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Comparison of iron and steel production energy use and energy intensity in China and the U.S.

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ABSTRACT

The goal of this study was to develop a methodology for making an accurate comparison of the energy intensity of steel production in China and the U.S. Such values are often sought by policy-makers when making decisions related to energy, greenhouse gases, and competitiveness. The methodology addresses issues related to boundary definitions, conversion factors, and technology structure. In addition to the base case analysis, four sensitivity and two factor analyses were developed to assess the effect of different factors on energy intensities. The results of the analysis show that for the whole iron and steel production process, the final energy intensity in 2006 was equal to 14.90 GJ/t crude steel in the U.S. and 23.11 GJ/t crude steel in China in the base-case analysis. In another factor analysis that assumed the Chinese share of electric arc furnace production in 2006 (10.5%) in the U.S., the energy intensity of steel production in the U.S. increased by 54% to 22.96 GJ/t crude steel. This result highlights the fact that when comparing the energy intensity of the U.S and Chinese steel industry, the technology structure, especially the share of electric arc furnace should be taken into account. A number of policy implications are also discussed.

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1. Introduction

Production of iron and steel is an energy-intensive manufacturing process. In 2006, the iron and steel industry accounted for 13.6% and 1.4% of primary energy consumption in China and the U.S., respectively (U.S. DOE/EIA, 2010a; Zhang et al., 2010). The energy efficiency of steel production has a direct impact on overall energy consumption and related carbon dioxide (CO_2) emissions.

Blast furnace/Basic Oxygen Furnace (BF/BOF) and electric arc furnace (EAF) steel production routes are the most common today. IEA, 2010, BF/BOF steel production accounted for approximately 65% of the steel manufactured worldwide, and EAF steel production accounted for approximately 30% (worldsteel, 2011b). In BF/BOF production route, steel is produced from iron ore, while in EAF the main raw material is recycled steel scrap. As the result, the energy intensity of EAF steel production is significantly lower than that in the BF/BOF steel production. For example, only for BF, Energetics, Inc. (2004) gives a range of energy use of 13.0–14.1 GJ/t pig iron, while the range of energy use for EAF is given as 2.1–2.4 GJ/t crude steel (Energetics, Inc. 2004). The production of steel by EAF route is constrained by steel scrap availability.

Previous comparisons of international steel industry energy use and intensity have employed a range of methods. Worrell et al. (1997) found that physical-based indicators provided a more robust basis for international comparison than economic indicators of steel sector energy efficiency and intensity. Within the range of physical-based analyses, a variety of study boundaries, units of analysis and conversion factors are used. For example, whereas Worrell et al. (1997) use crude steel production as their unit of analysis, Stubbles (2000) calculated energy use and emissions per ton of shipped steel. Likewise, whereas Andersen and Hyman (2001) include coke-making energy use, Kim and Worrell (2002) omit coke making. The International Energy Agency (IEA) also includes country-specific steel sector energy analysis in their overview of potential energy efficiency savings to 2050 (IEA, 2010). Based on 2007 data, the IEA found that China could save 6.1 GJ/t crude steel and the U.S. could save 2.4 GJ/t of crude steel through adoption of best available technologies (IEA, 2010).

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Energy consumption and energy intensity are often estimated based on different definitions of an industry's boundaries, making comparison at best difficult, at worse invalid (Tanaka, 2008). A review of comparison studies shows that boundary and conversion factor assumptions are not always explicitly stated, but appear to vary widely, especially for characterizing imported or off-site produced inputs. Consensus has yet to form on boundaries and conversion factors for international comparison of steel production energy efficiency, resulting in widely disparate results which are difficult to interpret and compare. For example, Tanaka (2008) presents a case study on Japan's iron and steel industry that illustrates the critical role of proper boundary definitions for a meaningful assessment of energy efficiency in industry. Depending on the boundaries set for the analysis, the energy consumption per ton of crude steel that Tanaka calculated ranges from 16 to 21 GJ. Also, Farla and Blok (2001) studied the data problem for physical energy intensity indicators for the steel industry and found that some mistakes were made in the reported energy data, which makes reliable international comparisons of countries even more difficult.

Furthermore, different international GHG accounting and reporting frameworks, which are also used as basis for energy use accounting, have set different boundaries for the iron and steel industry. Fig. 1 shows the different boundary definitions by international guidelines for GHG emissions of blast furnace integrated steel plants (Tanaka, 2008).

