Methodology for the free allocation of emission allowances in the EU ETS post 2012

Sector report for the iron and steel industry

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Disclaimer and acknowledgements

Disclaimer

The views expressed in this study represent only the views of the authors and not those of the European Commission. The focus of this study is on preparing a first blueprint of an allocation methodology for free allocation of emission allowances under the EU Emission Trading Scheme for the period 2013 – 2020 for installations in the iron and steel industry. The report should be read in conjunction with the report on the project approach and general issues. This sector report has been written by the Fraunhofer Institute for Systems and Innovation Research

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Table of content

1 Introduction

The iron and steel sector covers the production of crude steel via the primary and secondary production routes, including the pre-production steps coke making, sintering and pelletisation, as well as further processing of ferrous metals.

In order to acquire information and data on the iron and steel sector, the Fraunhofer Institute for Systems and Innovations Research (ISI) is in contact with Eurofer (European Confederation of Iron and Steel Industries[1]) and CAEF (The European Foundry Association).

In Annex I to the amended Greenhouse Gas Emission Allowance Trading Directive[2] iron and steel production is divided into production of coke, metal ore roasting or sintering including pelletisation, production of pig iron or steel (primary or secondary fusion) and production and processing of ferrous metals where combustion installations with a total rated thermal input exceeding 20 MW are operated. Table 1 gives an overview of the classification of these Annex I activities.

Table 1 Division of the iron and steel industry according to Annex I to the amended Directive and corresponding activities in NACE Rev. 1.1 classification

Annex I category of activities	NACE code (Rev. 1.1)	Description (NACE Rev. 1.1)
Production of coke	23.10	Manufacture of coke oven products
Metal ore (including sulphide ore) roasting or sintering, including pelletisation	13.10	Mining of iron ores
The production of pig iron or steel (primary or secondary fusion)	27.10	Manufacture of basic iron and steel and of ferro-alloys
Production and processing of ferrous metals (including ferro-alloys) where combustion installations with a total rated thermal input exceeding 20 MW are operated. Processing includes, inter alia, rolling mills, re-heaters, annealing furnaces, smitheries, foundries, coating and pickling.	27.10	Manufacture of basic iron and steel and of ferroalloys
	27.21	Manufacture of cast iron tubes
	27.22	Manufacture of steel tubes
	27.31	Cold drawing
	27.32	Cold rolling of narrow strip
	27.33	Cold forming or folding
	27.34	Wire drawing
	27.51	Casting of iron[1]
	27.52	Casting of steel[2]
	28.40	Forging, pressing, stamping and roll forming of metal; powder metallurgy
	28.51	Treatment and coating of metals

[1] This class includes activities of iron foundries. It further includes: casting of semi-finished iron products, casting of grey iron castings, casting of spheroidal graphite iron castings, casting of malleable cast-iron products, manufacture of tubes, pipes and hollow profiles and of tube or pipe fittings of cast-iron. Source: Eurostat (http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm)

[2] This class includes activities of steel foundries. It further includes: casting of semi-finished steel products, casting of steel castings, manufacture of seamless tubes and pipes of steel by centrifugal casting, manufacture of tube or pipe fittings of cast-steel. Source: Eurostat (http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm)

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[1] Eurofer represents 100% of steel production within the EU.

[2] Directive 2009/29/EC amending Directive 2003/87/EC

It has to be kept in mind that according to the NACE methodology, companies are classified under the code of their main activity. For this reason, activities such as sintering, coking of coal, casting, etc. are registered under NACE 27.10 when carried out in a steel plant.

The main differences between the definition of the installations in the original Directive and the amended Directive are shown in Table 2. They are due to the inclusion of down-stream processes in the ETS in the third trading period.

Table 2 Main differences in the definition of the installations between the original and the amended Directive

Relevant categories of activities in Annex I to the original Directive
Energy activities - Combustion installations with a rated thermal input exceeding 20MW (except hazardous or municipal waste installations) - Mineral oil refineries - Coke ovens
Production and processing of ferrous metals - Metal ore (including sulphide ore) roasting or sintering installations - Installations for the production of pig iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2.5 t per hour

Relevant categories of activities in Annex I to the amended Directive
Energy activities - Combustion of fuels in installations with a total rated thermal input exceeding 20MW (except in installations for the incineration of hazardous or municipal waste) - Refining of mineral oil - Production of coke
Production and processing of ferrous metals - Metal ore (including sulphide ore) roasting or sintering, including pelletisation - Production of pig iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2.5 t per hour. - Production and processing of ferrous metals (including ferro-alloys) where combustion units with a total rated thermal input exceeding 20 MW are operated. Processing includes, inter alia, rolling mills, re-heaters, annealing furnaces, smitheries, foundries, coating and pickling.

A second major difference comes from the fact that the original Directive has no mentioning of waste gases while the amended Directive states the following:

- Recital (18) ... These harmonised rules may also take into account emissions related to the use of combustible waste gases when the production of these waste gases cannot be avoided in the industrial process; in this respect the rules may provide for allowances to be allocated for free to operators of installations combusting the waste gases concerned or to operators of the installations where these gases originate. (...)
- *"Article 10a"* ... No free allocation shall be made in respect of any electricity production, except for cases falling within Article 10c and electricity produced from waste gases.

According to our interpretation these lines contain three messages:

- Recital (18) points to the fact that waste gases "may" be included in the benchmarking rules. It is our view that including the waste gases in the benchmarks is reasonable as the ETS would therefore set incentives to reduce the amount of waste gas produced and it may assure an efficient use of the waste gases if there are proper incentives.
- The allocation between producer and user of the waste gas is left open in the amended Directive.
- Electricity produced from waste gases may receive free allocation. Our interpretation is that the possible free allocation to waste gases used for electricity generation is a decision to be taken in the political process involving the EU Commission, the EU Member States and the industrial stakeholders. This decision also needs to settle on which amount of the total CO_2 emissions from waste gases used for electricity generation may be allocated for free. The implications of such a decision will be discussed further in this report.

Information on the number of iron and steel related production installations in the EU 27 that are included in the ETS has been provided by Eurofer[3] and CAEF[4]. An overview is given in Table 3.

Table 3 Overview of EU27 installations included in the ETS (Eurofer 2009, CAEF 2009)

Activity		**Number of ETS installations, EU27[1]**
Coke production		42
Sinter production		32
Hot metal production[2]		41
Electric arc furnaces (EAF)	ca.	200
Further processing of steel[3]	ca.	1100
Foundries[4]	ca.	40

[1] There is an overlap in the number of coke, sinter and hot metal installations, due to integrated production sites.
[2] Hot metal production implies here and in the following tables the blast furnace as well as the basic oxygen furnace operation and continuous casting.
[3] These installations split up into about 500 hot rolling and about 600 processing plants.
[4] Figure contains only CAEF members included in the ETS. In addition there are about 5200 non-ETS installations in Europe.

Emissions data for the iron and steel processes for the years 2005 – 2007 are reported from CITL (2009) in Table 4, allocations for 2008-2012 in Table 5. In the CITL in 2008 there are 21 installations in group 3 (coke), 32 installations in group 4 (sinter), 254 installations in group 5 (iron and steel). CITL data is however to be taken for provisional estimations only, since boundary issues were interpreted differently by the reporting member states and in some cases misreferencing occurred.

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[3] Personal communication – Eurofer via e-mail, 16th of April 2009 and 3rd of September 2009. Norway and Iceland are not included.

[4] Personal communication – CAEF via e-mail, 4th of July 2009 and 16th of September 2009. Norway and Iceland are not included.

Table 4 Verified emissions in t of CO_2 per year 2005-2008 (CITL, 2009)

Year	Coke Ovens	Roaster & Sinter[1]	Iron & Steel
2005	19193122	7755757	134175457
2006	21301035	8014586	138933815
2007	22077817	24939780	132240616
2008	20984288	17642624	132966950

[1] The significant increase in 2007 originates from the inclusion of Romania in the data acquisition. Several Romanian steel plants were reported in the category "roaster & sinter".

Table 5 Allocation in t of CO2 per year 2008-2012[5] (CITL, 2009)

Year	Coke Ovens	Roaster & Sinter	Iron & Steel
2008	22526586	21928309	184806369
2009	22306066	20158136	179958197
2010	-	-	-
2011	-	-	-
2012	-	-	-

An approximate estimation of the emissions of the individual processes can furthermore be determined from data on production volume and approximate emission factors of the years 2005-2008 that have been provided by Eurofer[6] and CAEF[7] and are reported in Table 6. It has to be emphasised that the approximate GHG emissions given in Table 6 are calculated as the product of production volume and approximate emission factors and shall provide a first impression of the GHG emissions for lack of the exact values that may later be derived from benchmarking curves.

Electricity production is significant in the iron and steel sector. Parts of the waste gases stemming from the coke oven, the blast furnace (BF) or the basic oxygen furnace (BOF) are used for electricity production. Power plants burning the waste gases can either be owned by the furnace operator or an external electricity producing company. Electricity production takes place at the site where waste gases occur and is usually consumed by the site itself. The overall electricity demand of the iron and steel sector can however not be covered by waste gas electricity alone. According to an internal survey of Eurofer about one fifth of the electricity needs has to be covered by imports.[8]

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[5] The higher allocations for 2008-2012 in comparison to the emissions of 2005-2007 are due to the fact that certificates for the carbon content of waste gases are allocated to the waste gas producer while emissions are reported by the waste gas consumer and therefore partly do not occur in the iron and steel sector.

[6] Personal communication – Eurofer via e-mail, 20th of May 2009

[7] Personal communication – CAEF via e-mail, 4th of July 2009 and 16th of September 2009

[8] Personal communication – Eurofer via e-mail, 11th of July 2009

Table 6 Approximate GHG emissions (indicative 2005-2008) from the iron and steel production chain calculated from production volume and direct specific emissions (Eurofer 2009, CAEF 2009, calculations from Fraunhofer ISI 2009)[9]

Activity	Production vol. EU27 (Mt)	Approx. specfic emissions (kg CO_2/t product)	Approx. GHG emissions (Mt of CO_2-eq.)	Share in total sector emissions (%)
Coke[1]	46	500	23	9.1
Sinter	128	250	32	12.7
Hot metal	113	1550	175	69.3
EAF steel	81	102	8.3	3.3
of which				
(EAF- non-alloy steel)	(73)	(100)	(7.3)	(2.9)
(EAF – high-alloy and other alloy steel)	(8)	(120)	(1.0)	(0.4)
Hot rolled steel	62[2]	100[3]	6.2	2.5
Processed steel	90	?	4.5	1.8
of which				
(Cold rolled steel)[4,5]	(50[3])	(50)	(2.5)	(1.0)
(Coated steel)[3,4]	(40)	(50)	(2)	(0.8)
Foundry products	4	400 – 600[6]	3-4	1.4
Total			**252.5**	**100.0**

[1] The coke making benchmark is the most demanding with respect to the calculation. The CO_2 value is extremely sensitive to small changes in the raw data and the raw data itself is prone to high uncertainties.

[2] This value covers only estimated production in stand-alone units. Production in units on integrated sites is estimated with 120 Mt and their emissions are included in the hot metal section.

[3] A wide range of values is expected, because these categories cover a wide range of products and processes.

[4] Both products are the result of production steps employing heat-treatment operations. To an unknown extent there can be double counting if heat treatment is performed after both cold rolling and coating (metal coating).

[5] For the purpose of this table it has been assumed that CO_2 will stem either from heat treatment connected to cold rolling or from surface treatment. According to Eurofer this division into two groups allows the simplest approach to combine related data on production volumes and CO_2 emissions, which at a correct level could only be provided after a full data collection on all supposed ETS participants of this group.

[6] Estimation based on data from Germany. (BREF Smitheries and Foundries, 2005) mentions for cold blast cupola furnaces 400-500 kg CO_2/t of metal charge and for hot blast cupola furnaces 350-480 kg CO_2/t of metal charge. However, the definition of the perimeter of the foundry process still needs further investigation.

According to Article 10a (6) of the amended Directive, Member States may also adopt financial measures in favour of sectors or sub-sectors determined to be exposed to a significant risk of carbon leakage due to costs relating to greenhouse gas emissions passed on in electricity prices, in order to compensate for those costs and where such financial measures are in accordance with state aid rules applicable and to be adopted in this area. Those measures shall be **based on ex-ante benchmarks of the indirect emissions of CO_2 per unit of production**. The ex-ante benchmarks shall be calculated for a given sector or sub-sector as the product of the electricity consumption per unit of production corresponding to the most efficient available technologies **and of the CO_2 emissions of the relevant European electricity production mix**.

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[9] Eurofer stresses that these figures are preliminary. Norway and Iceland are not included. A detailed data collection undertaken by Eurofer will give more concrete figures.

Since exact data on electricity consumption are also not available, an approximate calculation can be done using the same methodology as for the emissions data (see Table 7). It must be underlined that the main focus of this report is on direct emissions from the iron and steel chain within the EU ETS. However, as EAF steel production is one of the largest industrial electricity consumers and hence possibly concerned by compensation mechanisms for indirect effects of the ETS via the inclusion of allowance prices into the electricity prices, the relevant data are also collected her to allow for a discussion of electricity benchmarks.

