 2,029 MW_{th}[6]. These boiler schemes have metered fuel inputs and heat outputs.

These boiler schemes were carried forward for further analysis and map to EU ETS Phase II Sectors as follows:

Table 2 Mapping of boiler scheme to EU ETS sector

EU ETS Phase II Sector	No. Boiler Schemes	No. Boilers	Total Boiler Capacity (MWth)
Chemicals	15	42	921.6
Food and Drink	7	17	235.2
Other Electricity Producer	1	2	40.0
Other B[7]	1	6	33
Pulp and Paper	7	22	488.8

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[3] As distinct from heat recovery boilers

[4] The heart of a CHP system and is a mechanical machine which drives the electricity generator or develops mechanical power for direct use

[5] 2004/8/EC

[6] Estimated to be ~16% of the sum of the capacities of all boilers in EU ETS Phase II.

[7] Aerospace, vehicles, semi-conductors, woodboard

Services	11	36	273.1
Not in EU ETS Phase II	7	14	37.5
Total	49	139	2,029.2

Figure 1 shows a ranking plot of boiler efficiency (Net Calorific Value (NCV)) for these 49 boiler schemes. Each bar in the plot corresponds to a particular boiler scheme.

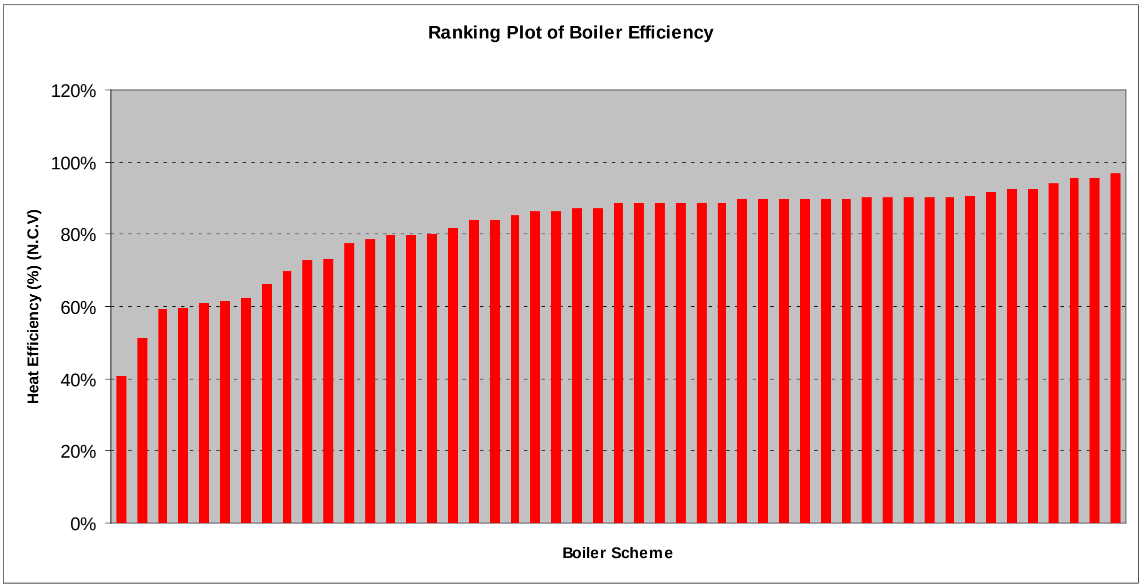

Figure 1 Ranking plot of boiler efficiency (N.C.V) for 49 boiler schemes, comprising 139 separate boilers and 2,029 MW_{th} of capacity

34 of the 49 schemes analysed have net efficiencies >80% and 13 schemes >90%. The average unweighted efficiency was 82.2%. The average efficiency of the best 10%, as shown in Fig. 1, is ~ 95%. This is similar to the European Commission's consultant latest proposal to base the heat benchmark on a gas fired boiler with annual efficiency of 93% (based on net calorific value of the fuel). (N.B. the efficiency value of 95%, presented above, is likely to be higher than the real value due to an underestimate in the enthalpy of the condensate return (see Section 6.4.1). It should also be kept in mind that the boilers covered in the above analysis are those with heat metering, which are likely to be towards the newer end of the spectrum and, therefore, towards the higher end of the efficiency spectrum).

Taking into consideration the fuel mix for these 49 schemes and their respective heat efficiencies allows the generation of the following ranking plot of CO_2 emissions per unit of heat generated, in this case $kgCO_2/MWh_{th}$.

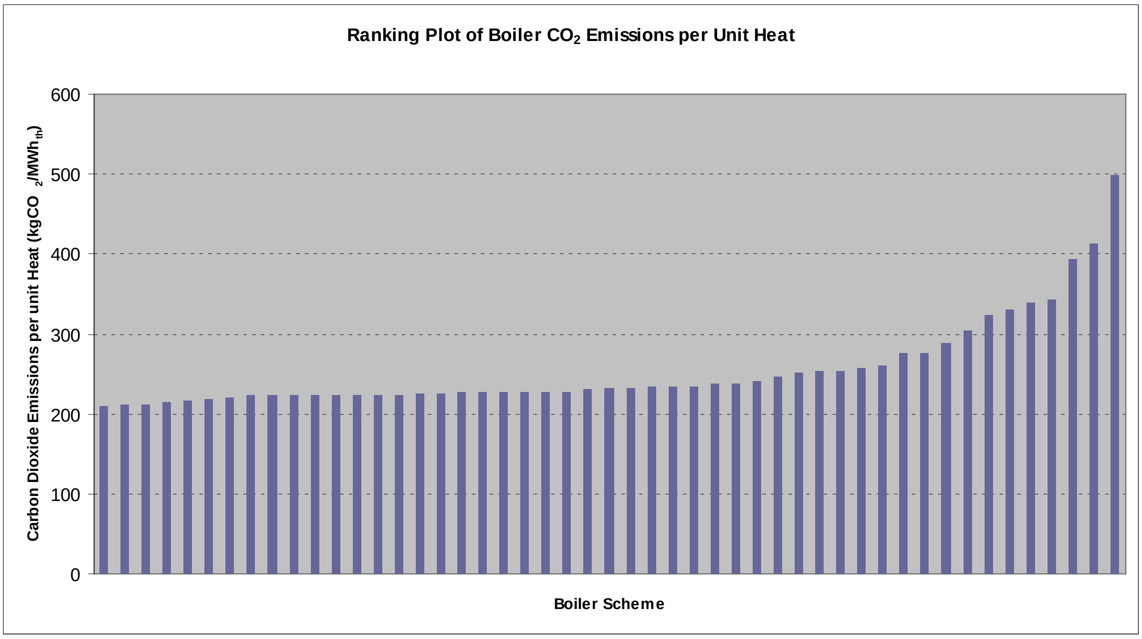

Figure 2 Ranking plot of CO_2 emissions per unit heat for 49 boiler schemes, comprising 139 separate boilers and 2,029 MW_{th} of capacity

Figure 2 is put into context by considering that the emissions from a boiler operating with an efficiency of 90% (NCV) on natural gas will be 224 $kgCO_2/MWh_{th}$. Emissions much in excess of this value are indicative of boilers using fuels more CO_2 intensive than natural gas, boilers operating with thermal efficiencies lower than 90% (NCV) or a combination of the two. The use of fuels of CO_2 intensity less than natural gas (biofuels or waste heat, for example) will tend to reduce the CO_2 per unit heat. There are two such schemes in the analysed population, with one scheme using biogas and the other using waste heat. This shows that the majority of heat generating boilers in the UK are gas fired, and suggests that any heat benchmark should be based on natural gas as being the main fuel of choice. This has also been recognised by the European Commission's Consultants.

Looking ahead to the possibility of relying on another of the fallback options for deriving installation allocations (fuel mix benchmark), Figure 3 shows the CO_2 emissions per unit fuel input for the 49 boiler schemes examined.

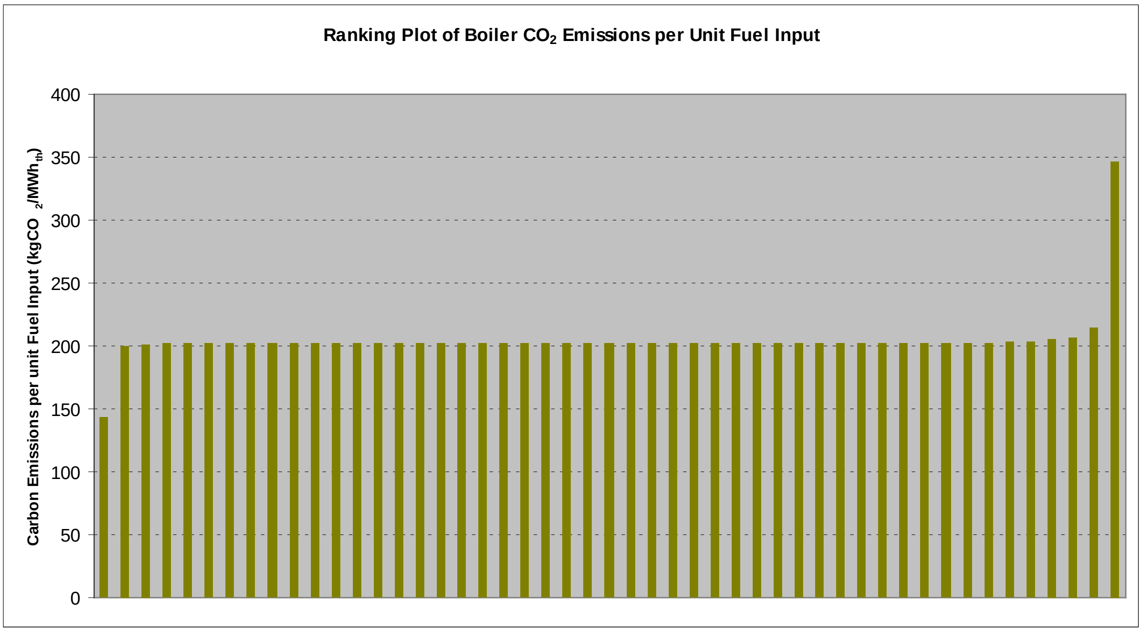

Figure 3 Ranking plot of CO_2 emissions per unit fuel input heat for 49 boiler schemes, comprising 139 separate boilers and 2,029 MW_{th} of capacity

This shows that the overwhelming majority of boiler schemes examined used only natural gas, as evidenced by the long plateau against an emission level of 202 kgCO_2/MWh fuel, which is the emission level for natural gas per unit of heat released (NCV). For the 49 schemes analysed, natural gas made up 96% of the fuel used, on a NCV basis.

This finding would support the relevance of adopting a fuel mix benchmark based on natural gas, should a fuel mix benchmark be adopted and where there is no alternative but to apply such a benchmark[8]. However, it should be remembered that this analysis is based on UK boiler schemes with metered fuel and heat. Such schemes are likely to be towards the younger end of the age spectrum of the existing boiler population and, therefore, are more likely to burn natural gas. Moreover, a large proportion of the boiler population examined here are contained within CHP schemes.

2.3.2 Heat from CHP

Information relating to the fuel consumed in the generation of heat and the quantity of this heat generated in the CHP prime mover has been obtained from one source. This is:

UK CHPQA scheme information. Section 2.3.1. described the EU cogeneration Directive analysis activity carried out by AEA, on behalf of DECC, in respect of CHP schemes assessed and certified by CHPQA programme which include “stand-alone” boilers . As well as identifying the fuel and heat associated with stand-alone boilers, the same is achieved for the CHP prime mover where heat is a by-product of power generation. Fuel and heat for CHP is also available in respect of CHPQA schemes without boilers, as all fuel input and heat outputs are attributable to the prime mover[9].

112 separate CHP schemes (with a capacity of 1,295 MWe) have been analysed from the point of view of the fuel input to the prime mover and heat generated during electricity generation. However, as fuel to the CHP engine is used for the generation of power and heat, and allocations will not be made in respect of the former in EU ETS Phase III, it is necessary to apportion the total fuel to the CHP scheme to the separate heat and power outputs. This then enables the fuel, and therefore emissions, associated with the heat output to be determined.

There are three possible methodologies for apportioning fuel to heat and power. These are:

Method 1. $^1/_3$:$^2/_3$ Method. Under the UK’s Climate Change Agreements[10] (CCAs), this method used to apportion fuel use to heat and power assumes that twice as many units of fuel are required to generate each unit of electricity than are required to generate each unit of heat. This follows from the observation that the efficiency of the generation of electricity (at electricity only generating plant) varies from as little as 25% to 50%, while the efficiency of the generation of heat in fired boilers ranges from 50% to about 90%.

Mathematically, this can be represented as follows:

$$Heat\ Energy = \left(\frac{Total\ Fuel\ Input}{(2 \times Electricity\ Output) + Heat\ Output} \right) \times Heat\ Output$$

$$Electricity\ Energy = \left(\frac{2 \times Total\ Fuel\ Input}{(2 \times Electricity\ Output) + Heat\ Output} \right) \times Electricity\ Output$$

Where:
‘Total Fuel Input’ is the total fuel to the prime mover

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[8] However, this report goes on to recommend the application of a fuel input benchmark, the function of which is explained in Section 2.7, as a means of encouraging both the efficient generation and consumption of heat, in cases where the quantity of heat generated is not or cannot be measured.

[9] Some CHP only schemes have heat recovery boilers (HRBs) to recover the waste heat associated with the electricity generating step. In some cases, the HRBs also have supplementary firing, where additional fuel is introduced into the hot gasses passing through the HRB and is combusted there. This supplements the heat from the prime mover. This increment of additional heat is not considered CHP heat, as it was not generated as a result of a power generating step, and it is removed from the analysis along with its associated fuel.

[10] Climate Change Agreements (CCAs) are agreements between UK energy intensive industries and UK Government, whereby industry undertakes to make challenging, but achievable, improvements in energy efficiency in exchange for a reduction in the Climate Change Levy (CCL).

‘Heat Output’ is the heat generated by the prime mover

‘Electricity Output’ is the electricity (or the electrical equivalent of mechanical power) generated by the prime mover

‘Heat Energy’ is the fuel to the prime mover apportioned to the heat generated

‘Electricity Energy’ is the fuel to the prime mover apportioned to the electricity generated.

This method is used only in the UK for accounting for primary energy inputs to CHP where the CHP generated heat and electricity is used within a facility with a CCA. As such, it is not readily understood within EU and for this reason may be difficult to apply across the EU. It is also based upon assumptions about the efficiency with which heat is generated within the CHP and requires the heat generated from the CHP to be disaggregated from that generated in boilers in the reference year in order for an allocation to be made. This is not always possible, as is illustrated later in this report.

Method 2. Boiler Displacement Method. Under this convention it is assumed that the heat generated by the CHP displaces heat raised by a boiler with an efficiency of 90%[11] (NCV), but that the boiler uses the same fuel mix as the actual fuel mix to the CHP[12].

Mathematically, this can be represented as follows

$$Heat\ Energy = \left(\frac{Heat\ Output}{0.9} \right)$$

Where the Heat Energy and Heat output are as defined for Method 1, above.

This method has wider understanding within EU and has the advantage that it would be compatible with other allocation methodologies for heat, should this be based on best available technology, i.e. 90% efficiency (NCV) boiler.

A slight variation on this approach would be to assume that the CHP heat displaces heat generated in a natural gas boiler operating with an efficiency of 90% (NCV). This approach would be simpler to apply as not only would it avoid the need to distinguish between heat raised separately in boilers and in CHP or heat recovered from industrial processes, thereby removing the need for separate metering of heat from these two sources, but it would also overcome the need to collect site specific fuel mix data.

Method 3. Power Station Displacement Method. Under this convention it is assumed that the electricity generated by the CHP displaces electricity generated by conventional power only plant with an efficiency (NCV) of 52.5%[13]. This establishes the fuel for electricity and the balance of the fuel to the prime mover is then assumed to be for the generation of heat.

Mathematically, this can be represented by:

$$Heat\ Energy = Total\ Fuel\ Input - \left(\frac{Electricity\ Output}{0.525} \right)$$

Where Heat Energy, Total Fuel Input and Electricity Output are defined for Method 1, above.

This method is also well understood in Europe. However, as with method 1, it is based upon assumptions about the efficiency with which heat is generated within the CHP and requires the heat

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[11] This is the reference efficiency quoted in Annex II of Commission Decision 21 December 2006, establishing efficiency reference values for the separate production of electricity and heat

[12] This is also the way recommended by Ecofys in their final “Report on the project approach and general issues”, p. 11., http://ec.europa.eu/environment/climat/emission/pdf/bm/BM%20study%20-%20%20Project%20Approach%20and%20general%20issues.pdf

[13] This is the reference efficiency quoted in Annex I of Commission Decision 21 December 2006, establishing efficiency reference values for the separate production of electricity and heat in application of Directive 2004/8/EC of the European Parliament and of the Council *(notified under document number C(2006) 6817)*

generated from the CHP to be disaggregated from that generated in boilers in the reference year in order for an allocation to be made. This is not always possible, as is illustrated later in this report.

Moreover, this method raises the question of which power generation efficiency to use. Using such a high power generation efficiency, as in the example above, assigns more fuel and, therefore, emissions to the heat generated and has the effect of making heat look more carbon intensive than that provided by boilers. This delivers the wrong message about CHP heat, as CHP heat has always been considered as low-carbon heat. Moving away from the EU reference power efficiency for modern CCGT[14] power station, used above, raises the question of what should be used in its stead, i.e. the national average, the EU average or BAT. This would introduce additional complexity into the allocation methodology.

Figures 4-6 show ranking plots of CO_2 emissions per unit heat, for heat derived from CHP, with fuel for heat apportioned using the three methods above.

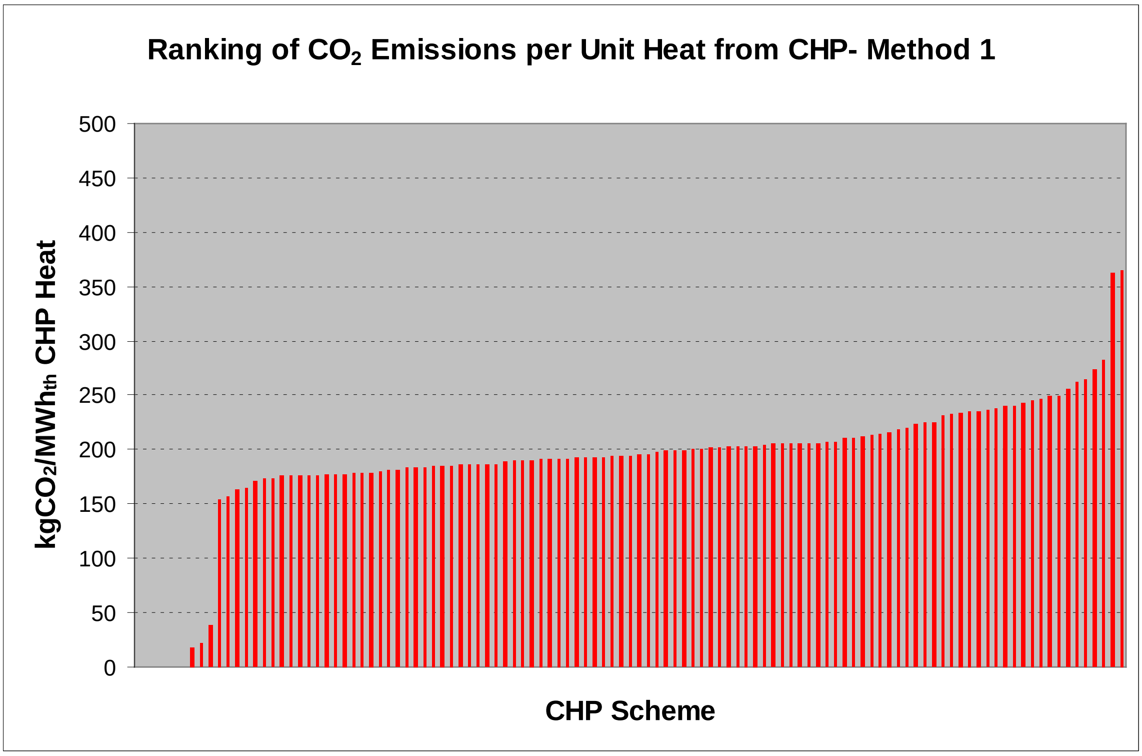

Figure 4 Ranking plot of CO_2 emissions per unit heat from CHP using Method 1

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[14] CCGT – Combined Cycle Gas Turbine

