Benchmarking Study for Thailand's Iron & Steel Industries

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1 Identification of target sub-sectors

The targeted four sub-sectors for distributing questionnaires in the steelmaking sector in Thailand for this study are shown in Table 1. The No. 1 and No. 2 sub-sectors are scrap recycling electric arc furnace (EAF) based steel plants that produce flat and long products. The No. 3 and No. 4 sub-sectors are steel plants without EAF, such as re-roller plants, that produce flat and long products.

Table 1: Target sub-sectors in this study

<table>
<tr><th>No.</th><th>Target sub-sectors</th><th>Kind of product</th></tr>
<tr><td>1</td><td rowspan="2">Steelmaking plant
with EAF</td><td>Flat</td></tr>
<tr><td>2</td><td>Long</td></tr>
<tr><td>3</td><td rowspan="2">Steelmaking plant
without EAF
(Re-roller)</td><td>Flat</td></tr>
<tr><td>4</td><td>Long</td></tr>
</table>

2 Brief introduction of questionnaire

Three questionnaires were prepared for the benchmarking study.

(i) Total Energy Consumption and CO2 Emission in steel plant
(ii) EAF plant: Specification, operation and performance
(iii) Hot rolling mills: Specification, operation and performance

(i) is based on ISO 14404-2, which is an international standard for the calculation method of total energy consumption and CO2 emissions in a steel plant with EAF. (ii) is a specific questionnaire for EAF, LF, and CCM, and (iii) is specific questionnaire for RHF. Questionnaires for EAF and RHF in hot rolling mills are designed basically for the survey of (1)-(3) below.

(1) Equipment specifications
(2) How to operate
(3) How much to use energy and materials

The questionnaires are also designed to collect benchmarking data in Thai steel plants, and to make appropriate recommendations for improving the energy efficiency of individual equipment and plant operations. Ladle furnaces and CCM are also considered in the questionnaires. The questionnaires also ask for information on auxiliary equipment related to EAF (Figure 1).

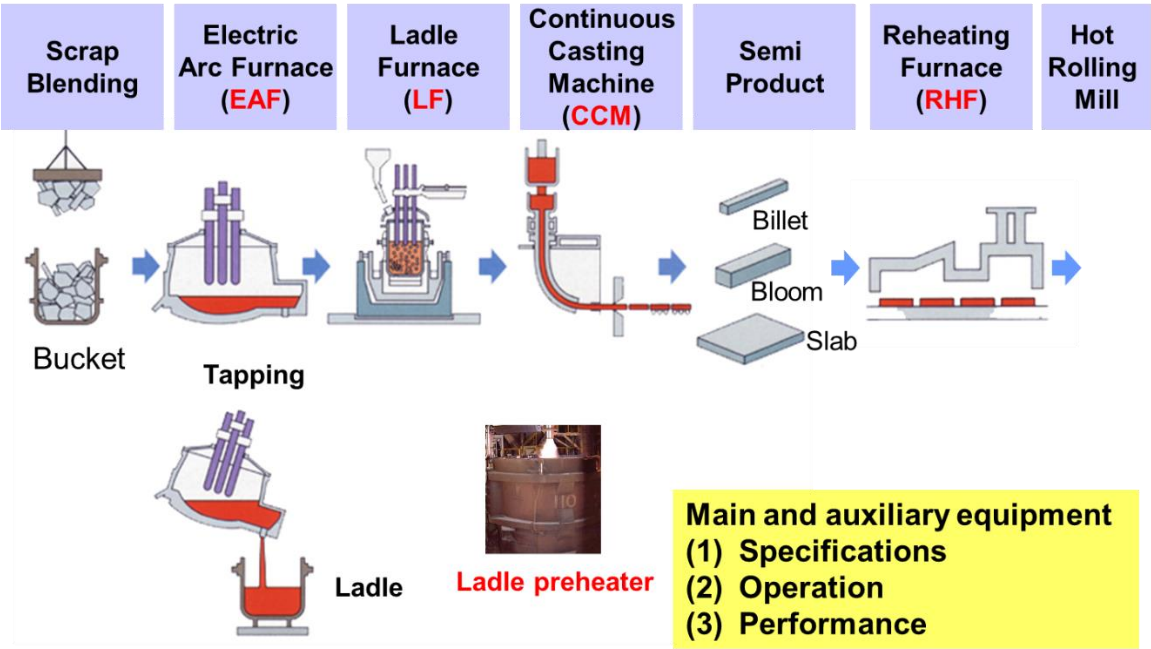

Figure 1: Contents of question for EAF base steel plant and re-roller

3 Response rate of questionnaire

The questionnaire was distributed to 63 companies through ISIT. Figure 2 shows the questionnaire response rate. The total response rate was 27%. The data useful for analysis included 9 EAFs, 20 RHFs, for a total of 29 furnaces. The ratio of amount of production of respondent companies to the total amount of steel products in Thailand was over 70%.

Category	Number of steel mills		Furnaces in plants that responded**		Production of final products in 2016	
	Total number	Number of Responses	EAF (Number of plant)	RHF	Total Mt-steel/y	Responded Mt-steel/y
FLAT with EAF	2	2 [100%]	2 (2 *)	1 (5*)	1.3	1.3 [100%]
FLAT without EAF	2	2 [100%]	-	4	1.3	1.5 [>100%]
LONG with EAF	14	8 [57%]	7 (10*)	10 (10*)	3.4	2.5 [74%]
LONG without EAF	45	5 [11%]	-	5	1.9	0.6 [32%]
Grand total	***63***	***17*** ***[27%]***	***9 (12*)***	***20 (15*)***	***7.9***	***5.8*** ***[73%]***
			total 29 (27*) [107%]			

* target number of furnaces, ** data used for analysis

Figure 2: Questionnaire response rate

4 Results of questionnaire analysis of energy consumption pattern

4.1 Operation conditions for analysis

Table 2 and Table 3 show the operating conditions under analysis. Text in blue refers to specifications of equipment, and text in red refers to operation conditions. Capacity of EAFs in this study ranged from 24 ton/ch to 180 ton/ch. Operation ratio ranged from 15% to 96%, and the average was 59%. As for the type of ladle preheater, both oxygen burners and regenerative burners in addition to conventional burner are used in Thai plants. Information on ladles and CCMs were collected in consideration of the effect process time has on energy efficiency.

Information on fuel consumption in RHFs was collected accounting for hot charge, cold charge, and monthly average. Various types of RHF are applied in Thai plants, including pushers, walking beams, and walking hearths. The operation ratio, Rop (=actual production / production capacity) was 16% through 100%, the average 54% (Figure 3). All steel plants with EAF apply hot charging. Information on recuperator performance was also collected. Responses with few or unsatisfactory answers were excluded from analysis.

Table 2: Operation conditions of EAF for analysis

No	Electric arc furnace(EAF)	Specifications/ Conditions	unit
1	EAF Type	AC (8/9), DC (1/9)	-
2	EBT	with (8/9), without (1/9)	-
3	Capacity	24 - 180	t/ch
4	Transformer	21 - 130	MW
5	Scrap preheater(SPH)	with (2/9), without (7/9)	-
6	Type of burner	Oxy/Fuel (1/9), JetBox (2/9), Jet burner (1/9), RCB (2/9), etc.	-
7	Nominal production (A)	220,000 – 1,250,000	t/year
8	Actual production (B)	60,000 - 730,000 (2016)	t/year
9	Operation ratio (=B/A)	15 - 96	%
10	Iron source mix	Scrap: domestic/16-98%, import/2-64%, Pig iron: 0-20%, etc.	%
11	Fuel	NG(6/9), PLG(1/9), Light oil(1/9), No use(1/9)	-
12	Oxygen consumption	30 - 50	m3N/t
13	Coke injection	8 - 20	kg/t
14	Lime addition	15 - 50	kg/t
15	Tapping temperature	1600 - 1650	°C
16	Tap-Tap time	44 - 85	min.
17	Electricity consumption	360 - 550	kWh/t
18	Electrode consumption	1.0 - 3.0	kg/t
19	Fe yield	85.9 - 90.8	%
20	Auxiliary equipment	EAF dedusting fan, Cooling water pump	-
	Ladle furnace (LF)		unit
21	Temperature increase	5 - 60	°C
22	Electricity consumption	33 - 70	kWh/t
	Ladle preheater		
23	Preheater type	O2 burner(3/9), regenerative burner (1/9), conventional burner	-
23	Preheater energy consumption	0.19 - 0.90	GJ/t
	Ladle logistics		
25	Average number of heats per day(C)	9.3 - 25	heats/day
26	Number of ladle under operation(D)	3 - 5.5	-
27	Ladle rotation ratio (=C/D)	1.7 - 8.3	heats/ladle/day
28	Time from tapping start to CC end	67 - 161	min.
29	Time from casting end to tapping start	9 - 35	min.
	Continuous casting machine (CCM)		
30	Tundish(TD) capacity	9 - 35	t
31	Tundish preheater	O2 burner(3/9), No use(2/9), conventional burner	-
32	Shape of mold	Thin slab(2/12), Billet(9/12), Bloom(2/12), Beam Blank(1/12)	-
33	Metallurgical length	4 - 33	m
34	Casting temperature of steel in TD	1520 - 1565	°C
35	Casting speed	0.75 - 4.5	m/min