Table 7 Approx. electricity consumption (average 2005-2008) from the iron and steel production chain calculated from data on production volume and specific electricity consumption (Eurofer 2009, calculations from Fraunhofer ISI 2009, BREF Iron and Steel 2001, BREF Smitheries and Foundries 2005)

Activity	Production vol. EU27 (Mt)[1]	Specific electr. consumption (kWh/t product)[2]	Approx. power consumption (GWh)	Share in total sector electr. consumption (%)
Hot metal	113	103	11639	16.8
Coke	46	6	276	0.4
Sinter	128	27	3456	5.0
EAF	81	440	35640	51.6
Hot rolled steel	62	120	7440	10.8
Processed steel	90	?	10250	14.8
(o.w. cold rolled steel)	(50)	(185)	(9250)	(13.4)
(o.w. coated steel)	(40)	(25)	(1000)	(1.5)
Foundry products	4	100[3]	400	0.6
Total			**69101**	**100.0**

[1] Eurofer data

[2] Values taken from BREF Iron and Steel (2001)

[3] Values taken from BREF Smitheries and Foundries (2005). For cupola furnaces: Figure includes electricity for the flue-gas cleaning equipment (fans, etc.) and for the holding furnace. However, the definition of the perimeter of the foundry process still needs further investigation.

Issues to be further debated in that context are CO_2 emission factors for the electricity mix to be associated and whether there should be a correspondence in the structure of direct emission benchmarks and electricity benchmarks, i.e. which parts of the iron and steel production chain is to be included in the consideration of electricity benchmarks.

2 Production process and GHG emissions

2.1 Description of the production process

The production of crude steel is in principle carried out via two routes, differing as well in the metallurgical process, energy input and process emissions as in the quality and application purpose of the products. Starting from iron ore, BOF crude steel is produced via the production of hot metal in a blast furnace and its following conversion to crude steel in a basic oxygen furnace, while EAF steel is produced by the smelting of scrap or direct reduced iron in an electric arc furnace.

The production of BOF steel requires two preceding processes, namely coke making and sintering. The process of coke making is the conversion of coal to coke by heating of coal in absence of air (or oxygen) to remove the volatile components and other substances like tars, which will be contained in coke oven gas. In the sintering process, iron ores of different grain size are agglomerated together with additives to create a material feed for the blast furnace with improved permeability and reducibility. Hot metal is most commonly produced in blast furnaces that are fed with sinter, coke and additives. To make best possible use of the heat of roughly 1600 °C, hot metal is conveyed as fast as possible to the basic oxygen furnace, where its conversion to crude steel takes place. Oxygen is blown through molten hot metal in the BOF in order to drive out the carbon content. Scrap is added to the BOF to be able to control the reaction and keep the temperature within limits.

Alternatively to the blast furnace process iron ore can also be converted into metallic iron in a direct reduction process. The product yielded is often referred to as "direct reduced iron (DRI)" or "sponge iron". Direct reduced iron is used instead of scrap as input for electric arc furnaces.

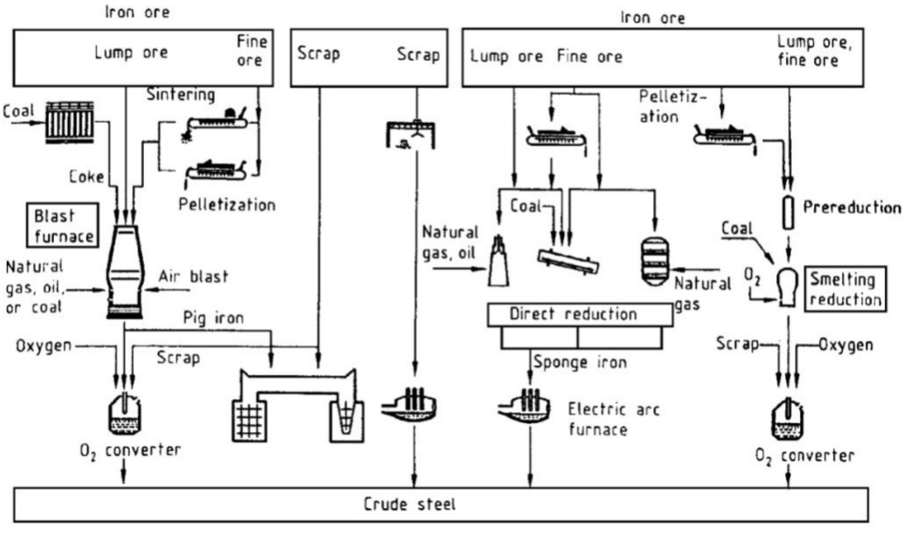

Figure 1 Crude steel production processes (Ullmann's 1994)

Before further treatment, crude steel can go trough a refining process step, such as ESR (electro-slag remelting), vacuum remelting or remelting under a nitrogen atmosphere. Semi-finishing of crude steel is performed onsite in a continuous casting process. Following secondary metallurgy, crude steel is transformed into finished end-products via various foundry, casting, rolling (hot rolling and cold rolling) and finishing steps (pickling, annealing, coating, welding, etc.).

2.2 Direct emissions and steam use

In the coke production process, direct CO_2 emissions occur from the fuel used for under-firing. In integrated plants, under-firing heat is provided by blast furnace gas because of its low heating value, while in stand-alone plants, coke oven gas is used. In addition to that, steam can be applied in by-product plants and in the coal moisture control process. The carbon content of coal fed into to the coke oven is transferred to coke (~ 90 %) and coke oven gas (~ 10 %).

In the sinter production process, direct CO_2 emissions occur due to fuel used in the sintering process, from the recycling of residue materials and in form of process emissions from limestone calcination.

The production of hot metal in the blast furnace results in direct CO_2 emissions from fuel used for the stoves. In addition to that, the carbon content from coke and coal input to the blast furnace is transferred to BF gas. The conversion process of hot metal to crude steel leads to direct CO_2 emissions from fuel used in the basic oxygen furnace. The carbon content of hot metal fed into the basic oxygen furnace is transferred to BOF gas.

For crude steel produced via the EAF route, direct CO_2 emissions result from fuel and carbon from electrodes and scrap that is oxidised in the electric arc furnace. As regards the production of high alloy steels, CO_2 emissions stem from ferro-alloys rather than from scrap. (Scrap grades usually fed in the EAF for this type of production have low carbon contents.)

In the casting, rolling, surface treatment and further processing of steel, direct CO_2 emissions stem from fuel used in the various processing steps. Steam use is often possible as well.

2.3 Waste gases

In the production processes of coke and hot metal a significant outflow of (partially) oxidised carbon occurs in form of waste gas, in addition to direct emissions. Since waste gas from blast furnaces, basic oxygen furnaces and special ferrochromium smelters contain a considerable amount of carbon monoxide (CO) and waste gases from coke oven plants an amount of methane (CH_4) and hydrogen (H_2), they are not directly emitted to the atmosphere but recovered and used for electricity production, for the stoves in the blast furnaces, for under-firing of coke oven plants, ignition of sinter stands and reheating of furnaces.

3 Benchmarking methodology

3.1 Background

The variety of products in the iron and steel sector is very large and covered by about 130 PRODCOM codes. The following table gives an overview of the products involved in the crude steel production processes and neglects the downstream processes. For the latter about 115 more PRODCOM codes would have to be mentioned.

Table 8 PRODCOM codes of iron and steel products (based on NACE Rev. 1.1)

Product	**PRODCOM Code**
Agglomerated iron ores and concentrates (excluding roasted iron pyrites)	13.10.10.50
Coke-oven coke (obtained from the carbonization of coking coal, at high temperature), gas-works coke (by-product of gas-works plants)[10]	23.10.10.30
Pig iron and spiegeleisen in pigs, blocks or other primary forms. Ferrous products obtained by direct reduction of iron ore and other spongy ferrous products	27.10.11.00
Granules and powders, of pig iron, spiegeleisen, iron or steel	27.10.12.50
Slag and dross	27.10.13.10
Ferrous scrap	27.10.13.20
Flat semi-finished products (of non-alloy steel)	27.10.31.10
Ingots, other primary forms and long semi-finished products for seamless tubes (of non-alloy steel)	27.10.31.21
Other ingots, primary forms and long semi-finished products including blanks (of non-alloy steel)	27.10.31.22
Flat semi-finished products (slabs) (of stainless steel)	27.10.32.10
Ingots, other primary forms and long semi-finished products for seamless tubes (of stainless steel)	27.10.32.21
Other ingots, primary forms and long semi-finished products (of stainless steel)	27.10.32.22
Flat semi-finished products (of alloy steel other than of stainless steel)	27.10.33.10
Ingots, other primary forms and long semi-finished products for seamless tubes (of alloy steel other than of stainless steel)	27.10.33.21
Other ingots, primary forms and long semi-finished products (of alloy steel other than of stainless steel)	27.10.33.22

In spite of the large variety of products in the iron and steel sector, according to a rough estimation of Eurofer, about 88% of the sector's CO_2 emissions can be attributed to the production of only coke, sinter, BOF crude steel and EAF crude steel, while the remaining 12% stem from downstream processes like foundry casting, hot rolling, cold rolling, surface treatment (tinning and galvanizing) and further processing. According to Table 6, even 95%

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[10] This PRODCOM code is taken from 2004 PRODCOM classification (based on NACE Rev.1). The product category "coke-oven coke" does not appear anymore in more recent versions.

are covered by the mentioned processes but this figure is too high, still including integrated hot rolling mills and integrated processed steel plants.

BOF crude steel and EAF crude steel can be regarded as distinctly different products in respect of steel qualities. Differences in steel types produced by European manufacturers consist in metallurgical composition – the presence of impurities and of desired trace elements – or in the metallurgical structure of the material. Depending on the steel quality different products can be manufactured from a specific steel type. Generally, basic oxygen steel allows creating a wider variety of products as it is newly produced from iron ore and does not contain alloy elements that have been carried over from the scrap input. These alloy elements usually would not be desired in the newly made product. Different to this, electric arc steel made from scrap contains the alloy elements that are brought into the product with the scrap. They cannot be simply separated from the steel and hence electric arc steel usually is considered to be of lower quality than basic oxygen steel. Hence, basic oxygen steel usually goes into the products that require higher material qualities like e.g. sheets for car manufacturing. Electric arc steel is used more for products that are less sensitive to the material quality like e.g. concrete reinforcing bars. Due to these different quality characteristics we recommend separate benchmarks for the BOF crude steel and EAF crude steel production routes.

Coke and sinter are traded intermediate products in the BOF crude steel production route and should receive own benchmarks in order to allow allocation to installations selling these intermediate products. (See starting point 6 of the previous study.) Alternatively to sinter, pellets can be used as input for the blast furnace. Composition and product characteristics of pellets differ, however, significantly from sinter, why a common benchmark for sinter and pellets cannot be applied. Since there is only one integrated steel plant in the EU27, where pellet production takes place, we do not recommend benchmarking for pellet production, but appliance of a fall-back approach (see section 5 of the report on the project approach and general issues), just as for pellets produced at mining sites (see sector report on iron ore).

In accordance with the overall architecture of the ETS and the principles laid down in Chapter 4 of the report on the project approach and general issues, pig iron should as a traded intermediate product receive a separate benchmark as well. This approach was followed in Ecofys / Fraunhofer-ISI (2009). There are, however, also arguments for one single "hot metal" benchmark instead of two benchmarks for the BOF route (one for pig iron and the other for BOF crude steel):

- First of all, hot metal, i.e. pig iron in liquid form, is only in very few cases cooled down and sold[11], but usually directly fed into the basic oxygen furnace. In some cases it may also be transported in liquid form but usually it is used for internal purposes in an integrated plant. Following the hot metal benchmark proposition, in the rare cases of sold pig iron, the vendor would need to agree with the BOF operator on the transfer of allowances together with the pig iron. If a BOF installation treats larger amounts of purchased iron this may lead to a distortion in the benchmarking curve but

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[11] In 2008 imports of pig iron in EU27 countries amounted to 5,4 Mt (5% of the overall production) and exports to 1 Mt (1% of the overall production). Source: Worldsteel (2009)

Eurofer does not see this as a large problem. Stand-alone BOF could in principle be a problem but do not seem to exist in large number.

