CO_2 intensity and energy intensity of Iron and Steel production in Thailand

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Abstract

The Iron and steel industry is one of the most energy-intensive industries. This paper presented CO_2 intensity and energy intensity of Iron and Steel production in Thailand. The technical data were obtained from 5 semi-finished steel production plants which represent 66.07% of the total semi-finished steel production capacity and 26 finished steel production plants which represent 63.77% of the total finished steel production capacity during the year 2004-2010. The scope of GHGs emission calculation was gate-to-gate boundary. The amount of greenhouse gas emission was calculated by following the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines for national greenhouse gas inventory. The results showed that CO_2 intensity of semi-finished steel product was 0.44 tCO_{2eq}/t product whilst the CO_2 intensity of finished steel product was 0.17 tCO_{2eq}/t product. The uncertainty values ranged from 4.09% to 8.66%. Energy intensities of semi-finished steel product and finished steel product were 1.98 and 1.63 GJ/t product, respectively. The electricity consumption was a major source of greenhouse gas emission contributing 58.42%, followed by fuel combustion (33.17%) and chemical reaction (8.41%).

Key words: CO_2 intensity/ Energy intensity/ Iron and steel industry/ Thailand

1. Introduction

Steel is one of the most versatile structural materials because of its flexibility, durability and high strength offer significant advantages in the material efficiency of various product applications. However, the iron and steel industry is known as one of the most energy intensive manufacturing sectors. In 2005 the energy consumption of iron and steel industry accounted for 20% of the world industrial energy use and produced 30% of direct CO_2 emission (IEA, 2008). In Thailand, most of the iron and steel productions are midstream and downstream industries which import semi-finished steel products such as slabs, blooms and billets etc. from foreign countries. The crude steel production in 2011 was 4.25 million tons, increasing by 0.19 million tons from the year 2010. However, steel demand was up to 14.7 million tons in 2011, an increase of 0.69 million tons from the year 2010 (ISIT, 2012). The increase in demand for steel was mainly caused by the development of some infrastructural works especially for real estate projects. Due to the high domestic demand for iron and steel products, the Board of Investment (BOI) proposed the road map for primary iron production establishment in Thailand. In 2009, the first mini-blast furnace was operated by Tata Steel (Thailand) with a production capacity of 500,000 tons per year (Jelsoft Enterprises Ltd., 2010) However, the domestic consumption is still much higher than domestic production. It is expected that steel demand will rise to 18 million tons in 2015 (ISIT, 2010). The establishment of the primary iron and steel industry provides benefits in term of economics. However, in environmental aspects, the iron production causes adverse environmental impacts such as high energy consumption, air pollution and greenhouse gas (GHGs)

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emission. This research aims to calculate the CO_2 intensity and energy intensity of iron and steel production in Thailand. The outcomes from this research will provide a technical database for setting up emission reduction targets contributed by the iron and steel production in Thailand.

2. Methodology

2.1. Collection of data from the iron and steel industry in Thailand

The plant specific data were obtained from 5 semi-finished steel production plants which represent 66.07% of the total of semi-finished steel production capacity and 26 finished steel production plants which represent 63.77% of the total finished steel production capacity during the year 2004-2010. The iron and steel production capacity of each product used in this study compared with total production capacity of each product in 2010 was summarized in Table 1. It can be seen that the production capacity of slab, hot rolled coil and picking & oil steel in this study, sample were collected from 100% of the total production capacity of each product. However, the production capacity of cold rolled steel, coated steel, metallic coated and prepainted steel and bar, samples were collected more than 50% of the total production capacity of those products.

Table 1 Production capacity of iron and steel industry used in this study compared with total production capacity in Thailand (year 2010).

Products	Production capacity in this study * (%)
Semi-finished steel (EAF process)	
- Slab	100.00
- Billet	38.71
Finished steel	
Flat products	
- Hot rolled coil	100.00
- Cold rolled steel	84.62
- Coated steel	79.83
- Picking & Oil steel **	100.00
- Metallic coated and prepainted steel (includes only coating lines)	78.00
Long products	
- Bar	50.51
- Annealed wire	36.21
- Hot rolled structural steel	30.52
Pipe	
- Electric resistance welded (ERW) pipe	14.30

* production capacity of each product used in this study compared with the total production capacity of each product in 2010.

