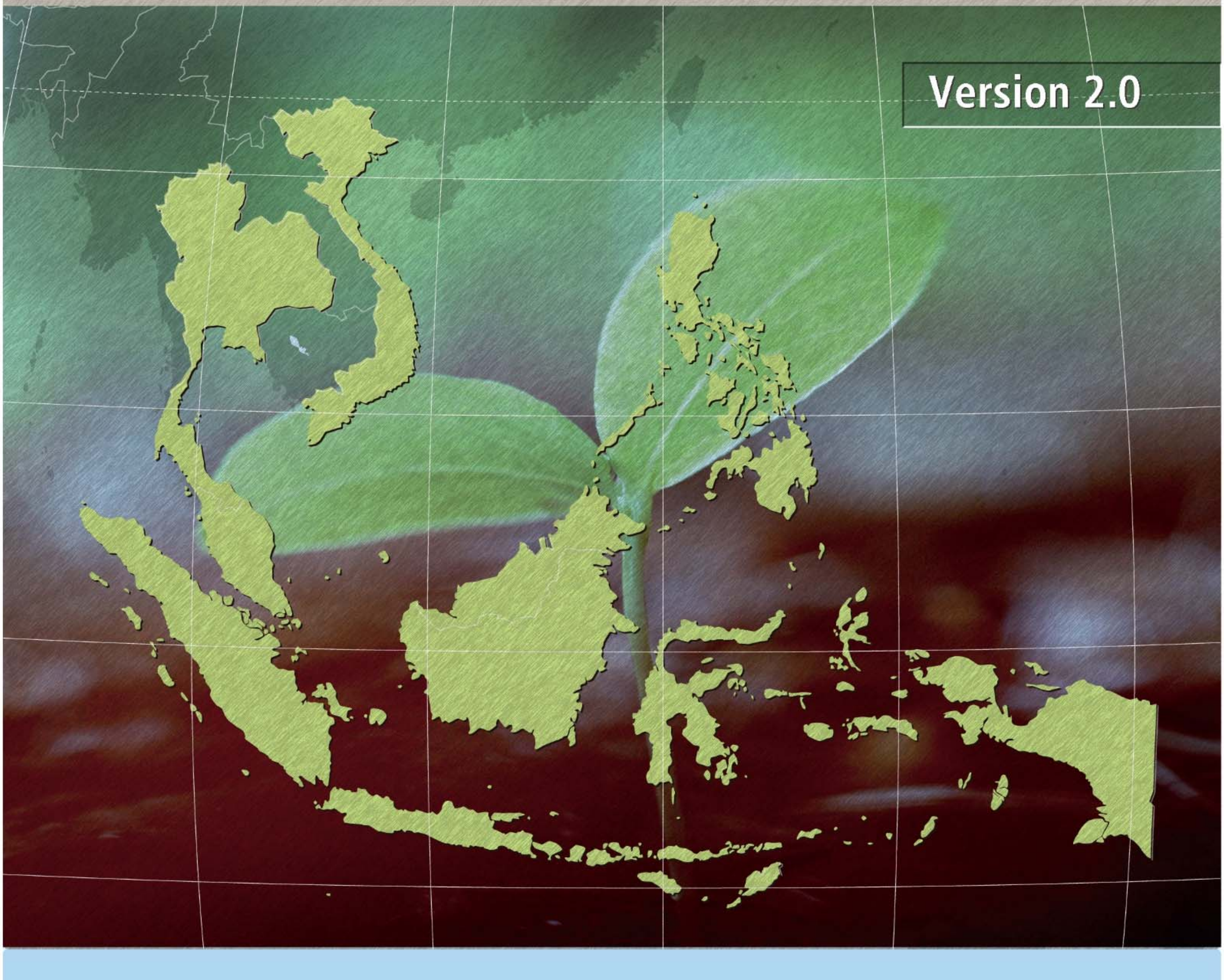
Technologies Customized List

For Technology Transfer to ASEAN Iron and Steel Industry
With regard to Energy-Saving, Environmental Protection, and Recycling