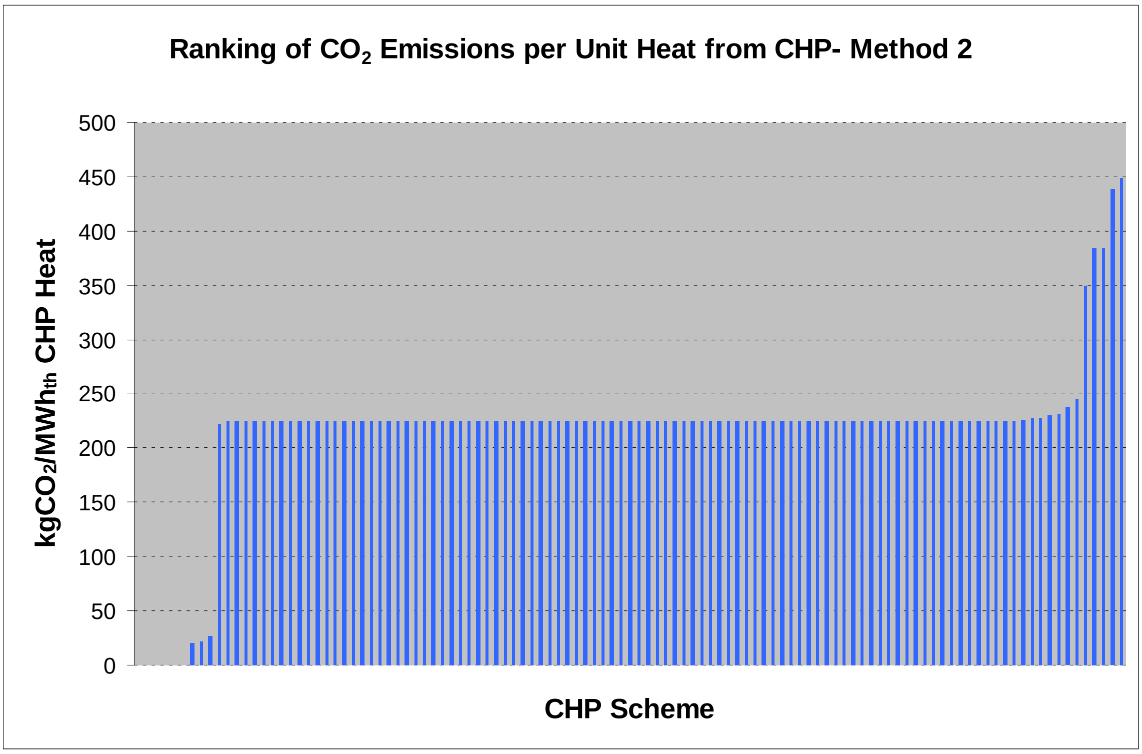

Figure 5 Ranking plot of CO_2 emissions per unit heat from CHP using Method 2

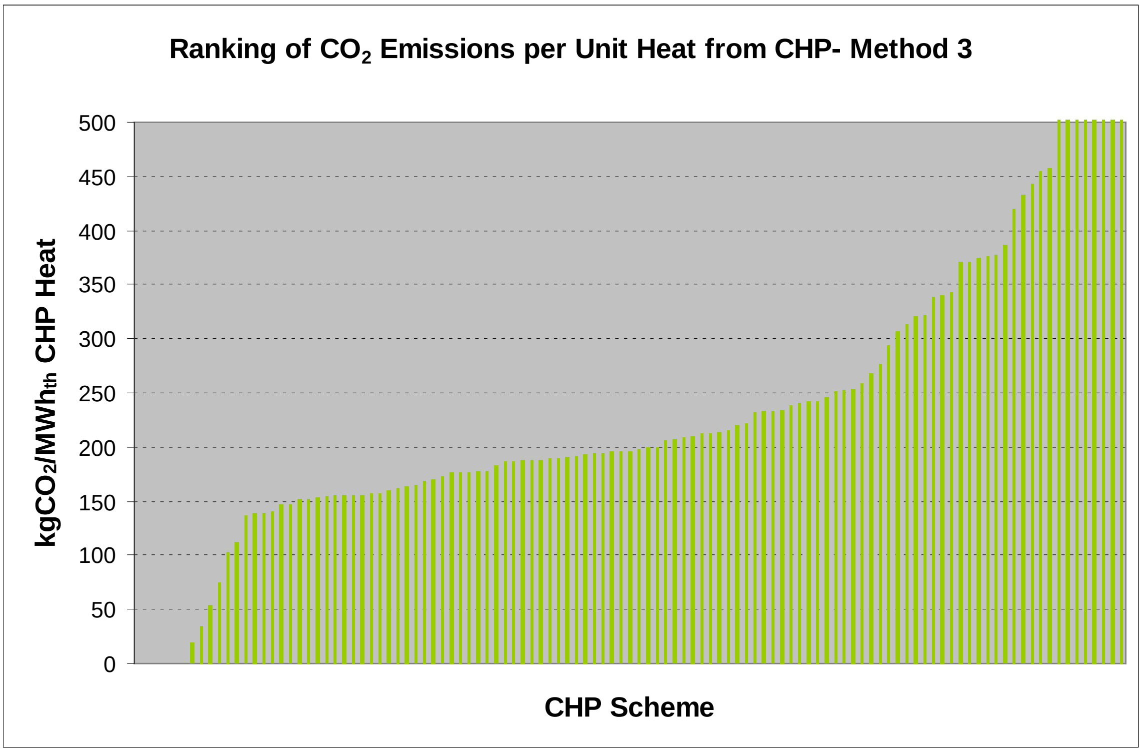

Figure 6 Ranking plot of CO_2 emissions per unit heat from CHP using Method 3

Again, a good point of reference in the consideration of the above plots is that a boiler fired by natural gas and operating with an efficiency of 90% (NCV) will produce heat with an emission intensity of 224 $kgCO_2$ per MWh of heat.

Fig. 4 shows some emission intensities very much higher than 224 $kgCO_2$/MWh and some very much lower. In the former case this is invariably due to the use of more carbon intensive fuels as inputs to the CHP (e.g. coal). In the latter case, this is invariably due to the use of renewable fuels (e.g. biogas from sewage treatment works) or, in some cases, waste heat constituting all or part of the fuel input to the CHP prime mover.

Fig.5 gives an indication of the range of fuels used in CHP. The long plateau at 224 $kgCO_2$/MWh is representative of schemes where natural gas is the only fuel input. Values above and below this are due to the use of fuels more carbon intensive than natural gas and the use of bio-fuels and waste heat, respectively.

Fig. 6, with a larger number of points at higher carbon intensity values than in Fig. 4, is illustrative of the large assignment of fuel (and hence emissions) to heat when the power efficiency of the CHP is low. A low power efficiency leads to a lower absolute power output in relation to the total fuel input and, therefore, the total emissions from the CHP. Assigning fuel to power using a high reference power efficiency (as in Fig. 6 – Method 3) exacerbates the effect described above, whereby heat is made to look more carbon intensive. This is because a lower absolute power output leads to an even greater proportion of overall emissions being assigned to the CHP heat when using Method 3. This is the case for older CHP technologies such as steam turbines with high heat to power ratios. CHP recovering low amounts of heat will also be situated towards this end of the plot, and such schemes should not be incentivised.

2.3.3 Heat from Direct Firing

In order to obtain information that could be used to derive a benchmark for heat resulting from direct firing of fuels, where this heat is not carried via a medium that enables it to be easily determined, a request was put out to industry to supply information relating to “Other Combustion Plant” operated at industrial sites. Other Combustion Plant covers a variety of equipment including driers, furnaces, tunnel kilns, and ovens but excludes boilers and CHP.

15 installations responded by supplying information on combustion plant including those mentioned above and also thermal oxidisers, flares and pilots. The information supplied related to plant with a combined thermal input rating of 3,427 MWth

Of these 15 installations only two operated plant where the heat output was in some way metered or deduced, and these plant had a combined capacity of 67 MWth. This represents only about 2% of the total figure.

In the first case the heat output was in the form of steam raised by the recovery of heat from a thermal oxidiser. However, it is recognised that some of this heat will have been derived from the combustion of the gasses being abated, as well as the natural gas input. This raises the question of what an appropriate allocation would be in respect of heat from such plant. However, if heat is treated equally, regardless of its source or fuel used, then such a distinction will not have to be made.

In the second case, the heat was deduced for hot oil heaters by measuring the temperature change of the oil between entry and exit points of the process.

From these findings it is clear that there is an extreme lack of metered heat data for the types of combustion plant that will be included in EU ETS for the first time in 2013, and that this will make the application of a heat production benchmark difficult.

2.4 A Consideration of the Use of a Heat Benchmark as a Component of Other Annex I Activity Benchmarks

A number of other Annex I activities have had product benchmarks proposed as a means of determining the number of allowances that will be allocated to them. These include:

- Refinery products
- Some chemical products
- Cement
- Lime
- Paper products

It has been possible to propose product benchmarks for these products since they are sufficiently similar and there are a sufficiently large number of producers of these products for the benchmarking principles of the revised Directive to be observed.

A fair operation of different benchmarking methodologies requires that they return the same or a similar number of allowances in respect of the same activity at the same installation. This is necessary because the availability of baseline data (or lack thereof) may determine the use of one benchmarking methodology over the other. Should there be a difference between the allocation returned for a particular activity via a heat benchmark and a product benchmark, different installations carrying out exactly the same activity, but benchmarked on a different basis due to differences in the availability of baseline data, will not be treated the same, i.e. one installation may receive a more generous allocation than the other, resulting in the potential for competitive distortion.

With this in mind, and in order to check the equivalence of the application of heat benchmarking and product benchmarking in respect of the same activity, a case study has been undertaken into the outcome of the separate application of the heat benchmark approach and a product benchmark approach at the same installation. We have chosen to do this for installations engaged in the production of different paper and board products. The rationale and the results of this study are presented in Section 4.2. The results are discussed in Section 4.4.

These case studies highlight the challenges faced with the universal application of a single ‘generic’ improvement factor to the allocation calculation for heat benchmarked sites with varying levels of heat end use efficiency.

If a heat benchmark were to be used as a component of other Annex I activity benchmarks, it is understood that this would be for allocating allowances for combustion emissions associated with the generation of heat at an installation that incurs both combustion and process emissions, but which could receive a product benchmark. Section 4.4 discusses the pitfalls of this in terms of the possibility of over allocating to installations that use heat inefficiently and also the possibility of penalising early adopters of heat end use efficiency measures if an attempt is made to correct for this over allocation by the adoption of a generic improvement factor.

2.5 Task 1 Discussion

There is information available that can be used to derive a benchmark for heat, based upon the quantity of heat output, when the heat generators are stand alone boilers or CHP prime movers.

In the case of Other Combustion Plant the evidence available strongly suggests that there is insufficient historic information to allow a benchmark for heat from such plant to be established, where that benchmark is based upon the quantity of heat output. It naturally follows that, should a heat benchmark be established for heat, based on quantity of heat output, for example from existing boiler or CHP heat data, attempts to apply this to other combustion plant would likely be unsuccessful due to a lack of the necessary baseline data (quantified heat output).

Considering the case for boilers in more detail, the availability of data necessary to establish a heat benchmark, based upon the quantity of heat output, is limited. This also means that the success of the application of such a benchmark would be questionable, due to the unavailability of the necessary historic baseline (quantified heat output).

The low response from, for example, the food and drink sector to the request for metered heat data from boilers is taken as an indication of a severe shortage of the required data in this sector. This postulation has been validated by discussions with the sector who have told AEA that, in such applications it is normal practice to monitor fuel input but not heat output. In such a case it would be more appropriate to apply the fuel mix benchmark, based on the carbon intensity of natural gas.

At the other end of the spectrum is the chemicals industry where the required information is much more prevalent, but is unlikely to be universal. The same applies to stand-alone boilers sitting within CHP scheme boundaries. The reporting requirements of the UK CHPQA force a certain minimum level of heat metering. However, this minimum is not sufficient to allow the heat from stand-alone boilers to be disaggregated from that of the CHP prime mover in all cases. A consequence of this is that the use of different benchmarks for heat from different heat generating sources could make the allocation of allowances to producers of products that are likely to be product benchmarked very difficult, where the following are true:

- The EU ETS producer imports the required heat from a steam ring main fed by a steam generator that is another EU ETS installation
- The EU ETS installation that is a steam generator feeds steam into the steam ring main from CHP, boilers and, possibly, other steam raising plant, such as thermal oxidisers or heat recovered from exothermic reactions that are not the combustion of a fossil fuel. This point will be discussed in more detail later in Section 5.2.

2.6 Task 1 Main Findings

- The UK CHPQA data and boiler data from industry allows a heat benchmark, based on the quantity of heat output, to be established for CHP heat. However, the information required to do this is not available for all CHP schemes. This is because the heat outputs of some CHP schemes include boiler heat and the level of heat sub-metering is not sufficient for the two to be disaggregated in all cases. **However, it is worth noting that this will not be an issue should boiler heat and CHP heat have the same heat benchmark**.
- There is some data available to allow a heat benchmark, based on the quantity of heat output, to be established for boiler heat. However, the information to do this is less prevalent than in the case of CHP heat, and the prevalence of this information depends on the location of the boiler in question, with the required information more likely to be available when the stand-alone boiler is in a CHP scheme or in certain sectors (e.g. chemicals). The required information is less available in other sectors, for example the food and drink sector.
- There is insufficient information available to allow a heat benchmark, based upon quantity of heat output, to be established for heat derived from Other Combustion Plant.
- Given the requirement to use baseline data (quantity of heat output) from 2005-2008 to establish allocations for heat in Phase III, and the fact that our analysis has sought data from 2007 in establishing benchmarks for the different types of heat, the limitations mentioned above for the establishment of benchmarks will also be experienced in the application of benchmarks and verification of heat data.
- For situations where heat is generated at the same EU ETS installation by boilers and CHP, the current prevalence of the necessary sub-metering, and some site complexities (see Section 5.6), would make the application of separate benchmarks for boiler heat and CHP heat difficult.

2.7 Task1 Recommendations

1) Where heat metering permits, we recommend the application of one heat benchmark for all heat, regardless of its source (boiler, CHP, process waste heat) and that this benchmark is based on the boiler displacement method. We make this recommendation for the following reasons:

- Avoidance of complexity. It means that a separate allocation does not need to be worked out for the separate sources of heat common in industry.
- Practicality. It means that it maximises the cases where heat output benchmarking is possible by making it unnecessary for heat metering to have been in place in the reference year for each separate source of heat.
- Does not disincentivise environmentally sound options. Applying an allocation for process waste heat provides a further encouragement for its recovery, saving fuels that otherwise would be used to generate this heat.

Thus, it is recommended that all sources of “Useful Heat” (as defined in the EU CHP Directive’s guidelines), are treated the same. This is in line with the EU CHP Directive implementation Guidelines (Ref..C(2008) 7294), and the UK’s CHPQA programme. Applying the same benchmark to CHP heat as for other sources of heat represents the simplest and fairest option in respect of CHP heat (see Task 2).

2) Where heat metering does not exist, we recommend the application of a fuel input benchmark. This benchmark should be set at a level that captures the incentive to generate heat efficiently, inherent in the heat production benchmark, and the incentive to use heat efficiently, inherent in the product based

benchmark. We recommend that this allocation method should still use the heat benchmark figure when determining the CO_2 allocation, as follows:

CO_2 Allocation= Verified fuel input x standard boiler/direct firing efficiency x Heat Benchmark

Where standard boiler efficiency can be either based on average efficiency of combustion units or the manufacturer's design efficiency with allowance for boilers age degradation.

By invoking the heat benchmark incentive is provided for the efficient generation of heat and its generation using low carbon fuel.

By invoking the standard boiler efficiency/direct firing efficiency, incentive is provided to improve the efficiency of use of heat, as an allocation is only made for the useful heat, i.e. that heat generated which is actually used in the process.

In respect of other combustion equipment (i.e. not boiler and CHP) a direct firing efficiency is invoked to convert verified fuel input into useful heat, i.e. heat actually consumed in the process in question. We recognise that this factor will have to vary to account for the varying proportions of heat released during combustion that can be counted as useful heat. In some applications virtually all of the heat released during consumption can be counted as useful heat (e.g. fryers in the food industry) while in other applications only a proportion of this can be counted as useful heat (dryers), with the balance not used but rather exhausted. We believe that only allocating for useful heat provides an incentive for the balance of the heat released during combustion, currently unutilised, to be utilised, for example through heat recovery to displace fossil fuel consumption elsewhere or the generation of electricity. These factors should be a function of the process outlet temperature, and they could be in the range of 70% to 90%.

In order to minimise complexity the number of different direct firing efficiency factors should be kept to a minimum, but not be so small as to inadequately cover the range of direct firing activities. The range of direct firing activities for which this will have to be done is defined by those activities that use direct firing but will not have product benchmarks developed. These activities are expected to fall predominantly in the chemical and food and drink sectors. However, there will be some instances where a product benchmark is nominally available but the specialised nature of a particular operation makes its adoption inappropriate, in which case, where direct firing is used, a direct firing efficiency factor will have to be applied. The application of multiple direct firing efficiency factors is a way to ensure that specialised industry is not treated unfairly through the application of a broad benchmark. There are expected to be cases like this pertaining to the manufacture of hollow glass and to the production of asphalt.

3 Task 2

3.1 The Context of Task 2

The objective of Task 2 is:

"To identify what the benchmark level for heat would be taking into account the principles outlined in the revised Directive agreed in December 2008, most notably the top 10% most efficient installations rule."

Article 10a of the revised Directive makes two important points in relation to the level set for any heat based benchmark. These are:

- That the benchmark should be based on the average performance of the 10 % most efficient performing installations
- That the benchmark "should provide incentives for reductions in greenhouse gas emissions and energy efficient techniques, by taking account of ….cogeneration (CHP)." This is taken to mean that any allocation made in respect of CHP heat should not disincentivise the use of CHP.

Work in Task 1 has already pointed to the desirability, on practical grounds, of having one benchmark for heat from all sources. The level that this should be set at, observing the principles set out above, is explored in this Task 2, as is the effect upon the allocation made in respect of CHP generated heat when one heat benchmark is applied.

The approach taken is to use the data presented in Task 1 to derive separate benchmarks for boiler and CHP heat, using the principles set out in the Directive. We will set about establishing separate heat benchmarks for boiler heat and CHP heat while observing the above mentioned principles.

3.2 A Benchmark for Boiler Heat

Section 2.3.1 set out:

- Distributions of boiler efficiencies
- Distributions of CO_2 emissions per unit boiler heat generated
- Distributions of CO_2 emissions per unit fuel input to the boiler.

For the purposes of establishing a heat benchmark based upon the quantity of heat output the second distribution will be used. For the purposes of establishing a benchmark based upon fuel input to the boiler, the last distribution will be used.

3.2.1 Benchmark for Boiler Heat Based Upon Heat Outputs

Examining the distribution of CO_2 emissions per unit heat output from boilers presented in Fig. 2, it is clear, as already mentioned, that some or all of the fuel inputs to some of the boiler schemes are renewable or are in the form of process waste heat. The revised Directive makes clear in Article 10a the need to establish benchmarks that, inter alia, encourage the use of biomass and the recovery of waste gases. There are two arguments that can be advanced regarding the use of the data presented here to derive a benchmark that fulfils Article 10a. Below, for the purposes of comparison, we present the derivation of a heat benchmark for boilers burning all fuels and for boilers burning only fossil fuels.

There are also a number of boiler schemes shown within Fig.1 with efficiencies >95% (NCV). Reasons for these apparent very high boiler efficiencies could include faulty metering and/or an incorrect account being made for the enthalpy of condensate returning to the boiler. On the latter point, if the temperature of the condensate returning to the boiler, after it has given up its heat to process, is actually higher than that measured (or assumed) the actual heat given up to the process is lower than that measured (or assumed). The highest boiler scheme efficiencies relate to those included within UK CHPQA schemes, where, in the case of steam, condensate return enthalpies are assumed. It is likely, therefore, that in cases of very high apparent efficiency, as above, the actual enthalpy of the condensate is higher than that assumed. This will be an issue to take into consideration when establishing the activity level (heat output) for different schemes in the reference year against which emission allocations will be awarded (See Section 6 – Task 5). It will also be necessary to ensure that steam heat is accounted for in the same way across the EU. There will be different conventions for accounting for steam heat across the different Member States and it will be necessary to ensure that the same, agreed method is used when determining activity levels in the reference year. We believe the issue of condensate return and measurement of "useful heat" has been addressed by the Commission in their document for **"***establishing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC of the European Parliament and of the Council" (notified under document number C(2006) 6817).* Thus, we recommend that this approach is considered for measuring heat flows under the EU ETS. This means that where the conditions of the condensate return (mass and temperature) are not known, these are instead assumed to be at 10ºC and have the same mass as the steam delivered to the process, the actual heat delivered to the process as steam is considered to be 5% less than that suggested by the assumed condensate return values.

For the purposes of this analysis these very high boiler efficiencies have been left in, as it is presently not possible to determine beyond doubt whether the very high apparent efficiencies are due to differences between the actual and assumed condensate enthalpies.

Determining a heat benchmark for boiler heat, observing the Directive principle that any such benchmark should be based upon the 10% most greenhouse gas efficient installations, produces the values shown in Table 3.

Table 3 Characteristics of 10% most greenhouse gas efficient boiler schemes (heat output basis)

Boiler Population	No. Boiler Schemes	No. Boilers	Boiler capacity (MWth)	Benchmark ($kgCO_2$/MWh)
Excluding Schemes burning renewables	5	23	418	213.2
Including all schemes	5	19	376	212.8

3.2.2 Benchmark for Boiler Heat Based Upon Fuel Inputs

Following the same principle set out in Section 3.2.1, the fuel input benchmarks, based upon the whole boiler scheme population, and only those burning fossil fuels, are given below.

Table 4 Characteristics of 10% most greenhouse gas efficient boiler schemes (fuel input basis)

Boiler Population	No. Boiler Schemes	No. Boilers	Boiler capacity (MWth)	Benchmark ($kgCO_2$/MWh)
Excluding Schemes burning renewables	5	19	121	201.96
Including all schemes	5	17	259	189.56

3.3 A Benchmark for CHP Heat

Section 2.3.2 set out CO_2 emissions per unit of heat output from CHP prime movers, as determined using three possible methods for apportioning CHP fuel between electricity for heat generation.