The IPCC guideline includes GHG emissions from iron making, steel making, continuous casting and on-site power plants, and also counts emissions from includes rolling mills and other processes. On the other hand, EU ETS guideline excludes rolling mills and other processes, but counts emissions from by-product gas. The WRI/WBCSD guidelines have two scopes with scope 1 excludes electricity from off-site power plant and Scope 2 includes it. Both Scope 1 and 2 exclude by-product gas (Tanaka, 2008). Thus, it is clear that, first, the CO_2 and energy intensity calculated using different guidelines (IPPC, EU ETS, or WRI/WBCSD) cannot be compared to each other. Secondly, all boundaries defined in these guidelines are missing one or more important part of the steel production. Thus, there is need for a comprehensive definition of the steel production boundary which includes all the process that are important from energy use point of view and also takes into account the import and export of fuel and auxiliary and intermediary products such as pig iron, direct-reduced iron (DRI), pellets, lime, oxygen, and ingots, blooms, billets, and slabs. This is one of the main objectives of this paper.

It is difficult to provide policy-makers with a single energy intensity value for steel production for each country to be used to compare energy intensity across countries. Such values are often sought by policy-makers when making decisions related to energy, greenhouse gases, and competitiveness. This analysis illustrates that such a single indicator does not provide enough information to fully explain country-specific conditions.

The aim of this study is to develop a methodology for making an accurate comparison of the energy intensity (energy use per unit mass of steel produced) of steel production through a case-study analysis for China and the U.S. The methodology addresses issues related to boundary definitions, conversion factors, and indicators in order to develop a common framework for comparing steel industry energy use in these two countries. This may require more detailed data and more analysis compared to simply calculating the sectoral level energy intensity from the aggregate data and comparing them across country which can generate misleading results. The readily available data are often at the sectoral level and not the production route (BF/BOF and EAF) level. Since the energy intensity of different steel production routes are quite different from each other and the share of steel production by each of these production routes varies across countries, comparing the aggregate energy intensity of the sectors without further insight into process types can be misleading. We have tried to address these issues in our study.

To address the boundary issue, we have defined a similar boundary for the steel industry in both countries and have collected the data and conducted the calculation according to this boundary definition. We have also included the import and export of fuel and auxiliary/intermediary products in the boundary definition. With regards to the conversion factors issue, we have conducted several sensitivity analyses to assess the effect of different conversion factors on the results. Finally, concerning the technology structure of the industry (share of EAF steel production vs. BF-BOF steel production), we have conducted two factor analysis to evaluate the impact of EAF ratio on energy intensity of the steel industry in each country.

1.1. Overview of the iron and steel industry in China

China is a developing country and is currently in the process of industrialization. The iron and steel industry has grown rapidly along with the national economy. In 1996, China's crude steel production surpassed 100 million metric tonnes (Mt). Since then,

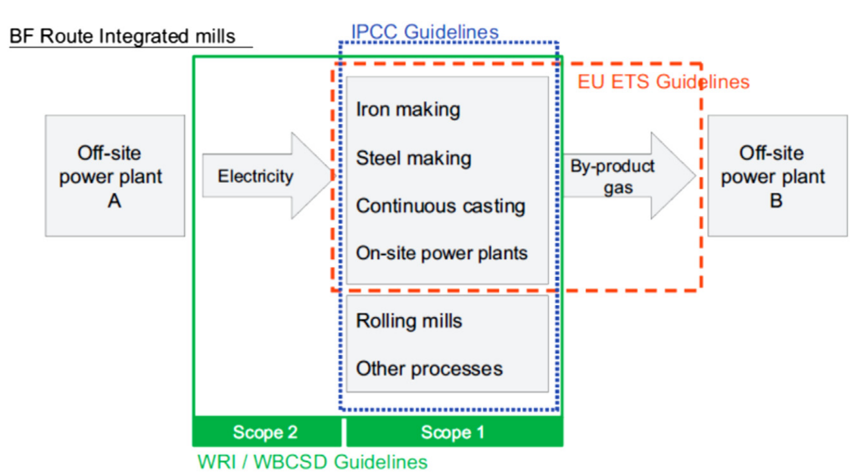

Fig. 1. Different boundary definitions by international guidelines for GHG emissions of blast furnace integrated steel plants (Tanaka, 2008).