- Furthermore, since the conversion of hot metal is an exothermic reaction, the major part of CO_2 emissions of the basic oxygen furnace results from the carbon content of hot metal and only very few additional CO_2 emissions arise from further inputs to the converter. In that sense, the converter is merely a down-stream equipment to the blast furnace. According to arguments from Eurofer the implementation of an independent converter benchmark would set a market distorting incentive to increase the share of scrap fed into the basic oxygen furnace (the more scrap is added, the more the carbon in the pig iron is diluted and the less CO_2 is emitted from the converter) and thereby divert scrap from the more appropriate secondary steel route. In the absence of scrap, EAF plants might even use pig iron in an inefficient manner to compensate. Eurofer therefore suggests assigning all emissions arising in the BF, the BOF and the following continuous casting process to hot metal. The association argues that these processes form a unity which, if broken up by separate benchmarks, would lead to wrong incentives (for the full argumentation, see chapter 6 to this report).
- Lastly the pig iron production influences strongly the conversion to crude steel for the following reason. Assuming two benchmarks with pig iron and crude steel as reference products, a blast furnace operating with high carbon intensity, situated at the right hand side of the pig iron benchmark curve, would release hot metal at higher temperature and with higher Si content. It would hence allow for higher scrap input rates and therefore lower specific emissions at the basic oxygen furnace – the associated BOF would set the crude steel benchmark. By contrast, a blast furnace operating with low carbon intensity, situated at the left hand side of the benchmark curve and setting the pig iron benchmark, will release hot metal at lower temperature with lower Si content, hence preventing high scrap input rates at the BOF. This BOF will be situated on the right-hand side of the benchmark curve. It is there fore impossible for a blast furnace and a basic oxygen furnace of the same site to perform simultaneously at the benchmark level, even if both furnaces constitute best available technique.

Balancing carefully the arguments for and against setting a hot metal benchmark as proposed by Eurofer, we recommend the hot metal benchmark as most appropriate solution. Eurofer's proposition to include the continuous casting process in the system boundary of the hot metal benchmark seems reasonable to us, since BOF crude steel leaving the basic oxygen furnace is always semi-finished onsite and sold only after the continuous casting process. Its inclusion in the benchmark facilitates the measurement of CO_2 emissions and increases the number of process steps covered by the benchmark approach[12].

Direct reduced iron (DRI) cannot be compared to hot metal or pig iron. Since its carbon content is much lower, it can alternatively to scrap be directly fed into the electric arc furnace, while hot metal has to be converted in the basic oxygen furnace to remove the carbon. Because of the need of very special circumstances (like the availability of cheap natural gas) for a cost-effective production of DRI, there is only one DRI producing plant in the EU. We

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[12] The definition of the benchmark boundaries is essential here. It has to be ensured that no double allocation for downstream/casting processes occurs.

therefore advise against an own benchmark for DRI but recommend the application of a fall-back approach (see section 5 of the report on the project approach and general issues) for the currently single DRI plant in Europe.

One could furthermore argue that separate benchmarks for the production of EAF non-alloy steel on the one hand and EAF high-alloy and other alloy steel on the other hand would be advisable. From a perspective of product types and qualities, high alloy steel can certainly be viewed as a distinctly different product to ordinary steel. Different to conventional non-alloy-steel production in electric arc furnaces, where scrap is the main raw material input, high alloy steel production needs ferro-alloys (ferro-chrome, ferro-nickel and others) as input in order to introduce the alloy elements to the product. These ferro-alloys can have a carbon content of up to 6 %. According to Eurofer, the differences in emission intensity for the production of carbon and high alloy steel in electric arc furnaces are significant (higher than 20 %)[13]. Nevertheless, the data in Table 6 indicate no substantial differences between the two processes. The decision between one ore two benchmarks for the EAF route can therefore only be taken after the receipt of data on the two production routes.

Since downstream processes following continuous casting do not only account for a relatively low share of the overall CO_2 emissions, but are also characterised by a large number of different products, we recommend considering them with a fall-back approach (see section 5 of the report on the project approach and general issues).

3.2 Final proposal for products to be distinguished

As a result of the presented arguments, we propose to determine benchmarks for the following four or five products (Table 9).

Table 9 Overview of the benchmark products of the iron and steel sector and their corresponding PRODCOM codes

Product	PRODCOM codes (based on NACE Rev. 1.1)	PRODCOM description
Coke	23.10.10.30[1]	Coke-oven coke (obtained from the carbonization of coking coal, at high temperature), gas-works coke (by-product of gas-works plants)
Sinter	13.10.10.50	Agglomerated iron ores and concentrates (excluding roasted iron pyrites)
Hot metal[2]	-	
EAF non-alloy steel[3]	27.10.31.10	Flat semi-finished products (of non-alloy steel)
	27.10.31.21	Ingots, other primary forms and long semi-finished products for seamless tubes (of non-alloy steel)
	27.10.31.22	Other ingots, primary forms and long semi-finished products including blanks (of non-alloy steel)

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[13] Personal communication – Eurofer via e-mail, 11th of July 2009

Continuation Table 9

Product	**PRODCOM codes (based on NACE Rev. 1.1)**	**PRODCOM description**
EAF high-alloy and other alloy steel[3]	27.10.33.10	Flat semi-finished products (of alloy steel other than of stainless steel)
	27.10.33.21	Ingots, other primary forms and long semi-finished products for seamless tubes (of alloy steel other than of stainless steel)
	27.10.33.22	Other ingots, primary forms and long semi-finished products (of alloy steel other than of stainless steel)
	27.10.32.10	Flat semi-finished products (slabs) (of stainless steel)
	27.10.32.21	Ingots, other primary forms and long semi-finished products for seamless tubes (of stainless steel)
	27.10.32.22	Other ingots, primary forms and long semi-finished products (of stainless steel)

[1] PRODCOM based on NACE Rev. 1

[2] Implying all direct emissions of the blast furnace as well as the basic oxygen furnace operation and continuous casting; For hot metal, no PRODCOM code or any other industry standard or classification number for the product could be found.

[3] It can currently not yet be decided whether one benchmark is the sufficient for EAF steel or whether two benchmarks are necessary for EAF non-alloy steel and EAF high-alloy and other alloy steel. This depends on the information provided by the currently ongoing more detailed data collection initiated by Eurofer.

These products would cover about 88 % of the emissions from the iron and steel production chain according to an estimation of Eurofer.

We recommend treating the remaining products, i.e. pellets, cold rolled steel, hot rolled steel and surface treated products from iron and steel (tinned and galvanized products) and cast products from iron and steel foundries, by the fall-back approach (see section 5 of the report on the project approach and general issues). Nevertheless, the establishment of two more benchmark could be considered:

- For foundry products: According to CAEF the production characteristics of the 40 ETS foundries in the EU27 are quite similar and one benchmark curve for the whole foundry sector might be possible. The installations are mainly cupola furnaces heated by coke and a few rotary furnaces. The spread across the benchmarking curve should according to CAEF not exceed a factor 1.3. Since foundries were not included in the ETS in Phase 1 and Phase 2, no data are, however, available to the present, which would allow for a decision on this issue. The definition of the perimeter of the foundries with respect to downstream processing is still open. The direct emissions amount to about 1.4 % of the overall direct emissions from the iron/steel sector within the ETS according to Table 6.
- For warm rolling: a separate benchmark for warm rolling could also be discussed and considered further, if a suitable classification of activities could be found without having to introduce a larger number of additional benchmarks.

3.3 Allocation to carbon containing waste gases crossing system boundaries in the iron/steel sector

In determining benchmark values for the iron and steel sector it is crucial to find a consistent method for attributing carbon containing waste gases when the benchmark curves are set up. Waste gas arises in the coke oven, the blast furnace and the basic oxygen furnace and is then transferred to other EU-ETS installations (or to non-ETS installations) and emitted there[14]. Coke making results in coke oven gas, which has a lower emission intensity than natural gas. In stand-alone coke oven plants, coke oven gas is used for the under-firing of coke oven batteries. Different to this, in integrated steel plants with an on-site coke oven plant, also blast furnace gas is used for the under-firing. This low-calorific gas – although usually considered as a fuel of very low value – is suitable for this purpose as it burns slowly and allows a more even distribution of heat across the walls of the coke oven chambers. In integrated steel works, blast furnace gas is used for many upstream (like coke making) and downstream processes (rolling) as well as for electricity production, which may also be outsourced. These processes however are also applied in stand-alone configurations and there have to rely on alternative fuels like natural gas.

It has to be decided if allowances for these waste gases are allocated to either their producer or consumer or to be split among them and benchmarks have to be determined respectively. The most obvious solution would be to allocate the emission allowances to the consumer, being the entity that has to surrender allowances, i.e. to the site where the waste gas is burnt. This is furthermore supported by the fact that efficient use of the gases can only be influenced by the consumer. On the other hand, it is only the waste gas producer who is able to influence the extent of waste gas generation, which supports that reduction incentives should be provided to him. The production of the waste gas is inevitably linked to the type of process used and can only be influenced to a limited amount. Furthermore, if the allocation was made to the consumer, problems could arise with regard to the contracts between waste gas producers and consumers owned by different companies: Since the allocation would be made ex-ante for a period of up to eight years, allowances would be given to the consumers in advance without consideration of contract duration.

Out of these considerations we recommend to split the allowances for waste gas between the producer and the consumer (see also Chapter 6 of the report on the project approach and general issues). Emissions intensity values are to be calculated for the producers of waste gas by correcting the actual emissions of the process with a deduction for the calorific value of the waste gas exported based on the difference in emission intensity between the waste gas and natural gas (emission factor of 56.1 kg CO_2 / GJ). By analogy, for calculating emission intensity values for the consumers of waste gas, the calorific value of the waste gas consumed should be taken into account as if it was natural gas. How many allowances are actually allocated to the consumer of the waste gas depends on how the waste gas consumer is treated. In fact the following cases may arise, although not all of them are equally relevant to the iron/steel industry:

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[14] It should be pointed out that the waste gas flows ACROSS the boundaries, for example from the hot metal aggregate to a hot rolling mill must be known (which could in practice sometime pose problems, if the site is integrated), however, it is not necessary to know all waste gas flows WITHIN the limits of the aggregate for example from the blast furnace to the cowpers.

1. The waste gas is **delivered to a user which is also benchmarked under the ETS** (for example the use of blast furnace gas in a coking plant). In such a case the emission factor of natural gas should be used in the benchmark calculation for that installation.
2. The waste gas is **delivered to a user which is within the EU ETS but may be dealt with using a fall-back approach** (e.g. possibly downstream processing in the iron/steel sector, see chapter 5 of the report on the project approach and general issues).
3. The waste gas is **delivered to a user which generates electricity**. This user could be the iron/steel producer itself or a third party if the electricity generation has been outsourced. This is the most relevant case for the blast furnace gas, as roughly 50% of the gas is used for electricity generation. If the reference for the consuming installations is auctioning (i.e. no free allocation), in principle no additional allowances need to be allocated[15]. One could argue, however, that the text in Article 10a (1) of the amended Directive on free allocation to electricity produced from waste gases implies that for electricity producers using the waste gas, the allocation should not be limited to the amount based on the emission intensity differences between the waste gas and natural gas as is proposed here, but that the total amount should be allocated. If so decided, this could be implemented by allocating to the electricity producer allowances based on the natural gas equivalent of the blast furnace gas used (however in such a case it must be assured that the sum of allocation to the waste gas producer and consumer does not exceed the allocation that would occur if all waste gas would be allocated under a benchmark approach to the producer only). It should be realized, however, that in doing so, the cost increase due to increased electricity prices is for waste gas producing sectors (partly) compensated via free allowances. This should be taken into account in the design of the financial compensation mechanism as outlined in Article 10a (6) of the amended Directive to prevent a double compensation if the waste gas producing sector is regarded eligible for such financial compensation. The method as proposed here makes the possible financial compensation for increased electricity prices independent of the free allocation methodology and makes a fair and equal treatment of all operations possible via a EU-wide and non-installation specific methodology.
4. The waste gas is **delivered to a user which is not part of the ETS**, for example to a small enterprise or to other small private consumers. In such cases, the emissions resulting from burning the waste gases are in principle no longer monitored and included within the EU ETS. In such cases, the allowances to the producers of the waste gas should be corrected to avoid allocation of allowances for emissions that are not accounted for in the EU ETS[16] [17]. It is expected that this will occur only in a very limited number of cases.
5. The waste gas is **not used** (flared[18]). In such a case no allocation occurs for the flared part.

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[15] But note that any difference in emission intensity between natural gas and the waste gas is allocated to the producer.

[16] The correction should be downwards if the emission factor of the waste gas exceeds that of natural gas, (e.g. blast furnace gas) or upwards if the emission factor of the waste gas is lower than that of natural gas (e.g. coke oven gas).

[17] Again, whether changes during the trading period should be reflected in the allocation and if the regulator should define rules for this is not further discussed in this study.

[18] Usually gases like blast furnace gas or coke oven gas are not flared. However, the flaring of waste gases may occur in other sectors, e.g. for carbon black. BOF gas could also be flared.

Since the basis for the allocation is known, the possible transfer of allowances between the consumer and producer has not necessarily to be regulated[19] and could be left to the two EU ETS installations.

Eurofer proposes an alternative approach for the allocation of allowances for waste gases by full allocation of allowances for the carbon content of waste gases to the waste gas producer and to base benchmark values on the total amount of carbon embodied in these waste gases and the additional fuel used. In case that waste gas was sold, the waste gas producer would be obliged to surrender the amount of allowances corresponding to the carbon content of the waste gas together with the waste gas itself to the customer. By this means, the incentive of reducing waste gas production would be provided.