DEVELOPED AT ASEAN-JAPAN STEEL INITIATIVE

Introduction

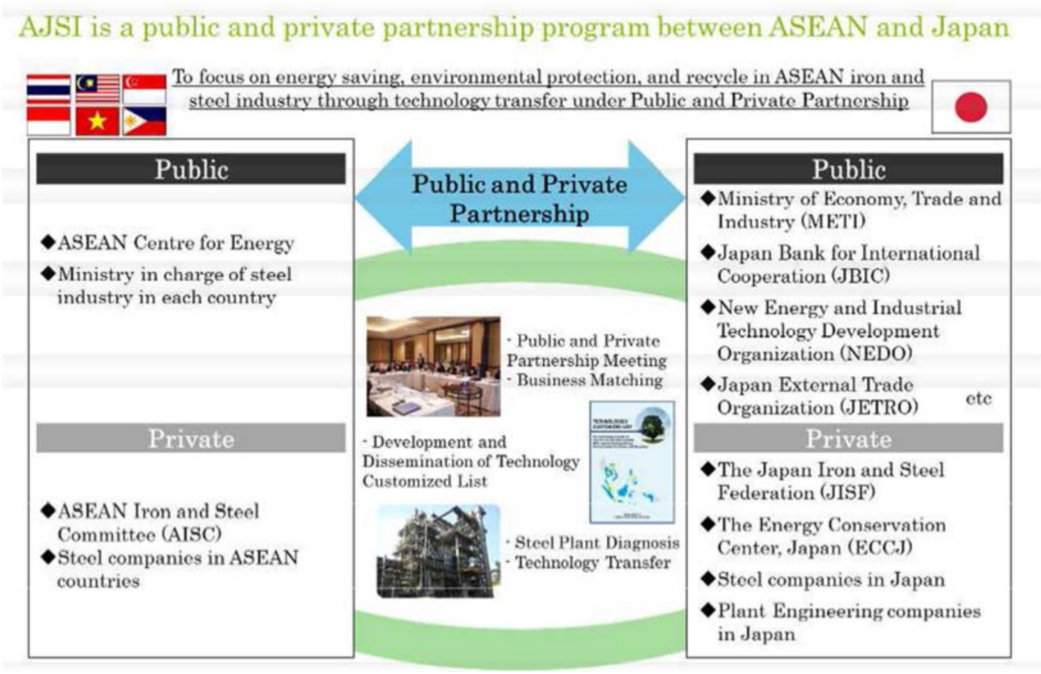
Overview

"Technologies Customized List" is a technology reference containing energy-saving, environmental-protection and recycling technologies, developed under a collaborative scheme of ASEAN-Japan Steel Initiative (AJSI) between ASEAN 6 countries (Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam) and Japan. The list is aimed at identifying appropriate technologies for the ASEAN steel industry and the first version of the list was published in November 2014.

The list reflects the knowledge acquired from public and private experiences of the Japanese steel industry, which achieves the highest energy efficiency in the world, and the technology needs of ASEAN steel industry. In this context, contents of the list are informative for public sectors for development of policies and measures, as well as for private sectors for the plan of the technology introduction and improvement of energy management activities in steel plants.

After the publication of the Technologies Customized List version 1, the list was employed on many occasions such as Steel Plant Diagnosis and Public and Private Collaborative Workshops. Through these activities, additional technology needs were specified. Technologies Customized List version 2 contains these new technologies and more detailed explanations of the existing technologies.