** process is coating steel with other metal paints or oil for corrosion resistance or to give it special characteristics

2.2. System boundary of iron and steel production process in this study

The gate-to-gate boundaries for semi-finished and finished steel product applied in this study are illustrated in Fig. 1 and Fig.2. Generally, semi-finished steel production from the EAF process uses scrap steel as its basic feedstock. Lime serves as a flux for removing impurities and graphite electrodes are electrical conductors used to make a circuit. While the finished steel production requires physical reformation and surface finishing. The energy consumption of steel products come from two sources; 1) from the combustion fuel and 2) from the electricity supplied to the process. According to GHG protocol, CO_2 emissions are divided into direct and indirect emissions. In this study, the direct emission came from fuel combustion and chemical reactions occurred in the EAF process. While the indirection emission was from electricity supplied to the process. It is noted that there is no CO_2 emission from chemical reaction in finished steel production.

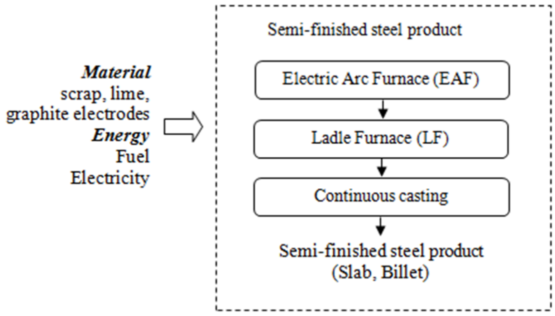

Figure 1 System boundary of semi-finished steel production (gate-to-gate)

2.3. Calculation of energy intensity and CO_2 intensity

The amount of GHGs emission in the unit of tCO_{eq}/t product was calculated by the method derived from the 2006 the Intergovernmental Panel on Climate Change (IPCC) guidelines for national greenhouse gas inventory (IPCC, 2006). The scope of GHGs emission calculation was set to only include the production process or gate-to-gate boundary. The energy intensity was measured in the unit of energy consumed per unit output (GJ/t product).

2.3.1. Calculation of CO_2 emissions from chemical reactions in process

The methodology of CO_2 emission calculation from chemical reactions depends on the acquisition of data. According to the 2006 IPCC guideline, the methodology is divided into 3 Tiers. Tier 1 method is based on national production data and default emission factors while Tier 2 method uses a mass balance approach and material- specific carbon contents. Tier 3 method requires plant-specific emissions or activity data aggregated to the national level for estimating CO_2 emissions. Due to the limitations of the activity data, Tier 2, a mass balance approach with material-specific carbon content, was applied in this study.

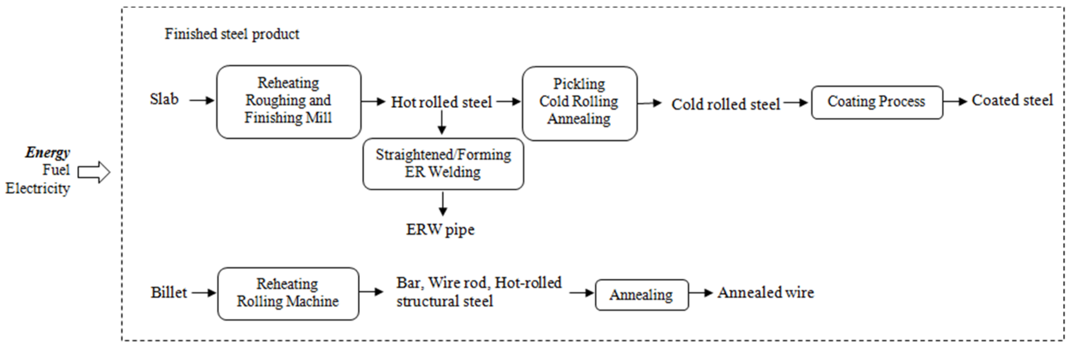

Figure 2 System boundary of finished steel production (gate-to-gate)

2.3.2. Calculation of CO_2 emission from fuel combustion

The CO_2 emission from fuel combustion was calculated by using Eq. (1). Emission factors come from the 2006 IPCC emission factors for stationary combustion in manufacturing industries and the heating values of fuels come from the Department of Alternative Energy Development and Efficiency (DEDE), Thailand (DEDE, 2010).

$$CO_{2\ emission} = \Sigma FC \times EF_{fuel} \qquad (1)$$

where;

FC is the amount of heating values of fuel consumed (TJ)

EF_{fuel} is the emission factor of each fuel used (tonne CO_2 /TJ)

2.3.3. Calculation of CO_2 emission from electricity consumption

The CO_2 emission from electricity consumption was calculated by Eq. (2). The average of CO_2 emission factor of electricity production in Thailand during the year 2007-2009 was obtained from the report of Thailand Greenhouse Gas Management Organization (TGO), which is 0.65 $kgCO_{2eq}/kWh$ (TGO, 2010).