The approach proposed in this study including the deduction based on natural gas has the following advantages:

- First of all, this allocation method establishes a convincing benchmarking methodology which is compatible with the general principles. There is not need to correct for outliers due to the use of waste gas on the consumer side if those are benchmarked.
- Second, a fair allocation to both integrated and non-integrated plants would be ensured. While in integrated steel works, in many upstream (coke, sinter making) and down-stream processes (rolling) waste gas is used, these processes are also applied in stand-alone configurations and there have to rely on alternative fuels like natural gas. By the proposed solution, a fair benchmarking allocation for the products of these processes is ensured in integrated as well as non-integrated plants. In the Eurofer approach, on the contrary, since the carbon content of waste gases would not be accounted for at the consumer's site, benchmarks could even be zero. As a consequence stand-alone installations using natural gas would be situated at the right-hand side of the benchmark curve and therefore disadvantaged.
- Thirdly, through the deduction for the amount of waste gas exported, an incentive against the flaring of basic oxygen furnace gas is provided. While waste gas producers are obliged to ensure the use of coke oven and blast furnace gas, BOF gas may be flared without further use. Following the Eurofer approach, a BOF operator flaring the BOF gas would receive full allocation just as the system in which the operator ensures the use of the gas. In our approach however, the BOF operator does not receive the full allocation and an incentive for making use of the BOF gas is provided.
- Finally, our approach ensures fair allocation to installations producing electricity from waste gas in comparison to other electricity producing installations. Since emission allowances are allocated to the producer based on the difference in emission intensity between the waste gas and natural gas, electricity production from waste gas is neither privileged nor disadvantaged in comparison to an installation producing electricity from natural gas. The possible issue of compensation for carbon leakage on

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[19] It is acknowledged that both production levels and the consumers of the waste gases can change over time. It is beyond the scope of this study to discuss in detail if and how this should be reflected in the number of allowances to be allocated over time and if the regulator should define rules for this. If such rules are developed, it is key that the initial allocation for the total system (i.e. for the producer and consumer together) is partly based on the activity of the producer of the waste gas producer (the difference in emission intensity between the waste gas and natural gas) and partly on the activity of the consumer of the waste gas consumer (the fact that a fuel is consumed).

the electricity side is then also independent from whether waste gas or natural gas is used to generate electricity.

We acknowledge that our approach is more difficult to implement, since it envisions splitting of free allocation between to entities, which can lead to complications when it comes to dynamic changes in the system such as the new entrants and the closure of facilities at the user side. A full allocation to the waste gas producer side might reduce those difficulties. However, despite the fact that constructing good benchmark curves may also in some cases result in our approach in some technicalities to be solved, we believe the advantages of the approach outweigh the difficulties.

We therefore recommend the following rules for the determination of final benchmark values:

1. The allocation approach to the producer of the waste gas and to the consumer of the waste gas should ensure that the emissions related to the waste gas are not double counted in the allocation

2. The values of the benchmark curve established for coke production should consider the direct emissions in the coke oven plant (in which waste gases other than coke oven gas should be accounted for as natural gas) and the waste gas exported from the coke oven plant multiplied with the emission intensity difference between the waste gas and natural gas[20]. In the previous benchmark study (Ecofys / Fraunhofer, 2009), a benchmark value of 0.090 t CO_2 / t was calculated using this method[21]. No negative allocation occurs.

3. The values of the benchmark curve established for sinter production should consider the CO_2 emissions resulting from the carbon input to the sintering plant minus the carbon which is embodied in the sinter and other material product output. The CO_2 emissions from waste gases used for sinter production are again to be calculated using the emission factor of natural gas 56.1 kg CO_2/GJ. In the previous benchmark study (Ecofys / Fraunhofer, 2009), a benchmark value of 0.119 t CO_2 / t was calculated for sinter.

4. The values of the benchmark curve established for hot metal should consider the direct emissions in the hot metal facility (in which waste gases other than blast furnace gas and basic oxygen furnace gas should be accounted for as natural gas) and the waste gases exported from the hot metal facility multiplied with the emission intensity difference between the waste gas and natural gas[20]. In the previous benchmark study (Ecofys / Fraunhofer, 2009), a benchmark value of 1.147 t CO_2 / t was calculated for pig iron using this method[21]. In the current study, a benchmark for hot metal is proposed, including the basic oxygen furnace and the continuous casting process. The value should therefore be corrected as follows (IISI, 1998):

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[20] Note that this is equal to the sum of emissions embodied in the waste gas produced, the emissions from waste gases originating from other processes taken into with the emission factor of natural gas, and the emissions of non-waste gas fuels, corrected for the export of waste gas from the production process using the emission factor of natural gas.

[21] In the previous study, all gaseous fuel used and the waste gas were considered with natural gas equivalent. This yields, however, exactly the same result as the formulas used here (see the appendix A).

- The deduction of 0.172 t CO_2 / t pig iron for carbon dissolved in pig iron is no longer relevant, because the carbon dissolved is released in the basic oxygen furnace.
- The fossil fuel use in the basic oxygen furnace and in the continuous casting process should be added (0.011 and 0.002 t CO_2 / t respectively).
- A correction for the export of basic oxygen furnace gas should be made (0.046 t CO_2 / t) has to be made

This results in a benchmark value of 1.286 t CO_2 / t hot metal.

5. The values of the benchmark curve established for EAF crude steel production should consider all carbon input to the electric arc furnace, minus the carbon which is embodied in crude steel and other material product ooutput. The CO_2 content of waste gas applied for EAF steel production is to be accounted for with 56.1 kg CO_2/GJ.

6. The values for allocation to downstream processes that are allocated using a fall-back approach should be based on these approaches.

In order to provide for a deeper insight of the proposed method, an example calculation is given in appendix A.

Substitutability between electricity and fossil fuel may play a role for EAF steel. Steel production via the Electric Arc Furnace route is an electricity intensive process. Besides electricity, thermal input from oxy-fuel burners is however also brought to the charge. Within certain limits and dependent on the product (carbon or high-alloy steel) the shares of electricity use versus fuel use can be controlled in the EAF process. Benchmark curves on direct emissions could therefore be dominated by the most electricity intensive instead of the most carbon efficient installations. A more solid data basis on the amount of emissions from oxy-fuel burners is, however, necessary to allow for a decision on this issue.

4 Benchmark values

4.1 Background and source of data

Eurofer has set up its own benchmarking model. The benchmarking concepts underlying this model are in accordance with our concepts described above except for the allocation rules for waste gas. As already described above, Eurofer favours full allocation of the carbon content of waste gas to the waste gas producer, but their approach for coke ovens and blast furnaces does not reflect differences in performances between different waste gas uses in constructing benchmark curves (see Section 6.2 for the EUROFER opinion on this issue). The approach suggested in this report avoids this by replacing waste gas use with an equivalent use of the reference fuel natural gas and allocating the difference between the emission factors of the gases to the producer.

In order to determine benchmark curves, Eurofer has started a data collection among its members. Flow charts have been established for this purpose, which allow the mapping of CO_2 emissions for the products named above including the tracking of waste gas flows. The data collection is, however, not yet completed and only average carbon intensity values have been provided to the project team[22]. The results are presented in Table 10. It is to be emphasised that these are average values which are higher than the benchmark values discussed in the next section. The comparison could indicate quite some spread in the benchmarking curves. However, other factors may also explain some of the difference such as Eurofer's method of determining the values from a carbon balance. This explains the high value for the coke compared to the value calculated in this study.

Table 10 Average direct emissions of EU 27 sinter, coke and hot metal installations, 2007-2008 derived from a carbon balance method (Eurofer, 2009)

Product	**Number of plants (EU 27)**	**Level of coverage (rel. t product)**	**Average carbon intensity (t CO_2/t product)**
Sinter	32	82 %	0.25
Coke	43	61 %	0.43
Hot metal	41	78 %	1.64

4.2 Final proposed benchmark values

With the data available to the present, the determination of benchmark values based on the average of the 10 % most carbon efficient installations as prescribed by the amended Directive is not possible for any of the iron and steel industry's subsectors. Indicative values based on Best Available Techniques will therefore be presented in this section, in order to provide a rough idea of the actual final benchmark values. It has to be emphasised, however, that these values only represent an approximation.

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[22] Personal communication – Eurofer via e-mail 3rd of September 2009. Norway and Iceland are not included.

Benchmark values for the iron and steel sector based on Best Available Technique have been investigated by part of the consortium in a previous benchmark study in 2008 (Ecofys/Fraunhofer-ISI, 2009). The results are summarized in Table 11.

Table 11 Overview of indicative benchmark values for iron and steel production, derived as BAT in a previous benchmark study (Ecofys/Fraunhofer-ISI 2009, IISI 1998)

Process	**Product**	**Benchmark (t CO_2/t product)**
Coke making	Coke	0.090
Sinter making	Sintered ore	0.119
Hot metal production	Hot metal	1.286[1]
EAF non-alloy, high-alloy and other alloy steel production[2]	EAF crude steel	0.058

[1] Corrected for the chance from pig iron to hot metal benchmark as explained in Section 3.3.

[2] Further differentiation between non-alloy steel on the one hand and high-alloy and other alloy steel on the other hand might be necessary.

4.3 Possibility of other approaches

The main alternative approach to the “hot metal” benchmark proposed here consists in two separate benchmarks for iron production and steel production. This approach was discussed in the initial benchmarking study published earlier in the year (Ecofys / Fraunhofer-ISI 2009).

The second major alternative to method proposed in this report is full allocation of allowances for the waste gases to the waste gas producers, as proposed by Eurofer.

5 Additional steps required

In the chapters 3.1 and 4.1 several open issues have been mentioned on which to the present no decision could be taken due to lack of data.

1. An exact product definition for hot metal is still missing. Since hot metal is not listed in the PRODCOM classification, an internal industry standard or classification will be required.

2. For further work on the determination of final benchmark values based on the average of the 10 % most carbon efficient installations, benchmark curves for the individual subsectors are required. Separate benchmark curves for EAF non-alloy steel on the one hand and EAF high-alloy and other alloy steel on the other hand are necessary to allow for a decision between one or two benchmarks for EAF steel.

3. It has to be defined, which casting steps are to be included in the hot metal benchmark and which will be considered as downstream activities and therefore treated by a fallback approach.

4. Further information is necessary on the question, in how far substitutability of electricity and fossil fuel plays a role for EAF steel production.

5. For foundries further data input is required from CAEF to determine the nature of the product, the process delimitation and the spread across the benchmarking curves if benchmarking may be considered as a suitable approach given the relatively small contribution to the emissions of the iron/steel sector.

6 Stakeholder comments

Comments on the concept developed for iron/steel have been made by Eurofer on the following issues[23]. Given the importance of the issue regarding waste gas, a reply from the project team to the issues raised have been included in the text.

6.1 Allocation for waste gases

General design of the method

Eurofer sees problems with the waste gas allocation proposal of Ecofys/Fraunhofer. The cause of the problems with the proposed approach is its focus on the creation of a benchmarking methodology which seamlessly can be applied across all sectors. Whilst from a methodological viewpoint this has been achieved, the proposed system fails to comply with the basic legal and political requirements of the amended Emission Trading Directive.

The most obvious issues which need to be addressed and solved are:

- The proposal of Ecofys/Fraunhofer does not take into account ***objectives of the amended Emissions Trading Directive***. Benchmark-based free allocation has been introduced to counter the danger of carbon leakage. As part of that discussion the European Parliament and Council acknowledged in the amended Directive explicitly that power production from waste gases must not be subject to auctioning, because that would directly impact the competitiveness of the waste gas generating sectors. Therefore the treatment of waste gas based electricity generation must follow the treatment of the waste gas generating sectors. This means full allocation in the case of waste gases from the carbon leakage endangered steel industry.

  Reply from the project team: We do not introduce with our methodology any final decision on the issue whether power production from waste gas may be allocated or not. Our reading from the relevant paragraphs in the amended ETS Directive is that this is an open issue. Our methodology only provides an indication for the split of allowances between the producer and possibly the user of the waste gas. The objective of avoiding carbon leakage may be taken into account either by financial compensation or an explicit allocation of allowances to electricity from waste gases. It is not up to our method to anticipate such a decision.

- ***Electricity produced from waste gases is CO_2-free***: Nevertheless, the Ecofys/Fraunhofer proposal places CO_2 costs on the so produced electricity. The steel industry does not discard the carbon used for steel making but collects it and produces gases (the so called “waste gases”) which in turn are used to produce electricity or heat. This saves CO_2 because instead of using coal for steel making <u>and</u> natural gas

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[23] Personal communications, Eurofer via e-mail 11th of July, 17th of September and 23rd of September 2009

for electricity production, only the coal is needed to produce both electricity and steel.

Reply from the project team: see reply to the previous point. Our methodology does not automatically imply a carbon price for electricity from waste gas. It to take into account the specific nature of the waste gases by allocating a larger amount with the producer of the waste gas. On the consumer side, waste gases are put on an equal foot with natural gas as the reference fuel, avoiding thus important distortion in the benchmarking curves of the consumers and making discussions on these distortions unnecessary.