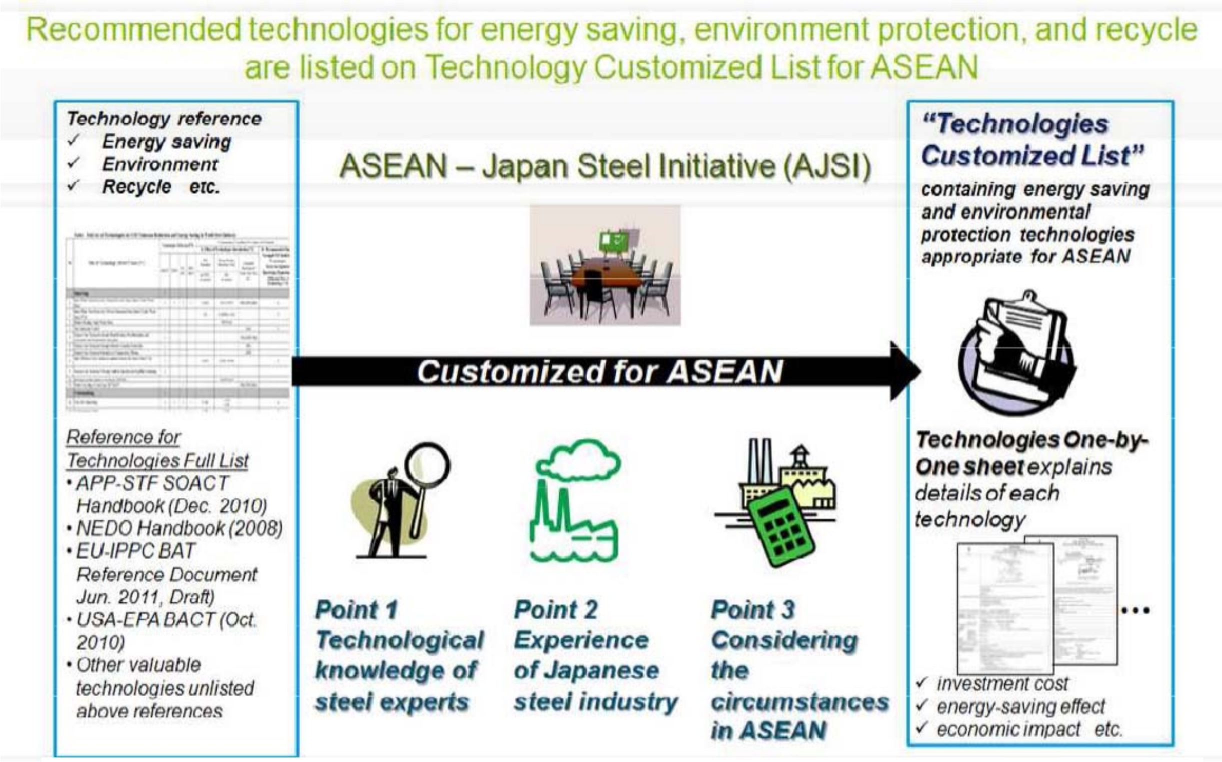
What is ASEAN-Japan Steel Initiative?



Development process of Technologies Customized List

Technologies on Technologies Customized List were chosen from several technology references in the world, based on three perspectives;

1) Technological knowledge of steel experts in ASEAN and Japan
2) Experience of Japanese steel industry
3) Circumstances in ASEAN steel industry



<Reference List>
SOACT Handbook: http://www.jisf.or.jp/business/ondanka/eco/docs/SOACT-Handbook-2nd-Edition.pdf
NEDO Handbook: http://ietd.iipnetwork.org/sites/ietp/files/Japanese%20Technologies%20for%20Energy%20Saving.pdf
EU-IPCC BAT: http://eippcb.jrc.ec.europa.eu/reference/BREF/IS_Adopted_03_2012.pdf
USA-EPA-BACT: https://www.epa.gov/sites/production/files/2015-12/documents/ironsteel.pdf

Version 2.0 September, 2016

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1. TECHNOLOGIES CUSTOMIZED LIST

Technology selection criteria

33 technologies on the "Technologies Customized List version 2" are considered to contribute to energy saving and environmental protection in ASEAN steel industry. These technologies were chosen based on the following criteria.

- Coverage: Technologies Customized List contains the technologies for energy saving, environmental protection and recycling in the steel plants with Electric Arc Furnace (EAF) in ASEAN region. Technologies for other purposes, such as quality improvement and production increase, are not covered in Technologies Customized List.