$$CO_{2\ emission} = EC \times EF_e \qquad (2)$$

where;

EC is electricity consumption (kWh)

EF_e is emission factor of electricity production in Thailand (0.65 $kgCO_{2eq}/kWh$)

2.4. Uncertainty assessment

The uncertainty of the calculated CO_2 intensity was evaluated by following the 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). Two convenient rules for combining uncertainties under addition and multiplication were used in this study. The uncertainty of plant specific data was approximately ± 5%. The uncertainty of all emission factors (from Tier 2) was ± 10%, except the emission factor of electricity from the Thailand Greenhouse Gas Management Organization (TGO) which has the uncertainty of 7.07%.

3. Results and Discussion

3.1. Energy intensity

Semi-finished steel product consists of slab and billet products. The energy intensity of slab production from electric arc furnace process (EAF) is 1.91 GJ/t product, mainly from electricity consumption (86.68%) and fuel combustion (13.32%). The energy intensity of billet production is 2.13 GJ/t product of which 84.42% is contributed by electricity consumption and 15.58% is from fuel combustion as shown in Figure 3. It can be seen that electricity is a major source of energy used in EAF process. In electric arc furnace (EAF), the steel scrap is molten by using electricity as the energy source and then the molten steel is continuously casted. Nevertheless, the energy intensity of billet production is a bit more than that of slab production due to different modern EAF technology. The weighted average of energy intensity of semi-finished steel products in Thailand is 1.98 GJ/t products.

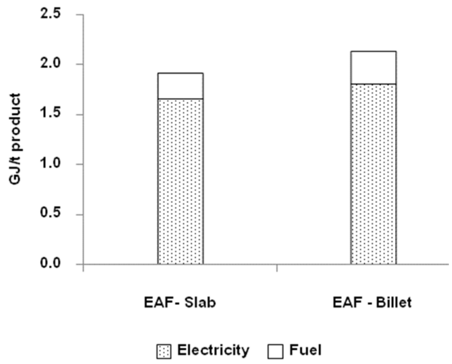

Figure 3 Energy intensity of semi-finished steel products

The energy intensity of finished steel products is shown in Figure 4. It is obviously seen that fuel combustion is the major source of energy consumption with the contribution of 70.27% whilst the electricity consumption share is merely 29.73%. Fuel is used as a source of energy in reheating the furnace and annealing process for finished steel production. As a result, the amount of fuel consumption is much more than the amount of electricity used. Interestingly, all energy used in metallic coating is from fuel which was used to melt metal in the coating bath but all energy used in ERW pipe production comes from electricity used for metal welding. In the case of electro galvanized steel sheet, an electro plating process is applied for zinc coating, resulting in more electricity consumption than fuel combustion. The weighted average of energy intensities of finished steel product in Thailand is 1.63 GJ/t products.

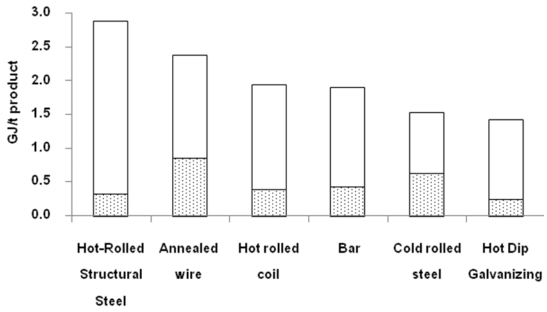

Figure 4 Energy intensity of finished steel products

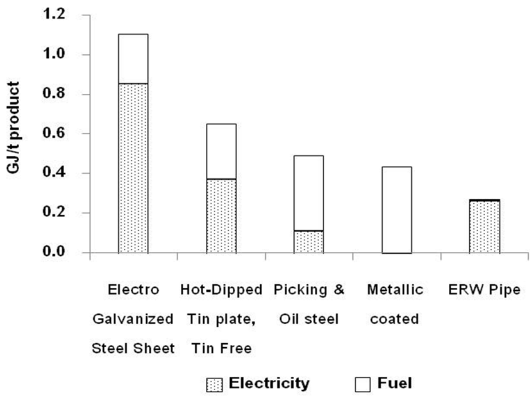

Figure 4 (continued) Energy intensity of finished steel products

The comparison between energy intensity calculated from this study and the study of Department of Alternative Energy Development and Efficiency (DEDE), Thailand is shown in Table 2. It is found that the values of energy intensity from this study are tentatively lower than that of DEDE especially billet and slab production from the EAF process. This is because energy sources investigated in this study excludes energy from oxygen in the EAF process. However, for hot rolled structural steel and hot dip galvanized steel sheet, the values of energy intensity from both studies are quite similar. The differences of the energy intensity between the two studies might be due to the fact that, different scopes, number of plants, total production capacity etc, were used