In Section 2.7 we recommended using Method 2 (boiler displacement method) for apportioning fuel (and therefore emissions) for CHP heat. We therefore present below benchmarks for CHP heat, one for all fuels, the other for only fossil fuels, returned from the distribution of CO_2 emissions per unit CHP heat for CHP schemes, constructed using Method 2.

3.3.1 Benchmark for CHP Heat Based Upon Heat Outputs

112 separate CHP schemes (with a capacity of 1,295 MWe) have been analysed from the point of view of the fuel input to the prime mover and heat generated during electricity generation.

Table 5 Characteristics of 10% most greenhouse gas efficient CHP schemes

CHP Population	No. CHP Schemes (best 10%)	CHP Capacity (MWe)	Benchmark ($kgCO_2$/MWh)
Excluding Schemes burning renewable	10	31	224.4
Including all schemes	11	120	46.97

3.4 A Combined Benchmark for Boiler Heat and CHP Heat

Up to this point the ranking of schemes by CO_2 emissions per unit of heat generated has been presented separately for boiler and CHP heat. Figure 7 presents boiler and CHP heat on the same benchmarking curve with the emissions associated with CHP heat derived using Method 2. Table 6 shows the two benchmarks derived for heat, one for schemes using all fuel types and one for schemes using only fossil fuels.

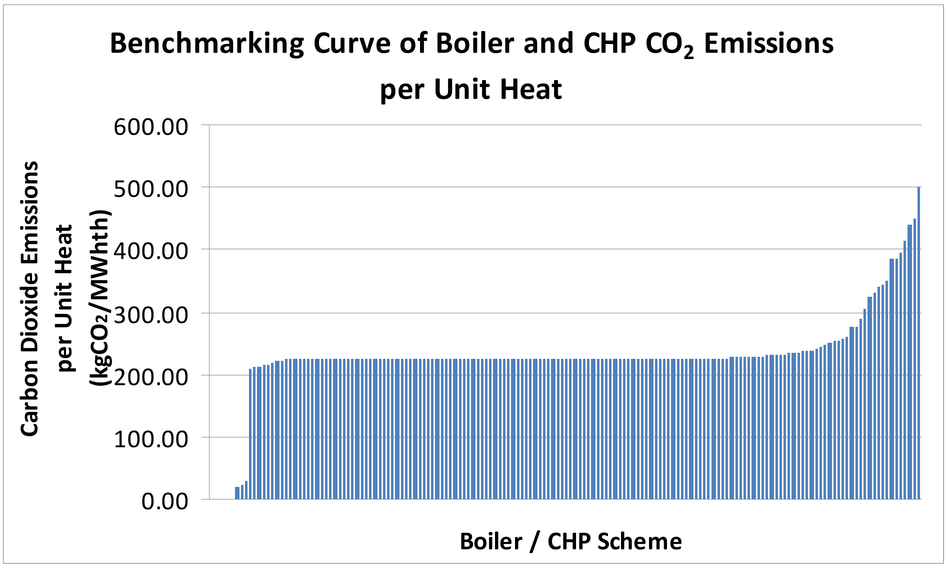

Figure 7 Benchmarking curve of CO_2 emissions per unit heat for boiler and CHP heat – CHP emissions derived using Method 2

Table 6 Characteristics of 10% most greenhouse gas efficient boiler CHP schemes

Boiler / CHP Population	No. Boiler / CHP Schemes (best 10%)	Benchmark ($kgCO_2/MWh$)
Excluding Schemes burning renewable	15	223.09
Including all schemes	16	98.31

3.5 A Benchmark for Other Combustion Plant

As explained in Section 2.3.3 there is almost no existing information to allow a benchmark for heat from Other Combustion Plant, based upon the quantity of heat output, to be established. This implies that the only option available regarding benchmarking of emissions from such plant would be on the basis of fuel inputs.

3.6 Task 2 Main Findings

- Observing the principles set out in the revised Directive for deriving benchmarks, and an analysis on boiler populations including those burning all fuel types and those burning only non-renewable fuels has produced the following benchmark values:
    - 212.8 $kgCO_2/MWh$ (All fuels, based on 19 separate boilers with a capacity of 376 MWth)
    - 213.2 $kgCO_2/MWh$ (Non-renewable fuels only, based on 23 boilers with a capacity of 418 MWth)
  - Observing the same principles for the establishment of a fuel mix benchmark for the boiler population produces the following benchmark values
    - 189.5 $kgCO_2/MWh$ (All fuels, based on 17 boilers with a capacity of 259 MWth)
    - 201.96 $kgCO_2/MWh$ (Non-renewable fuels only, based on 19 boilers with a capacity of 121 MWth)

- Using Method 2 for apportioning fuel (and therefore emissions) for CHP heat, and observing the principles set out in the revised Directive for deriving benchmarks, results in the following benchmarks for CHP heat:

    - Method 2 47.0 $kgCO_2/MWh$ of CHP heat output (All fuels)
    - Method 2 224.4 $kgCO_2/MWh$ of CHP heat output (Non-renewable fuels only)

- Combining on the same benchmarking curve the CO_2 emissions associated with boiler and CHP heat, and observing the principles set out in the revised Directive for deriving benchmarks, produces the following benchmarks for boiler and CHP heat together:

		Benchmark ($kgCO_2/MWh$)
CHP Heat Emissions Method 2	Excluding Schemes burning renewable	223.09
	Including all Schemes	98.31

There is insufficient information available to allow a heat output benchmark to be established for Other Combustion Plant. A benchmark for such plant would have to be established on the basis of fuel inputs. For the reasons discussed in Section2.7 we recommend adopting the following allocation method:

Carbon Allocation= Verified fuel input x direct firing efficiency x Heat Benchmark where the direct firing efficiency will be assumed and will depend upon the type of direct firing application taking place and the heat benchmark is as derived above .

3.7 Task 2 Recommendations

Within Task 1 we have already recommended the application of one benchmark for heat regardless of its source (boiler, CHP or process waste heat), where the quantity of this heat can be measured.

We consider benchmarking CHP heat using the boiler displaced method (Method 2) to be consistent with maximising the incentive for this low carbon technology. As such, and observing the principles of the revised Directive, we propose a heat benchmark of 98.3 kgCO_2/MWhth (all fuels basis) or 223.1 kgCO_2/MWhth (excluding renewable fuels). This latter figure is close to the benchmark implied by the European Commission's consultant's recent proposal for any heat benchmark to be based on gas fired boiler with annual efficiency of 93% (NCV). The European Commission's consultant's suggestion would imply a benchmark of 217 kgCO_2/MWhth.

Treating all sources of heat in the same way, as long as they deliver "useful heat", leads to a "level playing field". This will also make implementation easier, as it will require less metering and fewer verifications. It will also incentivise waste heat recovery and the utilisation of renewable fuels.

In respect of accounting for useful heat, where heat is delivered in the form of steam and the enthalpy of the condensate return needs to be taken into account, we recommend accounting for this in the way set out in the European Commission's document for *"establishing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC of the European Parliament and of the Council"* (notified under document number C(2006) 6817). This means that where the conditions of the condensate return (mass and temperature) are not known, these are instead assumed to be at 10ºC and have same mass as the steam delivered to the process, the actual heat delivered to the process as steam is considered to be 5% less than that suggested by the assumed condensate return values.

4 Task 3

4.1 The Context of Task 3

The objective of Task 3 is:

"To assess the feasibility of using a heat benchmark with a generic improvement factor as a fallback option for Annex I activities (excluding combustion) where a product-based benchmark cannot be developed and to assess which basis for the generic improvement factor would be most appropriate to use."

Article 10a of the revised Directive calls for, in principle, the use of benchmarks calculated for products, rather than for inputs, when determining the allocation of free allowances for installations. The European Commission's consultants have undertaken an examination of the feasibility of the application of product based benchmarking across the named Annex I activities that will be covered under EU ETS Phase III. In determining the feasibility of this they have observed a number of principles[15].

There are inevitably situations where the establishment of product benchmarks is either not sensible or not practicable. A sector may be engaged in the manufacture of many different types of product that are insufficiently distinct to warrant the establishment of separate benchmarks. Moreover, in the interests of keeping the number of separate benchmarks at manageable levels, the European Commission's consultants have taken the pragmatic approach that, so long as a large proportion of a sector's emissions are covered by product based benchmarks (~80%), it is acceptable for the remainder of the sector's emissions to be covered by one of the fallback approaches. This is the case with the Chemicals sector, which is characterised by a very large number of distinct products. The fallback approaches associated with CO_2 emissions from fuel use are:

- Heat production benchmark
- Fuel mix benchmark

When benchmarks based on CO_2 emissions per unit output are established for products they reflect the most carbon efficient means of producing that particular product. Since allowances are not awarded in respect of electricity generation, the product benchmark also does not include these emissions, and therefore reflects the most carbon efficient means of generating and consuming heat[16].

Carbon emissions associated with the generation and consumption of heat derive from three sources:

- The carbon intensity of the fuel being combusted to generate the heat (Fuel mix choice)
- The efficiency with which the heat of combustion is captured by the heat transport medium (Combustion efficiency)
- The efficiency with which the transported heat is used in the process application (Heat end-use efficiency)

A product benchmark embodies all of these factors and, therefore, when used to calculate the allowances for an installation, reductions in carbon intensity at all three stages are incentivised.

This is not the case for the other two fallback approaches for allocating allowances associated with fuel use. In the case of heat production benchmarking there is no incentive for efficiencies once the heat has been generated, i.e. there is no incentive explicit in the allocation for efficient use of the generated heat. In the case of fuel mix benchmarking, the incentive for efficiency explicit in the allocation does not extend beyond the choice of low carbon fuels. However, for fossil fuels, efficient generation can be incentivised in so far as boilers burning lower carbon fossil fuels like natural gas tend to be more efficient than boilers burning higher carbon fossil fuels like fuel oil or coal.

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[15] See Section 4.4, Methodology for the free allocation of emission allowances in the EU ETS post 2012, http://ec.europa.eu/environment/climat/emission/pdf/bm/BM%20study%20-%20%20Project%20Approach%20and%20general%20issues.pdf

[16] The product benchmark also reflects the 10% most carbon efficient means of operating in respect of process emissions, but this is outside the scope of this report.

This raises the question of fairness between different installations receiving allowances that have been determined by different allocation methodologies. The question of fairness has two facets that need to be considered. These are:

- Two installations may make separate products that are sufficiently different such that one is product benchmarked and the other is not. However, the products are sufficiently similar that they serve the same market and can be substituted for each other at the point of use. The question is does the application of different benchmarks give an undue advantage to one producer over the other.

- Two installations make the same product, which is not product benchmarked, but one installation receives an allocation based upon heat production benchmarking and the other on fuel mix benchmarking. Such a situation might arise if the first installation has data available for the quantity of heat generated in the reference year while the other installation only has this for the fuel used in heat generation (no heat metering). Again, there is the question of whether the two installations will receive similar treatment through the application of separate benchmarks. N.B. This can be resolved by using a fuel input benchmark, based on heat benchmark and standard boiler efficiencies for different fuels. See section 3.6.

Ecofys have suggested that any inequality in allocation between recipients of product benchmark allowances and heat benchmark allowances and between heat benchmark allowances and fuel mix benchmark allowances can be addressed by applying correction factors (or generic improvement factors) such that efficient heat end use is incentivised in the case of heat benchmarking and efficient generation of heat and end use is incentivised in the case of fuel mix benchmarking.

Two approaches have been proposed for the derivation of these generic improvement factors. These are:

- Improvement factors based on factors derived from benchmarked products
- Improvement factors based on an assessment of reduction potentials

The first approach is considered via Case Studies 1-2 below

4.2 Improvement Factors Based on Factors Derived from Benchmarked Products

The following case studies explore the need for and the basis upon which an improvement factor can be established for heat and fuel mix benchmarked activities.

In order to investigate this, we have selected sites carrying out Annex I activities with the following attributes:

1) The activity has no process emissions. This means that the only emissions against which an allocation will be made will be those associated with the generation of heat. This allows us to calculate the allocation that the activity would receive under a heat benchmark, under the hypothetical consideration that a product benchmark were not available.

2) The activity has had a product benchmark proposed for its output. We are therefore able to calculate the allocation that the activity would actually receive under the current proposed product benchmark.

Comparing the allocation made to the same site making one product, but under two different benchmarking methodologies, allows the relative fairness of the two methods to be examined.

Sites manufacturing paper products satisfy the above criteria and two case studies for the manufacture of paper and board products are presented below. Data used in these examples were provided by the sites via their UK Trade Association.

4.2.1 Case Study 1 - Site A Manufacturing Containerboard

Ecofys currently recommends a product benchmark for containerboard of 0.368 tCO_2/adt (air dried tonne).[17]

Site A satisfies its need for steam used in the containerboard making process using CHP and separate boilers. The steam output from the CHP is reliably metered, but the metering of steam from the boilers is less reliable. Gas to the boilers is, however, reliably metered and a good approximation has been made about the efficiency of the boilers in order to arrive at an overall figure for the steam heat used in 2007 and 2008 for the manufacture of containerboard.

The Table 7below shows the allocation that the site would receive using four different benchmark values:

- The product benchmark currently being proposed by Ecofys for containerboard[18]
- The heat benchmark value implied by the European Commission's current thinking of basing this on a natural gas boiler with an efficiency of 93% (NCV), i.e. 217.2 $kgCO_2$/MWh
- The heat benchmark derived in this study 223.1 $kgCO_2$/MWh, on the basis of not including renewable fuels in the benchmark curve (Section 3.6)
- The heat benchmark derived in this study 98.3 $kgCO_2$/MWh, on the basis of including renewable fuels in the benchmark curve (Section 3.6)

Table 7 Paper Site A – Allocation under proposed product benchmark and a range of heat benchmarks for 2007 and 2008

2007/2008 Average				
Site	Product B/M Allocation (tCO_2)	NG Boiler (93%) (tCO_2)	AEA Heat B/M (All Fuels Basis) (tCO_2)	AEA Heat B/M (Excl. Renewables) (tCO_2)
A	65,252	56,274	25,476	57,810

4.2.2 Case Study 2 - Site B Manufacturing Newsprint

Ecofys currently recommends a product benchmark for newsprint of 0.318 tCO2/adt (air dried tonne).

Site B satisfies its need for steam used in the newsprint making process using CHP and separate boilers. The steam output from the CHP and boilers is reliably metered and these metered values are used as the overall demand for steam heat in 2007 and 2008 for the manufacture of newsprint.

The Table 8 below shows the allocation that the site would receive using the four different benchmark values mentioned above for Site A.

Table 8 Paper Site B – Allocation under proposed product benchmark and a range of heat benchmarks for 2007 and 2008

2007/2008 Average				
Site	Product B/M Allocation (tCO_2)	NG Boiler (93%) (tCO_2)	AEA Heat B/M (All Fuels Basis) (tCO_2)	AEA Heat B/M (Excl. Renewables) (tCO_2)
B	64,605	94,634	42,841	97,218

4.3 Improvement Factors Based on Reduction Potentials

The other approach suggested by Ecofys for establishing improvement factors for heat benchmark values, to correct for the fact that they do not necessarily embody an incentive to consume the

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[17] See http://ec.europa.eu/environment/climat/emission/pdf/bm/BM%20study%20-%20Pulp%20and%20paper.pdf

[18] The current benchmarks being proposed by Ecofys for containerboard and newsprint are based on BAT as set out in the Reference document on Best Available Techniques in the pulp and paper industry, European Commission, Institute for Prospective Technical Studies, Seville, 2001, and as such may not represent actual BAT in the industry at the present time.

generated heat in the most efficient manner, is to consider the potential for reducing the end demand for the generated heat.

One possible means of doing this is to employ existing modelling tools set up to estimate the potential for improving energy end use efficiencies in various industrial sectors. One such modelling tool is the Energy **En**d-**U**se **Sim**ulation Model (ENUSIM). This is a bottom-up model used to derive marginal abatement cost (MAC) curves associated with various energy efficiency technologies available within different industrial sub-sectors. Underpinning these MAC curves are assumptions about the uptake of these technologies under Business As Usual (BAU) and All Cost Effective (ACE) scenarios, with the difference between the two at a given year representing the unfulfilled potential for the particular technology under consideration.

It is believed that this underpinning data could form the basis of establishing a generic improvement factor in respect of the efficiency of the end use of heat. A possible approach to this would be:

1) Map the Annex I activities which cannot be product benchmarked to industrial sectors identified in ENUSIM. In the case of Annex I activities that resolve down into a mixture of product benchmarks and heat benchmarks, ENUSIM would have to be interrogated at the industrial sub-sector level. This would be the approach adopted for the chemical sector, for example.

2) For the industrial sector and sub-sectors listed in ENUSIM corresponding to Annex I activities that would be heat benchmarked, identify those technologies associated with improving the efficiency of the end use of generated heat (heat end use efficiency technology), e.g. steam pipe work insulation.

3) For each year of EU ETS Phase III identify the modelled unfulfilled potential associated with each heat end use efficiency technology, i.e. the difference between the penetration of that technology under the BAU case and the ACE case.

4) Express the unfulfilled potential in terms of the percentage of the total heat consumption for that industrial sector or sub-sector. This factor could then represent the basis of an improvement factor for that heat end use efficiency technology in that sector or subsector.

5) Repeat 4) for each heat end use efficiency technology within a sector or sub-sector and sum these together. The result is an improvement factor specific to the sector or sub-sector.

Undertaking the above would require substantial effort that cannot be included in this study, but presents a possible way of increasing the ‘granularity’ of the fall-back approaches.

Note: *ENUSIM is currently being updated for the UK’s Committee on Climate Change (CCC) to help them make informed decisions when discharging their requirement to set 5 yearly carbon budgets. Using the same information to inform the establishment of benchmarks used to calculate the allocation of free allowances under EU ETS would aid consistency between the CCC’s higher level work on carbon budgets for the UK and the component of UK carbon emissions represented by EU ETS. This would be a separate project.*

4.4 Discussion of the Approaches for Establishing a Generic Improvement Factor

Regarding the first approach examined above for identifying the need for generic improvement factors there are two points worthy of note:

- There is a difference in allocation outcome in respect of the same (heat consuming) activity when product benchmarks and heat benchmarks are applied. This implies the need for some mechanism to ensure equivalence between the two methods.
- The application of the heat benchmark does not consistently return a larger allocation than that returned by the product benchmark, as might be expected if the heat benchmark failed to capture efficient end use of heat[19].

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[19] An important point to note is that this study is based upon the product benchmarks being proposed at the time of writing (November 2009). The product benchmarks eventually adopted, based upon EEA installation data, may be different from those assumed in this study.

However, in the case of Site A the allocation under the two methods is closer than for Site B. Establishing the specific heat consumption at the two sites and comparing these against Ecofys's stated 'lowest best available technology heat consumption', as derived from the BREF document for Pulp and Paper, produces the following results:

Table 9 Comparison of actual specific heat consumption and BAT for Site A and Site B

Site	Lowest BAT Specific Heat Consumption (GJ/adt)	Actual Specific Heat Consumption – Average for 2007/8 (GJ/adt)
A	5.9	5.3
B	5.1	7.7

This shows that in the case of Site A the site is already consuming heat more efficiently than the efficiency of consumption implied by the Ecofys product benchmark. Given this finding, and its consequence that the allocation under the heat benchmark is lower than under the product benchmark, it would seem perverse to apply a generic improvement factor to the heat benchmark derived allocation. However, the fact that specific heat consumption for Site A is lower than BAT suggests that BAT has moved on since 2001and that BAT specific heat consumption for a more recent year would be lower and, therefore, a product benchmark based on this would be tighter.

In contradistinction, Site B is consuming heat less efficiently than the efficiency of consumption underpinning the Ecofys product benchmark for its product. This results in Site B receiving a larger allocation under heat benchmarking than it would under product benchmarking. For Site B, therefore, there is a case for the application of a generic improvement factor in order to make the outcomes of the product and heat benchmark methods equivalent.

These case studies highlight some of the issues associated with the application of a generic improvement factor to a heat benchmark when there is a range of heat use efficiencies. As a heat benchmark is based upon the average of the 10% most greenhouse gas efficient heat generators, its application would lead to somewhere between 90 and 100% of sites being incentivised to improve heat use efficiencies. If the heat benchmark is further tightened via the application of a generic improvement factor a greater proportion of sites will fall under this category. Therefore, assuming that the generic improvement factor is necessary in order to make the outcomes of product and heat benchmarks equivalent, its application will incentivise a greater proportion of sites to improve heat end use efficiency but at the same time maintaining the current relative advantage of efficient sites over less efficient sites.

4.5 Recommendations

Deriving an improvement factor based upon actual reduction potentials would, on the face of it, have a better chance of addressing the need to take account of the actual state of heat end use efficiency at sites, highlighted above. However, this could only be done with absolute fairness if the reduction potential was assessed at the individual site level. It is difficult to see how assessing the reduction potential at the site level would be practical.

This report has presented the results from very limited case studies. We believe that if the principle of the broad application of a generic improvement factor were to be pursued, further work would be required to get a wider view of the spread of heat end use efficiencies across the affected sectors.. However, experience with trying to carry out a similar analysis as those presented in Section 4.2 in the chemical sector, where the relative treatments under product and heat benchmarks of similar products was investigated, demonstrated the complexity of isolating the heat use associated with the production of a product being heat benchmarked, and by definition the scope for heat end use efficiencies.

Notwithstanding the present uncertainties, described above, and assuming that a generic improvement factor is necessary to ensure equivalence between heat benchmarks and product benchmarks for a particular situation, the application of a generic improvement factor would not penalise early adopters of efficient heat end use technologies and techniques, with respect to less efficient sites, as the relative advantage (lower emissions for the same level of production activity) would be preserved.