- Availability: Target technologies should be commercially available. Technologies under development in Japan, which the supplier companies are not ready to diffuse in ASEAN region, are not eligible for Technologies Customized List.

Pre-Conditions for Calculations of Effects

Capacity and performance of the model steel plant to study costs and effects of energy saving project are assumed as below:

1) 100 % scrap use EFA plant to produce mild steel for construction use
2) Annual production is 500,000 ton/y with 80 ton EAF
3) Unit electricity consumption of EAF is 430 kWh/ton-billet
4) Unit thermal consumption of reheating furnace is 1,450 MJ/ton-billet
5) The plant possesses conventional facilities, without advanced technologies

Equipment List of Model Steel Plant

Annual Production			500,000 ton/year
EAF		RHF	
Equipment Name	Value	Equipment Name	Value
Nominal capacity	80 ton	Type	Walking beam
TTT	52 minutes	Nominal capacity	100 ton/h
Iron source	100 % scrap	Heated material	135 SQ billet
Scrap preheating	none	Heating temperature	1100 degC
Scrap charging	3 times	Fuel	Natural gas, LHV 44 MJ/m3N
Ladle furnace	used	Combustion air preheating	around 300 degC with low grade recuperator
NG burner	used only to facilitate melting	Computer control to set furnace temperature with heat transfer simulation	none
O2 and C lances	installed only at slag-door side, water-cooled type	Hot charge and/or direct rolling	none
Process control by exhaust gas analysis and/or computer	none	Insulation	firebrick
Electricity consumption	430 kWh/ton	Heat consumption	1,450 MJ/ton-steel
Oxygen consumption	30 m3N/ton		
Natural gas consumption	20 m3N/ton		
Coke consumption	15 kg/ton		
Product	Mild steel less than 0.2 % C		
Tapping temperature	1620 degC		

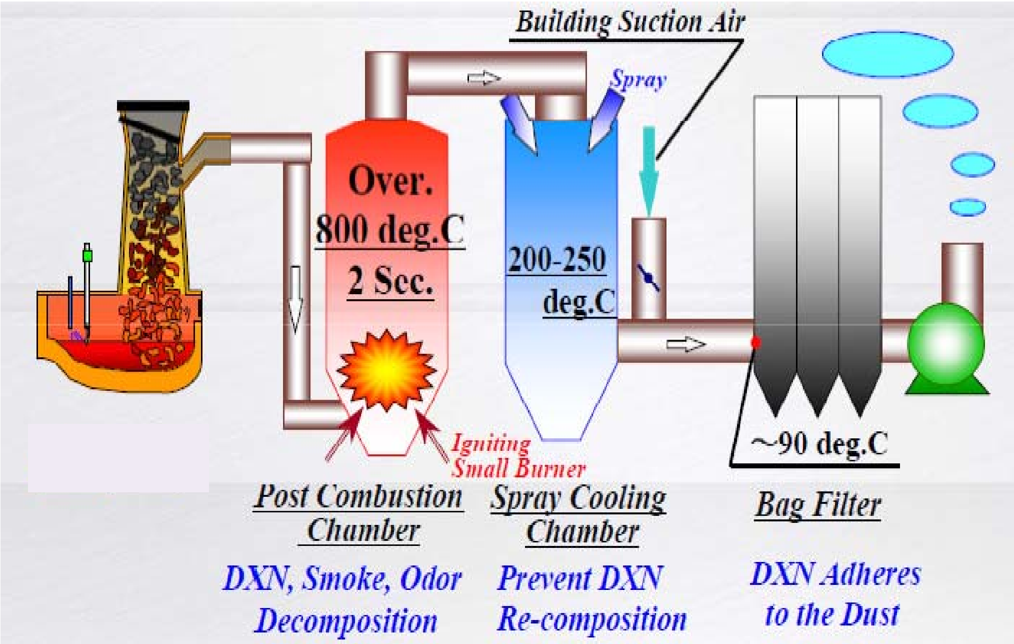
Technologies Customized List for Energy Saving, Environmental Protection, and Recycling for ASEAN Steel Industry (ver.2.0)