Table 3: Operation conditions of RHF for analysis

No	Reheating furnace(RHF)	Specifications/ Conditions	unit
36	RHF Type	Pusher(7/20), Walking Beam(7/20), Walking Hearth(5/20), Roller Hearth(1/20)	-
37	Shape of charging material	Slab(4/20), Thin slab(2/20), Billet(13/20), Bloom(2/20), Beam Blank(1/20)	-
38	Nominal production (E)	80,000 production	t/year
39	Actual production (F)	5,000 - 1,280,000 (2016)	t/year
40	Operation ratio (=F/E)	16 - 100	%
41	Actual capacity	Cold charge: 3 - 225	t/h
42	Number of plant applied hot charge	11/11 (100%)	-
43	Hot charge ratio	5 - 100 (ave. 42)	%
44	Inlet material temperature	RT - 900	°C
45	Air ratio	1.1 - 2.5	-
46	Furnace controlled pressure	1 - 30	Pa
47	Outlet material temperature	1000 - 1270	°C
48	Kind of fuel	NG(8/20), Heavy oil (10/20), etc.	-
49	Recuperator	off-gas inlet temperature: 430 - 1000	°C
51		heated air temperature: 190 - 550	°C
52	Fuel consumption	Hot charge: 0.61 - 1.23	GJ/t
53		Cold charge: 1.08 - 1.62	GJ/t
54		Monthly ave.: 0.79 - 3.06	GJ/t

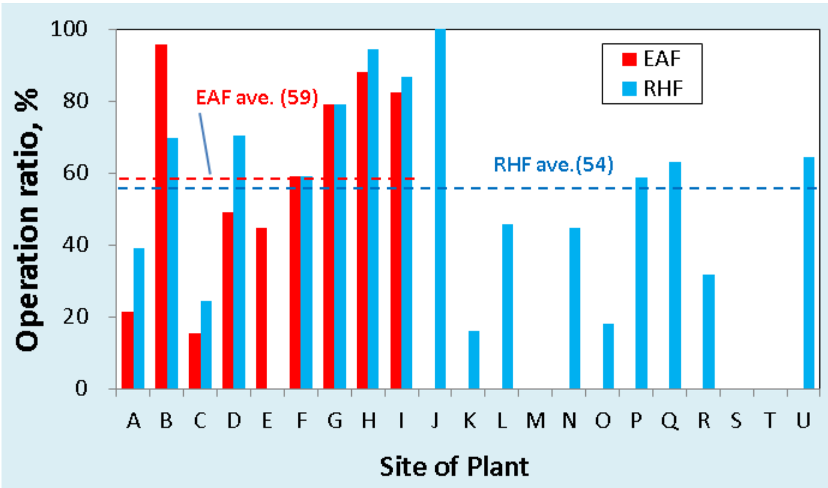

Figure 3: Operation ratio in steelmaking plants in this study

4.2 Energy consumption and CO2 emission in steelmaking plants

4.2.1 Energy consumption

Figure 4 shows the average energy consumption for Thai steel plants in the 3 years from 2014 to 2016. The average of 9 EAF based steel plants was 9.1 GJ/t-steel. Other data are shown in green for reference. The average value in the present study is 38% higher than the Japan average in 2016. The average of energy consumption for 6 re-roller plants was 2.5 GJ/t-steel. For this value, there is no reference data in Japan.

In the analysis, the difference in energy consumption due to the difference in the shape of the product to be manufactured was examined, but there was no clear influence on energy consumption based on the difference in product shape. Since there are few surveyed companies that manufacture flat products (2 companies with EAF, and 2 without EAF), there was concern that individual company names might be discerned if product shape information was described in the figures, so product shape information was not included in the figures.

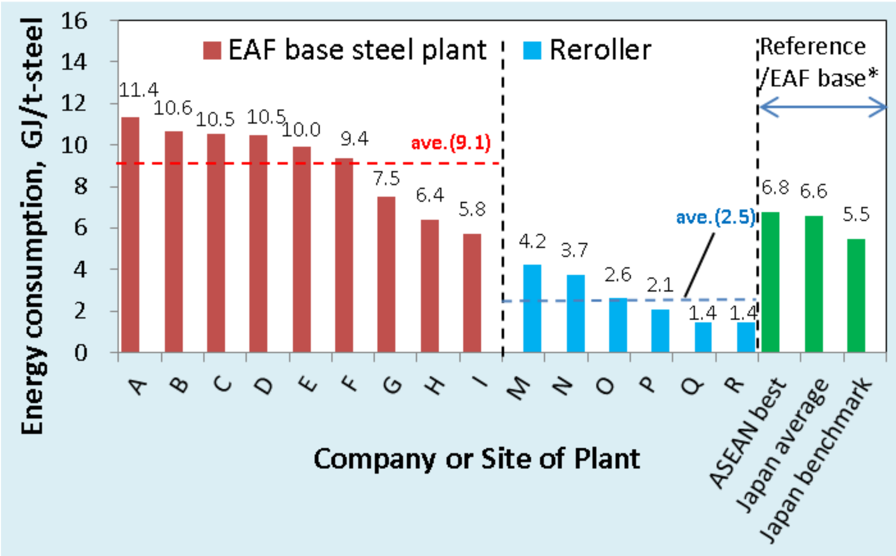

Figure 4: Energy consumption in steelmaking plant[1]

4.2.2 CO2 emissions

Figure 5 shows the average CO2 emissions for steel plants in the last 3 years. The CO2 emissions for steel plants with and without EAF was 0.56 and 0.19 t-CO2/t-steel, respectively.

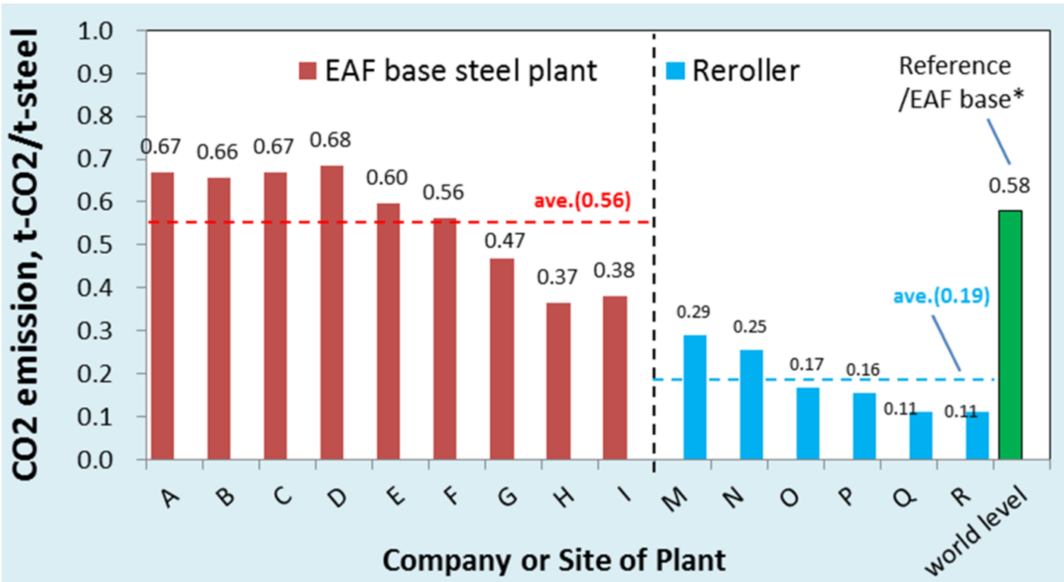

Figure 5: CO2 emission in steelmaking plant[2]

[1] Japan data in 2016 is referred from http://www.enecho.meti.go.jp/category/saving_and_new/benchmark/2016/benchmark28.pdf and ASEAN data in 2014 was researched by JFETEC.

[2] Reference data: JSCE-G, Vol.70, No.6, II_239-II_247, 2014.

4.3 Electric arc furnace (EAF)

4.3.1 Electricity consumption

Electricity consumption ranged from 360 to 550 kWh/t, and the average was 412 kWh/t (Figure 6). Reference data are also shown. The average value in the present study is 8% higher than the average electricity consumption in Japan.