5 Task 4

5.1 Context of Task 4

The objective of Task 4 is:

“To determine a methodology for allocating allowances to those installations that consume the heat rather than those installations that produce it, where the two are different, and to determine the likely impact of this approach”

The structure of industry in the UK is such that heat is sometimes consumed under a different permitting structure from where it is generated. In the context of EU ETS this means that heat is sometimes generated at one EU ETS installation and consumed at another.

Recital 23 of the revised Directive calls for the avoidance of undue distortions of competition between industrial activities carried out in installations operated by a single operator and production in outsourced operations. In the context of cross-boundary heat flows, the European Commission’s consultants have interpreted this to mean that “the methodology to allocate allowances in cases of cross-boundary heat flows should ensure that the total amount of emissions allowances for the heat concerned should be equal in all cases, regardless of the permitting structures of the heat producing and heat consuming installations. In other words, from an end-use perspective, all heat should be treated equally, regardless of the installation in which it is produced.”

Accordingly, the European Commission’s consultants have developed a number of methodologies for allocating allowances in respect of heat crossing installation boundaries. Currently, of the methodologies being considered to allocate allowances for cross-boundary heat, there are two that appear to be particularly viable:

- Method 1 Allocation of allowances to consumers of the heat
- Method 2 Allocation to both producers and consumers based on a heat production benchmark for the transferred heat. Within this method, there are different approaches that could be taken to deal with carbon leakage (this is discussed below).

  Below we discuss the practicalities and issues associated with the application of these two methods.

5.2 Cross Boundary Heat Flow Allocation Methodology-Method 1

5.2.1 Theoretical Operating Principles of Method 1

Under Method 1, where heat is generated in an EU ETS installation and exported over the boundary for consumption within another EU ETS installation, there is no allocation to the heat producer. In the case where the consuming installation produces a benchmarked product, then this installation simply receives an allocation associated with that product. It is understood that in cases where the consuming installation is in EU ETS and not product benchmarked the heat consumer will also receive the allowances associated with this heat.

Where heat is generated within an EU ETS installation and exported over the boundary to a non EU ETS installation, then the heat generating installation receives the allocation associated with this heat.

The following figure illustrates the operation of allocation Method 1 for more than one heat producer and heat customers of different EU ETS statuses.

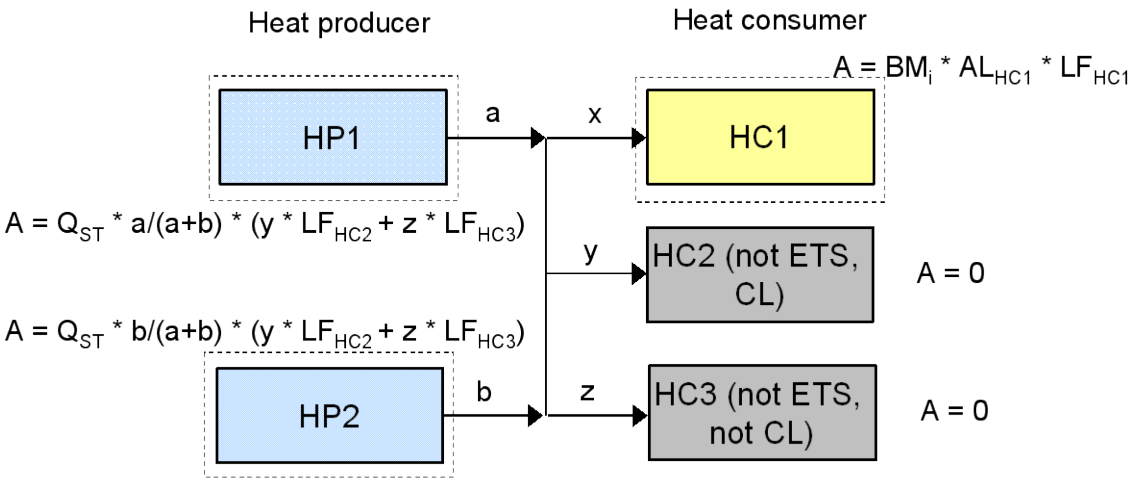

Figure 8 Operation of allocation Method 1, where heat producers are in EU ETS and heat consumers both inside and outside of EU ETS (Adapted from Climate Action)[20]

Where:
A is the allocation given to a particular installation
Q_{ST} is the benchmark for heat
B_{Mi} is the benchmark for the product produced within HC1
AL_{HC1} is the activity level for the production of HC1 in the reference year
LF_{HC1} ,LF_{HC2} and LF_{HC3} are the carbon leakage factors for installations HC1, HC2 and HC3, respectively
a and b are the quantities of heat generated and exported by heat producer HP1 and heat producer HP2, respectively, in the reference year
x, y and z are the quantities of heat imported by the installations HC1, HC2 and HC3, respectively, in the reference year

5.2.2 Method 1 Perceived Advantages and Disadvantages

Advantages

1) This is the only method that guarantees that the heat consumer will get the benefit intended with respect to the EU ETS Directive's provision to give free allocations to address the risk of carbon leakage. Contracts already in existence, but expiring after 2013, may not allow for the benefits associated with the full allocation for carbon leakage to be passed on to the heat consumer if other cross boundary methods, where some, or all, of the total allocation for the heat goes to the heat generator, are adopted.

2) There are no obstacles to the heat consumer changing supplier.

3) The main advantage with this methodology, from the point of view of application, is that the quantity of heat flow across the boundary does not need to be known when the importing installation is product benchmarked. This is an important advantage given the fact that this information is likely not to be available in all situations for the reference year, and this contrasts with the situation for Method 2 (see Sections 5.3 and 5.4) where this needs to be known in all cases when the importing installation is product benchmarked.

4) Under this method, the allocation made in respect of a quantity of heat is the same, regardless of whether the heat is generated in-house or imported.

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[20] Presentation "Cross-boundary heat flows", presentation given at Task force of Informal TWG on benchmarking, Brussels, 17 November 2009

Disadvantages

1) In situations where the consumer is not in EU ETS, under Method 1 it is still necessary to know the quantity of heat being imported (see Figure 10) and the carbon leakage factor associated with the heat importer in order for the correct allocation to be made to the heat producer. It is in respect of this second point that Method 1 may suffer a disadvantage compared with Method 2b, where the carbon leakage factor (that of the heat generator) is known with certainty (see Section 5.3).

2) The main disadvantage with this method is that the heat producing installation will have to purchase all of the allowances associated with the heat exported and consumed at EU ETS installations. It is natural to expect the heat generator to want to raise the price of the exported heat to cover this additional cost. However, depending upon the conditions of the contract existing between the heat producer and the heat consumer, this may not always be possible. It may be that supply contracts are already in existence that expire sometime after 2013. In such situations, there will be a period where the heat generator suffers financially unless an arrangement can be reached with its heat customers, outside of contract, to alleviate matters.

We have conducted an analysis of the likely size of this issue in the UK. Working on the assumption that the overwhelming majority of heat flowing between different EU ETS installations is generated by CHP, we have looked at the quantity of CHP heat actually generated at EU ETS installations and exported for consumption elsewhere. This has also been carried out for planned CHP schemes, where there is knowledge of the likely quantity of heat to be exported each year and the recipient can be identified.

The recipients of this heat have been categorised according to whether they are inside or outside of EU ETS. In the case of recipients within EU ETS we have determined their EU ETS sector and, therefore, whether or not they are likely to be product benchmarked. Where the sector of end use is a mixture of product benchmarking and fallback benchmarking option (e.g. chemicals), this is referred to as Part & Part. Consistent with what is said above for Method 1, it is in respect of heat exported to both product benchmarked installations and installations that are ‘Part and Part’ that the generating installation would definitely not receive allowances for its emissions.

Below is a summary of our estimates of the quantity of heat generated within EU ETS installations for export in 2008 (Sum of Total Heat Exports). Also presented are the CO_2 emissions associated with this exported heat, assuming that this heat displaces that generated within a boiler with an efficiency of 90% (NCV) using the actual fuel mix to the CHP. It is worth noting that the total exported heat represents about 46% of all of the heat generated by CHP in 2008 and the CHP plant generating this heat represents about 56% of the total Qualifying Power Capacity (QPC) in the UK.

	Data					
Method	**Count of REFNO**	**Sum of CHPQHO (MWh)**	**Sum of Total Heat Exports (GWh)**	**Sum of CHPQPC (MWe)**	**Sum of Total Carbon Emissions (tCO2)**	**Sum of Carbon Attributable to Exported Heat (tCO2)**
Part & Part	8	8,312	6,579	934	11,690,158	1,455,806
Product	20	16,851	16,816	2,027	26,017,957	3,523,882
To Non EU-ETS	7	725	616	82	295,485	92,099
Grand Total	**35**	**25,888**	**24,010**	**3,043**	**38,003,600**	**5,071,787**

Operating Schemes

Below is a summary of our estimate of the quantity of heat that will be generated within planned CHP EU ETS installations (New Entrant Schemes) and exported. These figures should therefore be considered as additional to those above for future years of operation and are listed separately in order to illustrate the likely (but not certain) future growth in the issue being discussed here.

New Entrant Schemes

	Data					
Method	Count of REFNO	Sum of CHPQHO (MWh)	Sum of Total Heat Exports (GWh)	Sum of CHPQPC (MWe)	Sum of Total Carbon Emissions (tCO2)	Sum of Carbon Attributable to Exported Heat (tCO2)
Part & Part	4	2,754	2,703	1,081	3,595,082	600,214
Product	6	1,587	1,540	128	221,536	121,087
To Non EU-ETS	2	98	98	6	37,757	22,083
Grand Total	**12**	**4,439**	**4,342**	**1,215**	**3,854,374**	**743,384**

Of existing schemes, 23,394 GWh (45% of all CHP heat generated in the UK) is exported to other installations that will be either product benchmarked or heat benchmarked. The electrical generating capacity of CHP schemes for which this is the case is 2,961 MWe (54% of the total Good Quality CHP capacity in the UK). Therefore, a significant proportion of heat producers (CHP operators) are likely to be disadvantaged as a result of cross boundary heat allocation Method 1. Some producers might not be able to recoup the additional cost they will encounter until heat supply contracts can be renegotiated. There is also a danger that marginal CHP schemes, not able to recoup the cost of CO_2, will shut down. The heat customers would then have to make alternative arrangements to meet their heat requirements. These arrangements are likely to be the installation of on site heat only boilers, as this would represent the lower cost, least technically risky option, and an opportunity to tap into the greenhouse gas efficiencies associated with CHP would be missed.

5.3 Cross Boundary Heat Flow Allocation Methodology-Method 2b

5.3.1 Theoretical Operating Principles of Method 2b

Under Method 2b, where heat is generated within an EU ETS installation and exported to another EU ETS installation, where that installation is product benchmarked, the benchmarked allocation associated with this heat is awarded to the producing installation. In order to ensure that the total allowances in respect of this heat remain the same, regardless of the heat supply situation, the same quantity of allowances is subtracted from the benchmarked allocation of the heat consuming installation. Under 2b, the carbon leakage factor of the heat producer is used to calculate the number of allowances awarded to the heat generator and, therefore, the number of allowances to be netted off from the product benchmark of the heat consumer. This can be compared against Method 2c, where the carbon leakage factor of the heat consumer is used to calculate the allocation to the generator and consumer (See Section 5.4.).

5.3.2 Method 2b Perceived Advantages and Disadvantages

Advantages

1) Method 2b operates in such a way as to incentivise both the carbon efficient generation of heat and the efficient consumption of heat.

2) Less information is required about the carbon leakage status of the consuming installations, as there is only one leakage factor that will be used under this method, i.e. that of the heat producer. This is a point recommending the use of Method 2b in situations of complex heat networks where there are a large number of consumers of heat, producing different products for which separate carbon leakage factors will have to be established, as would be the case, for example for Method 2c (see Section 5.4). However, it should be stressed that this information gathering would be a one-off burden and it is logical to expect this information to be available where the heat generator has a billing relationship with the heat customer.

Disadvantages

1) Under Method 2b, the heat generator will only be given allowances for heat consistent with no carbon leakage, and this could push up the price that a heat consumer, exposed to carbon leakage, is charged for this heat, compared with the situation where the heat generator receives 100% of the allowances associated with the heat (as under Method 2c). However, this is somewhat balanced by the fact that the heat consumer will retain more of the allocation for this heat, when compared against Method 2c. It is also possible that the heat generator may choose not to pass on any of the value of the allocation it receives in the form of a lower price to the heat consumer and the heat consumer may not be in a position to do anything about this.

2) Unlike for Method 1, in Method 2b there is the possibility of a negative allocation. This situation can arise where the heat consumer is product benchmarked and imports heat from a producing installation. As mentioned above, the allocation associated with this imported heat is netted off from the product benchmark based allocation made to the heat consumer, and this is then awarded to the heat producer. In cases where the efficiency of heat use is low in the reference year, this netted off allocation could be quite large and in theory could exceed the allocation made in respect of the product benchmark. In this situation the overall allocation due to the heat consuming installation could be less than zero. This is less likely to happen than under Method 2c and the chances of this happening reduce as the heat benchmark is made tighter.

3) Under Method 2b the situation whereby a different allocation is made in respect of the same quantity of heat, where this heat can be either generated on site or outsourced, is more likely to occur than under Method 1 or Method 2c.

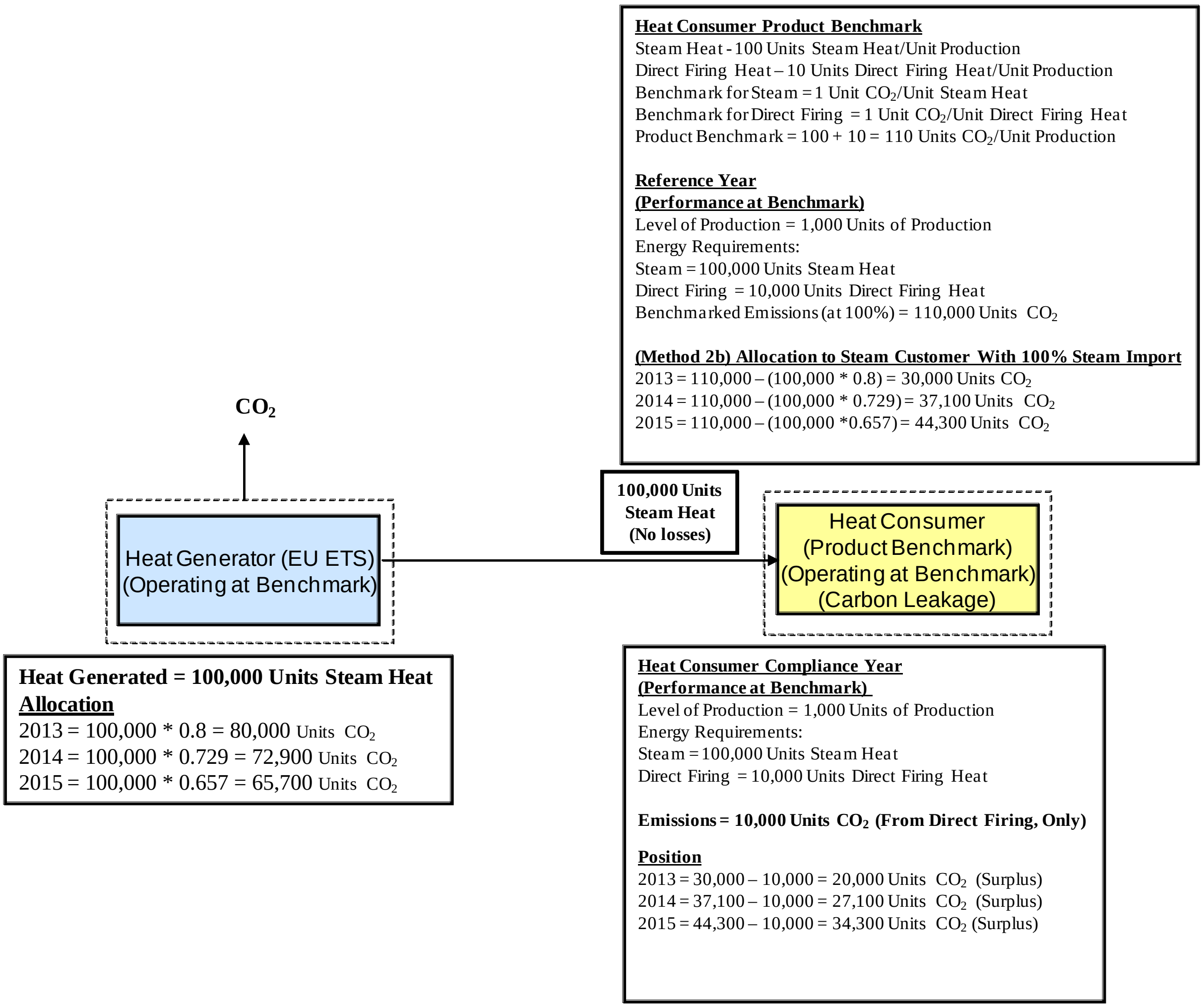
For example, under Method 1, whether or not the heat in question is imported or generated on site, all of the appropriate allocation associated with that heat is made to the consuming installation, with the appropriate allocation either being 100% of the amount determined (in the case of a heat consumer at risk of carbon leakage) or 80% reducing to 30% of the amount determined (in the case of a heat consumer not considered at risk of carbon leakage).

Under Method 2c the carbon leakage factor of the consuming installation is also observed when making the allocation for the heat. Therefore, in the case of a carbon leakage consumer generating heat on site, the consumer would receive 100% of the amount determined for this heat. If the same quantity of heat were imported the allocation would be exactly the same, but this time awarded to the heat producing installation.

4) Another disadvantage associated with the application of Method 2b is that it is possible for the heat customer to receive a free allocation that grows over time, if the heat customer is product benchmarked AND is deemed to be at serious risk of carbon leakage. However, it should be noted that the allocation in aggregate across the heat producer-consumer supply chain for this heat will be the same as for the situation where the heat consumer produces its own heat, i.e. 100% of the amount determined throughout Phase III.

This is illustrated in the example below where the following conditions pertain:

- The heat consumer is product benchmarked and produces a product that requires heat in the form of steam and direct heat to make.
- The average of the best 10% performers manufacturing this product need 100 units of steam and 10 units of direct heat to make each unit of the product.
- The heat consumer incurs emissions associated with the direct heat on its site, but imports all its steam requirements from an adjacent EU ETS heat generating installation, i.e. the emissions associated with this steam heat are incurred at another installation.
- The product manufacturer is operating at benchmark in the reference year and continues at this level of performance throughout Phase III.
- The heat generator is operating at benchmark in the reference year and continues at this level of performance throughout Phase III.



Heat Consumer Product Benchmark
Steam Heat - 100 Units Steam Heat/Unit Production
Direct Firing Heat – 10 Units Direct Firing Heat/Unit Production
Benchmark for Steam = 1 Unit CO_2/Unit Steam Heat
Benchmark for Direct Firing = 1 Unit CO_2/Unit Direct Firing Heat
Product Benchmark = 100 + 10 = 110 Units CO_2/Unit Production

Reference Year
(Performance at Benchmark)
Level of Production = 1,000 Units of Production
Energy Requirements:
Steam = 100,000 Units Steam Heat
Direct Firing = 10,000 Units Direct Firing Heat
Benchmarked Emissions (at 100%) = 110,000 Units CO_2

(Method 2b) Allocation to Steam Customer With 100% Steam Import
2013 = 110,000 – (100,000 * 0.8) = 30,000 Units CO_2
2014 = 110,000 – (100,000 * 0.729) = 37,100 Units CO_2
2015 = 110,000 – (100,000 *0.657) = 44,300 Units CO_2

Heat Generated = 100,000 Units Steam Heat
Allocation
2013 = 100,000 * 0.8 = 80,000 Units CO_2
2014 = 100,000 * 0.729 = 72,900 Units CO_2
2015 = 100,000 * 0.657 = 65,700 Units CO_2

Heat Consumer Compliance Year
(Performance at Benchmark)
Level of Production = 1,000 Units of Production
Energy Requirements:
Steam = 100,000 Units Steam Heat
Direct Firing = 10,000 Units Direct Firing Heat

Emissions = 10,000 Units CO_2 (From Direct Firing, Only)

Position
2013 = 30,000 – 10,000 = 20,000 Units CO_2 (Surplus)
2014 = 37,100 – 10,000 = 27,100 Units CO_2 (Surplus)
2015 = 44,300 – 10,000 = 34,300 Units CO_2 (Surplus)

Figure 9 Operation of allocation Method 2b, where the allocation for the heat generator and consumer is calculated using the carbon leakage factor of the producer

Under 2b the heat consumer is awarded 100% of the allocation associated with production of its product, but has netted off from this the allocation associated with the imported heat. The allocation associated with the imported heat falls each year, as this allocation is based upon the carbon leakage factor of the heat generator (80% falling to 30% by 2020). This means that the heat consumer continues to receive the full allocation for its product over the years but has a progressively smaller amount subtracted from this as time progresses.

The result, for constant levels of production, is a surplus in the first year which grows, without the site doing anything to reduce the emissions it has control over, i.e. the direct heat emissions which remain fixed at 10,000 units in this example. In so far as the increased carbon costs experienced by the heat producer will be passed on to the heat customer, this may not be experienced by the heat customer as a 'real' surplus. However, it does represent an anomaly in that a site will have an allocation that increases over time.