No.	ID	Title of technology	Technical description	Expected effects of introduction: Electricity saving (kWh/t of product)	Thermal energy saving (GJ/t of product)	Profit of Operation cost (US$/t of product, Japan)	Environmental benefits	Co-benefits	Assumed investment cost: Assumed investment cost (million US$ in Japan)	Payback time (year in Japan)	Main Japanese supplier
A. Energy Saving for Electric Arc Furnace (EAF)											
1	A-1	High temperature continuous scrap preheating EAF	Combination of the technologies of - Air tight structure - High temperature scrap preheating (over 700 degC) - Continuous preheated scrap charging - Automatic process control by using data logging - Post-combustion of generated CO gas - Dioxin decomposition by secondary combustion	**150.0**	**-**	**16.95**	- Decomposition and reduction of dioxin, dispersing dust, & noise	- Low electrode consumption (0.8 - 1.0 kg/ton-product at AC)	**38.00**	**4.5**	- JP Steel Plantech
2	A-2	Medium temperature batch scrap preheating EAF	- High melting efficiency batch charging type EAF with SPH - Preheated scrap temperature is about 250 - 300 degC - Fully enclosed automatic charging system to keep working floor clean - Minimize scrap oxidation by temperature controlling - Material limitation free	**40.0**	**-**	**4.52**	- Reduction of dioxin emission, dispersing dust, & noise	-No limit of material for high quality products as like stainless steel	**10.00**	**4.4**	- Daido Steel
3	A-3	High efficiency oxy-fuel burner/lancing for EAF	- Supersonic or coherent burner - Accelerate scrap melting during melting stage - Facilitate slag foaming during refining stage over the bath	**14.3**	**-**	**1.62**	-	- Reduction of nitrogen in steel for quality improvement	**2.05**	**2.5**	- Nikko - JP Steel Plantech
4	A-4	Eccentric bottom tapping (EBT) on existing furnace	- Slag free tapping - Reliable stopping and scraping mechanism	**15.0**	**-**	**1.70**	-	- Increase in Fe & alloy yield, productivity - Improve steel quality	**4.00**	**4.7**	- JP Steel Plantech - Daido Steel
5	A-5	Ultra high-power transformer for EAF	- Long arc by high voltage and low ampere operation - Water cooled wall-panel to protect refractories	**15.0**	**-**	**1.70**	-	- Productivity increase	**5.66**	**6.7**	- JP Steel Plantech - Nikko
6	A-6	Optimizing slag foaming in EAF	- Proper chemical ingredients of slag - High efficient burner and/or lance - Controlled O2 & C injection into EAF proper position - Keeping slag thickness with air-tight operation	**6.0**	**-**	**0.68**	- Noise reduction & working floor cleaning	-	**1.50**	**4.4**	- JP Steel Plantech - Daido Steel
7	A-7	Optimized power control for EAF	- Data logging and visualization of melting process - Automatic judgement on meltdown and additional scrap charge - Automatic phase power independent control for well-balanced melting	**15.0**	**-**	**1.70**	-	- Productivity increase - Manpower saving	**2.50**	**2.9**	- JP Steel Plantech
8	A-8	Operation support system with EAF meltdown judgment	Automatic Rapid Melting system - Data logging - Optimum electric power control - Alloy calculation - Automatic meltdown Judgment	**6.0**	**-**	**0.68**	-	- Productivity increase - Manpower saving - Operation standardization	**0.50**	**1.5**	- Daido Steel
9	A-9	Low NOx regenerative burner system for ladle preheating	- Regenerating burner use - High Energy Saving (about 40%) - Automatic control - FDI Combustion	**-**	**0.20**	**-**	- NOx reduction	- Contribute to better atmosphere around at workfloor	**0.40**	**0.2**	- Chugai-Ro - Nippon Furnace
10	A-10	Oxygen burner system for ladle preheating	- Rapid and high temperature ladle heating by oxygen burner - Automatic control - High Energy Saving (about 40%)	**-**	**0.20**	**-**	- NOx reduction	- Contribute to better atmosphere around at workfloor	**0.30**	**0.1**	- Chugai-Ro - JP Steel Plantech
11	A-11	Waste heat recovery from EAF	- Waste heat boiler based on the OG boiler technology - Specified for splash and dust containing	**132.0**	**-**	**14.92**	-	-	**60.00**	**8.0**	- JP Steel Plantech
12	A-12	Energy saving for dedusting system in EAF meltshop	- Damper openings and exhaust fan rotation are controlled in consonance - Combination of VVVF and proper damper opening	**6.0**	**-**	**0.68**	- Better working floor & atmosphere	-	**0.80**	**2.4**	- JP Steel Plantech - Daido Steel
13	A-13	Bottom stirring/stirring gas injection	- Inject inert gas (Ar or N2) into the bottom of EAF - Better heat transfer steel quality	**18.0**	**-**	**2.03**	-	- Fe yield increase 0.5 %	**0.26**	**0.3**	- JP Steel Plantech
14	A-14	Induction type tundish heater	- Application of induction heating - Possible to uniformize temperature in 3 minutes after power supply	**3.0**	**-**	**0.34**	-	-	**1.00**	**5.9**	- Fuji Electric
15	A-15	Scrap pretreatment with scrap shear [Newly-added technology]	- Long size or low bulk-density scrap is shredded and packed - Scrap pretreatment decreases the scrap-charging frequency, which will lead to energy saving	**20.0**	**-**	**2.26**	-	- Fe yield increase in 1.5 % (by Non-integrated steel producers' association)	**3.80**	**3.4**	- Fuji Car Manufacturing
16	A-16	Arc furnace with shell rotation drive [Newly-added technology]	- By rotating furnace shell 50 degree back-and-force, cold spot will be decreased to realize smooth melting - Assumed investment cost is the increase from the newly constructed conventional EAF	**32.0**	**-**	**3.62**	-	- Decreasing power-on time, melting fuel, and refractory material	**6.00**	**3.3**	- Daido Steel