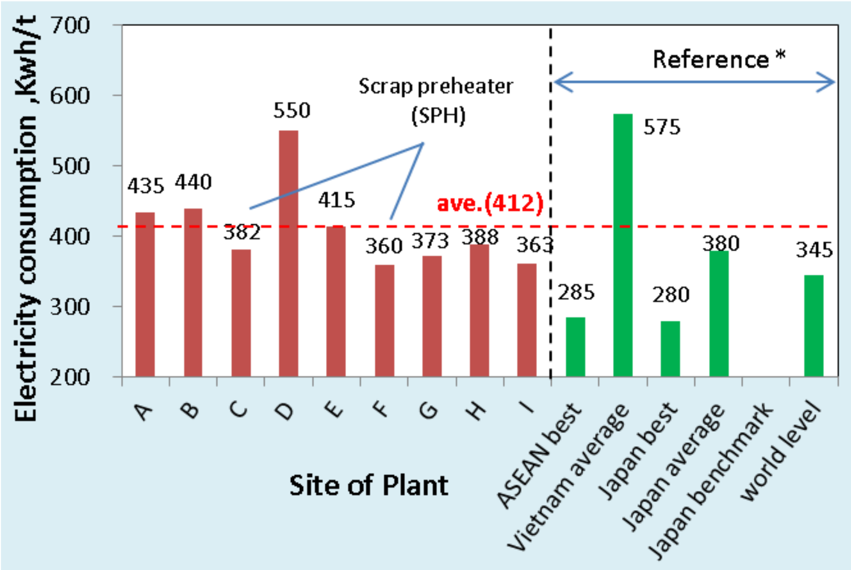

Figure 6: Energy consumption of EAF[3]

In an EAF, oxygen is injected with fuel to accelerate scrap melting. Therefore, electricity consumption should be evaluated along with O2 consumption, as shown in Figure 7. In this sense, electricity consumption in the present study seems to be little bit higher than electricity consumption among Japanese plants with a similar level of O2 consumption.

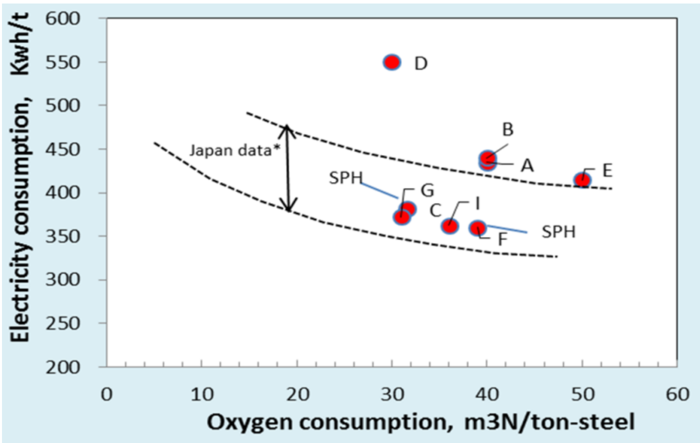

Figure 7: Effect of O2 consumption on energy consumption of EAF[4]

Generally, electricity consumption increases as the number of scrap charges increases. This tendency could not be found clearly in this study (Figure 8).

[3] Japan data;[1] Vietnam data was estimated by JFETEC on based with Nguyen Thi Ngoc Tho (Energy Efficiency and Conservation Center of Ho Chi Minh City), "Overview of Steel and Paper Industry – Energy Saving Potential" 2012; The “world level” was referred from P. Dahlmann, R. Fandrich and H. B. Lüngen: Stahl Eisen, 132(2012), Nr.10, 29

[4] Japan data: "Electric Steelmaking Technology", p.118, 2000, ISIJ

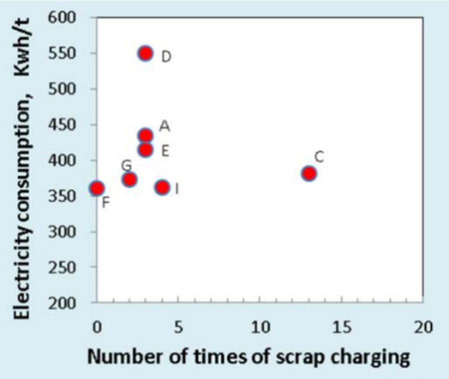

Figure 8: Relation between electricity consumption and number of scrap charging

4.3.2 Tap-tap time

Tap-tap time ranges between 44 and 85 min in the present study, and the average is 58 min (Figure 9). Tap-tap time is often discussed in relation to a ratio of transformer capacity to charging weight. Figure 10 shows this relation. The present data are plotted on the extension of Japan data in consideration of this relation. This means tap-tap time in Thailand also seems to be affected by EAF transformer capacity and charging weight. Positive effect of scrap preheater (SPH) on tap-tap time seems not to be seen in this study. More precise comparison is needed. The effect of electricity consumption, total input energy (=summation of electricity, fuel, and oxidation of electrode + Fe) and EAF capacity on tap-tap time were also analysed, but no clear relation between them could be found in the present study (Figure 11).

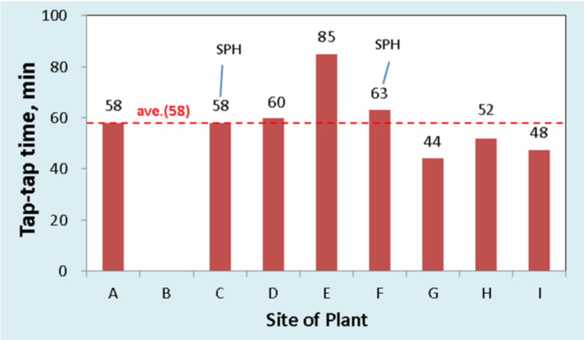

Figure 9: Tap-tap time

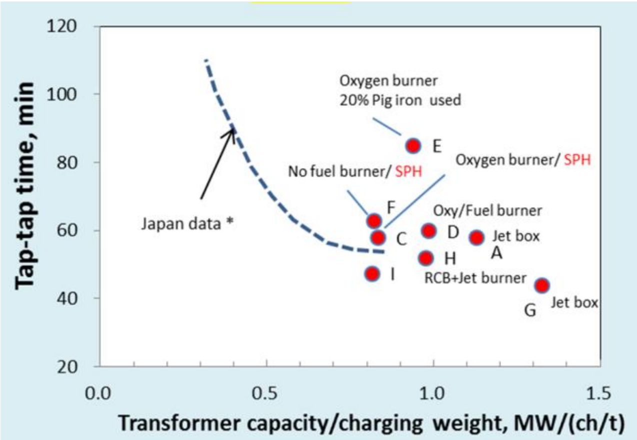

Figure 10: Effect of ratio of transformer capacity to charging weight on tap-tap time[5]

[5] Japan data: Recent Progress of Steelmaking Technology in Electric Arc Furnace, p.42, 3rd ed., 1993, ISIJ.

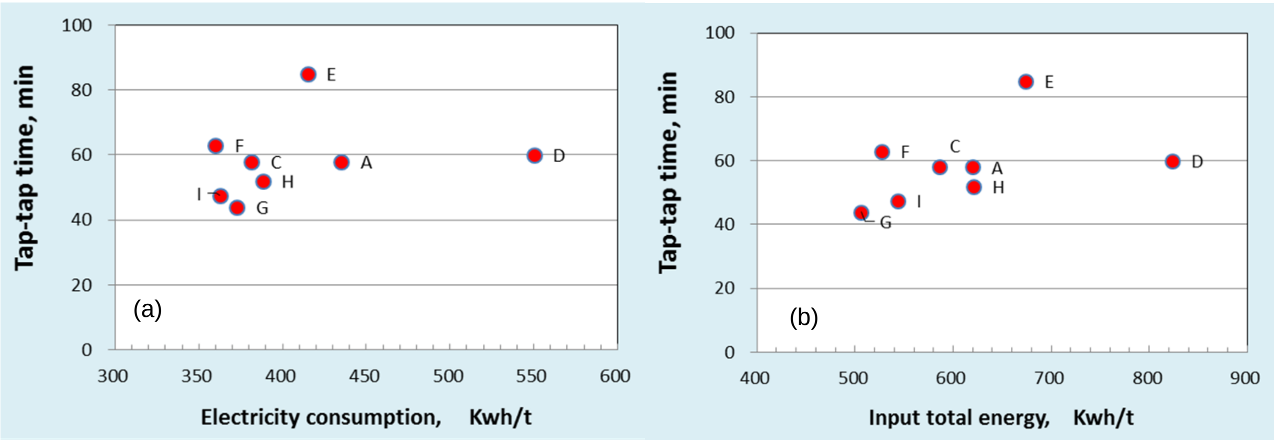

Figure 11: Effect of (a) electricity consumption and (b) total input energy on tap-tap time

4.3.3 Electrode consumption

Electrode consumption ranges between 1.1 and 3.0 kg/t. The average is 1.5 kg/t (Figure 12). Generally, electrode consumption is affected by electricity consumption. So, the relation between them is shown in Figure 13. The relation is similar to that in the Japan data. Therefore, there seems to be no difference between the present data and Japan data.