- The proposal of Ecofys/Fraunhofer ***disincentivises efficient fuel use***. This is in contradiction to the declared objective of the proposal of Ecofys/Fraunhofer. A waste gas producer which would stop flaring and make electricity instead would not be rewarded. Any efficiency improvements in electricity generation would have no effect.

  Reply from the project team: if waste gases are flared, all[24] *or part*[25] *of the emissions related to this flaring are not given allowances in our methodology which puts an incentive not to flare. In case of electricity generation from waste gas our methodology leaves it open for the policy debate whether waste gas electricity is to be compensated in leakage sectors like other electricity generation or may receive free allowances according to the "may"-provision of the amended EU ETS Directive.*

- According to the proposal of Ecofys/Fraunhofer even the ***best performers in the steel industry will by far not be able to cover their CO_2 emissions with free allowances***. There is a severe case of non-compliance with the Emissions Trading Directive. If best performers have to face an extra CO_2 burden inherent to the benchmarking system design, by collateral effect the whole industry will have its exposure to the leakage risk dramatically increased. Best performers in the steel industry would be disadvantaged against best performers in other industries, which is not in line at least with Recital 27 of the amended Emissions Trading Directive.

  Reply from the project team: In our methodology generally the best performers will receive full allocation in compliance with the amended EU ETS Directive as long as the users of the waste gases are also part of the EU ETS. Users outside the ETS will not receive allocation in agreement with the overall design of the ETS. The case of waste gas use for electricity generation is special as there are two goals in the EU ETS that need to be reconciled (no free allocation to electricity generation versus free allocation/compensation for electricity from waste gases).

- The ***proposal of Ecofys/Fraunhofer treats waste gas like a commercial fuel. This is not correct***, since waste gases cannot be avoided. The Emissions Trading Directive is very clear on this point ("unavoidable"). The parallel with heat production is irrelevant as heat is produced and delivered on demand. Consequently, equal treatment of waste gas and other fuels does not comply with the Emissions Trading

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[24] Case of coke oven gas with an emission factor lower than natural gas.

[25] Case of blast furnace or BOF gas with an emission factor higher than natural gas.

Directive. The steel maker has no possibility to stop producing waste gases if he wants to produce steel. Therefore, compensation for electricity cost is not an adequate substitution for free allowances. Compensation is uncertain, whilst the production of "waste gases" is unavoidable. Steel industry owned power plants are primarily designed and operated to supply a site with steam (see IPPC 2008). This is a huge difference to a commercial power plant. The unavoidable nature of waste gas generation in combination with allocation of allowances to the waste gas users amplifies the economically disadvantageous position of the waste gas producer.

Reply from the project team: Waste gas receives a special treatment in our approach as a larger fraction of the allowances is allocated to the producer in case of the waste gases with high emission factors. On the consumer side our methodology puts the waste gases on an equal foot with the reference fuel natural gas. Whether beyond that full free allocation is to be made for electricity generated from waste gases is a decision not to be made by our methodology but in the policy sphere.

- The proposal of Ecofys/Fraunhofer ***does not take into account that some waste gases are more CO_2-intensive than natural gas and others less.*** The same rule can not be applied to both. Example: Coke Oven Gas is less CO_2-intensive than natural gas. According to the proposal by Ecofys/Fraunhofer the natural gas related CO_2 must be subtracted, which will lead to a negative CO_2 value for the coke oven gas producer! Moreover in the case of the Coke Oven Gas the more gas would be produced the better it is for the total emissions. This could be interpreted as an incentive to produce more coke oven gas.

  Reply from the project team: This is a misinterpretation of our methodology. No negative allocation will occur as the coke oven gas as an input to the coke oven gas producer for the under-firing would also be considered with the emission factor of natural gas. The same would be the case if BF gas is used for the under-firing.

- ***Data demands by the proposal of Ecofys/Fraunhofer can not be met by historical data***. Consequence: The lack of robust and reliable data does not allow the construction of CO_2 distribution curves and therefore benchmarks with an appropriate level of accuracy. Necessary monitoring does not exist until now. As a number of waste gases flows would have to be monitored in volume, energy and carbon content, the application of the Ecofys/Fraunhofer model would require a hugely complex monitoring system prone to data quality issues.

  Reply from the project team: In difference to the approach favoured by Eurofer, waste gas streams need to be collected, however, only if crossing system boundaries to other uses. Waste gas flows within the hot metal benchmark for example need not to be monitored, only if they cross the boundary to a hot-rolling plant. Thus, the additional effort of collecting those data as compared to the gain in coherence of the methodology seems acceptable.

Dynamic aspects of the method

Eurofer further discusses the dynamic implications of the methodology proposed by the team, especially the dynamic aspects on the user side of the waste gases:

The amended ETS Directive explicitly allows the allocation in the case of waste gases to the gas producer, while not ruling out an allocation to the gas consumer. The waste gas user has at least on mid-term the choice of fuel switching and may impose demands on the price. If parts of the ex-ante allocations were to be given to the gas consuming unit as the consortium proposes, the following problems would arise:

- **In case of ceasing operations by the gas consumer,** no allocations would be given out anymore, but the waste gas is still being produced and needs to be processed. Unless this is done by a new entrant no possibility would exist to allocate certificates for such operations.

- **In case of ceasing steel making operations** (or any other benchmarked one such as coke making) the originally allocated certificates to the waste gas consumer cannot be withdrawn, because there is no change in his operations (which can be continued with e. g. natural gas). This would result in overallocation and true windfall profits.

- **Fuel switching** would be a very valuable option for consumers. Given that waste gas based electricity or heat production is much more CO_2-intensive than gas based, it would make sense for the waste gas consumer to receive the full allocation for eight years worth of waste gas at the beginning of the period, but then actually produce electricity or heat from natural gas and cash in the unused certificates allocated. This would not be a significant change of operations requiring a withdrawal of allocations and anyhow in most cases some proportion of natural gas would be burned in such waste gas electricity plants anyhow. This is difficult to control by legislation and by private contracts.

- Increased steel production leads to **increased waste gas production**. How would the waste gas combusting installation be incentivised to take the additional waste gas? Given that using waste gas requires special equipment (burners, etc.) it is highly unlikely that one could just sell small quantities as supplements to other users.

- EUROFER asks to note that due to the nature of the waste gas (unavoidability, necessity of immediate use) the waste gas user is always in a stronger position than the waste gas producer.

- Most importantly perhaps, any savings of CO_2 emissions through lowering the waste gas produced would not benefit the responsible gas producer, but only the gas consumer; therefore there is **no incentive for the waste gas producer to invent or invest** adequately. In any case, switching between waste gas consumers would become extremely difficult for the gas producer so that the **administrative burden** alone could imply that efficient and climate friendly novel uses for waste gases would even not be considered. How to construct a system by which **newly entering waste gas consumers** can be adequately allocated ex-ante appears very unclear.

Reply from the project team: While we acknowledge that some of these dynamic aspects may need further considerations, especially through provisions on the new entrants, we think that these are technical points that can be solved while maintaining the integrity of the method. However, given the fact that the EU ETS is designed as an ex-ante allocation system, by definition not all dynamic effects can be corrected.

Impacts on benchmarking curves

EUROFER acknowledges the concerns of the consultants on possible unjustified differentiated treatment of plants with waste gas access and plants which have no waste gas access. The system proposed by EUROFER takes this into consideration. In the following, EUROFER discusses the possible scenarios for the different activities of the steel industry.

- Sintering does use very little waste gas, if any. In some cases part of ignition gas needs are covered by waste gases. In such a case the maximum share of affected CO_2 emissions is 1.6 %.

- Coke making and blast furnace making can make use of other waste gases or other fuels than the one directly produced. In the case that these fuels are non-waste, the respective installation will be placed towards the CO_2-intensive side of the CO_2 intensity distribution curve. In the case that waste gases are used, the position of this installation on the CO_2 intensity distribution curve will not be affected (because the waste gases used are accounted for by the benchmark value of the gas producing installation). The overall effect of this system is to place the benchmark value at the process that utilises the maximum of the resulting waste gases for coverage of its own energy needs. This is a very conservative approach which aims both at process improvements and resource conservation.

- Downstream operations can not produce waste gases but may consume them. Where they are placed under a CO_2 intensity distribution curve, waste gas using operations would constitute the benchmark but at levels, which could not be achieved by installations which have no access to waste gases.

A complication arises regarding the position of units using waste gas and units which do not in a benchmark curve. As consumed waste gases are not taken into consideration in the benchmarks to avoid double counting, the first will be best performers whilst the latter will be in the tail of the curve and hence disadvantaged. To avoid misalignments in CO_2 intensity distribution curves of waste gas using installations, these should be treated as outliers and receive a benchmarking alternative. Due to their relatively small share of CO_2 emissions, this could be the general rule for processes other than coke making, sintering and blast furnaces. Grandfathering of their non-waste gas related CO_2 is the option favoured by EUROFER.

Reply from the project team: In our methodology artificial correction for plants which use waste gases is unnecessary. We see the fact that benchmarking curves on the user side of the waste gases are distorted as a major drawback of this method.

Rules for transfer of allowances

In the third trading period, we must assume significant under-allocation, i.e. installations will emit actually more CO_2 than the benchmarks allow for, plus the correction factor defined in Article 10a (5). This must be taken into consideration when **designing rules for transfer of allowances** together with waste gases or hot metal. This is also an argument for allocating to the gas producer, because then the resulting shortage arises at the place where decisions about production and hence gas volumes can be made. There are **two possible approaches** currently debated:

- **French approach**: waste gas related certificates are allocated at the producer, who is also responsible for surrendering certificates amounting to the resulting emissions from these waste gases irrespective of their emission location. This approach has the merits of simplicity and improved transparency. The rules must be designed so that on calculating emissions (MRV[26] rules) waste gases or hot metal leaving the installation would be equated with their eventual CO_2 emission, while such streams entering a site are not considered in the carbon balance calculation identifying the CO_2 emissions. Conditional for its EU wide application is the solid legal refutation of legal opinions (e.g. in Germany) that it is not compatible with European law for the reason that the emitting source must surrender certificates.

- **German approach**: waste gas related certificates are allocated at the producer, who is required to forward them together with the waste gas that is sold or otherwise transferred to another operator. This approach is a legal obligation to transfer certificates with the waste gas[27]. However, owing to adequate allocation, the issue was never settled in court how many certificates need to be transferred if the initial allocation is short. This could introduce serious limitations on the workability of this approach in an environment dominated by underallocation. The issue is however slightly complicated by the fact that in some cases there are already contracts existing for the transfer of waste gases or hot metal which do not specify anything with respect to certificate transfer. It might be possible to introduce a special provision to allow opening of such long term contracts or allowing special cancellation terms if no agreement could be reached. Given the limited number of cases this appears to be a manageable issue. One could suggest that the default solution is to calculate the ration of allocated certificates to total emissions including waste gas related ones for the gas producing unit. This ration will be used to determine for a given waste gas how many certificates need to be transferred. Such a rule should be open to be replaced by contractual agreements between the parties involved.

Reply from the project team: Our methodology while recognizing the importance of the producer of the waste gases, sets also incentives for the user of the waste gases to use them efficiently which is in our view better in agreement with the general design of the EU ETS than the only allocation to the waste gas producer.

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[26] MRV: Monitoring, Reporting, Verifying

[27] It does not apply to hot metal as this currently is not included in the blast furnace allocation in Germany.

Allocation for downstream activities

The partial use of waste gases in downstream processes adds a complexity to the fall-back allocation in the iron and steel sector, since it has to be ensured that double allocation will be avoided. The obvious solution for the treatment of downstream activities is a grandfathering system, which is based only on non-waste gas emissions. This would provide a fair system allowing sufficient allocation in particular for stand-alone units, but also for integrated production sites operating such facilities. Its disadvantage is that it does not reward better performers (to the contrary), but its advantage is that it can acceptably handle the multitude of individually different installations quite effectively.

Such an allocation would in any case be subject to the correction factor of Article 10a (5), because this prescribes a ceiling for all free emissions.

Looking forward to 2021 and the fourth period one could then envisage a benchmark system based on the detailed data then available through the CITL database for these installations. However, in doing this, one would have to find a solution for allocation rules taken into consideration that some units have access to and use waste gases while others do not.

Reply from the project team: Our methodology makes it considerably easier to move in some point in time to a benchmarking based approach for products which may now be dealt with a fall-back approach because it allows to establish unbiased benchmarking curves also on the user side. It is also compatible with a fall-back approach itself, because waste gases are taken into account on the user side with the emission factor of natural gas.

6.2 Eurofer proposition for some special installations

1. Production of liquid ferrochromium: The ferrochromium smelter is a process similar to iron reduction in a blast furnace. The carbon intensity of ferrochromium production via this process route is comparable to the blast furnace process carbon intensity. Therefore it is appropriate to include the ferrochromium production via ferrochromium smelter in the “hot metal” benchmark.