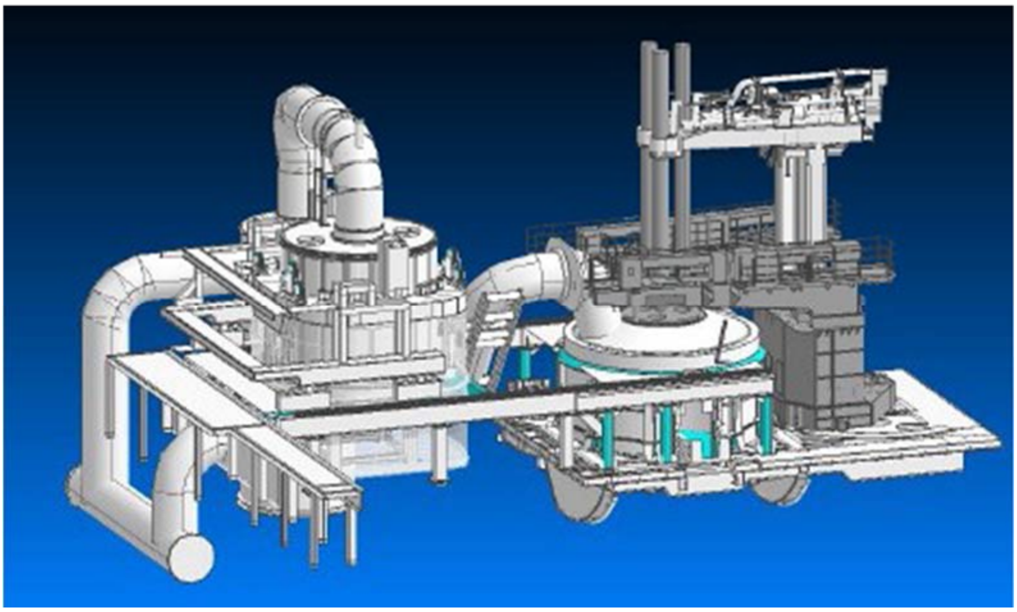
Technologies Customized List for Energy Saving, Environmental Protection, and Recycling for ASEAN Steel Industry (ver.2.0)