This anomalous outcome with the operation of Method 2b has the potential to be quite widespread; this is because a large number of products for which product benchmarks can be established have been deemed to be at significant risk of carbon leakage.

5.4 Cross Boundary Heat Flow Allocation Methodology- Method 2c

5.4.1 Theoretical Operating Principles of Method 2c

Under Method 2c, where heat is generated within an EU ETS installation and exported to another EU ETS installation, where that installation is product benchmarked, the benchmarked allocation associated with this heat is awarded to the producing installation. In order to ensure that the total allowances in respect of this heat remain the same, regardless of the heat supply situation, the same quantity of allowances are subtracted from the benchmarked allocation of the heat consuming installation. The carbon leakage factor for the heat consuming installation needs to be known in order for the correct allocation to be made to the heat generating installation and for the correct number of allowances to be netted off from the heat consumer's allocation.

In situations where the heat consumer is not within EU ETS the heat producer is awarded the allowances associated with this heat. For the correct allocation to take place the carbon leakage factor of the heat consumer still needs to be known, even if not within EU ETS.

The following figure illustrates the operation of allocation Method 2c for more than one heat producer and heat customers of different EU ETS statuses.

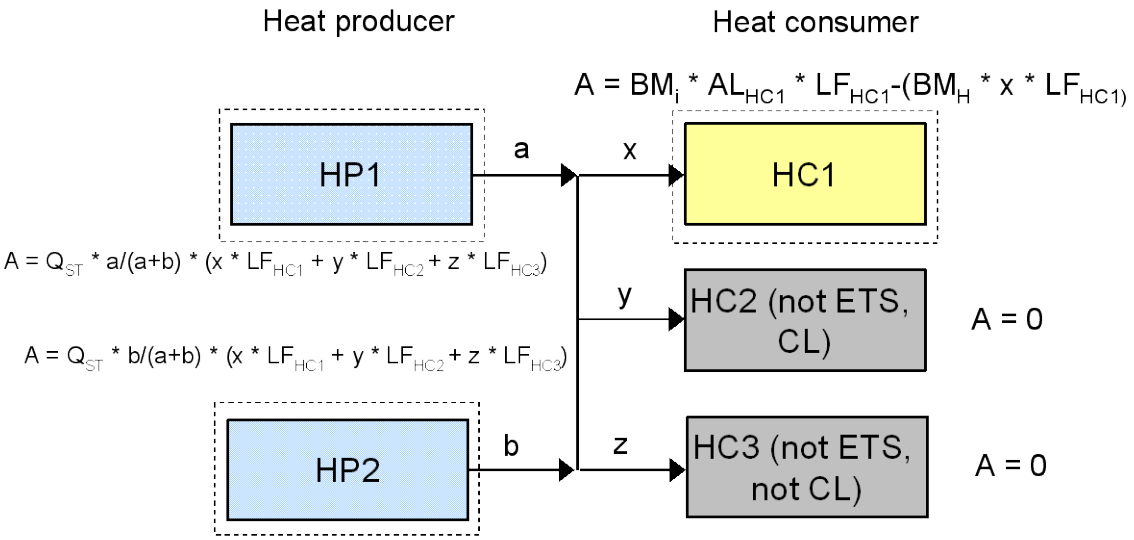


Figure 10 Operation of allocation Method 2c, where heat producers are in EU ETS and heat consumers both in and outside of EU ETS (Adapted from Climate Action)[21]

5.4.1 Method 2c Perceived Advantages and Disadvantages

Advantages

1) Method 2c ensures that the allocation in aggregate across heat producer-consumer supply chain remains at 100% of the heat benchmark throughout Phase III and is therefore consistent with the intention of the carbon leakage provisions in the directive.

2) Method 2c operates in such a way as to incentivise both the carbon efficient generation of heat and the efficient consumption of heat.

3) By observing the carbon leakage factor of the consuming installation when calculating the allocation to be made in respect of a quantity of heat, the same allocation is made whether this heat is generated on site or outsourced.

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[21] Presentation "Cross-boundary heat flows", presentation given at Task force of Informal TWG on benchmarking, Brussels, 17 November 2009

Disadvantages

1) Method 2c it is possible that the heat generator may choose not to pass on any of the value of the allocation it receives in the form of a lower price to the heat consumer and the heat consumer may not be in a position to do anything about this.

2) As opposed to Method 1, under Method 2c there is the possibility of a negative allocation where the heat consumer is product benchmarked and imports heat from a producing installation. The incidence of this would logically be greater than in the case of 2b and the size of any negative allocation would not decline over time under Method 2c, whereas under Method 2b it would.

3) Under Method 2c the burden of data gathering for application of the method is greater than either Method 1 or Method 2b. Compared against Method 2b, Method 2c requires the carbon leakage factor of all heat consumers to be known. However, it should be stressed that this information gathering would be a one-off burden and it is logical to expect this information to be available where the heat generator has a billing relationship with the heat customer.

5.4.2 Simplified Method 1 and Hybrid Method 1/Method 2b Approaches

It has already been mentioned that the advantages held by Method 1 over Methods 2b and 2c with respect to reduced historic data requirements at initial stages do not extend to situations where the heat consumer is not in EU ETS. In this situation the allocation must be made to the heat producer and for this to be possible under Method 1 the carbon leakage factor of the heat consumer needs to be known. This constitutes a data burden.

Workarounds to this have recently been proposed whereby a default carbon leakage factor (80-30%) is applied where evidence of carbon exposure is absent, and a revision to Method 2b in highly complex structures with a large number of installations connected to a heating grid. We agree that these would reduce the complexity associated with the application of Method 1.

5.5 Practical Application of Methods 1, 2b and 2c

Presented in the previous sections is how the different cross-boundary heat flow allocation methodologies will work in theory. The operation of these in practice needs to be tested in order to check their feasibility and whether any unintended negative consequences result from their application.

With this in mind, below we present a description of the production, metering and EU ETS Phase III organisational characteristics of a complex chemicals manufacturing site. This particular complex was chosen as a case study as it provides a testing ground for many of the above mentioned issues associated with the application of a heat benchmark and, most importantly, allocation of allowances in respect of cross-boundary heat flows.

The key complexities embodied in this site include:

- The site comprises more than one EU ETS Phase III installation
- The installations produce products that both can and cannot be product benchmarked
- The site generates heat via both CHP and boilers
- Heat is consumed at an installation different from where it was generated
- Heat consumed by EU ETS installations is generated at both EU ETS installations and non-EU ETS installations
- The physical separation of heat generation and consumption can be appreciable, which raises the issue of heat losses
- One EU ETS installation at the site includes heat generating plant whose main purpose is emissions abatement, which may present uncertainties regarding its EU ETS Phase III status
- The presence of steam raising plant, producing steam consumed by EU ETS and non-EU ETS installations, that itself will not be included in EU ETS Phase III.

In considering the issues associated with the application of a heat benchmark, we have taken on board Ecofys' current recommendations on the scope for product benchmarking and the candidate methods currently under consideration for dealing with situations where heat is generated and consumed at different EU ETS installations. The application of these candidate methods to this example site raises a number issues for further consideration, and these are listed at the end of this section of the report.

5.1 Case Study 3: Large Chemicals Complex

5.1.1 Introduction

This study is based on a real chemicals complex to demonstrate that certain issues can arise in real life that may not have been addressed by the rules. However for reasons of commercial sensitivity and to avoid introducing un-necessary complexity, full details of the complex have been with-held and its energy supply systems are shown only in sufficient detail to illustrate the points we wish to illustrate.

The site is occupied by a number of different legal entities, some of which are sister companies, but others are totally unrelated. Energy systems on the Site are controlled by the largest company (the Host Company) which is responsible for purchasing gas and electricity, generating steam and the distribution of these utilities around the complex. Steam, gas and electricity are sold by the Host Company to the other companies on the complex. In the case of sister companies, the terms of supply are specified in Service Level Agreements; in the case of other companies, true commercial agreements are in place.

The gas-fired steam raising operations on the Site – comprising a CHP plant and a conventional boilerhouse – are covered under EU ETS Phase III. We call this Installation 1 and it is operated by the Host Company. None of the steam consuming plants operated by the Host Company will be covered by product benchmarking under EUETS Phase III. However one of the plants operated by another company (Company 2) produces Product E, which will be brought into the EUETS under Phase III. This plant will be covered by product benchmarking, and we refer to this plant as Installation 2.

5.1.2 Energy Flow Structure

Natural Gas Flows
The site has a main gas supply which is under the control of the Host Company. Gas is used by the Host Company for its own purposes, but some is also sold on to both sister and other companies, including Company 2.

Steam Flows
There is a steam ring main carrying the steam required by all the steam consumers at the site. The following facilities produce steam which is fed into the steam ring main:

- CHP plant operated by Host company
- Fired Boiler Plant operated by Host company
- Thermal Oxidiser which recovers steam from waste heat; operated by the Host Company
- A plant operated by a different company (Company 3) which produces steam in an exothermic process. There are no CO_2 emissions from this plant.

The following facilities extract steam from the steam ring main:

- Plants operated by the Host Company, producing a variety of products, none of which will be product benchmarked under Phase III
- A plant operated by Company 2 for the production of Product E, which will be product benchmarked under Phase III.
- Plants operated by Company 4 for the production of a variety of products, none of which will be product benchmarked.

It is also important to note that there is an imbalance between metered steam fed into the ring main and metered steam taken from it i.e. the sum of the metered consumption of steam is less than the sum of the metered generation of steam. This imbalance has historically always been in excess of 10%. This imbalance is due to three factors:
(i) Unavoidable meter errors
(ii) Steam consumed by users that are too small to justify individual sub-metering
(iii) Genuine steam losses due to leaks, loss through insulation, steam traps etc. For a steam distribution of the size of that at this Complex, these real losses should be of the order of 6% to 8%

5.1.3 Schematic of Installations and Energy Flows

Figure 11 shows the situation at the Runcorn chemical complex regarding installation boundaries and energy flows.

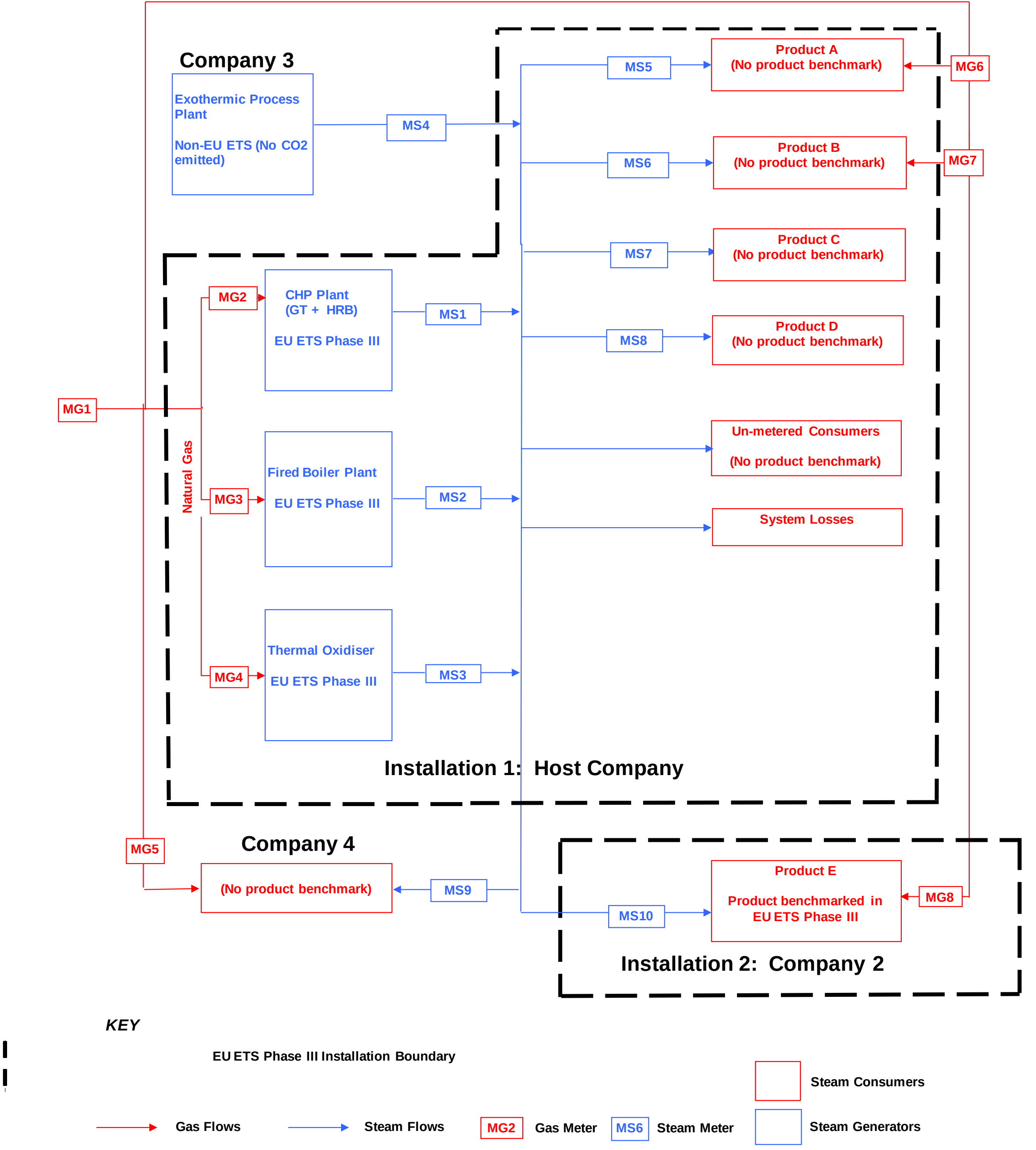


Figure 11 Schematic of EU ETS Installations (present and future) and energy flows at the Runcorn chemical complex

In order to fully consider any issues associated with the application of heat benchmarks, product benchmarks, the fact that some heat is generated and consumed at different installations and the fact that there are different types of heat generating plant (boilers, CHP, heat recovered from exothermic reactions that are not the combustion of fossil fuels), it is instructive to formulate the allocations for the two installations that will be in EU ETS Phase III, while following the principles set out in the revised Directive and the recommendations given by Ecofys on dealing with cross-boundary heat flows. Below, these are examined for Methods 1, 2b and 2c.

In order to do this it is necessary to define a number of terms, as follows:
Q_{ST} = Heat benchmark for steam ($kgCO_2/MWh$ heat consumed)
Q_{DF} = Heat benchmark for direct firing ($kgCO_2/MWh$ fuel in)
LF_G = Leakage Factor Steam Generator (80%)

$\mathbf{LF_{HC}}$ = Leakage Factor Host Company
$\mathbf{LF_2}$ = Leakage Factor Company 2
$\mathbf{LF_4}$ = Leakage Factor Company 4

The activity levels of the Host Company (which produces non-product benchmarked products) will be in terms of the quantity of steam it produces and the quantity of gas it consumed for direct firing in the reference year. This means that the activity levels will be in terms of the meter readings MS1+ MS2 and MG6 and MG7 for the reference year.

$\mathbf{AL_E}$ = Activity Level (level of production) of Product E in the reference year
$\mathbf{BM_E}$ = Benchmark for Product E (kgCO_2/tonne production)

In Method 2c for making allocations for heat where the heat is generated and consumed at different EU ETS installations, and the consuming installation is producing a product that is product benchmarked, it is necessary to net off from the product benchmark allowances the allowances awarded to the heat generating installation. Therefore, under Method 2c it is necessary to know:

- The quantity of heat entering the consuming installation
- The quantity of heat entering the consuming installation that was **generated** at the generating installation

In the case of Method 1, neither of these needs to be known where the heat importing installation is product benchmarked.

In the present example heat entering a consuming installation over the course of a year will have been generated in a number of different places, each with a different status under EU ETS. For example, Installation 2 produces Product E that will be product benchmarked and it extracts steam from the ring main. The steam it extracts from the ring main will have come from Installation 1 and the exothermic process operated by Company 3, the latter not being in Phase III. A strict application of the Ecofys Method 2b and 2c will make it necessary it know the proportion of steam consumed by Installation 2, taken from the ring main, that was generated at Installation 1. To do this the quantity of heat entering the ring main from all of the separate generating entities needs to be metered.

A strict application of the Ecofys Method 2b and 2c therefore makes it necessary to introduce the concept of proportions of steam originating from different locations but drawn from a common place.

In the present example, the proportion of steam in the ring main generated at Installation 1 is:

(MS1+MS2+MS3)/(MS1+MS2+MS3+MS4). Therefore, the quantity of steam consumed by Installation 2 that was generated at Installation 1 is:

MS10 *[(MS1+MS2+MS3)/(MS1+MS2+MS3+MS4)]

For the purposes of simplicity, the ratio (MS1+MS2+M3)/(MS1+MS2+MS3+MS4) will now be known as $\mathbf{F_{INST\ 1}}$, which is the proportion of the total amount of steam fed into the steam ring by all generators that was generated at Installation 1

5.1.4 Allocation Formulae for Installations

Taking account of the principles and observations set out in Section 5.2-5.4, below are presented the allocation formulae for the Installations 1 and 2 for the cross boundary heat allocation methods currently being considered, i.e. Method 1, Method 2b and Method 2c.

Allocation Under Method 1

Method 1 Allocation Formula for Installation 1
$[Q_{ST} * (MS5 + MS6 + MS7 + MS8) * F_{INST\ 1} * LF_{HC}]+$
$[Q_{ST} * MS9 * F_{INST\ 1} * LF_4] +$
$[Q_{DF} * MG6 * LF_{HC}] +$
$[Q_{DF} * MG7 * LF_{HC}]$

Method 1 Allocation Formula for Installation 2
$(BM_E * AL_E * LF_2)$

Allocation Under Method 2b

Method 2b Allocation Formula for Installation 1
$[Q_{ST} * (MS5 + MS6 + MS7 + MS8) * F_{INST\ 1} * LF_{HC}] +$
$[Q_{ST} * MS9 * F_{INST\ 1} * LF_G] +$
$[Q_{ST} * MS10 * F_{INST\ 1} * LF_G] +$
$[Q_{DF} * MG6 * LF_{HC}] +$
$[Q_{DF} * MG7 * LF_{HC}]$

Method 2b Allocation Formula for Installation 2
$(BM_E * AL_E * LF_2) – (Q_{ST} * MS10 * F_{INST\ 1} * LF_G)$

N.B. In the above formulae, where a site is a heat generator/consumer, the carbon leakage factor of the site as a consumer is assumed to operate.

Method 2c Allocation

Method 2c Allocation Formula for Installation 1

$[Q_{ST} * (MS5 + MS6 + MS7 + MS8) * F_{INST\ 1} * LF_{HC}] +$
$[Q_{ST} * MS10 * F_{INST\ 1} * LF_2] +$
$[Q_{ST} * MS9 * F_{INST\ 1} * LF_4] +$
$[Q_{DF} * MG6 * LF_{HC}] +$
$[Q_{DF} * MG7 * LF_{HC}]$

Method 2c Allocation Formula for Installation 2
$(BM_E * AL_E * LF_2) – Q_{ST} * MS10 * F_{INST\ 1} * LF_2)$

5.2 Observations Made and Issues Identified

1) The first and most obvious point to make is that, at a complex site such as this, a strict application of the principles of the revised Directive and the methodologies for allocating for cross boundary heat flow requires a high degree of metering. This is the case for both Method 1 and Methods 2b and 2c, but more so for Method 2b and 2c.

While MS1, MS2 and MS3 may be thought of as redundant for the purposes of executing the allocation - all are associated with one installation and could, in theory be replaced by one meter metering this installation's contribution to the steam on the ring main - the absence of MS4 would make the allocation difficult for all Methods, as this would make it impossible to determine the share of heat consumed by any of the heat consumers that was generated only at Installation 1. Considering this point further, it is considered that Complex in question is very much towards the well-metered end of the spectrum. However, any allocation methodology is vulnerable to metering problems and inaccuracies. For example, it is known for a fact that MS2 is unreliable, in that it overestimates the quantity of heat produced by the Fired Boiler Plant.

2) Separate heat benchmarks for CHP plant and the Fired Boiler Plant could be supported within this Complex. This is for two reasons:

- The heat from the CHP scheme flowing into the ring main is metered separately and could be accounted for separately. However, it is worth noting that this would add another layer of complexity to the allocation calculations, especially as there are so many customers of heat from the ring main.
- The CHP scheme does not have boilers within its boundary. If it did, which is often the case, there would have to be adequate internal sub-metering in order to separate the CHP heat from the boiler heat. The analysis carried out in Task 1 has shown that this is not the case in many situations.

3) Assuming that the steam meters at the consumer side are used to determine the allocation, application of Method 2b and 2c will tend to under-allocate allowances to Installation 1 in respect of heat it generates that is subsequently consumed at Installation 2. Under Method 2c, for example, the netting off from the product based allocation for Product E will be: (Q_{ST} * MS10 * $F_{INST\ 1}$ *LF_2). In the interests of symmetry this quantity should then be allocated to Installation 1. However, because of losses in the ring main, a quantity of heat greater than that passing through MS10 must be generated at Installation 1 in order for the required quantity of heat to pass through MS10. This means that Installation 1 will emit more CO_2 in supplying this heat than it will get an allocation for. Contrariwise, if the steam meters at the producer side are used, then there will be an under allocation to the heat consumer.

