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A comparison study of EU and Japan methods to assess CO_2 emission reduction and energy saving in the iron and steel industry

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HIGHLIGHTS

► We calculated CO_2 emission from steel works of different energy efficiency level.
► We investigated the effect of different two methods of EUETS and Japan.
► Energy and CO_2 differ more than 10% by using different calculation methods.
► Some of methods may not fully account for energy saving efforts.
► Points of concern are identified for future ETS and setting benchmarks.

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ABSTRACT

Information on energy consumption and carbon dioxide (CO_2) emissions from the iron and steel industry may become important to the assessment of energy saving and the design of emissions trading schemes. This paper focuses monitoring aspects, used two methods to calculate CO_2 emission, the European Union Emission Trading Scheme and a method developed by the Japanese Iron and Steel Federation, to investigate the effect of the accounting method on the assessment of energy saving by four model steel mills with different levels of energy efficiency. Depending on the calculation method used, the calculated energy savings and calculated CO_2 emissions for a given mill were found to differ from 5% to 15% and 4% to 14% respectively, simply by using different calculation methods. Methodologies that evaluate only CO_2 emission and track emissions by process may not fully account for energy saving efforts such as using waste heat, generating power using byproduct gases, and energy management efforts applied over the whole mill rather than on a single process. Points of concern in the iron and steel industry are identified in the areas of calculating energy saving, determining CO_2 emissions, and setting benchmarks.

1. Introduction

Steel is widely used in our lives, and was a crucial material in human technological development. Steelmaking involves many processes that use large amounts of energy, including sintering, coke production, and reduction of iron ore. Steelmaking is estimated to have consumed 29 EJ globally in 2009, or 6% of total global energy consumption, and while emitting 2.5 Gt-CO_2 of greenhouse gases (WSA, 2011). Therefore, the possibility of energy saving and CO_2 emission reduction in the iron and steel industry has long attracted interest, both within academia and at the plant operations level.

The levels of energy consumption and CO_2 emission from steelmaking may become important fundamental information in the pursuit of energy savings and climate change mitigation, because these data could be used to assess overall energy saving performance and in the design of emission trading schemes. However, different assumptions and methods of calculation, such as determining individual processes, the degree of integration, and boundary definitions, result in different estimates of energy consumption and CO_2 emission (Tanaka, 2008; Siitonen et al., 2010). No calculation method is currently used as the global standard. Instead, a number of calculation methodologies are used around the world, including the European Union Emission Trading Scheme (EUETS) and the methodology adopted by the Japanese Iron and Steel Federation, which is used as a reporting format for the World Steel Association, and for the voluntary initiative by Keidanren (Japan Business Federation) also submitted to national committees related to deliberations on CO_2 emissions. Some of these methodologies may not fully or uniformly assess energy saving efforts in steel plants operating under different conditions.

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This paper presents results of a calculation of CO_2 emission using the methods of both the European Union Emission Trading Scheme [1] and the Japanese scheme in order to show the effects of these different accounting methods. Energy usage and CO_2 emissions were calculated for a set of model steel mills having different energy balances, using the methodology from the Emissions Reporting Form of EUETS and the method of the Japanese Iron and Steel Federation. The latter method is currently under discussion as a candidate for a standardized methodology for energy and CO_2 accounting at the International Organization for Standardization (ISO) and the World Steel Association. This study addresses the appropriateness of the methodologies and clarifies points of concern in calculating energy consumption, CO_2 emission, and energy saving, as well as in defining and using benchmarks and consumption rates in the steelmaking industry.

2. CO_2 emission calculation methodologies in EUETS

Reporting on CO_2 emission in EUETS is outlined in the COM Document "14. REPORTING FORMAT" (EC, 2007). These methodologies can be broadly separated into two groups: calculation-based methodologies based on material balance, and measurement-based methodologies based on actual measurement. The latter uses continuous emission measurement systems (CEMS), and can be used if the governing agency has determined that emissions can be quantified more accurately than with a calculation-based methodology. The details of the method are not discussed in this paper.