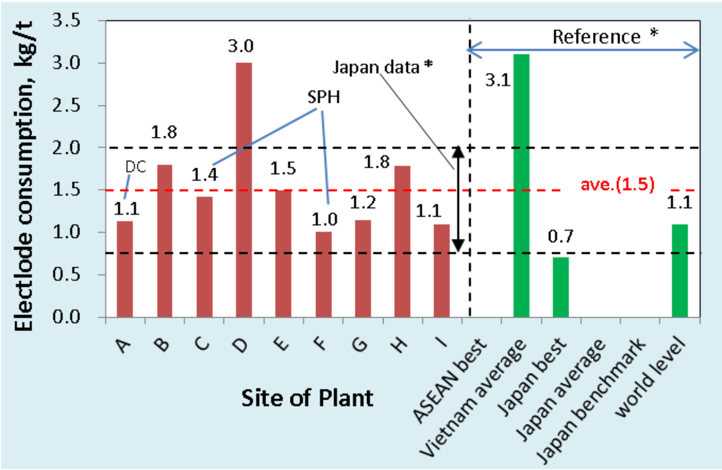

Figure 12: Electricity consumption in EAF[6]

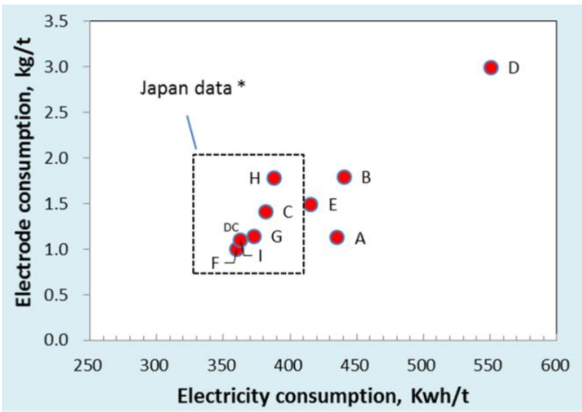

Figure 13: Effect of electrode consumption on electricity consumption in EAF[6]

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[6] Japan data: Industrial Heating, Vol.40, No.5, p.40, 2003, JIFMA; Japan's best data is based on research by JFETEC. Data of Vietnam and world level were referred to previously.[3]

4.3.4 Fe yield

Fe yield was indicated between 86% and 91% (Figure 14). The average is 89%, which value is 3% lower than Japan data. It is well known that Fe yield is affected by amount of oxygen injected in EAF. This is because the injected oxygen oxidizes steel. Figure 15 shows the effect of oxygen consumption on Fe yield. The present data are plotted along with the extension of Japan data. The yield data is a little bit scattered, but not so different from Japan data considering the O2 consumption. EAF steel plants in Japan are said to be strict in yield management. So, to prevent decreasing the yield, some plants inject aluminium dross in addition to carbon.

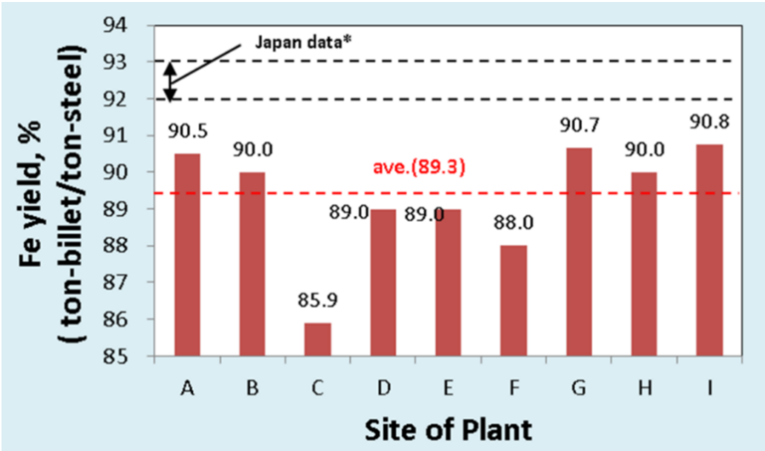

Figure 14: Fe yield[7]

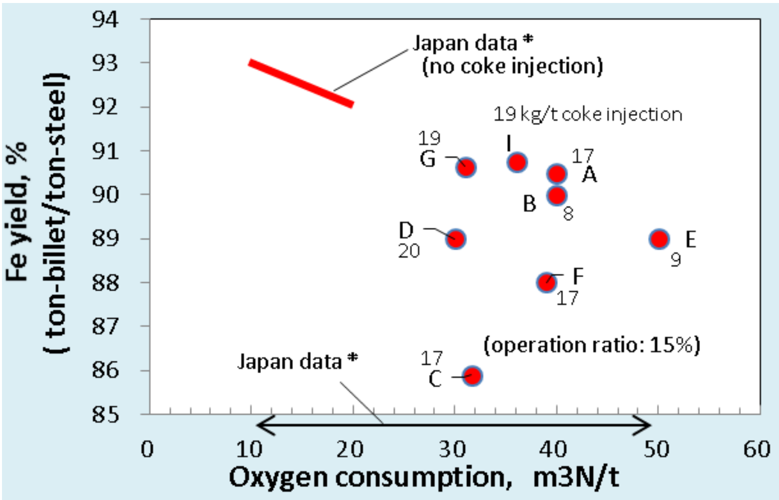

Figure 15: Effect of oxygen consumption on Fe yield[8]

4.3.5 Energy efficiency

Figure 16 shows a result of energy efficiency analysis of EAF. Energy efficiency is defined here as the ratio of output energy to input energy. Input energy is considered as a summation of electricity, fuel, and oxidation of electrode + Fe. Output energy is calculated as increase in heat content of steel from charging to tapping. The energy efficiency is 62% on average and this value is nearly the same as Japan data.

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[7] Japan data: “Electric Steelmaking Technology”, p.119, 2000, ISIJ

[8] Japan data: “Electric Steelmaking Technology”, p.118-119, 2000, ISIJ

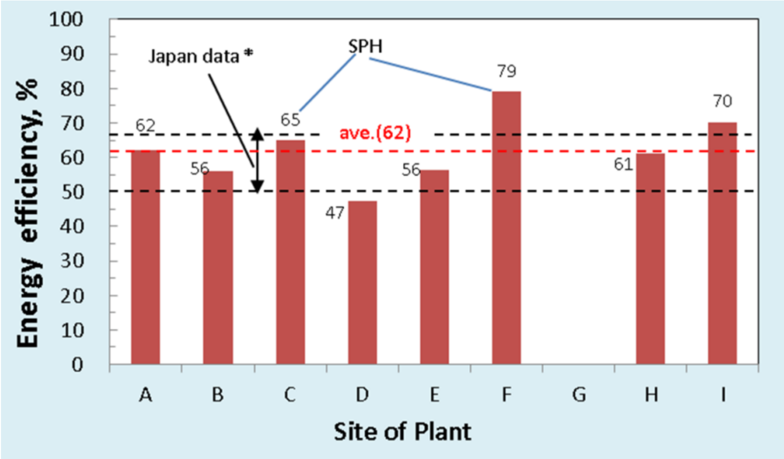

Figure 16: Energy efficiency of EAF[9]

4.4 Ladle furnace (LF)

4.4.1 Electricity consumption

Electricity consumption of the ladle furnace is from 33% to 70%, and the average is 45% (Figure 17).

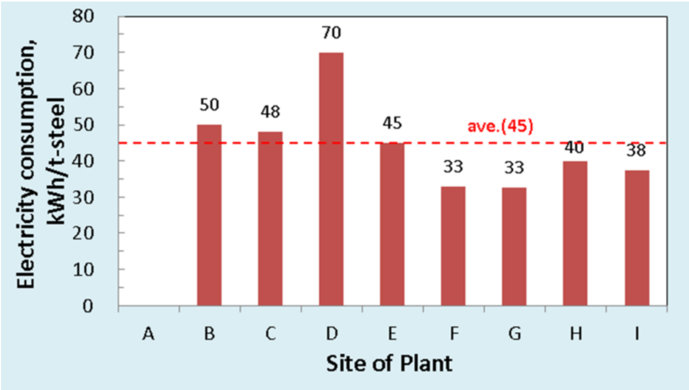

Figure 17: Electricity consumption of LF

4.4.2 Energy efficiency

From the relation between the amount of temperature increase in molten steel and electricity consumption (Figure 18), the energy efficiency of the LF can be estimated. Energy efficiency is defined here as the ratio of energy used for heating up molten steel in LF to electricity consumption. Here, energy used for heating up molten steel is calculated with this formula: [0.23 kWh/°C/t x (amount of temperature increase)]. The efficiency is estimated to be 3% to 35%, and the average 17% is 18 points lower than the Japan average 35% (Figure 19).