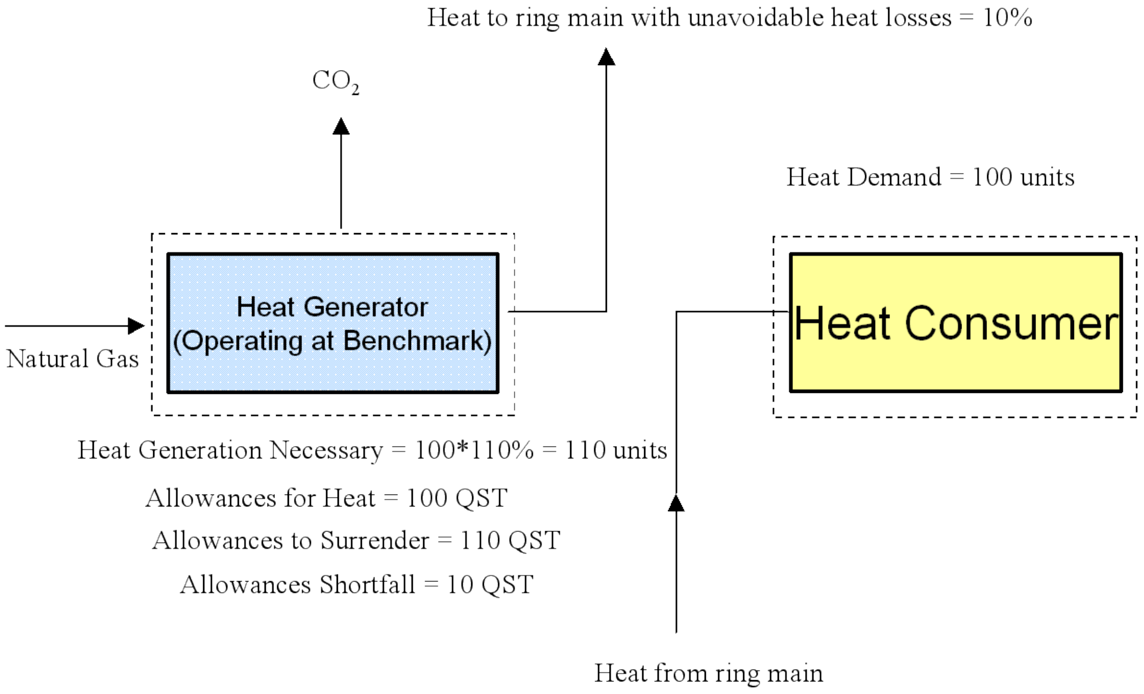


Figure 12 Schematic showing shortfall in allowances for a heat generator operating at benchmark but exporting heat to a steam ring main with unavoidable losses

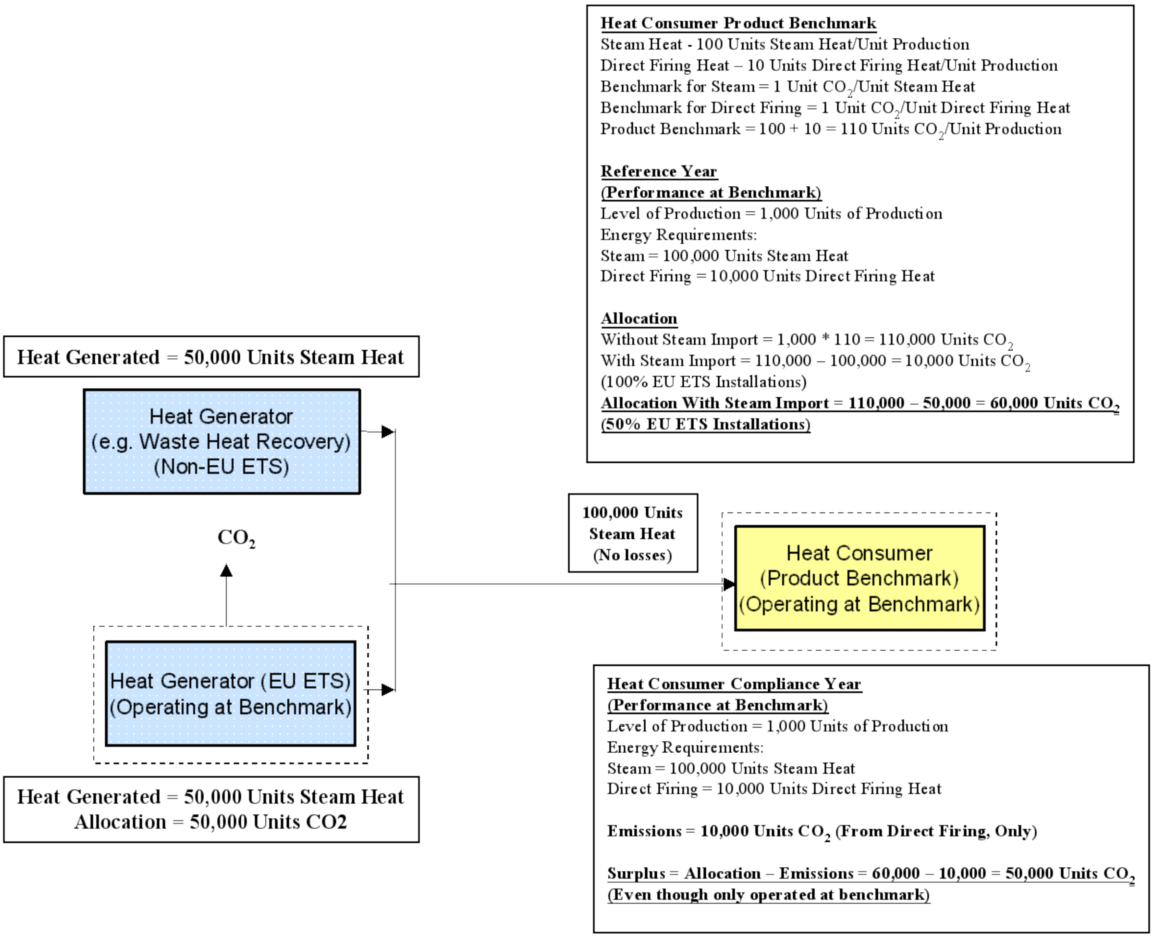
At this site the imbalance between metered steam production and metered steam consumption is currently running at >10%. It is estimated that genuine steam losses through insulation and steam traps are of the order of 6%-8%, and losses of this order of magnitude will be unavoidable even when best practice is adopted regarding insulation and steam trap maintenance. This means that, even when adopting best practice, a strict application of the allocation methodologies 2b and 2c will penalise the heat generator. It may therefore be appropriate to consider an adjustment upwards to the heat generator's allocation in such complex cases in respect of unavoidable heat losses. An adjustment could be made to make the sum of consumer side heat equal to the sum of producer side heat, but this should only be made for unavoidable losses.

This problem of a shortfall in generator allowances will apply in the following cases where unavoidable heat losses are incurred because of the use of an extended heat supply network:

- Method 1 – Non-EU ETS
- Method 2b – All types of heat customer (EU ETS product benchmark, EU ETS non- product benchmark and non-EU ETS)
- Method 2c – All types of heat customer (EU ETS product benchmark, EU ETS non- product benchmark and non-EU ETS)

4) In connection with the application of Method 2b and 2c, the question remains in the minds of the authors of how to deal with the heat consumed by Installation 2 that will be generated by heat generators not in EU ETS Phase III. If the allocation associated with this heat is not subtracted from Installation 2's product based allocation, then Installation 2 will be left with more allowances than it

needs, or deserves to have. If the allocation associated with this heat is subtracted from the Installation 2's, symmetry is broken in that there is no EU ETS generating installation to award it to. Figure 12 illustrates this point with an example of a product benchmarked heat consumer outsourcing its steam demand to 3rd parties, one in EU ETS and the other not. In this example the heat customer, despite operating at benchmark, would have a surplus of allowances if only those allowances associated with heat generated at EU ETS installations were netted off from its allocation.



Heat Consumer Product Benchmark
Steam Heat - 100 Units Steam Heat/Unit Production
Direct Firing Heat – 10 Units Direct Firing Heat/Unit Production
Benchmark for Steam = 1 Unit CO_2/Unit Steam Heat
Benchmark for Direct Firing = 1 Unit CO_2/Unit Direct Firing Heat
Product Benchmark = 100 + 10 = 110 Units CO_2/Unit Production

Reference Year
(Performance at Benchmark)
Level of Production = 1,000 Units of Production
Energy Requirements:
Steam = 100,000 Units Steam Heat
Direct Firing = 10,000 Units Direct Firing Heat

Allocation
Without Steam Import = 1,000 * 110 = 110,000 Units CO_2
With Steam Import = 110,000 – 100,000 = 10,000 Units CO_2
(100% EU ETS Installations)
Allocation With Steam Import = 110,000 – 50,000 = 60,000 Units CO_2
(50% EU ETS Installations)

Heat Consumer Compliance Year
(Performance at Benchmark)
Level of Production = 1,000 Units of Production
Energy Requirements:
Steam = 100,000 Units Steam Heat
Direct Firing = 10,000 Units Direct Firing Heat

Emissions = 10,000 Units CO_2 (From Direct Firing, Only)

Surplus = Allocation – Emissions = 60,000 – 10,000 = 50,000 Units CO_2
(Even though only operated at benchmark)

Figure 13 Schematic illustrating the issue with the operation of Method 2c, whereby a heat customer has a surplus of allowances when importing some of its heat from non EU ETS installations

This situation exists at the Complex in question for heat used by Installation 2 that is generated at the Exothermic Process Plant.

4) Heat consumed by Installation 2 is ultimately generated by a number of different types of heat generating plant, not within its installation boundaries, including fired boilers, a CHP plant, a thermal oxidiser and an exothermic reaction that does not give rise to CO2 emissions. If separate heat benchmarks were established for these plants, the strict application of all of the candidate methods of accounting for cross-boundary heat flows would require knowledge of the proportion of heat consumed by Installation 2 originating separately at these plants. This knowledge does not exist at this Complex, despite its high level of sub-metering. Indeed, there is no level of sub-metering that would make this possible in the case of a common steam ring main fed by a range of heat generating technologies. This supports the idea that one benchmark for heat should be adopted and applied.

5.3 Recommendations

Compared to Method 2, Method 1 requires less historic information on quantity of heat flows for an allocation to be made. This would be an advantage where this information is difficult to determine for the reference years. However, it is worth noting that this advantage is limited to cases where the recipient of the heat is product benchmarked. When the recipient is heat benchmarked, the quantity of heat in the reference year needs to be known in order to complete the allocation. Method 1 also ensures that the total number of allowances allocated for a quantity of heat is the same, whether the heat is generated on site or outsourced and avoids the possibility that the heat generator fails to reflect in the price it changes a heat consumer exposed to carbon leakage the value of the allowances it receives for the heat.

However, Method 1 has a significant disadvantage in that the generator of heat, and therefore emitter of CO_2, will not receive any free allowances in respect of heat it exports to another EU ETS installation. Section 5.2.2 set out the scale of this problem and showed that a significant proportion of UK CHP Good Quality capacity (54%) will be vulnerable to having to purchase all allowances necessary to cover its exported heat. Since at this stage it is not clear whether contractual arrangements between heat generators and their customers would allow for the generator to be compensated for this, **we would recommend not using Method 1 to make allocations in respect of heat crossing installation boundaries**. We recommend that further work is carried out into the flexibility of heat supply contracts to determine the true vulnerability to heat generators and exporters.

Methods 2b and 2c work in a way to incentivise both the generator and consumer of heat to operate more efficiently. It also awards an allocation to the heat producer in respect of heat it generates and exports. However, both Methods 2b and 2c run the risk of negative allocations in respect of product benchmarked sites, with this risk being greater for Method 2c than for 2b. In such cases a solution could be to set the allocation at zero.

Method 2b would appear to have the potential to lead to an anomalous outcome in that an EU ETS consumer of cross-boundary heat that is product benchmarked and deemed to be at risk of carbon leakage, operating at benchmark levels of greenhouse gas efficiency for that product, could be awarded an allocation that grows over time. This could be the case for paper and board manufacturers and manufacturers of some other inorganic and other organic chemicals who import steam generated at another EU ETS installation, as these product groups are deemed to be at risk of carbon leakage. Such arrangements between generators and consumers are common in these sectors and so this problem could be significant. However, it should be pointed out that, although the allocation to the heat consumer might increase with time, the total allocation in respect of the heat crossing the installation boundary remains the same, and the increment of increase could be viewed as compensation to the heat customer for any increased carbon costs experienced by the heat generator being passed through to the heat customer. This could be dealt with by having provision in the Community-wide implementing measures prohibiting an installation from receiving an increasing allocation.

There would appear to be an advantage of Method 2 over Method 1, but an even balance of advantages and disadvantages between Methods 2b and 2c, making it currently difficult to recommend one over the other.

We also recommend that the following issues associated with Method 2 are examined in greater depth:
1) Undertake work to estimate the number of cases where a negative allocation would result from the application of Method 2b and 2c.

2) Adjusting upwards the allocation to the heat generator to compensate for unavoidable heat losses between the point of supply and the point at which exported heat is metered. This is necessary in order not to penalise the generator for losses it can do nothing about.

3) Subtracting from the allocation to a product benchmarked steam importer the CO_2 associated with steam raised at both EU ETS AND non-EU ETS installations, so as not to award to the heat customer allowances associated with heat it did not have to generate and, therefore, incur CO_2 emissions.

6 Task 5

6.1 Context of Task 5

The objective of Task 5 is:

"To assess different methodologies by which individual heat flows within installations may be determined and make a recommendation."

In order to be in a position to make allocations in respect of heat it is necessary to be able to quantify the flow of heat within and between installations during the reference years used for setting activity levels. Depending upon the degree of discrimination between grades of heat and sources of heat, it may be necessary to have a very detailed picture of heat flows. For example, should a decision be made to apply different benchmarks for hot water and steam and for steam from boilers and steam from CHP, the level of metering in the reference year may have to be very extensive in order to make the necessary discrimination. Moreover, it has been shown in Section 5 that complex sites comprising multiple installations and heat generating technologies would be susceptible to difficulties in making correct allocations if a small proportion of the existing heat metering infrastructure were to fail.

For this reason we have recommended that the same benchmark be applied to heat from all sources, i.e. boiler, CHP or process waste heat.

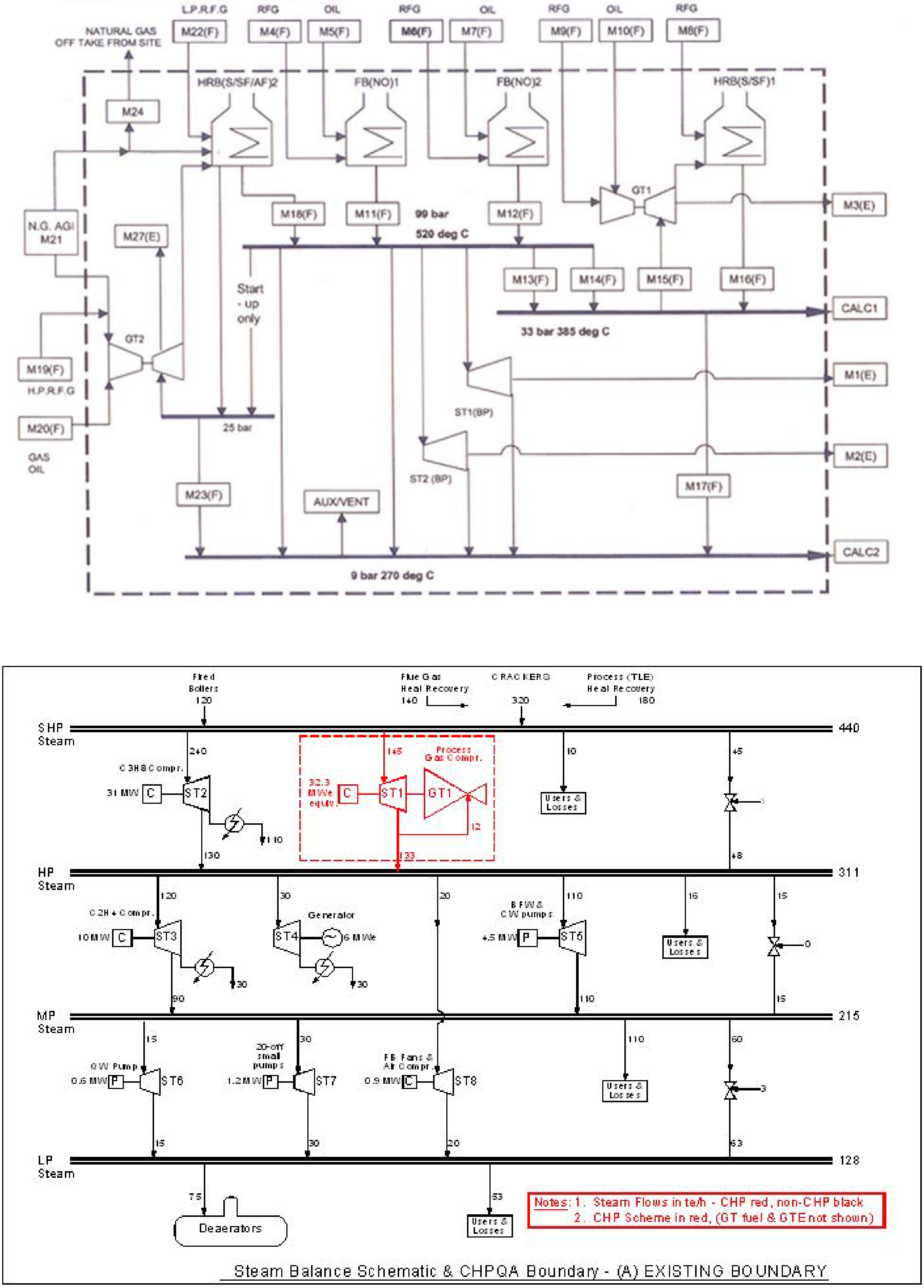
Against this challenging background, we will work to the assumption that benchmarks for heat should be common, irrespective of grade and generating technology, unless a clear perverse outcome would result from such an approach.

6.2 Distinguishing Between Heat Flows in the Form of Hot Water, Hot Oil, Steam and Hot Air (Direct Firing)

The data collected for this study is not sufficiently diverse to carry out an analysis of the case for establishing separate benchmarks for steam, hot water and hot oil. However, we do not believe that this would be appropriate for the following reasons:

- Most installations would not have sufficient sub-metering to establish the quantity of heat carried and consumed by each media in the reference year.
- In most cases, there is unlikely to be a significant difference in the efficiency with which steam, hot water and hot oil are generated in boilers.
- In most industrial applications hot water is generated from steam generated in a boiler, which means that the same boiler efficiency pertains for both grades of heat.
- Establishing separate benchmarks for different steam pressures, hot water and hot oil would add a level of complexity to the allocation methodology that, given the two points made above, would probably be unnecessary.

At most chemical and refining sites, where different grades of steam/heat are required, steam is usually generated at the high pressure, and is then either passed through steam turbines or let-down stations in order to reduce the steam pressure/temp to the required conditions (see Figure 14 below).



Notes: 1. Steam Flows in te/h - CHP red, non-CHP black
2. CHP Scheme in red, (GT fuel & GTE not shown)

Steam Balance Schematic & CHPQA Boundary - (A) EXISTING BOUNDARY

Figure 14 Typical arrangements at a site for delivering a diversity of steam conditions from one original generated condition

This shows although different grades of steam/heat are eventually provided for end use, the generation efficiency of such steam is the same, as it is ultimately generated in the same boiler(s).

As such, at this stage, and in the absence of evidence of any perverse outcomes resulting, we propose the adoption of a single heat benchmark for steam, hot water and hot oil.

More consideration is required in respect of distinguishing between hot air and the other heat carriers (steam, hot water and hot oil).

6.3 Distinguishing Between Heat Flows From Boilers and CHP

There are two important considerations to be made when determining whether a distinction is necessary between boiler and CHP heat. These are:

- That the use of CHP should not be disincentivised, relative to other fossil fuel burning heat generating technologies, through the adoption of a particular benchmark value.
- Common benchmark levels should be sought, in order not to introduce unnecessary complexity to the allocation process.

Section 3 (Task 2) proposes the level at which a heat benchmark should be set at in order to achieve these two objectives and the fact that we believe that a distinction should not be made between heat from CHP and boilers (or process waste heat).

6.4 Methods for Determining Heat Flows Within and Between Installations

This section considers the practical issues that need to be taken into consideration when collecting data with the aim of accurately determining the quantity of heat generated in the reference year.

6.4.1 Recommendation on Determining the Quantity of Steam Heat

When determining the quantity of heat generated in the reference year for the purposes of calculating an allocation, we believe that it is important to make a distinction between useful heat and non-useful heat. Useful heat is that heat delivered to the process. Non-useful heat is heat rejected to the environment without any beneficial use, for example heat rejected from condensers and radiators. We recommend that an allocation be made only in respect of useful heat, where useful heat is an economically justifiable supply of heat.

When heat is delivered in the form of steam not all of the heat it contains (when measured relative to the datum point of 0^{o}C, 1bara) is delivered to the process. Some of the heat remains in the condensate returned to the heat generator. Determining the actual quantity of heat delivered to the process (useful heat) would require netting off from the enthalpy of the steam delivered to process (measured relative to 0^{o}C, 1 bara) the enthalpy of the condensate, which is typically in the range 80-120^{o}C. There is an agreed way of accounting for this condensate enthalpy set out in the European Commission’s document for the establishing of harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC. We recommend that this method be adopted for determining the quantity of useful heat.