2. Blast furnace used for recycling: Iron containing waste materials are processed in a sintering installation to sinter, which is used to produce foundry crude iron and zinc concentrate in the blast furnace. The consumption of reducing agents and the specific emissions are considerably higher than in the usual blast furnace due to higher inputs of zinc and alkali, higher specific slag amounts and higher silicon content of crude iron. The process does not fit into the crude iron benchmark curve. There is only one blast furnace operating this way worldwide. It should be investigated, which allocation method would fit best to this process; presumably a fallback option has to be chosen.

3. Pelletisation in integrated sites: Pelletisation of iron ore in integrated sites is different from pelletisation of magnetite iron ore in mines. Pelletisation installations in integrated sites must be aggregated with the sinter strands onsite because they are not independent. Indeed, the parameters used for both the pelletisation and the sintering process are linked so as to suit best the quality needs of the charge fed to the blast furnace.

4. Iron powder production: There is one iron powder production facility in the EU27, operating direct reduction in a tunnel kiln followed by a final reduction step in belt furnaces. The emissions are comparable to the emissions of the production of steel via the BF-BOF process. It must be investigated whether this product can be included in the hot metal benchmark.

5. Induction melting furnaces, steel remelting furnaces and dust reduction/reclamation furnaces: These electro-intensive melting processes should not be considered as secondary metallurgy and therefore are beyond the perimeter of the steel production benchmark. It should be investigated which allocation method would fit best to these processes.

6. Spiral welding of tubes: Some installations have quite significant emissions of CO_2. Depending on the interpretation of the aggregation clause, this process might be covered by the ETS. The product to be considered in relation with this process is the welded product which can hardly be benchmarked. The best option would be to treat this production step separately and apply a fall-back option.

7 References

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Appendix A: Example for waste gas benchmarking and allocation

For the discussion of the example it is important to distinguish the setting of the benchmarking curve from the allocation and from the real emissions. We will therefore separately discuss these issues. We discuss two cases: the case of coke ovens with a waste gas having lower emission intensity than natural gas, and the case of blast furnaces having higher emission intensity than natural gas.

We use in this annex the methodology proposed in the main report on the project approach and general issues but we discuss in the last section of this annex two equivalent methods.

A.1 Coke ovens

The amended Directive prescribes benchmarks based on the average emission intensity of the 10 % most efficient installations producing the same product. In the following we determine the emission intensity (position in the benchmarking curve) of an example coke oven plant and of a user for the waste gas (coke oven gas) according to the method described in chapter 3.3 (split of allowances for the carbon content of waste gas between producer/consumer.)

Producer of the coke oven gas

An assumed energy performance for the example coke oven plant is given in Table 12.

Table 12 Assumed performance of an example coke oven plant (values per t of coke)

Carbon content of coal input (t CO_2)	**Fuel input for under-firing (GJ)**	**Carbon content of coke output (t CO_2)**	**Energy content of coke oven gas output (GJ)**
3.802	2.618	3.438	8.080

[1] For simplicity, we ignore steam use in by-product plants and steam for the coal moisture process

In the determination of the emissions intensity of the example coke oven plant, we assume four different configurations that all perform according to this performance:

Coke oven 1:	Using blast furnace gas (BFG) for the under-firing and exporting the coke oven gas to other users
Coke oven 2:	Using natural gas (NG) for the under-firing and exporting the coke oven gas to other users[28]
Coke oven 3:	Using coke oven gas (COG) for the under-firing and exporting the remaining coke oven gas to other users
Coke oven 4:	Supplying its demand of fuel with 50% NG and 50% COG[1] and exporting the remaining COG

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[28] This is not a very likely configuration, as in practice only BFG and COG is used, but is added for explanatory reasons

In line with the formula given in Chapter 6.2 of the report on the project approach and general issues, the CO_2 emission intensity of these plants are calculated using the following formula:

- \+ Direct emissions from the coke oven plant (thereby taking the emission factor of NG for waste gases produced in other processes such as BFG used for the under-firing of the coke ovens)
- \+ Exported COG * (emission factor of COG – emission factor of NG)

The resulting emission intensity is given in Table 13 and leads to an emission intensity of 0.058 t CO_2/t coke for all four coke ovens. In Table 14 we give the emission intensity for a coke oven which has an under-firing which is about 15% less efficient, but the same coke yield.

Table 13 Calculation of the emission intensity per t coke of example coke oven plants. Individual figures might not match due to rounding.

	Configuration 1	**Configuration 2**	**Configuration 3**	**Configuration 4**
Energy for under-firing (GJ / t)	2.618	2.618	2.618	2.618
Fuel used	BFG	NG	COG	NG / COG
Emission factor used in calculation (t CO_2 / GJ)	0.0561	0.0561	0.0451	0.0506
Direct emissions (t CO_2 / t)	0.147	0.147	0.118	0.132
COG export (GJ / t)	8.080	8.080	5.462	6.771
Difference in emission factor COG and NG (t CO_2 / GJ)	-0.0110	-0.0110	-0.0110	-0.0110
Deduction (t CO_2 / t)	0.089	0.089	0.060	0.074
Emission intensity (t CO_2 / t)	**0.058**	**0.058**	**0.058**	**0.058**
Actual emission factor (t CO_2 / GJ)	0.2702			
Actual emissions (t CO_2 / t)	0.707			

Table 14 Calculation of the emission intensity per t coke of example coke oven plants with 15% more energy use in under-firing. Individual figures might not match due to rounding.

	Configuration 1	Configuration 2	Configuration 3	Configuration 4
Energy for under-firing (GJ / t)	3.000	3.000	3.000	3.000
Fuel used	BFG	NG	COG	NG / COG
Emission factor used in calculation (t CO_2 / GJ)	0.0561[1]	0.0561	0.0451	0.0506
Direct emissions (t CO_2 / t)	0.168	0.168	0.135	0.152
COG export (GJ / t)	8.080	8.080	5.080	6.580
Difference in emission factor COG and NG (t CO_2 / GJ)	-0.011	-0.011	-0.011	-0.011
Deduction (t CO_2 / t)	0.089	0.089	0.056	0.073
Emission intensity (t CO_2 / t)	**0.079**	**0.079**	**0.079**	**0.079**
Actual emission factor (t CO_2 / GJ)	0.2702			
Actual emissions (t CO_2 / t)	0.811			

[1] For consumers of waste gas from other processes, the emission factor of NG is used, see below

In the method by EUROFER, the basis for the emission intensity is the CO_2 embodied in the total amount of coke oven gas. Based on Table 12 this can easily be calculated as 0.364 t CO_2 / t (i.e. 3.802 t CO_2 in coal – 3.438 t CO_2 in coke). To this, the non waste gas emissions are added. For the example coke oven plant, the resulting emission intensity is:

Configuration 1:	0.364 t CO_2 / t (no other non-waste fuels used)
Configuration 2:	0.511 t CO_2 / t (natural gas used)
Configuration 3:	0.364 t CO_2 / t (no other non-waste fuels used)
Configuration 4:	0.437 t CO_2 / t (half natural gas used)

For the coke oven plant with 15% more energy use for under-firing, the resulting emission intensity is:

Configuration 1:	0.364 t CO_2 / t (no other fuels used)
Configuration 2:	0.532 t CO_2 / t (natural gas used)
Configuration 3:	0.364 t CO_2 / t (no other fuels used)
Configuration 4:	0.448 t CO_2 / t (half natural gas used)

Figure 2 shows that the four configurations appear at the same level in the benchmarking curves, as they have the same performance, but different configuration with respect to fuel used. They will get the same allocation and determine the benchmark level. Figure 3 shows that this is not the case when there is full allocation to the producer, i.e. the EUROFER method. Furnaces using waste gases, including the own waste gas, appear as better in the benchmarking curves (i.e. having a lower emission intensity) for the producers because the fuel for under-firing needs to be set to zero in order to avoid double counting. When natural gas is used, the fuel for under-firing has to be taken into account. This implies that even if natural gas would be used at the benchmark level of energy use it would not receive allocations to the benchmark level. Figure 4 and Figure 5Figure 5 show similar curves for the same four furnaces but operating at a less efficient level (roughly 15% higher use of gas for under-firing). The benchmark level set by the furnaces of Figure 2 and Figure 3 is also shown. As expected the four furnaces are above the benchmark level and get a smaller share of their emissions allocated when emissions are split between producer and user (Figure 2). On the other hand, Figure 3 shows that the less efficient coke ovens using waste gas for the under-firing would still be at the same position in the benchmark curve (i.e. with the same emission intensity) because the waste gases for the under-firing have to be set to zero.

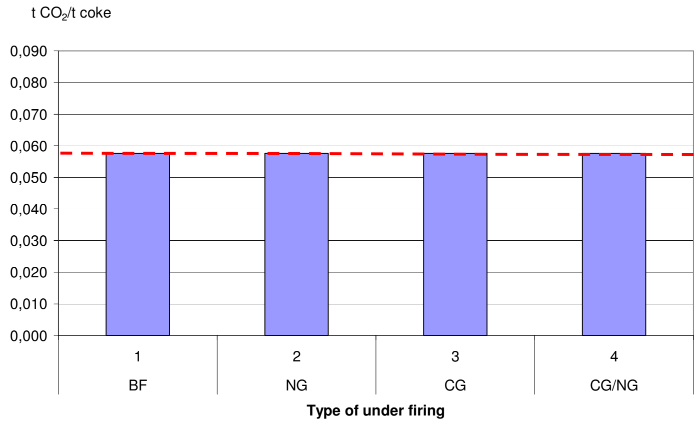

Figure 2 Benchmarking curves for the producer of waste gas (coke oven) in the case of split allocation between producer and user (all four furnace operate at BM)

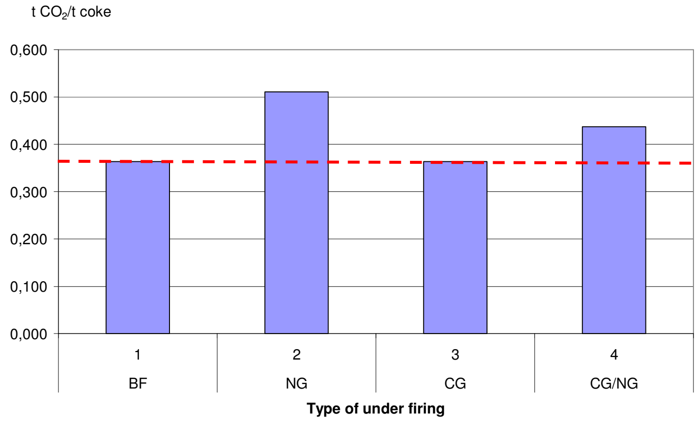

Figure 3 Benchmarking curves for the producer of waste gas (coke oven) in the case of full allocation to the producer (all four furnace operate at BM)

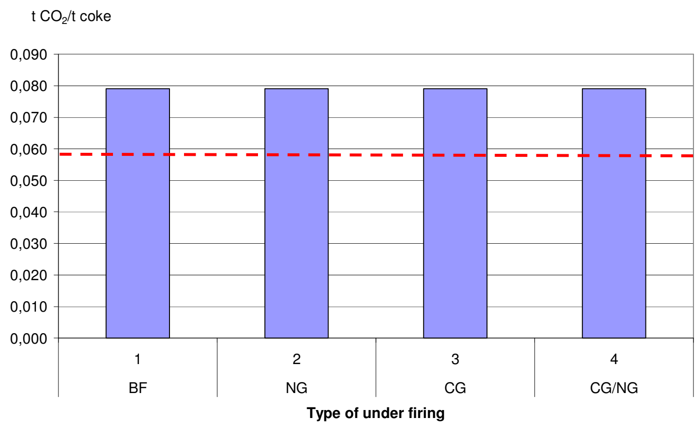

Figure 4 Benchmarking curves for the producer of waste gas (coke oven) in the case of split allocation between producer and user (all four furnaces less efficient than BM)

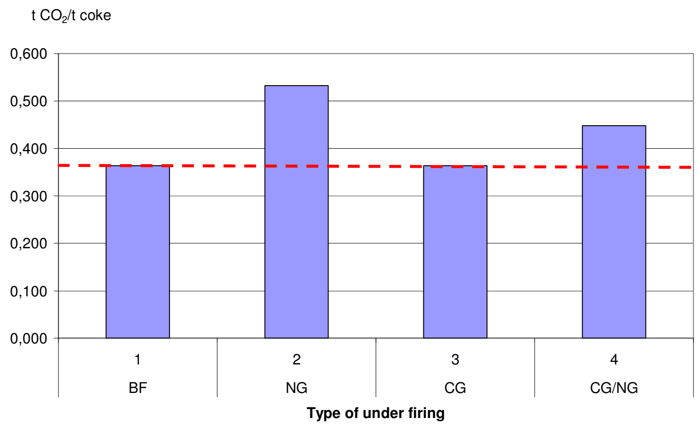

Figure 5 Benchmarking curves for the producer of waste gas (coke oven) in the case of full allocation to the producer (all four furnaces less efficient than BM)

User of the coke oven gas

We assume a coke oven gas user that is also part of the EU ETS and benchmarked[29]. This user of the coke oven gas will, according to the methodology proposed, have to take into account the coke oven gas with an emission factor equivalent to natural gas in the calculation of its emission intensity (NB, this is also how BFG is treated in the coke oven gas example above).