[9] Japan data: "Electric Steelmaking Technology", p.107, 2000, ISIJ; No164, p.1, November 2010 , SHASE

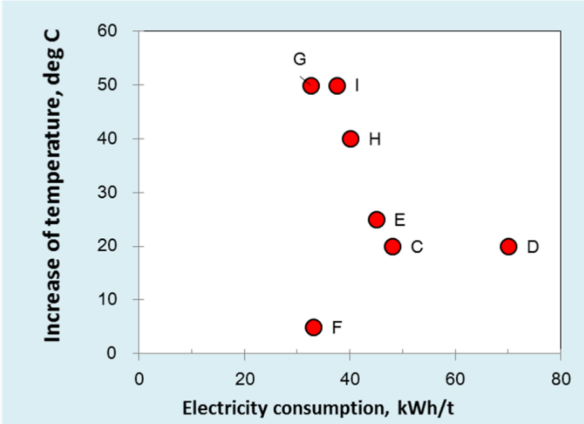

Figure 18: Relation between temperature increase of molten steel & electricity consumption of LF

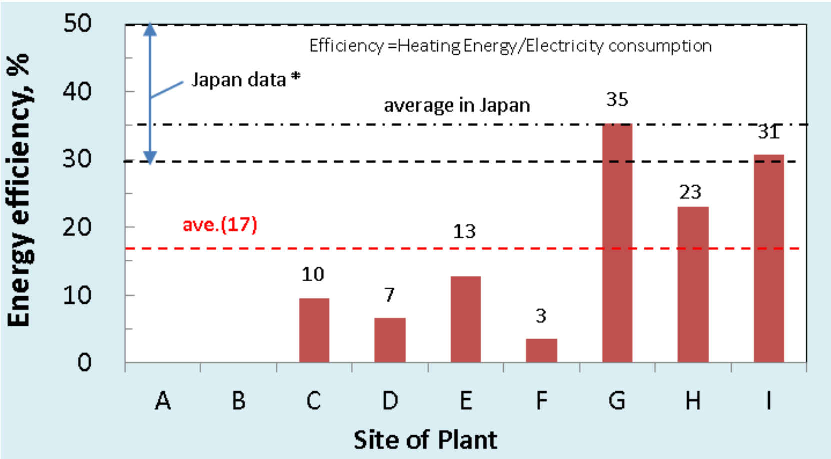

Figure 19: Energy efficiency for heating up molten steel in LF[10]

4.5 Ladle (LD)

4.5.1 Ladle preheater fuel consumption

LD fuel consumption ranges from 0.19 to 0.90 GJ/t, and the average is 0.57 GJ/t (Figure 20). Additionally, oxygen burner preheaters consume 0.3 GJ/t on average. This value is about 50% lower than the other types of burner. The best fuel consumption with an oxygen burner is same as that of regenerative burners in Japan.

[10] Japan data: “Recent Progress of Steelmaking Technology in Electric Arc Furnace”, p.141, 3rd ed., 1993, ISIJ.

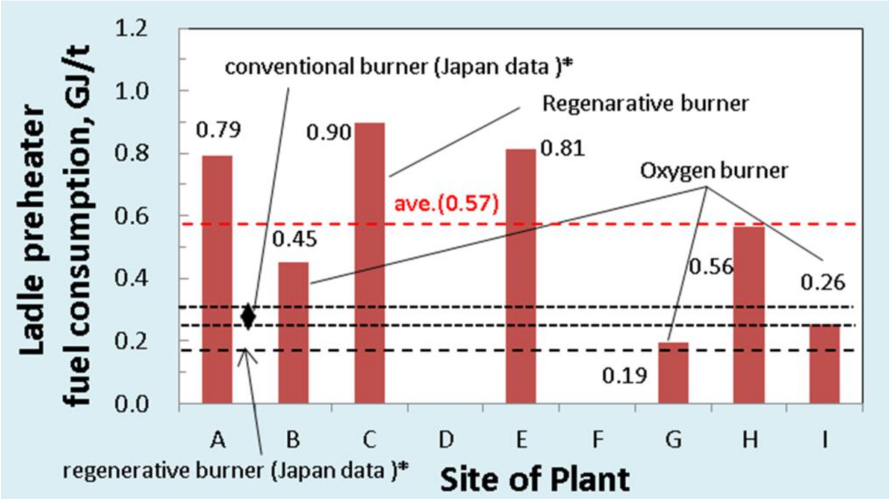

Figure 20: Ladle preheater fuel consumption[11]

4.5.2 Ladle logistics

Ladle logistics between EAF and CCM is important for efficient energy usage. One of the key factors used to evaluate ladle logistics is the ladle rotation ratio, which is defined as a ratio of the number of times the ladle is heated per day to the number of operating ladles. The ladle rotation ratio signifies the number of times per day that molten steel can be received by the same ladle. Therefore, this ratio can be considered as an index to evaluate performance of ladle logistics. A higher ratio means better performance of ladle logistics. In this sense, with a ladle rotation ratio of 6.0 on average, which is nearly the same as Japan data (Figure 21), it appears that LD logistics are effectively managed.

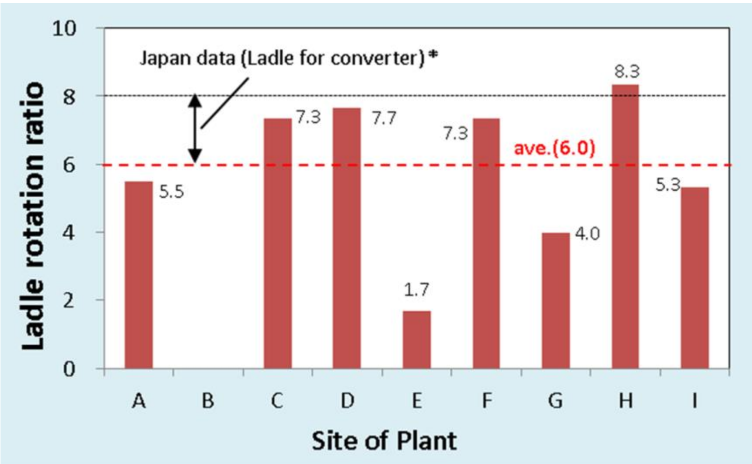

Figure 21: Ladle rotation ratio[12]

The ladle rotation ratio can be estimated to affect heat content of ladle refractory. Therefore, it can be estimated that the more ladle rotation ratio increases, the lower temperature drop by tapping becomes. Figure 22 shows a relation between the temperature drop by tapping and the ladle rotation ratio. The effect of the ladle rotation ratio on the temperature drop seems to have appeared qualitatively.

[11] Japan data : DENKI SEIKO, vol.78, no.1, p.57, 2007
[12] research by JFETEC

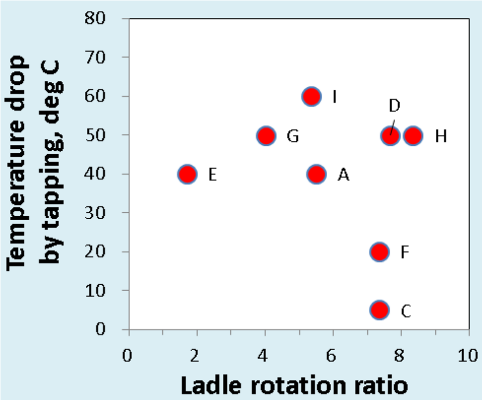

Figure 22: Relation between the temperature drop by tapping and ladle rotation ratio

Cycle time of ladle from the start of tapping start to casting end is another index of evaluation for ladle logistics. On the basis of reference data in Japan, the shorter the cycle time becomes, the lower EAF+LF total electricity consumption becomes. The present data in Thailand also indicates similar relationship as the Japan data (Figure 23). But electricity consumption is 50 kWh/t higher than Japan data in comparison with the same cycle time. In order to decrease the electricity consumption, ladle logistics seems to be one of the important indexes to improve energy saving.

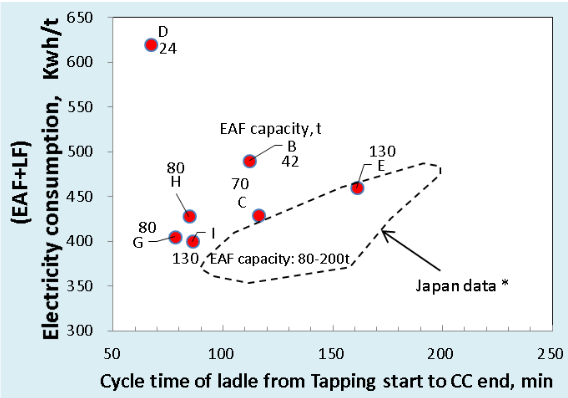

Figure 23: Effect of cycle time of ladle from tapping start till casting end on EAF+ LF electricity consumption[13]

4.6 EAF auxiliary equipment

4.6.1 Dedusting fan

Dedusting fan electricity consumption is 26 kWh/t in minimum, 52 kWh/t in maximum, and 36 kWh/t in average (Figure 24).

[13] Japan data: Handbook of Iron and Steel , p.225, 5th edition, 2014, ISIJ.

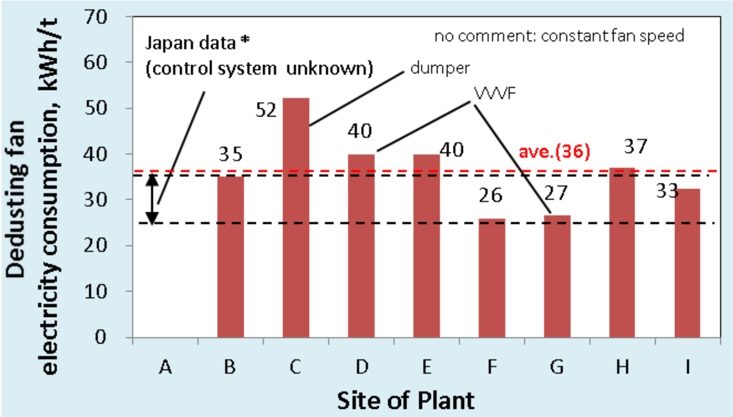

Figure 24: Dedusting fan electricity consumption in EAF plant[14]

In order to improve electricity consumption, it should be understood that specific electricity consumption decreases as EAF capacity increases. This happens because increasing EAF capacity makes dedusting efficiency improve. The relation between dedusting fan electricity consumption and EAF capacity is shown in Figure 25. Dedusting fan electricity consumption is higher than Japan data in comparison with the same EAF capacity. It can be seen, however, that electricity consumption of the VVVF (Variable Voltage Variable Frequency) dedusting control system indicates the same level in comparison with Japan data.