We recommend that meters for measuring the mass flow of steam should have an overall uncertainty equal to or less than 2% of full scale (3% of actual readings). Overall uncertainties greater than these values should be deemed to have excess uncertainty and a correction should be made to the heat reading in respect of this excess uncertainty. In the case of useful heat measurements this would mean a revising down of the quantity of heat (and therefore the allocation). We recommend CHPQA Guidance Note 17 (Uncertainty in metered inputs and outputs) as a useful reference source on acceptable metering accuracies and how corrections should be made in respect of uncertainties that are deemed to be in excess of those that are acceptable.

6.4.2 Recommendation on Determining the Quantity of Hot Water and Hot Oil Heat

The principle of determining useful heat and only making an allocation in respect of this applies in the case of heat carried by hot water and hot oil. In the case of the former, this can be generated in a CHP reciprocating engine, where the demand for generated electricity may occur at times of no (or reduced) demand for hot water. When this happens, it is sometimes the case that the site will continue to generate electricity but will have no option but to dump all (or part of) the heat generated as part of the electricity generation. It is important, therefore, for this dumped heat not to be included with the useful heat and, therefore, not to have an allocation made in respect of it. Excluding this dumped heat in this way will provide the site with an incentive to improve its operation, for example by working to bring its electricity and heat demands in phase with each other.

Metering of the quantity of heat delivered by hot water is achieved by measuring the integrated flow of hot water over the period in question and the difference in temperature between the flow to and return from the process.

Whether the flow rate is fixed or variable, the temperature difference between flow and return will have to be determined ‘upstream’ of any dump radiator, otherwise the useful heat may include heat rejected to the atmosphere. The correct location for temperature measurements, in order to exclude dumped heat, can be appreciated from Figure 15.

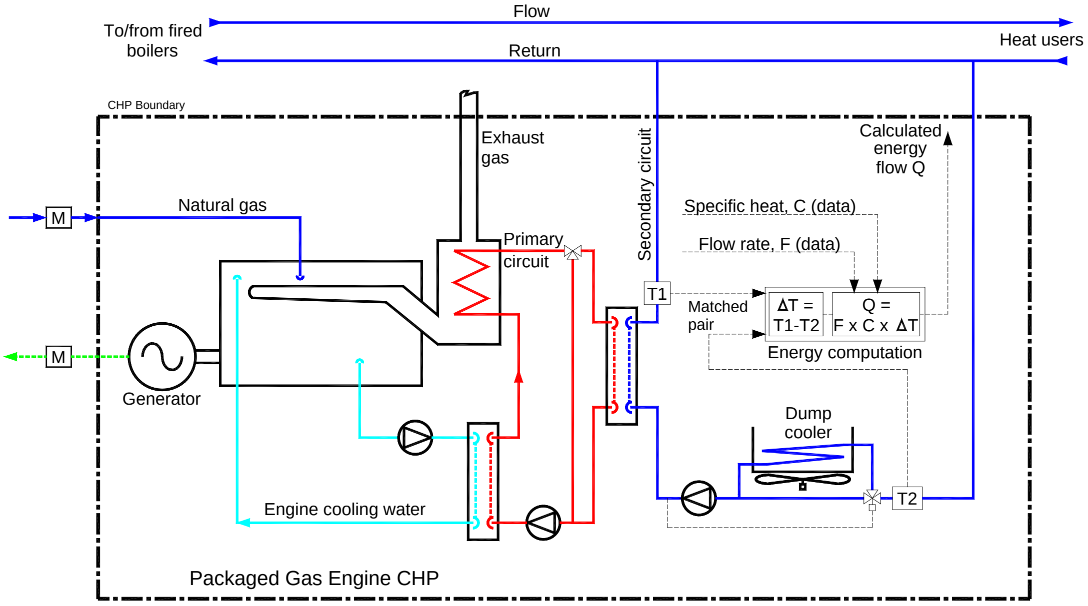


Figure 15 The correct location for temperature measurements in order to measure the useful heat delivered to the process

Temperature measurements using matched platinium thermocouples would not entail unacceptable uncertainties. The accuracy of flow meters would have to be within the acceptable range of 2% of full scale (3% of actual readings) otherwise corrections for excess uncertainty would have to be carried out.

6.4.3 Recommendation on Determining the Quantity of Heat in Hot Air Consumed

In cases where the useful heat that needs to be determined is not carried by a medium that can be easily metered (steam, hot water or hot oil), for example heat used for direct heating of drying applications, we would normally expect the allocation to be determined via a fuel mix benchmark rather than a heat output benchmark.

However, where there is sufficient information available regarding key variables in the reference year, the useful heat delivered to the process can be satisfactorily deduced from the following:

- Mass flow and composition of hot gasses into and out of the process under consideration
- Temperature and humidity of hot gasses into and out of the process under consideration.

A method for doing this, and the associated measurement standards is set out in CHPQA Guidance Note 21 (Indirect Determination of Heat Outputs).

7 Task 6

The objective of Task 6 is:
“***To assess the impacts of varying levels of free allocation for heat including full auctioning in a 20% and 30% emissions reduction scenario.”***

7.1 Effect of Varying Levels of Free Allocation for Boiler Heat, Including Full Auctioning

The following section considers the effect on the costs of generating heat from boilers into the future for different allocation scenarios.

The following analysis has been performed upon the following four different tranches of boiler scheme size:

- 20 to <38 MWth
- 38 to <45 MWth
- 45 to <70 MWth
- 70 to <155 MWth

Six different allocation scenarios are presented. Scenarios 1-3 are based on carbon prices consistent with the EU reducing greenhouse gas emissions by 20% by 2020 (‘a 20% World’) and Scenarios 4-6 are based upon carbon prices consistent with the EU reducing its emissions by 30%by 2020 (‘a 30% World’). In summary, the scenarios are:

- Scenario 1 20% World. Allocations decrease from 80% in 2013 to 30% in 2020 and then to 0% by 2027
- Scenario 2 20% World. Allocations decrease from 80% in 2013 to 20% in 2020 and then to 0% by 2027
- Scenario 3 20% World. Full auctioning from 2013
- Scenario 4 30% World. Allocations decrease from 80% in 2013 to 30% in 2020 and then to 0% by 2027
- Scenario 5 30% World Allocations decrease from 80% in 2013 to 20% in 2020 and then to 0% by 2027
- Scenario 6 30% World. Full auctioning from 2013

The following assumptions have been made in this analysis:

- An allocation benchmark for heat of 223.1 kgCO_2/MWhth. This is the figure derived earlier in this study and presented in Section 3.6.
- An average gas price of £24/MWh[22]
- In the case of Scenarios 1-3 a central carbon price is taken from the DECC guidance on the “Valuation of energy use and greenhouse gas emissions for appraisal and evaluation”[23]
- For Scenarios 4-6, only a single carbon price scenario of €40 in 2020 has been assumed. The rate of increase in the carbon price to 2020 is comparable with the central carbon price forecast presented in the DECC guidance used for Scenarios 1-3.
- The relative scarcity of allowances under the 30% World is captured by assuming that the number of free allowances available at each year is about 98% of that available for the same year in a 20% World.

7.1.1 Carbon Cost Profiles for the Six Scenarios (Tranche 20 to <38 MWth Boiler Scheme Capacity)

Figure 16 shows the profiles of the cost of CO_2 per unit heat generated over time for one of the five tranches investigated (20 to< 38 MWth). Scenarios 1-6 are presented (i.e. 20% World and 30%

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[22] Natural gas prices are the average over 2008 for medium sized gas consumers (Table 3.1.1, Quarterly Energy Prices, September 2009

[23] [23] www.decc.gov.uk/en/content/cms/statistics/analysts_group/analysts_group.asp
x

World). In the case of Scenarios 1-3 a central carbon price is assumed. The equivalent plots for the other tranches are provided in Appendix 1.

In all cases there is a step change at 2020 in the increase in carbon costs over time and this is a consequence of the projected carbon prices used in this study, which also show this step change.

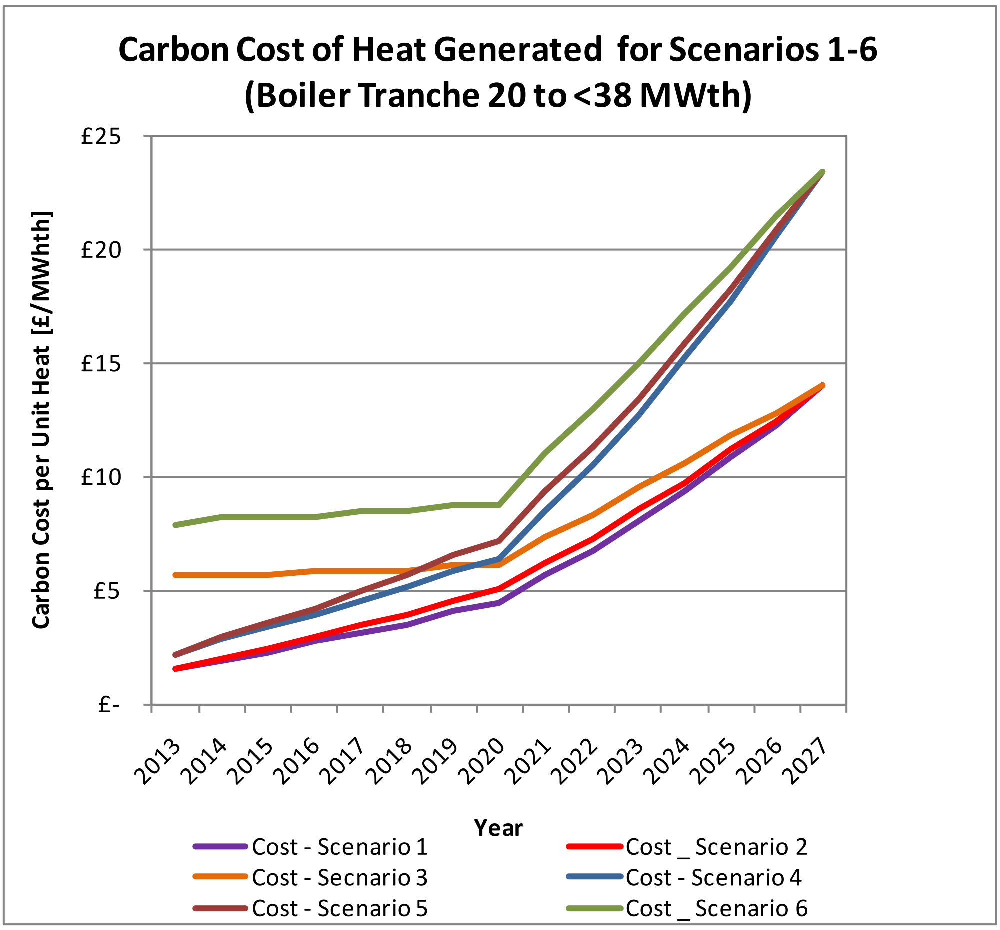

Figure 16 Carbon cost of heat generated for Scenarios 1-6 for boiler tranche 20 to <38 MWth

7.1.2 Proportion of costs taken up by carbon costs

An informative way of comparing the effects of the different scenarios upon operators is to consider the proportion of fuel and carbon costs taken up just by the cost of carbon, averaged over the period 2013-2027. The following tables show these proportions, expressed in percentages as a function of scenario and carbon price assumption for different tranches of boiler scheme size.

Table 10 Proportion of fuel and carbon costs taken up just by carbon costs for different scenarios and boiler scheme sizes

20% Overall Reduction					30% Overall Reduction				
Boiler Scheme Size	Scenario 1 Central	Scenario 2 Central	Scenario 3 Central	Average	Boiler Scheme Size	Scenario 4	Scenario 5	Scenario 6	Average
20 to <38 MWth	20.7%	21.8%	27.8%	22.6%	20 to <38 MWth	32.7%	34.3%	42.8%	36.6%
38 to <45 MWth	21.1%	22.1%	28.1%	22.9%	38 to <45 MWth	33.2%	34.8%	43.3%	37.1%
45 to <70 MWth	20.2%	21.4%	27.8%	22.3%	45 to <70 MWth	32.0%	33.7%	43.0%	36.2%
70 to 155 MWth	23.0%	24.2%	30.5%	25.0%	70 to 155 MWth	36.3%	38.0%	47.1%	40.5%
Average	21.3%	22.4%	28.6%		Average	33.6%	35.2%	44.1%	

Table 10 shows that, under the assumptions we have made about the price and scarcity of allowances under a 30% World, up to 47% of the fuel and carbon cost associated with generating heat could be due just to the carbon cost. This proportion will be lower when all of the costs associated with generating heat (maintenance etc.) are taken into consideration. This could have a meaningful impact upon some sectors where the costs of heat account for a large proportion of the overall income.

7.2 Effect of Varying Levels of Free Allocation for CHP Heat, Including Full Auctioning

Since there will be no allocation in respect of electricity generation in EU ETS Phase III CHP will only receive an allocation for the heat it produces. The allocation for each unit of heat generated will fall with time during Phase III.

Against this background, the following section considers the effect on CHP for the six same allocation scenarios used in analysing boiler heat generation, namely:

- Scenario 1 20% World. Allocations decrease from 80% in 2013 to 30% in 2020 and then to 0% by 2027
- Scenario 2 20% World. Allocations decrease from 80% in 2013 to 20% in 2020 and then to 0% by 2027
- Scenario 3 20% World. Full auctioning from 2013
- Scenario 4 30% World. Allocations decrease from 80% in 2013 to 30% in 2020 and then to 0% by 2027
- Scenario 5 30% World Allocations decrease from 80% in 2013 to 20% in 2020 and then to 0% by 2027
- Scenario 6 30% World. Full auctioning from 2013

The analysis that follows makes the following assumptions:

- A CO_2 intensity for conventional electricity generation feeding into the grid of 497 tonnes CO_2/GWh (all fuels), operating into the future. (This was the actual, provisional figure for 2008, quoted in DUKES 2009[24])
- A CO_2 intensity for conventional electricity generation feeding into the grid of 605 tonnes CO_2/GWh (fossil fuels only), operating into the future. (This was the actual, provisional figure for 2008, quoted in DUKES 2009)

Figure 17, below, presents the carbon costs per unit of CHP power generated under the six different Scenarios investigated and, for comparison, the carbon costs associated with conventional, non CHP, power generation. Under this method the CO_2 allocation for heat is subtracted from the CO_2 emissions associated with all fuel burned by the CHP (for heat and electricity). The balance represents the CO_2

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[24] Digest of United Kingdom Energy Statistics (DUKES) 2009

emissions for which allowances would have to be purchased and this is expressed as a cost per unit power generation[25].

As points of reference, the carbon costs experienced by a conventional generator are also presented, with the assumption made that the carbon intensity of "all grid" and "all fossil fuel" remains fixed at the 2008 value and that the cost of carbon experienced by conventional generators in a particular year is the same as that experienced by the CHP generators. In the analysis full actuating[26] applies to conventional generators from 2013.

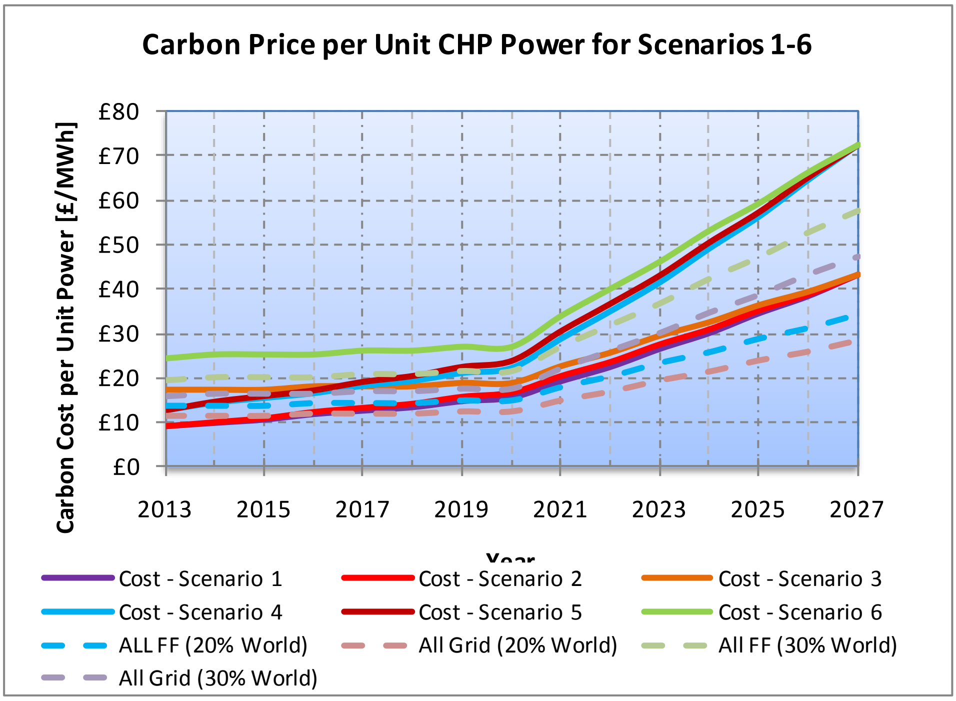

Figure 17 Evolution over time of the carbon price associated with CHP electricity and conventional grid electricity for Scenarios 1-6

The salient point of note is that, in all cases, the carbon cost of CHP electricity is always higher than conventional grid electricity when full auctioning operates. This is because, on average - and certainly for the sample of CHP schemes analysed in this study, the power generating efficiency of CHP is lower than for conventional generating installations. Since under full auctioning (Scenarios 3 and 6) heat will not receive any free allocation this leads to the carbon cost of CHP electricity being higher than for the conventional equivalent. For earlier years, where there is an allocation for heat, the carbon cost of conventional and CHP electricity are closer, with CHP having a lower cost for some years and scenarios. However, it is important to note that the primary energy savings associated with CHP mean that the carbon costs associated with the combined electricity and heat outputs of CHP are lower than for the separate, conventional generation of heat and electricity, where the former is generated in power only plant and the latter in stand alone boilers.

The overall cost to a site with a demand for heat and electricity will be different when this demand is satisfied by CHP from when it is satisfied by the separate generation of heat on site and the purchase of electricity from the grid. The relative costs of these two options of satisfying demand for heat and electricity, under the different allocation scenarios set out above, are presented below for three different CHP schemes.

The following costs have been established for the three real CHP schemes using operating data for 2007. These are presented alongside the change in costs that would be encountered in the hypothetical situation that these demands were met separately by grid electricity and on-site boilers.

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[25] An alternative method would be to remove the boiler fuel equivalent – assuming that the CHP displaces boiler heat generated with an efficiency of, say 90% - with the remaining fuel (and associated emissions) being attributable to the generated power

[26] In this context, "full actuating" means that electricity generators will have to purchase allowances to cover all of their CO2 emissions and that they will have to do this from 2013.

This difference in value represents the advantage (where positive) or disadvantage (where negative) enjoyed by CHP. The three examples cover CCGT CHP schemes performing at different heat efficiencies:

- o **Scheme 1** is in Chemical Sector and in 2007 provided 430GWh electricity and 1,430GWh heat with a heat efficiency of 51% (GCV basis).
- o **Scheme 2** is in Paper & Publishing Sector and in 2007 provided 740GWh electricity and 790GWh heat with a heat efficiency of 32%.
- o **Scheme 3** is in Paper & Publishing Sector and in 2007 provided 400GWh electricity and 92GWh heat with a heat efficiency of 11%.

The total carbon cost for each year 2013 – 2027 has been established for Scenarios 1 to 6 as described earlier in this section. This analysis is based upon the following assumptions:

- The allocation benchmark for heat is 223.1 $kgCO_2/MWh_{th}$. This is the figure derived earlier and presented in Section 3.6
- For scenarios 1 to 3, costs of carbon in a “20% World” are based on Low, Central and High projections referred to in Section 7.1.
- For scenarios 4 to 6, cost of carbon in a 30% world is determined on the same basis as given in Section 7.1
- The carbon emission factor for natural gas is 0.184 tCO_2/MWh on a GCV basis.
- The carbon emission factor for grid electricity (excluding transmission losses) is 0.497tCO_2/MWh. This was the provisional “all fuels” figure for 2008 quoted in DUKES 2009[27]
- Transmission losses for grid electricity are 8%.
- On-site boilers are fired on natural gas and have an efficiency of 82.5% on a GCV basis (~90% on a NCV basis)

Figures 18, 19 and 20 present total carbon costs for example Schemes 1, 2 and 3, respectively for the period 2013 to 2027 and for each allocation scenario under the central and “30% World” projections of carbon cost. All three schemes exhibit the same behaviour under variations in carbon price and allocation scenarios, however Scheme 1 exhibits a greater spread in costs in 2013 due to a greater proportion of its energy output being heat and so receiving a more substantial free allocation. In contrast, the heat output of Scheme 3 makes a smaller contribution to the output of the scheme. As a result the spread in carbon costs in early years is not as strongly affected by the allocation scenario adopted for this Scheme. For all three schemes, total carbon costs in 2013 where equivalent to up to 25%[28] of total fuel costs, depending on the allocation scenario, while by 2027 these costs rise to as much as 75%[29] of total fuel costs.

Figure 24-26 (See Appendix 1) present the difference in total carbon costs between CHP and separate supply of electricity and heat, for Schemes 1, 2 and 3, respectively. For all three schemes these values are positive, indicating that the CHP option presents lower carbon costs compared to separate supply (electricity from the Grid and heat from on site boilers). Furthermore, this difference will increase between 2013 and 2027 as underlying carbon costs increase. Equally, this benefit is more pronounced for higher carbon cost projections. Importantly, this relative benefit is unaffected by the allocation scenario adopted, as the free allocation, based on heat output, will be the same for both CHP and separate heat supply. Therefore, as this allocation is reduced this affects both options in the same way. Hence, while the allocation scenario has influence on the absolute carbon costs for both cases this does not impact on the difference between the two.