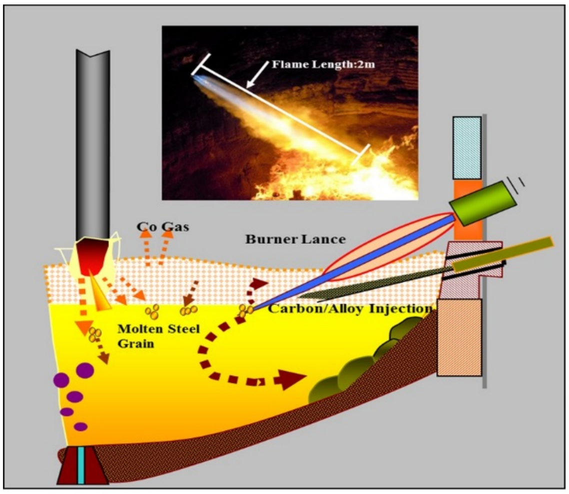
No.	ID	Title of technology	Technical description	Expected effects of introduction: Electricity saving (kWh/t of product)	Thermal energy saving (GJ/t of product)	Profit of Operation cost (US$/t of product, Japan)	Environmental benefits	Co-benefits	Assumed investment cost: Assumed investment cost (million US$ in Japan)	Payback time (year in Japan)	Main Japanese supplier
B. Environmental Protection for Electric Arc Furnace											
17	B-1	Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF	- Improved design configuration of the direct evacuation for treating hot unburned gas from much fuel use - Minimize dust and gas dispersion from EAF with enough capacity and suitable control	-	-	-	- Better workfloor & environment	-	-	-	- JP Steel Plantech - Daido Steel
18	B-2	Floating dust control in EAF meltshop	- Analyze air flow in EAF building	-	-	-	- Restrict dust loading on working floor to less than 5	-	1.00	-	- JP Steel Plantech - Daido Steel
19	B-3	Dioxin adsorption by activated carbon for EAF exhaust gas	- Packaged cartridges of activated carbon fixed at the exit of bag-filter adsorbs and removes dioxins and heavy metals to an extremely low level	-	-	-	- Dioxin will be lower than 0.5 ng TEQ/m^3N	-	-	-	- JFE Engineering
20	B-4	Dioxin adsorption by mixing EAF exhaust gas with building dedusting	- Cooling direct evacuation gas by mixing with building dedusting gas	-	-	-	- Dioxin will be lower than 5.0 ng TEQ/m^3N	-	-	-	- JP Steel Plantech - Daido Steel
21	B-5	Dioxin adsorption by 2 step bagfilter technology for EAF exhaust gas	- 2 step bag system can remove over 99% DXN's from EAF. - This system provide a clean working environment. - Effective evacuation decrease the consumption of electricity.	-	-	-	- Dioxin will be lower than 0.5 ng TEQ/m^3N	-	-	-	- JP Steel Plantech - Daido Steel
22	B-6	PKS charcoal use for EAF	- Charcoal made from PKS can be used instead of injected coke into EAF.	-	-	-	- 39,000 ton-CO2/y GHG reduction	-	-	-	- JP Steel Plantech
C. Material Recycle for Electric Arc Furnace											
23	C-1	EAF dust and slag recycling system by oxygen-fuel burner	- Zn recovery rate will be expected to be 95% - Fe in EAF dust cannot be recovered as metal	-	-	-	-	- Zn material and concrete aggregate can be gained from EAF	-	-	- Daido Steel
24	C-2	EAF slag agglomeration for aggregate use	- Molten slag is rapidly cooled by jet air, and becomes 0.5 - 3.0 mm heavy and strong ball - Suited to use aggregate mixed with cement	-	-	-	- Slag satisfies the safety code	- Saved processing time: 10 minutes	1.00	-	- Nikko
D. Energy Saving for Reheating Furnace											
25	D-1	Process control for reheating furnace	- Setting furnace temperature by targeted billet temperature curve - Precise air ratio control and O2 analysis in exhaust gas	-	0.050	1.01	-	-	2.50	-	- Chugai-Ro
26	D-2	Low NOx regenerative burner total system for reheating furnace	- High efficient and durable burner system	-	0.189	3.82	- CO2 & NOx Reduction	-	8.00	-	- Chugai-Ro - Nippon Furnace
27	D-3	High temperature recuperator for reheating furnace	- Heat transfer area is expanded - Special material tube is used instead of stainless	-	0.100	2.02	-	-	1.50	-	- Chugai-Ro
28	D-4	Fiber block for insulation of reheating furnace	- Low thermal conductivity - High temperature change response (low thermal-inertia)	-	0.039	0.79	- Reduction of Heat accumulation	-	1.50	-	- Chugai-Ro
29	D-5	Air conditioning by absorption type refrigerating by using reheating furnace exhaust	- Use reheating furnace exhaust gas at the outlet of recuperator, about 300-350 degC	3.0	-	0.34	-	-	0.90	-	- Hitachi Infrastructure Systems Company
30	D-6	Induction type billet heater for direct rolling [Newly-added technology]	Compensate temperature drop of billets transferred from CC to rolling mill (from 950 degC to 1050 degC). Advantages: - Automatic control - Less exhaust gas (without reheating furnace)	-40.0	1.45	24.80	- Better working floor & atmosphere	-	1.00	-	- MES Power-Electronics Industry Co., Ltd.
E. Common systems and General Energy Savings											
31	E-1	Inverter (VFD; Variable Frequency Drive) drive for motors	Applying the Multi-Level Drive for motors enables to save energy cost from vane and valve control (constant speed motor). ・Eco-Friendly ・Power Source Friendly ・Less Maintenance ・Motor Friendly	13%	-	-	- CO2 Reduction	-	1.50	-	- Hitachi - Major electric equipment suppliers
32	E-2	Energy monitoring and management systems	- Energy data are collected in process computer for evaluation	-	0.120	2.43	-	-	-	-	- Major electric equipment suppliers
33	E-3	Management of compressed air delivery pressure optimization	- Energy saving in compressors requires consideration of the following points. * Selection of the appropriate capacity * Reduction in delivery pressure	285 MWh/y	-	-	-	-	-	-	- Major electric equipment suppliers