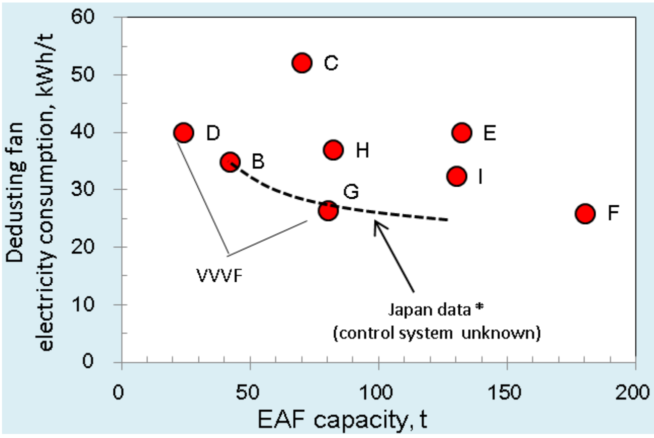

Figure 25: Relation between dedusting fan electricity consumption and EAF capacity[14]

4.6.2 Cooling water pump

As for the cooling water pump, electricity consumption ranges from 22 kWh/t minimum to 51 kWh/t maximum, and the average is 31 kWh/t. All data indicate relatively stable values except for plant site C (Figure 26). One reason that plant site C indicates a higher value is may be that the dedusting fan is operated all day in spite of lower EAF operation ratio (Figure 27). There is no published data in Japan related to subject, so a comparison is not possible.

[14] Japan data: "Recent Progress of Steelmaking Technology in Electric Arc Furnace", p.301, 3rd edition, 1993, ISIJ.

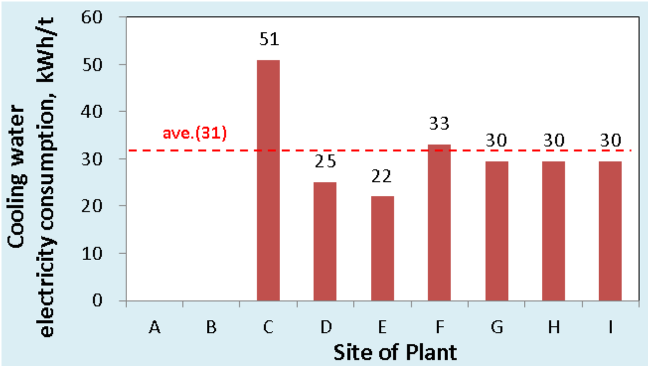

Figure 26: Electricity consumption of cooling water pump

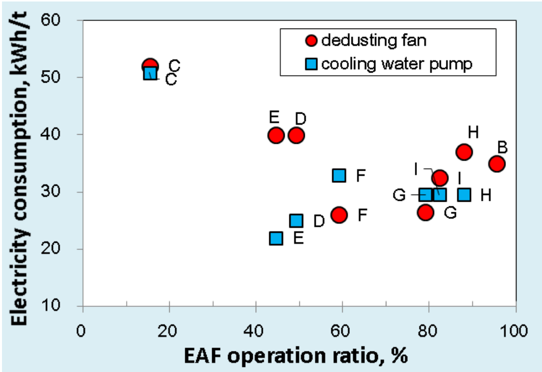

Figure 27: Relation between electricity consumption of cooling water pump and EAF operation ratio

4.7 Continuous casting machine (CCM)

4.7.1 Charging temperature to RHF

In CCM, part of casted semi-products such as billet, bloom and slab are transferred directly to RHF for hot charging. All companies in the present study apply hot charging to some extent. The average hot charge ratio (Rhot) reached 42%. To improve energy efficiency, it is desirable to make the charging temperature of the semi-product higher. Figure 28 shows the effect of charging temperature on the travelling time of the cast from mold to exit of CCM. Ideally, x-axis should be travelling time from mold to entrance of RHF, but in this study that data was not collected. The charging temperature qualitatively seems to have a tendency to increase by shortening the travelling time. This travelling time can be controlled by casting speed in CCM if quality problem does not occur.

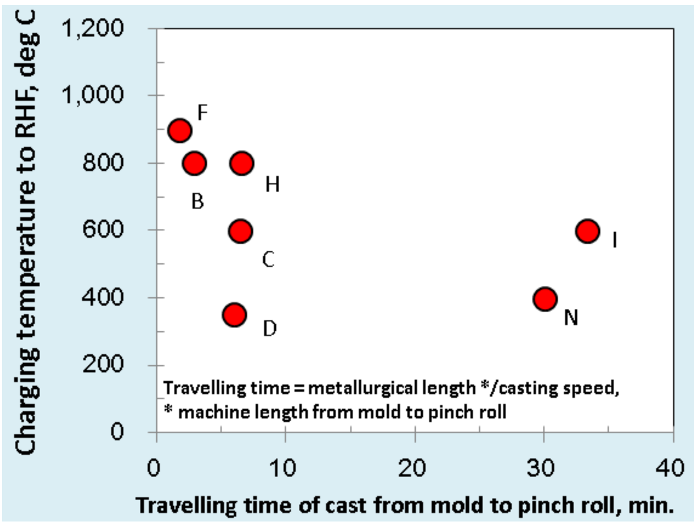

Figure 28: Effect of charging temperature on travelling time of the cast from mould to casing machine exit

4.7.2 Possibility of increase in casting speed for higher charging temperature

Figure 29 shows a rough estimation of the possibility of an increase in casting speed for higher charging temperature of the cast on the assumption of solidification constant k=24 mm/min$^{0.5}$. It can be seen that casting machine length (metallurgical length) is effectively used, that is, when actual casting speed is nearly same as estimated maximum casting speed. But, some machines would have room to increase casting speed in case no quality problems arise.

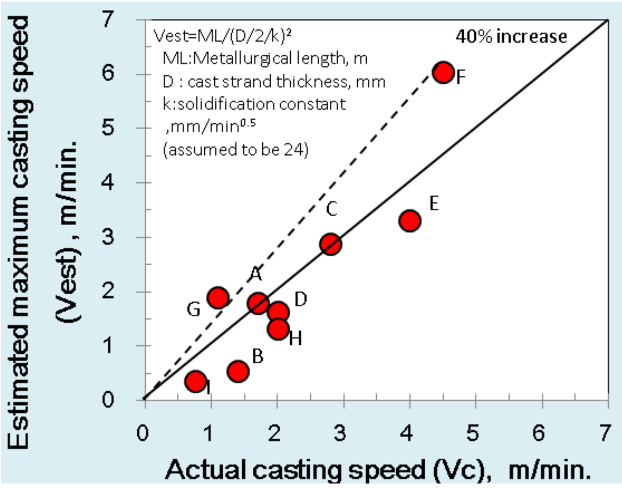

Figure 29: Comparison between maximum casting speed estimated from machine specifications and actual speed

4.8 Reheating furnace (RHF)

4.8.1 Fuel consumption

Fuel consumption levels were shown with hot charge, cold charge, and monthly average, respectively in Figure 30. Comments in the figure provide information affecting to fuel consumption. Fuel consumption in hot charge indicates the lowest value 0.95 GJ/t of the three conditions. This value is 29% lower than that in cold charge. The monthly average 1.44 GJ/t is 34% higher than the Japan average.

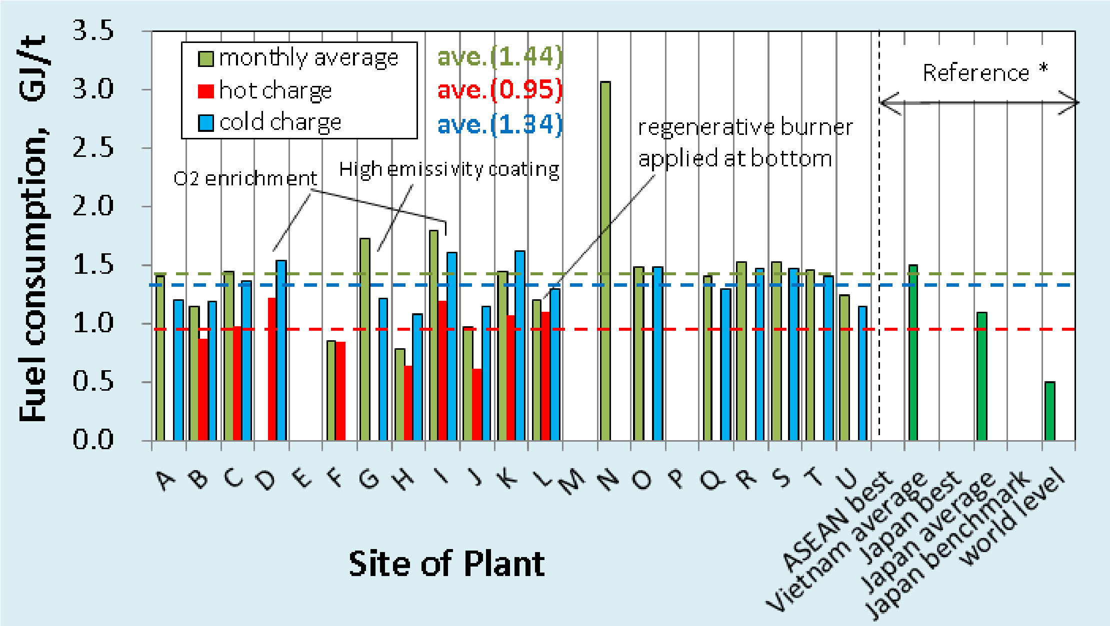

Figure 30: Fuel consumption in reheating furnace[15]

4.8.2 Effect of hot charge ratio on fuel consumption

Fuel consumption is strongly affected by hot charging ratio and the temperature of charging material. Figure 31 shows effect of the hot charge ratio (Rhot) on fuel consumption. Fuel consumption decreases as the ratio increases.