It is therefore apparent that where a CHP scheme exhibits a benefit over the separate supply of heat and power under initial 2013 conditions this benefit can be expected to continue through to 2027. This means that under EU ETS Phase III CHP will continue to have a carbon cost advantage when compared against the conventional alternative of the separate generation of heat and power and that this advantage will reach a maximum when full auctioning starts.

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[27] Digest of United Kingdom Energy Statistics (DUKES) 2009

[28] Based on Full Auctioning from 2013 with carbon cost projections for “30% World” and based upon a gas Price of £23.98/MWh (GCV Basis) at 2009 prices.

[29] Carbon cost projections for “30% World” – gas price of £23.98/MWh.

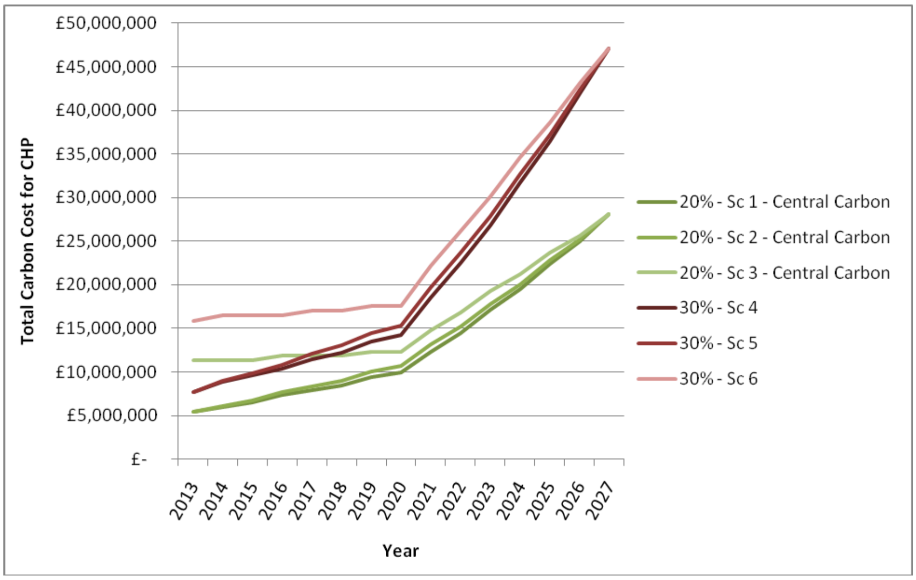

Figure 18

Total Annual Cost of Carbon between 2013 and 2027 for example CHP Scheme 1

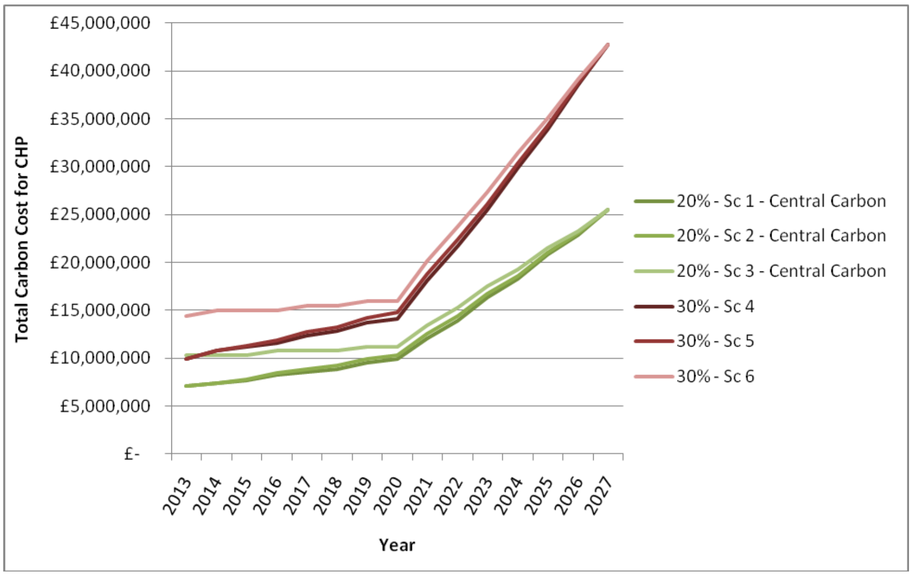

Figure 19

Total Annual Cost of Carbon between 2013 and 2027 for example CHP Scheme 2

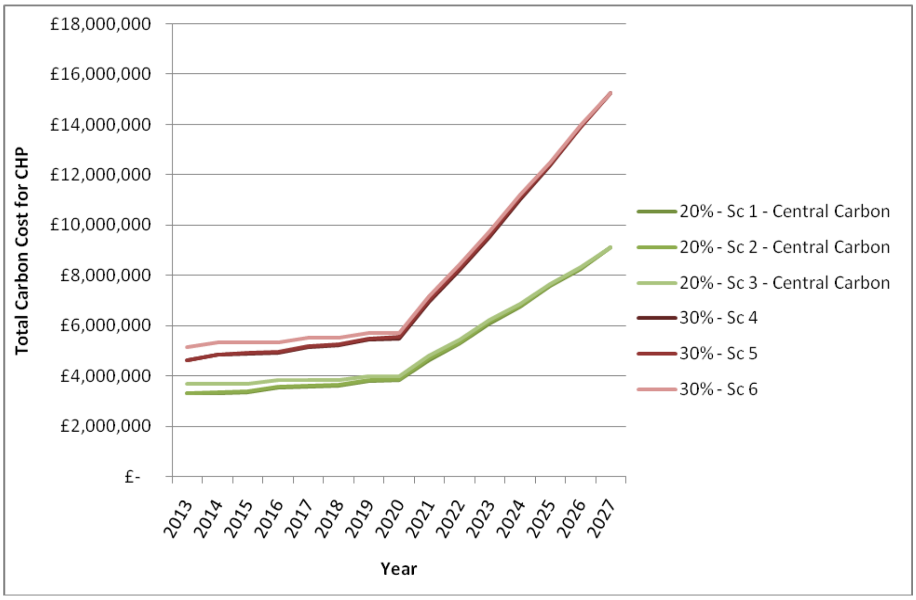

Figure 20

Total Annual Cost of Carbon between 2013 and 2027 for example CHP Scheme 3

Appendix 1

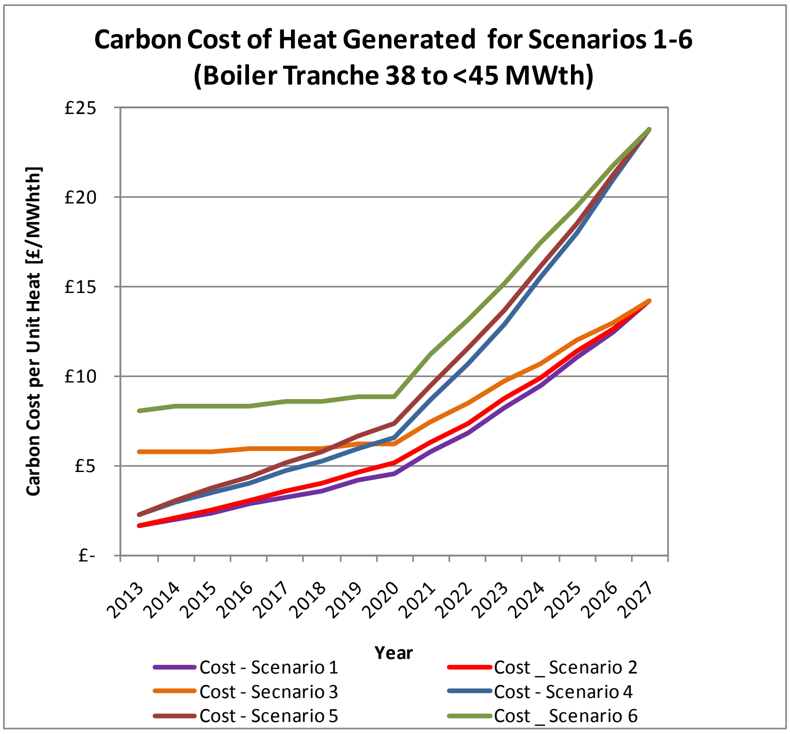

Figure 21 Carbon cost of heat generated for Scenarios 1-6 for boiler tranche 38 to <45 MWth

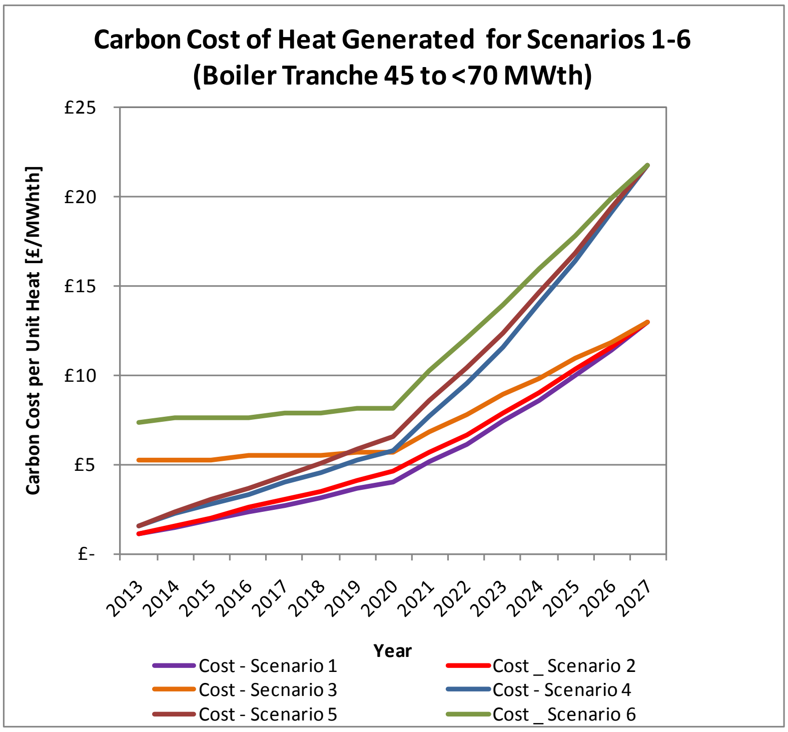

Figure 22 Carbon cost of heat generated for Scenarios 1-6 for boiler tranche 45 to <70 MWth

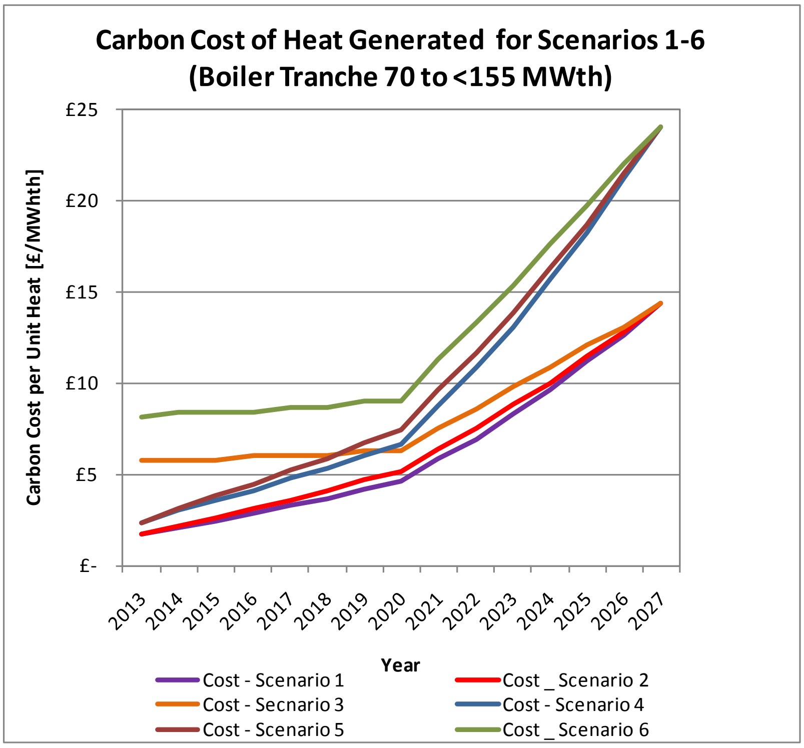

Figure 23 Carbon cost of heat generated for Scenarios 1-6 for boiler tranche 70 to <155 MWth

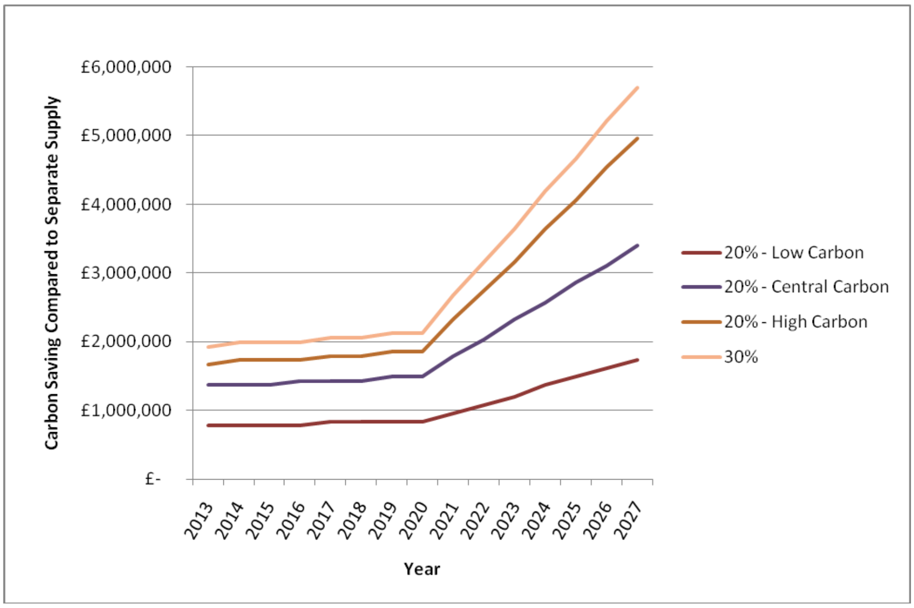

Figure 24 Carbon Saving of CHP against separate supply between 2013 and 2027 for example CHP Scheme 1

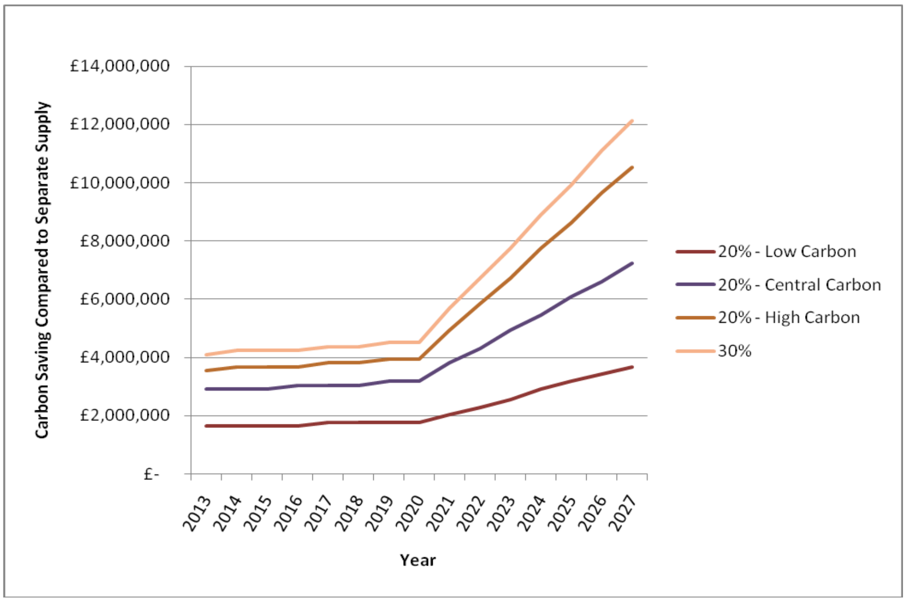

Figure 25 Carbon Saving of CHP against separate supply between 2013 and 2027 for example CHP Scheme 2

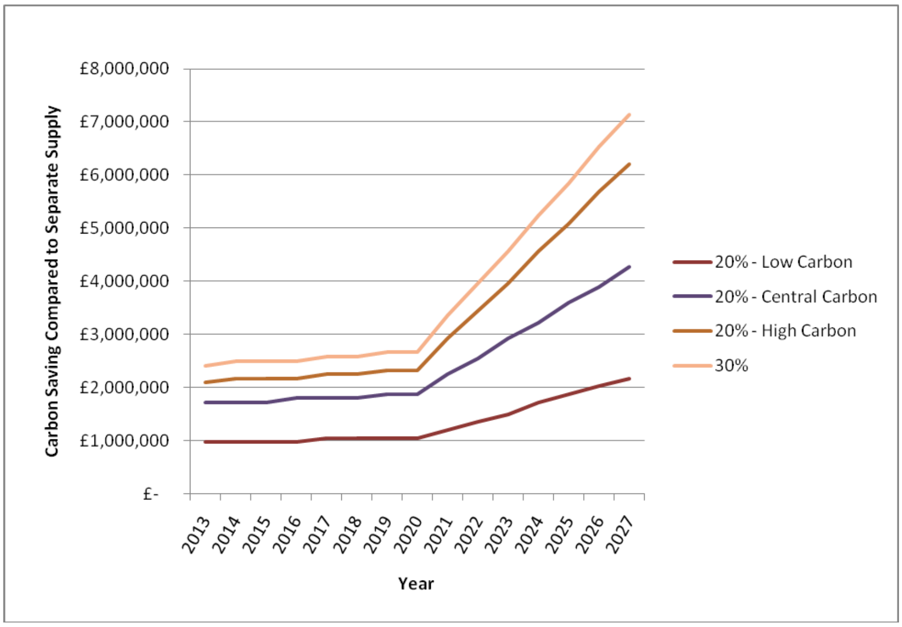

Figure 26 Carbon Saving of CHP against separate supply between 2013 and 2027 for example CHP Scheme 3

Glossary

20% World - Refers to a situation where the EU reduces it CO2 emissions by 20% by 2020 and the price of carbon brought about by that situation.

30% World - Refers to a situation where the EU reduces it CO2 emissions by 30% by 2020 and the price and availability of carbon brought about by that situation.

BAT - Best Available Techniques. The best techniques, economically and technically viable, for providing the highest general level of protection to the environment.

CCA - Climate Change Agreements. Agreements set up in the UK between Government and energy intensive industry whereby the latter undertakes to make measurable, verifiable improvements in energy efficiency in exchange for the former granting exemption on a proportion of the Climate Change Levy (CCL) that would otherwise be paid.

CCL - Climate Change Levy. A charge put on the energy consumption of the public and private sector. The levy does not apply to the domestic, transport or energy sectors or to selected energy sources such as renewable fuels.

CCGT - Combined Cycle Gas Turbine.

CHP - Combined Heat and Power. The simultaneous generation of heat and power, the latter usually in the form of electricity. This represents a more fuel (and carbon) efficient method of satisfying heat and power requirements than their separate generation in power only plant and stand alone boilers.

CHP prime mover - The plant in which power is generated and from which the waste heat associated with this generation is extracted.

CHPQA - Combined Heat and Power Quality Assurance. An initiative by Government to monitor, assess and improve the quality of UK CHP schemes.

Commission's Consultants - Ecofys who, in collaboration with the Fraunhofer Institute for Systems and Innovation Research and the Oko-Institut, have been tasked with deriving a methodology for the free allocation of emission allowances in the EU ETS post 2012.

Condensate return - In the case of steam as a heat carrying medium, the water returning to the heat generating plant as a result of steam giving up useful heat to the process.

EfW - Energy from Waste.

ENUSIM - Energy End **U**se **Sim**ulation Model

EU ETS - European Union Emission Trading System

EU ETS Installation - The site comprising the stationary technical unit, where one or more of the activities listed in Annex I of the Directive (2009/29/EC) are carried out, together with any other directly associated activities.

GCV - Gross Calorific Value. Amount of heat released during the combustion of a fuel, including that used to vaporise any water in the products of combustion.

HVC - High Value Chemical Products. A collective term for the products of steam cracking of a petrochemical feedstock, e.g. naptha, gas oil and gaseous feedstocks, and includes such products as ethylene, propylene, butadiene and hydrogen.

Leakage Factor - The factor applied in the calculation used to determine the CO_2 allocation made in respect of a particular activity in a particular year. For activities deemed to be at serious risk of carbon leakage, this factor is 1. For activities not deemed to be at risk of serious carbon leakage, this factor in 0.8 in 2013 and declines with time at a rate to be confirmed.

MMA Methyl Methacrylate - The monomer which when polymerised becomes Poly Methyl Methacrylate (PMMA), known by a variety of trade names including Perspex.

NAP - National Allocation Plan.

NCV - Net Calorific Value. Amount of heat released during the combustion of a fuel, excluding that used to vaporise any water in the products of combustion.

Prime Mover - The heart of a CHP system and is a mechanical machine which drives the electricity generator or develops mechanical power for direct use

Stand alone boiler – A boiler that on its own is able to generate heat, as opposed to a heat recovery boiler that must receive waste heat from another source in order to generate heat.

AEA group
329 Harwell
Didcot
Tel: 0870 190 xxxx
Fax: 0870 190 xxxx