Table 2 Comparison of energy intensity between this study and DEDE

Products	Energy intensity (GJ/t product) (weight average)	
	This study	**DEDE, 2006**
Continuous process (with EAF)		
- Billet - Long products	3.51	5.09
- Slab - Hot rolled products	3.19	4.71
Finished steel product		
- Hot-rolled structural steel	2.88	2.89
- Annealed wire	2.66	3.21
- Hot rolled coil	1.93	2.25
- Bar	1.91	2.08
- Cold rolled steel	1.53	1.79
- Hot dip galvanizing	1.43	1.44
- Electro galvanized steel sheet	1.12	1.30
- Hot-dipped tin plate, tin free	0.65	0.88
- Picking & Oil steel	0.49	N.A.
- Metallic coated and prepainted steel products (coated process only)	0.44	N.A.
- Pipe (ERW)	0.27	0.24

N.A. is not available

Table 3 presents the energy intensity in some iron products from this study compared with that from some developing countries, which are Brazil, China, India, Mexico, and South Africa, and the world best practice values. The results show that the energy intensity from this study is lower than that of key developing countries but not much different from the world best practice values. To determine the potential gap between the energy intensity in Thailand with that of the world best practice, Energy efficiency indices (EEI) were computed by using Eq. (3). If the EEI is equal to 1, this means the iron production in Thailand operated at the best-practice level.

$$EEI = (EI_{Thailand})/(EI_{world\ best\ practice}) \quad (3)$$

EI is energy intensity.

It can be noted that billet production from the EAF process and EAF continuous casting hot rolling process have an EEI greater than 1.00 suggesting that the industry can reduce their energy consumption to comparable levels of the world best practice. Whist the hot rolling process has an EEI of less than 1 therefore the processes exhibits a good performance for energy consumption. Thus, the improvement of energy efficiency for EAF process for billet production and EAF continuous casting hot rolling process are required to reduce energy intensity to the comparable levels of the world best practice.

Table 3 Comparison of energy intensity between this study and the developing countries

Process	Energy intensity (GJ/t steel)			EEI
	key developing countries (Price et al., 2001)	World best practice (Worrell, and Neelis, 2007)	This study	
EAF-billet	N.A.	2.10	2.13	1.01
EAF-continuous casting-hot rolling	9.30	2.40	3.19	1.33
Hot rolling	2.30-5.40	1.98	1.93	0.97
Cold rolling	1.60-2.80	N.A	1.53	N.A

N.A. is not available

3.2 CO_2 intensity

As illustrated in Figure 5 the CO_2 intensity of slab production from electric arc furnace process (EAF) is 0.43 tCO_{2eq}/t products. The electricity consumption is a major source of greenhouse gas emissions which contributes 69.46%, followed by chemical reactions in the process (27.27%) and fuel combustion (3.27%). The CO_2 intensity of billet production is 0.45 tCO_{2eq}/t product. The greenhouse gas emission derived from electricity consumption is 75.78%, followed by chemical reaction in the process (19.78%) and fuel combustion (4.44%). The weighted average of CO_2 intensity of semi-finished steel product in Thailand is 0.44 tCO_{2eq}/t product. It can be seen that electricity consumption in EAF is a major source of GHG emission because electricity is mainly used for melting scrap in EAF. While CO_2 emission from chemical reactions comes from carbonaceous material input and fluxing agents such as steel scrap, lime and graphite electrodes. Therefore appropriate GHGs reduction measures for steel production should emphasize improving energy efficiency, reducing the fluxing agents and minimizing emissions from grid generation. Improved process controls in the EAF process can reduce electricity consumption 0.11 GJ/t and reduce GHGs emission 17.6 $kgCO_2$/t. Scrap preheating tunnel furnace (consteel) can reduce electricity consumption by 0.22 GJ/t and reduce GHGs emission by 35.2 $kgCO_2$/t (EPA, 2010).