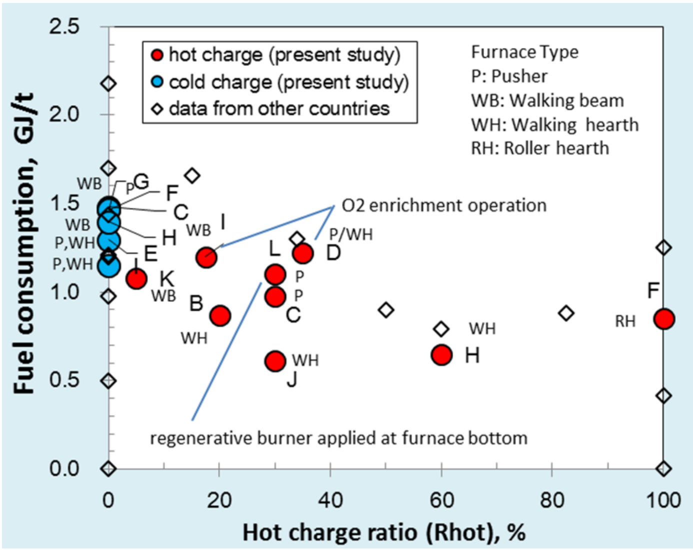

Figure 31: Effect of hot charge ratio on fuel consumption

Figure 32 shows effect of heat content of charging material on fuel consumption. The x-axis expresses the multiplied value of the hot charge ratio and heat content of charging material. It can be seen that fuel consumption decreases as the heat content increases, and this relation is similar to that in Japan. Simulation[16] results are also plotted as a cross mark, and are well fitted to the Japan data in the case of slab. The furnace type is also described beside the symbols. Walking hearth type (WH) indicates relatively lower value.

[15] Estimated from Japan data[17] on the assumption of Rhot=50% and slab charging temperature=500 degC by JFETEC
[16] Simulation method is explained in Appendix “Energy Efficiency Manual for Thailand Iron & Steel Industries”

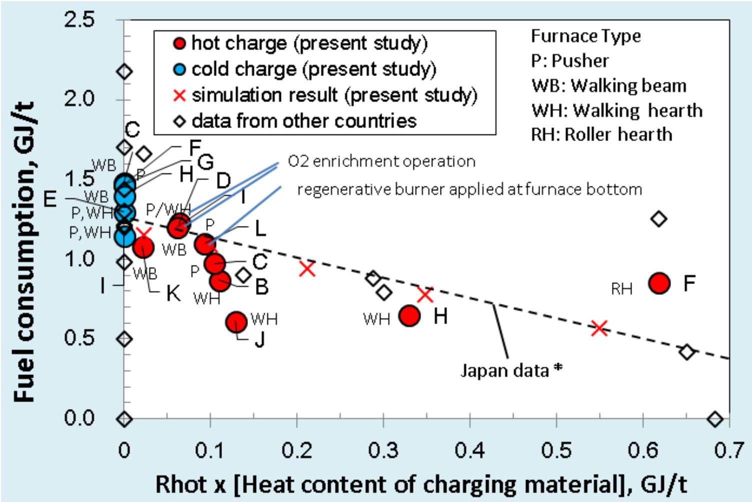

Figure 32: Effect of heat content of charging material on fuel consumption[17]

4.8.3 Effect of operation ratio on fuel consumption

Figure 33 shows the effect of the operation ratio of hot charge and cold charge on fuel consumption. Where the terms are defined as follows:

Operation ratio of hot charging = Rop x Rhot, %
Operation ratio of cold charging = Rop x (100-Rhot), %.
Where Rop: actual production / production capacity, Rhot: hot charge ratio

Fuel consumption efficiency has a tendency to improve as the operation ratio of hot charging and cold charging increase.

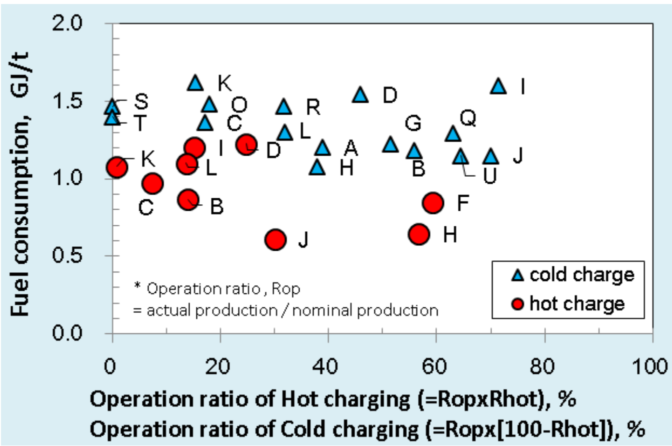

Figure 33: Effect of operation ratio for hot and cold charge on fuel consumption

4.8.4 Recuperator performance

Figure 34 shows a comparison of temperature between inlet off-gas and preheated combustion air. Inlet off-gas temperature is around 670 °C on average, and outlet preheated air temperature is around 380 °C on average.

[17] Japan data: Handbook of Iron and Steel, p.216, 5th edition, 2014, ISIJ

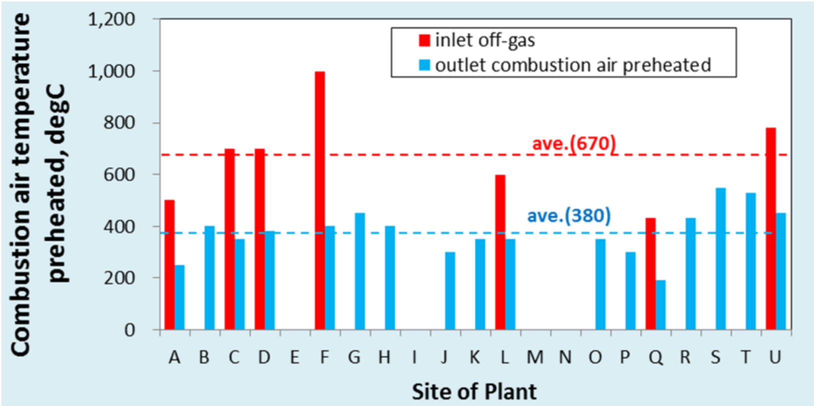

Figure 34: Temperature of inlet off-gas and preheated combustion air

Performance of recuperator can be evaluated by recuperator temperature efficiency, which is defined as preheated combustion air temperature (Tair) / Inlet temperature of off-gas, so this factor can be calculated as a slope of a line in Figure 35. The efficiency is calculated to be 40% to 60%, and 51% on average. This value is lower than the Japan average of 80%. There is no information regarding whether these data were collected for hot charge or cold charge.

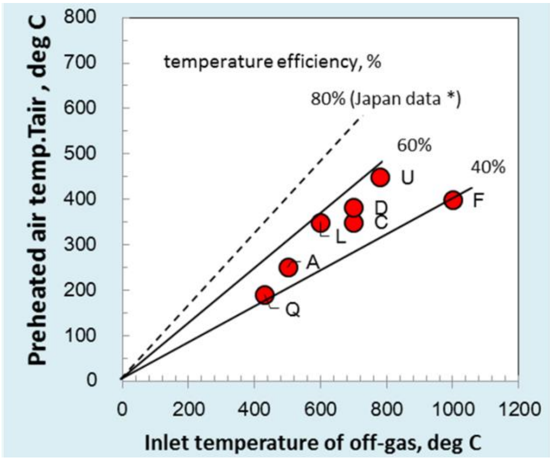

Figure 35: Relation of temperature between inlet off-gas and preheated combustion air[18]

The performance of the recuperator can be evaluated from the difference between target temperature (according to specifications) and actual temperature in Figure 36. Almost 50% (=5/11) of recuperator does not reach the target temperature.