CO_2 emissions from combustion and from steelmaking processes in a calculation-based methodology are determined using the following equations:

$$E_{CB} = C_{FUEL} \times NCV \times F_{CO2} \times F_{O2}$$

$$E_{PR} = C_{FUEL} \times NCV \times F_{Conv}$$

where E_{CB}=CO_2 emissions from combustion, E_{PR}=CO_2 emissions from processing, C_{FUEL}=fuel consumption [t or Nm^3], NCV=net calorific value of fuel [TJ/t or TJ/Nm^3], F_{CO2} is an emission factor [tCO_2/TJ], F_{O2} an oxidation factor, and F_{Conv} the CO_2 to carbon conversion factor (CO_2/C). The C_{FUEL} is the summation of the amount of fuel used and stock change.

In addition to quantities defined above, the level of accuracy should be reported. Accuracy levels, or tiers, are determined for the quantities C_{FUEL}, F_{CO2}, F_{O2}, and F_{Conv}, and the minimum accuracy tier is determined for each process. The accuracy becomes relevant in actual reporting, but is not relevant in this paper since we discuss the modeled performance of virtual steel mills.

The quantities F_{O2} and F_{Conv} are coefficients showing how much fuel or carbon content is converted into CO_2; normally 1 is used for both coefficients. The value of F_{CO2} determined in the 2006 IPCC Guidelines and given in EC (2007) is used in the EU scheme. Table 1 shows a partial list of the fuels used in steelmaking along with their emission factors. Table 2 shows non-fuel materials used in steelmaking that must be included in calculation of CO_2 emission.

Individual F_{CO2} emission factors, derived for example by sample composition analysis, may also be used with permission of the governing agency granted before the reporting period. Sampling methods are determined by the CEN standard (the standard of the European Commission), or using ISO or national standards if the CEN standard does not exist. If none of these standards are available, industrial best practice guidelines are used. The same applies for F_{O2} and F_{Conv}.

Table 1
CO2 emission per net calorific value (NCV) for fuel.
Source: EC 2007 p33 Table 4.

Fuel	Emission factor (tCO_2/TJ)
Coking coal, other bituminous coal	94.5
Coke oven coke	107.0
Coal tar	80.6
Blast furnace gas	259.4
Coke oven gas	44.7
Oxygen steel furnace gas	171.8
Crude oil	73.3
Kerosene	71.8
Gas/diesel oil	74.0
Liquefied petroleum gases	63.0
Natural gas liquids	64.1

Table 2
CO_2 emission factors of non-CO_2-carbon in process output.
Source: EC 2007 p67 Table 1. These numbers are originally from (IPCC, 2006).

Material	Emission factor (tCO_2/t)
Directly reduced iron (DRI)	0.07
Hot briquetted iron	0.07
EAF carbon electrodes	3.00
Purchased pig iron	0.15
Scrap iron	0.15
Steel	0.04

3. CO_2 emission reporting boundary in EUETS

When an installation reports emissions using the EUETS calculation-based methodology, emission levels are normally calculated for each activity that needs to be reported (see Section 3.1). However, mass balance calculations can be used (see Section 3.2) if activities cannot be calculated separately from those of the entire installation.

3.1. Calculation methodology per specific activity

Since a number of activities that require reporting of emissions are likely to exist in each steelmaking installation, the EUETS defines the reporting boundaries for emission reporting. Emission of CO_2 by each activity is given as the total emission from combustion of all fuel and processes associated with the activity.

Activities that require reporting are outlined for each category in the reporting form. Definitions of activities are given in the common reporting format (CRF) of the UNFCCC reporting guidelines and in the reporting form of the European Pollutant Release and Transfer Register (EPRTR) Regulation, EC 166/2006[2]. Activities in the EPRTR reporting form are categorized into more detailed segments. Table 3 shows activities related to iron and steel making.

A few activities are individually summarized in the Annex of EC (2007).

Annex IV (p 57): Coke furnace.

Annex V (p61): Sintering.

Annex VI (p64): Pig iron, steelmaking and continuous casting process.

[1] As regards to the EUETS, when the EUETS Directive was revised (EC, 2009), benchmarks had been introduced for allocation of emission allowances. This paper, however, mainly focuses monitoring aspects which will become bases of benchmarking and have influences on further discussion of ETS.

[2] Directive 2003/87/EC p43 15. Reporting Category.