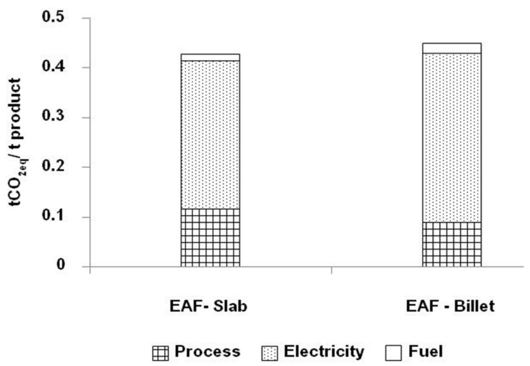

Figure 5 CO_2 intensity of semi-finished steel product

The CO_2 intensity of finished steel product is shown in Figure 6. Sources of CO_2 emission come from electricity consumption (50.46%) and fuel combustion (49.54%). There are no GHGs emission from chemical reactions in this finished steel production. The weighted average of CO_2 intensity of finished steel products is 0.17 tCO_{2eq}/t product. Fuel oil used in finished steel production is a major source of GHGs emission. Increasing fuel combustion efficiency and switching to low carbon fuels is one promising technology enabling control of GHG emissions from finished steel production.

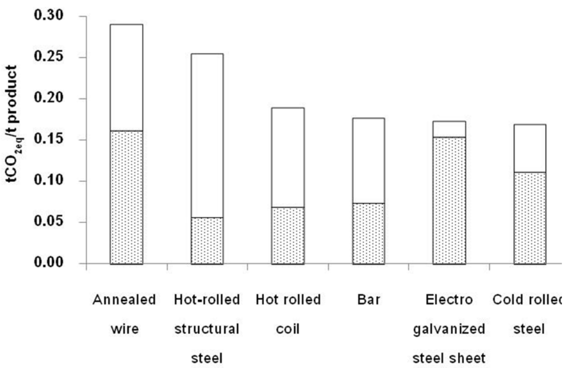

Figure 6 CO_2 intensity of finished steel product

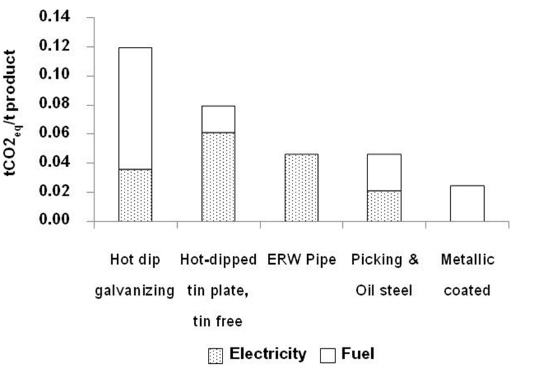

Figure 6 (continued) CO_2 intensity of finished steel product

When comparing the CO_2 intensity from this study with other studies from Thailand Greenhouse Gas Management Organization (TGO, 2010) and Thailand Research Fund (TRF, 2010), the total weighted average of CO_2 intensity in all products excluding the data from mini-blast furnace in this study is 0.30 tCO_{2eq}/t product. This value is in a range between the value from TRF (0.32 tCO_{2eq}/t product) and from TGO (0.29 tCO_{2eq}/t product). This difference might be caused by the availability of data, calculation methods and emission factors used in each study. For example, the data used in this study were obtained from 31 companies during the year 2004-2010 while the data from the study of TGO came from 5 plants during the years 2004-2008. Additionally, the calculation method and emission factor of electricity used in this study and TGO were similar, but different from the study of TRF, which used the emission factor of electricity from Electricity Generating Authority of Thailand (EGAT).

3.3. Uncertainty assessment

The uncertainties of CO_2 intensity for slab production and billet production from the EAF process are 4.09% and 6.88%, respectively. The Uncertainty range of CO_2 intensity for all finished steel products is 6.99-8.66%. It is noted that the uncertainty values of CO_2 intensity in this study are less than 10% which is statistically acceptable at the 90% confidence level.

4. Conclusion

The country-specific energy intensity of semi-finished steel and finished steel product in Thailand are 1.98 and 1.63 GJ/t product. The country-specific CO_2 intensities of semi-finished steel and finished steel product in Thailand are 0.44 and 0.17 tCO_{2eq}/t product. Electricity consumption is a major source of greenhouse gas (GHGs) emission which contributed 58.42%, followed by fuel combustion 33.17% and chemical reactions in the process 8.41%. Therefore, the improvement of electricity consumption efficiency is recommended to be the first priority for GHGs mitigation in iron and steel industry in Thailand. Several technologies such as improving energy efficiency in the process, using scrap preheating tunnel furnace (consteel), reducing fluxing agents and minimizing emissions from grid generation could be applied as GHGs reduction measures for the iron and steel industry in Thailand.

5. Acknowledgement

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