[18] Japan data: Handbook of Iron and Steel, p.217, 5th edition, 2014, ISIJ

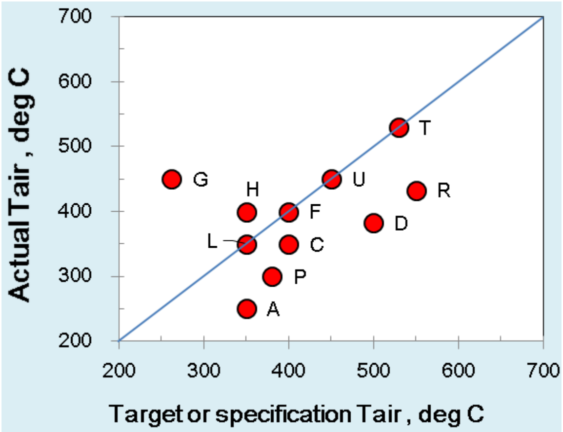

Figure 36: Comparison of Tair between target (specifications) and measurement

4.8.5 Energy efficiency of RHF

Figure 37 shows the energy efficiency of RHF. Energy efficiency is defined here as increased heat content of charging materials in the furnace relative to the heat consumption. This value is 35% for hot charge and 57% for cold charge.

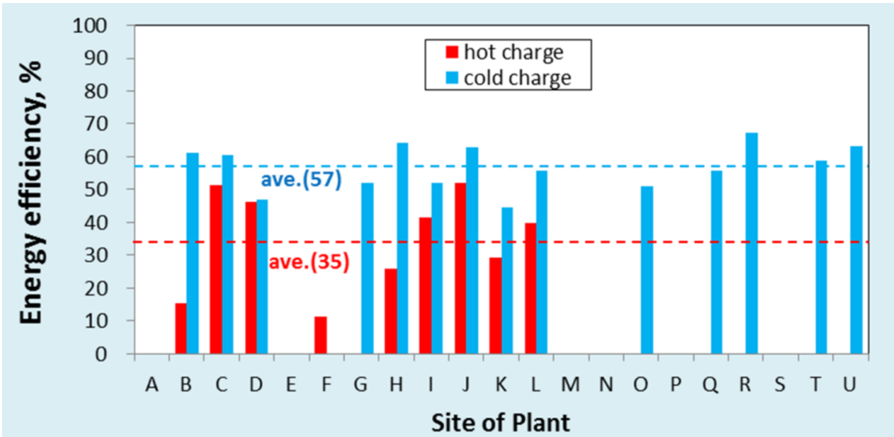

Figure 37: Energy efficiency of RHF

The energy efficiency is affected by charging temperature (Figure 38). The more the temperature increases, the more efficiency decreases. The amount of heat transfer from furnace atmosphere to charging material is proportional to temperature difference between the atmosphere and the material. The relation is qualitatively similar to the estimated one in the Japan data in Figure 32. But the value is lower than the estimated values in Japan at the same charging temperature.

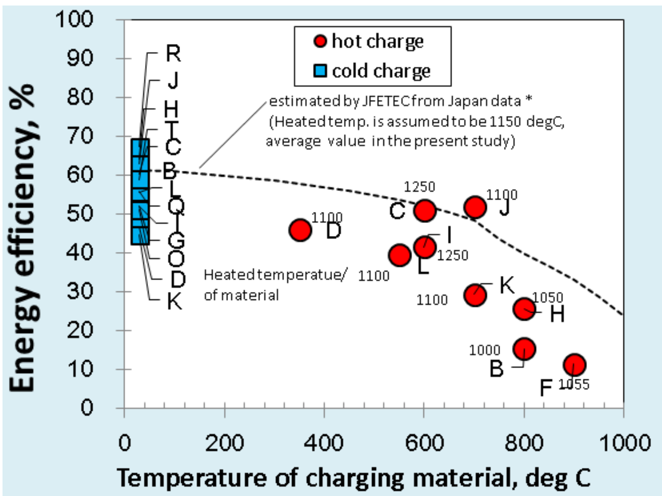

Figure 38: Effect of charging material temperature on energy efficiency[15]

5 Summary

5.1 Comparison with Japan data

Table 4 is a summary of the comparison with Japan data. It was found that there is the potential to improve energy efficiency in EAF and RHF. As for EAF plants, plant energy consumption was indicated to be 38% higher than Japan data. In the table, reference values for benchmark (which are calculated as the mean minus the standard deviation in cases of energy and fuel[19] and are calculated as mean plus standard deviation in the case of efficiency[20]) of various evaluation indexes concerning energy consumption are also shown. For European benchmark values, specific energy consumption is calculated as the average from the top 10%.[21] When applying this idea to the EAF based steel industry in Thailand, the best data becomes to be the benchmark because the number of data collected this time (N = 9) was less than 10.

As a result, to improve EAF electricity consumption, LF energy efficiency, ladle preheater fuel consumption, and dedusting fan may be good candidates for energy improvements. As for RHF plants, energy consumption was roughly 34% higher than Japan data. To improve RHF energy consumption, energy efficiency and recuperator temperature efficiency may be good candidates for energy improvements.

[19] Based on Agency of Natural Resources and Energy, Japanese government: for example, http://www.meti.go.jp/committee/sougouenergy/shoene_shinene/sho_ene/koujo_wg/2016/pdf/001_03_00.pdf
[20] Calculated for reference
[21] Official Journal of the European Union (2011/278/EU), Commission Decision of 27 April 2011

Table 4: Summary of questionnaire analysis on the basis of comparison with Japan data

Factor	unit	Thailand		Japan	Comparison with Japan data
		average	reference for benchmark *1		
Plant with EAF Electric Arc Furnace (EAF)					
Plant Energy consumption (with EAF)	GJ/t	9.1	7.1	6.6	38% higher
Plant CO2 emission (with EAF)	t-CO2/t	0.56	0.44		
Electric Arc Furnace					
EAF Electricity consumption	kWh/t	412	352	380	8% higher
EAF Electrode consumption	kg/t	1.5	0.9	0.8-2.0	same performance
Fe yield	%	89	90.9	92-93	3% lower, but no significant difference in consideration of O2 consumption
Oxygen consumption	Nm3/t	30-50	-	10-20	
EAF Energy efficiency	%	62	72	50-67	no significant difference
Ladle furnace					
LF Energy efficiency	%	17	30	35	20% lower
Ladle preheater					
Ladle preheater fuel consumption	GJ/t	0.57	0.29	0.2-0.3	2 times higher
Oxygen burner	GJ/t	0.3	-	-	
Regenarative burner	GJ/t	0.9	-	0.17	5 times higher
Ladle logistices					
(EAF+LF) Electricity consumption vs time(t) from tapping start to CC end	GJ/t				50kWh/t larger (at t=100min.)
Auxiliary equipment					
Dedusting fan electric consumption	kWh/t	36	28	ca. 30	20% higher, influenced by operatio ratio
Reheating Furnace (RHF)					
Plant Energy consumption (without EAF)	GJ/t	2.6	1.4	-	
Plant CO2 emission (without EAF)	t-CO2/t	0.18	0.11	-	
Reheating Furnace					
RHF Fuel consumption (monthly)	GJ/t	1.44	0.94	1.1	34% higher (Thai: billet, bloom & slab, Japan ave.: 50% hot charge at 500degC of slab)
RHF Fuel consumption (cold charge)	GJ/t	1.34	1.17		
RHF Fuel consumption (hot charge)	GJ/t	0.95	0.73		
RHF Fuel Energy efficiency	%	47		57	10% lower (at 500 degC of charging temp.)
Recuperator Temperature efficiency	%	51	58	80	30% lower

*1: average-standard deviation (energy and fuel), or average+standard deviation (efficiency)

5.2 Comparison among Thai companies

Table 5 is a summary on the comparison of operating performance among steel plants in Thailand. Four technologies in particular were found to be effective for improving energy consumption. Those are 1) Scrap preheating, 2) Ladle preheating by oxygen burner, 3) Dedusting fan control by VVVF (Variable Voltage Variable Frequency) and 4) Hot charging operation.

Table 5: Summary comparison of operating performance among surveyed steel plants in Thailand

Factor	unit	with	without	Performance evaluation of "with"	
Scrap preheater					
EAF Electricity consumption	kWh/t	371	423	12% lower	○
	N	(2)	(7)		
EAF Electrode consumption	kg/t	1.2	1.6	27% lower	○
	N	(2)	(7)		
Tap-tap time	min.	61	58	3 minites shorter	△
	N	(2)	(6)		
EAF Energy efficiency	%	72	59	13 points higher	○
	N	(2)	(6)		
Fe yield	%	87.0	90.0	3 points lower	△
	N	(2)	(7)		
Ladle preheater by Oxygen burner					
Fuel consumption	GJ/t	0.30	0.72	2.5 times lower	○
	N	(3)	(3)		
Ladle preheater by Regenarative burner					
Fuel consumption	GJ/t	0.90	0.72	25% higher	×?
	N	(1)	(3)		
Dedusting fan control by VVVF					
Electricity consumption	kWh/t	34	37	10% lower	○
	N	(2)	(6)		
Hot charging into RHF					
Fuel consumption	GJ/t	0.95	1.34	29% lower	○
	N	(9)	(16)		

Remarks ○: better performance, △: relatively poor performance, ×?: need more survay