For simplicity reasons we assume that the user is consuming 8.08 GJ/t of product (which is the benchmark energy performance) and that the demand is met with the coke oven gas from the coke oven, or with natural gas. For the coke oven plant that is performing according to the benchmark (Table 13), the resulting situation is given in Table 15, for the coke oven plant having 15% less efficient under-firing, the resulting situation is given in Table 16.

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[29] In case the user would be allocated with a fallback approach, the arguments would be similar.

Table 15 Calculation of the emission intensity for COG user that operates at benchmark performance while the coke oven gas producer also operates at benchmark level. Individual figures might not match due to rounding.

	Configuration 1	**Configuration 2**	**Configuration 3**	**Configuration 4**
Energy used by COG user (GJ / t)	8.080	8.080	8.080	8.080
Of which COG	8.080	8.080	5.462	6.771
Of which NG	-	-	2.618	1.309
Emission factor used in calculation (t CO_2 / GJ)[1]	0.0561	0.0561	0.0561	0.0561
Emission intensity (t CO_2 / t)	**0.453**	**0.453**	**0.453**	**0.453**
Actual emission factor (t CO_2 / GJ)	0.0451	0.0451	0.0486	0.0469
Actual emissions (t CO_2)	0.364	0.364	0.393	0.379

[1] For consumers of waste gas from other processes, the emission factor of NG is used

Table 16 Calculation of the emission intensity for COG user that operates at benchmark performance while the coke oven gas producer operates at less efficient level. Individual figures might not match due to rounding.

	Configuration 1	**Configuration 2**	**Configuration 3**	**Configuration 4**
Energy used by COG user (GJ / t)	8.080	8.080	8.080	8.080
Of which COG	8.080	8.080	5.080	6.580
Of which NG	-	-	3.000	1.500
Emission factor used in calculation (t CO_2 / GJ)[1]	0.0561	0.0561	0.0561	0.0561
Emission intensity (t CO_2 / t)	**0.453**	**0.453**	**0.453**	**0.453**
Actual emission factor (t CO_2 / GJ)	0.0451	0.0451	0.0486	0.0469
Actual emissions (t CO_2)	0.364	0.364	0.397	0.381

In the method by EUROFER, waste gas should not be taken into account (to avoid double counting). For the example COG user, the resulting emission intensity is:

Configuration 1: 0 t CO_2 / t (only waste gases used)
Configuration 2: 0 t CO_2 / t (only waste gases used)
Configuration 3: 0.147 t CO_2 / t (the natural gas used)
Configuration 4: 0.074 t CO_2 / t (the natural gas used)

For the coke oven plant with 15% more energy use for under-firing, the resulting emission intensity for the COG user is:

Configuration 1: 0 t CO_2 / t (only waste gases used)
Configuration 2: 0 t CO_2 / t (only waste gases used)
Configuration 3: 0.168 t CO_2 / t (the natural gas used)
Configuration 4: 0.084 t CO_2 / t (the natural gas used)

These figures show that the emission intensity for the waste gas users is zero. Obviously, this has little to do with benchmarking the consuming process[30].

In summary, we conclude that the approach for waste gases proposed in this study avoids the following problems:

- Distortion of the producer benchmark curves (which result from the fact that producer installations are also users, configuration 1)
- Distortion of the user benchmark curves
- Similar allocation for more or less efficient use of waste gases in producer installations

Allocation of allowances and actual emissions

The method as suggested results in the same number of allowances for the configurations 2/3/4 where only the coke oven gas and the coke oven gas consumer are part of the system. For configuration 1, obviously also the blast furnace benchmark should be taken into account to give a full picture on emissions and allocations for the total system. We leave this exercise to the reader. It is clear from the summarising table that, although there is a match between the total emissions and the total allocation of the system in case both consumer and producer perform at benchmark level, there is a difference between the allocation and emissions for the producer (a shortage of allowances) and consumer (an excess of allowances). Since the basis for the allocation is known, the possible transfer of allowances between the consumer and

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[30] If the consuming process would be treated with fuel mix benchmark as fall-back approach in which the emissions from natural gas are allocated, the EUROFER method would result in a larger amount of allowances in configuration 3 and 4 (where the COG is not used in the coke oven but elsewhere) or in a larger amount of allowances for the situation where the coke oven is less efficient (compare configuration 3 and 4 for the two situations).

producer not necessarily has to be regulated[31] and could be left to the two EU ETS installations[32].

Table 17 Allocation and actual emissions for coke both coke oven and COG user at benchmark level

	Configuration 1	**Configuration 2**	**Configuration 3**	**Configuration 4**
Allocation to producer (t CO_2)	0.058	0.058	0.058	0.058
Emissions of producer (t CO_2)	0.707	0.147	0.118	0.132
Allocation to consumer (t CO_2)	0.453	0.453	0.453	0.453
Emissions of consumer (t CO_2)	0.364	0.364	0.393	0.379
Total allocation (t CO_2)	**0.511**	**0.511**	**0.511**	**0.511**
Total emissions (t CO_2)	**1.071**	**0.511**	**0.511**	**0.511**

Table 18 Allocation and actual emissions for coke oven plant 15 % less efficient under-firing and COG user at benchmark level

	Configuration 1	**Configuration 2**	**Configuration 3**	**Configuration 4**
Allocation to producer (t CO_2)	0.058	0.058	0.058	0.058
Emissions of producer (t CO_2)	0.811	0.168	0.135	0.152
Allocation to consumer (t CO_2)	0.453	0.453	0.453	0.453
Emissions of consumer (t CO_2)	0.364	0.364	0.397	0.381
Total allocation (t CO_2)	**0.511**	**0.511**	**0.511**	**0.511**
Total emissions (t CO_2)	**1.175**	**0.532**	**0.532**	**0.532**

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[31] It is acknowledged that both production levels and the consumers of the waste gases can change over time. It is beyond the scope of this study to discuss in detail if and how this should be reflected in the number of allowances to be allocated over time and if the regulator should define rules for this. If such rules are developed, it is key that the initial allocation for the total system (i.e. for the producer and consumer together) is partly based on the activity of the producer of the waste gas producer (the difference in emission intensity between the waste gas and natural gas) and partly on the activity of the consumer of the waste gas consumer (the fact that a fuel is consumed).

[32] It should be noted that in many cases, both user and consumer are part of the same EU ETS installation.

A.2 Pig iron

In the following we determine the emission intensity (position in the benchmarking curve) of an example blast furnace and of a user for the waste gas (blast furnace gas) according to the method described in chapter 3.3 (split of allowances for the carbon content of waste gas between producer/consumer). For simplicity reasons, rather than assuming a hot metal benchmark and two waste gases (BFG and basic oxygen furnace gas), we assume a pig iron benchmark with only BFG production.

Producer of the blast furnace gas

An assumed energy performance for an example blast furnace is given in Table 12.

Table 19 Assumed performance of an example blast furnace (values per t of pig iron)

Carbon content of coal and coke input ($t\ CO_2$)	Fuel input for stoves (GJ)	Carbon content of pig iron ($t\ CO_2$)	Energy content of coke oven gas output (GJ)
1.518	1.442	0.172	4.982

In the determination of the emissions intensity of the example blast furnace plant, we assume three different configurations that all perform according to this performance:

BF 1:	Using NG for the stoves and exporting the blast furnace gas to other users
BF 2:	Using BFG for the stoves and exporting the remaining BFG to other users
BF 3:	Supplying its demand of fuel with 50% natural gas and 50% BFG and exporting the remaining BFG

In line with formula given in Chapter 6.2 of the report on the project approach and general issues, the CO_2 emission intensity of these plants are calculated using the following formula:

\+ Direct emissions from the BF
\+ Exported BFG * (emission factor of BFG – emission factor of NG)

The resulting emission intensity is given in Table 20 and leads to an emission intensity of 1.147 t CO_2/t coke[33] for all three blast furnaces. In Table 21, we give the emission intensity for a blast furnace which has a fuel use in the stoves which is about 20% less efficient, but the same BFG production.

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[33] Please note that in the approach suggested by Eurofer (that is full allocation to the producer), item 4 is not deduced for the benchmarking value. The value in item 2 for the under-firing depends in the approach on the type of fuel. If it is natural gas, it is the same value; if it is a waste gas, it is zero in order to avoid double counting.

Table 20 Calculation of the emission intensity per t pig iron of example blast furnaces at the benchmarking level. Individual figures might not match due to rounding.

	Configuration 1	**Configuration 2**	**Configuration 3**
Fuel use in stoves (GJ / t)	1.442	1.442	1.442
Fuel used	NG	BFG	NG / BFG
Emission factor (t CO_2 / GJ)	0.0561	0.2702	0.1631
Direct emissions (t CO_2 / t)	0.081	0.390	0.235
BFG export (GJ / t)	4.982	3.540	4.261
Difference in emission factor BFG and NG (t CO_2 / GJ)	0.2141	0.2141	0.2141
Deduction (t CO_2 / t)	-1.067	-0.758	-0.912
Emission intensity (t CO_2 / t)	**1.147**	**1.147**	**1.147**

Table 21 Calculation of the emission intensity per t pig iron in example blast furnaces with 20% more energy use in stoves. Individual figures might not match due to rounding.

	Configuration 1	**Configuration 2**	**Configuration 3**
Fuel use in stoves (GJ / t)	1.730	1.730	1.730
Fuel used	NG	BFG	NG / BFG
Emission factor (t CO_2 / GJ)	0.0561	0.2702	0.1631
Direct emissions (t CO_2 / t)	0.097	0.467	0.282
BFG export (GJ / t)	4.982	3.252	4.117
Difference in emission factor COG and NG (t CO_2 / GJ)	0.2141	0.2141	0.2141
Deduction (t CO_2 / t)	-1.067	-0.694	-0.882
Emission intensity (t CO_2 / t)	**1.164**	**1.164**	**1.164**

In the method by EUROFER, the basis for the emission intensity is the CO_2 embodied in the total amount of blast furnace gas. Based on Table 12 this can easily be calculated as 1.346 t CO_2 / t). To this, the non waste gas emissions are added. For the example blast furnace, the resulting emission intensity is:

Configuration 1: 1.427 t CO_2 / t (natural gas used)
Configuration 2: 1.346 t CO_2 / t (no other fuels used)
Configuration 3: 1.394 t CO_2 / t (half natural gas used)

For the blast furnace with 20% more energy use in the stoves, the resulting emission intensity is:

Configuration 1: 1.443 t CO_2 / t (natural gas used)
Configuration 2: 1.346 t CO_2 / t (no other fuels used)
Configuration 3: 1.386 t CO_2 / t (half natural gas used)

Figure 6 shows that the three configurations appear at the same level in the benchmarking curves, as they have the same performance, but different configuration with respect to fuel used. They will get the same allocation. Figure 7 shows that this is not the case when there is full allocation to the producer, i.e. the EUROFER method. Furnaces using waste gases, including the own waste gas, appear as better in the benchmarking curves (i.e. having a lower emission intensity) for the producers because the fuel for under-firing needs to be set to zero in order to avoid double counting. When natural gas is used, the fuel for under-firing has to be taken into account. This implies that even if natural gas would be used at the benchmark level of energy use it would not receive allocations to the benchmark level. Figure 8and Figure 9 show similar curves for the same four furnaces but operating at a less efficient level (roughly 20% higher use of gas in the stoves). The benchmark level set by the furnaces of Figure 6 and Figure 7is also shown. As expected the four furnaces are above the benchmark level and get a smaller share of their emissions allocated when emissions are split between producer and user (Figure 6). On the other hand, Figure 7 shows that even for the less efficient blast furnace, the one where waste gas is used in the stove, they would still be at the same position in the benchmark curve (i.e. with the same emission intensity) because the waste gases for the stoves have to be set to zero.

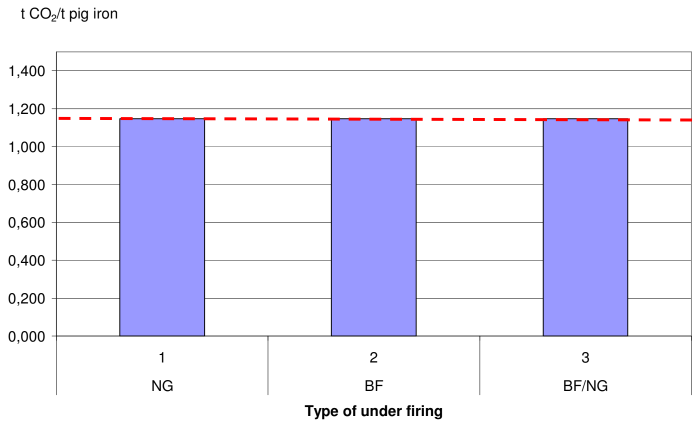

Figure 6 Benchmarking curves for the producer of waste gas (BF) in the case of split allocation between producer and user (all three furnaces operate at BM)

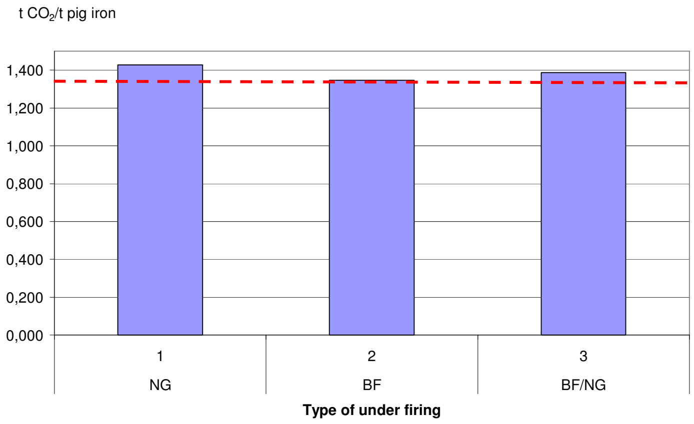

Figure 7 Benchmarking curves for the producer of waste gas (BF) in the case of full allocation to the producer (all three furnaces operate at BM)

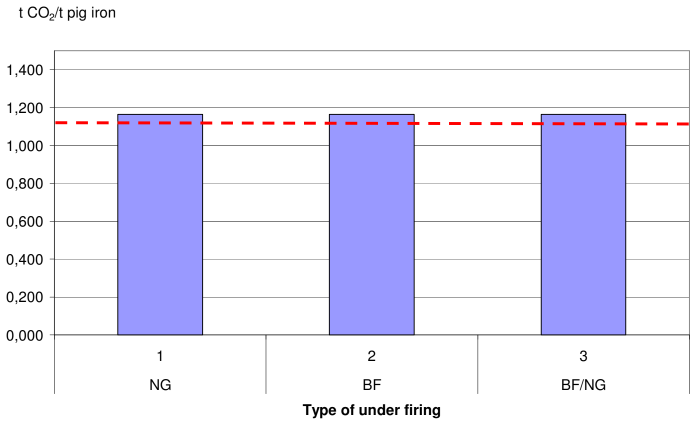

Figure 8 Benchmarking curves for the producer of waste gas (coke oven) in the case of split allocation between producer and user (all three furnaces less efficient than BM)

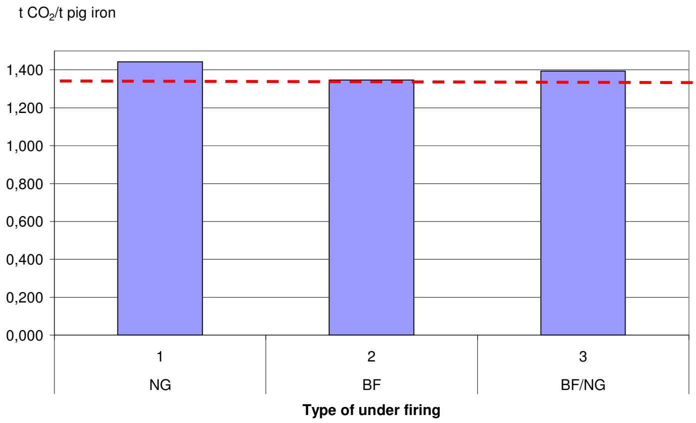

Figure 9 Benchmarking curves for the producer of waste gas (coke oven) in the case of full allocation to the producer (all three furnaces less efficient than BM)

User of the blast furnace gas

We assume a BFG user that is also part of the EU ETS and benchmarked. This user of the BFG gas will, according to the methodology proposed have to take into account the BFG with an emission factor equivalent to natural gas in the calculation of its emission intensity.

For simplicity reasons we assume that the user is consuming 4.982 GJ/t of product (which is the benchmark energy performance) and that the demand is met with the BFG from the blast furnace, or with NG. For the blast furnace that is performing according to the benchmark (Table 19), the resulting situation is given in Table 22, for the coke oven plant having 15% less efficient under-firing, the resulting situation is given in

Table 22 Calculation of the emission intensity for BFG user that operates at benchmark performance while the BFG producer also operates at benchmark level. Individual figures might not match due to rounding.

	Configuration 1	**Configuration 2**	**Configuration 3**
Energy used by BFG user (GJ / t)	4.982	4.982	4.982
Of which BFG	4.982	3.540	4.261
Of which NG	-	1.442	0.721
Emission factor used in calculation (t CO_2 / GJ)[1]	0.0561	0.0561	0.0561
Emission intensity (t CO_2 / t)	**0.279**	**0.279**	**0.279**
Actual emission factor (t CO_2 / GJ)	0.2702	0.2082	0.2392
Actual emissions (t CO_2)	1.346	1.037	1.192

[1] For consumers of waste gas from other processes, the emission factor of NG is used

Table 23 Calculation of the emission intensity for BFG user that operates at benchmark performance while the BFG producer operates at less efficient level. Individual figures might not match due to rounding.

	Configuration 1	Configuration 2	Configuration 3
Energy used by BFG user (GJ / t)	4.982	4.982	4.982
Of which BFG	4.982	3.252	4.117
Of which NG	-	1.730	0.865
Emission factor used in calculation (t CO_2 / GJ)[1]	0.0561	0.0561	0.0561
Emission intensity (t CO_2 / t)	**0.279**	**0.279**	**0.279**
Actual emission factor (t CO_2 / GJ)	0.2702	0.2082	0.2392
Actual emissions (t CO_2)	1.346	0.976	1.161

[1] For consumers of waste gas from other processes, the emission factor of NG is used

In the method by EUROFER, waste gas should not be taken into account (to avoid double counting). For the example blast furnace user, the resulting emission intensity is:

Configuration 1:	0 t CO_2 / t (only waste gases used)
Configuration 2:	0.081 t CO_2 / t (the natural gas used)
Configuration 4:	0.040 t CO_2 / t (the natural gas used)

For the blast furnace with 15% more energy use in the stoves, the resulting emission intensity is:

Configuration 1:	0 t CO_2 / t (only waste gases used)
Configuration 2:	0.097 t CO_2 / t (the natural gas used)
Configuration 3:	0.049 t CO_2 / t (the natural gas used)

This figures show that the emission intensity for the waste gas users is zero. Obviously, this has little to do with benchmarking the consuming process[34].

Allocation of allowances and actual emissions

The method as suggested results in the same number of allowances for all configurations. It is clear from the summarising table that, although there is a match between the total emissions and the total allocation of the system in case both consumer and producer perform at benchmark level, there is a difference between the allocation and emissions for the producer

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[34] If the consuming process would be treated with fuel mix benchmark as fall-back approach in which the emissions from natural gas are allocated, the EUROFER method would result in a larger amount of allowances in configuration 2 and 3 (where the BFG is not used in the BF process but elsewhere) or in a larger amount of allowances for the situation where the blast furnace is less efficient (compare configuration 2 and 3 for the two situations).

(an excess of allowances) and consumer (an shortage of allowances). Since the basis for the allocation is known, the possible transfer of allowances between the consumer and producer not necessarily has to be regulated[35] and could be left to the two EU ETS installations[36].

Table 24 Allocation and actual emissions for blast furnace and BFG user at benchmark level

	Configuration 1	**Configuration 2**	**Configuration 2**
Allocation to producer (t CO_2)	1.147	1.147	1.147
Emissions of producer (t CO_2)	0.081	0.390	0.235
Allocation to consumer (t CO_2)	0.279	0.279	0.279
Emissions of consumer (t CO_2)	1.346	1.037	1.192
Total allocation (t CO_2)	**1.426**	**1.426**	**1.426**
Total emissions (t CO_2)	**1.426**	**1.426**	**1.426**

Table 25 Allocation and actual emissions for blast furnace 20 % less efficient under-firing and BFG user at benchmark level

	Configuration 1	**Configuration 2**	**Configuration 2**
Allocation to producer (t CO_2)	1.147	1.147	1.147
Emissions of producer (t CO_2)	0.097	0.467	0.282
Allocation to consumer (t CO_2)	0.279	0.279	0.279
Emissions of consumer (t CO_2)	1.346	0.976	1.161
Total allocation (t CO_2)	**1.426**	**1.426**	**1.426**
Total emissions (t CO_2)	**1.443**	**1.443**	**1.443**

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[35] It is acknowledged that both production levels and the consumers of the waste gases can change over time. It is beyond the scope of this study to discuss in detail if and how this should be reflected in the number of allowances to be allocated over time and if the regulator should define rules for this. If such rules are developed, it is key that the initial allocation for the total system (i.e. for the producer and consumer together) is partly based on the activity of the producer of the waste gas producer (the difference in emission intensity between the waste gas and natural gas) and partly on the activity of the consumer of the waste gas consumer (the fact that a fuel is consumed).

[36] It should be noted that in many cases, both user and consumer are part of the same EU ETS installation.

The main difference between the case of the coke oven gas and the blast furnace gas is in the comparison of the actual emissions of the user with the allocated emissions. For coke oven gas the actual emissions are lower, for the blast furnace gas considerably higher. However, if the allocation rules also follow the natural gas equivalent, this is not an issue as becomes clear from the summarising tables.

A.3 Methodological discussion of split allocation

There are two main ways to present the split of allocations over producers and users:

- The one used in the example can be characterised as **being based on the differences in emission factors between the reference fuel natural gas and the waste fuel**. One inconvenience of this method is that it is less self-explaining and treats in appearance the waste fuel used in the process from where it is emitted in another way than waste fuels taken up from other processes.
- The second approach associates with the waste gas not the difference in emission factor between the reference fuel natural gas and the waste fuel **but the total emission factor of natural gas**. In this case not only the exported waste gas needs to be considered but the whole waste gas except the parts which are flared.

Both approaches deliver, however, the same emission intensities, which is shown by the following formulas. The configuration is a coke oven that uses part of its own coke oven gas and other gases for the inputs. It exports part of its coke oven gas.

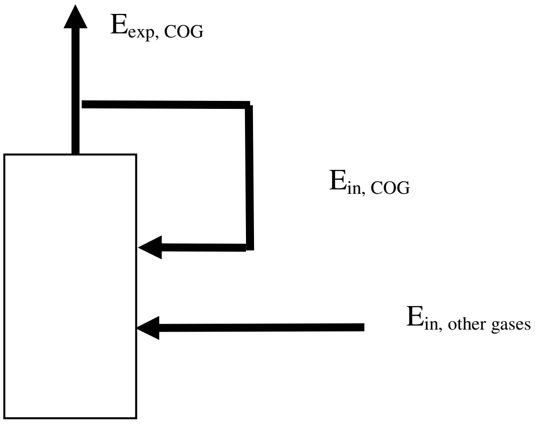

Figure 10 Configuration to show the equivalence of both methods

1) Method 1 based on differences in emission factors

\+ Direct emissions from the coke oven plant (thereby taking the emission factor of NG for waste gases produced in other processes such as BFG used for the under-firing of the coke ovens)
\+ Exported COG * (emission factor of COG – emission factor of NG)

In formula this is

$$\text{Emission intensity} = (E_{in, COG} * EF_{COG} + E_{in, other\ gas} * EF_{NG}) + E_{exp, COG} * (EF_{COG} - EF_{NG})$$

$$\boxed{= (E_{in, COG} + E_{exp, COG}) * EF_{COG} + E_{in, other\ gas} * EF_{NG} - E_{exp, COG} * EF_{NG}}$$

2) Method 2 based on absolute emission factors

+ Coal inputs
- Coke outputs
+ Direct emissions from the coke oven plant (thereby taking the emission factor of NG for ALL gases used for the under-firing of the coke ovens)
- Total coke oven gas (either used in the own plant or exported[37]) in natural gas equivalent

In formula this is

Emission intensity

$$= (\text{Coal}_{in} - \text{Coke}_{out}) + (E_{in,\ COG} * EF_{NG} + E_{in,\ other\ gas} * EF_{NG}) - E_{total,\ COG} * EF_{NG}$$

$$= E_{total,\ COG} * EF_{COG} + (E_{in,\ COG} * EF_{NG} + E_{in,\ other\ gas} * EF_{NG}) - E_{total,\ COG} * EF_{NG}$$

$$= (E_{in,\ COG} + E_{exp,\ COG}) * EF_{COG} + (E_{in,\ COG} * EF_{NG} + E_{in,\ other\ gas} * EF_{NG}) - (E_{in,\ COG} + E_{exp,\ COG}) * EF_{NG}$$

$$\boxed{= (E_{in,\ COG} + E_{exp,\ COG}) * EF_{COG} + E_{in,\ other\ gas} * EF_{NG} - E_{exp,\ COG} * EF_{NG}}$$

Conclusion:

Both ways calculate exactly the same emission intensity for the producer.

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[37] Note that this excludes flared parts of the waste gas. In such a way the emission intensity of a producing installation that flares is increased by these emissions, hence its position in the producer benchmarking curve becomes less favourable.