2. TECHNOLOGIES ONE BY ONE SHEETS

<table>
<tr><td rowspan="2">A-1</td><td>A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td>High temperature continuous scrap preheating EAF</td></tr>
<tr><td>Item</td><td>Content</td></tr>
<tr><td>1. Process Flow or Diagram</td><td>
</td></tr>
<tr><td>2. Technology Definition/Specification</td><td>Preheating scraps with high-temperature exhaust gas is possible because the preheating shaft and melting chamber are directly and rigidly connected, so the scraps are continually present, from the steel to preheating areas.
This enables high-temperature preheating of the scraps, resulting in a significant reduction of power consumption.
The melting chamber is sealed off from outside air, to prevent the excess air inlet. It prevents over oxidation of scrap under high temperature preheating. As this equipment keeps always flat bath operation, electrode consumption is significantly improved.
Furthermore, the electric facilities necessary to meet power quality regulation can be drastically reduced on it may not even unnecessary depending on required regulation.
Dioxins are decomposed through an exhaust gas combustion chamber and rapid quench chamber in the exhaust gas duct system. Not only dioxins but also a volatile material that causes foul odors and white smoke will be decomposed and the dispersal of them are also prevented. The furnace prevents diluting of exhaust gasses. Therefore, the CO within the exhaust gas can be used as fuel, reducing the amount of fuel gas consumed. Flat bath operation dramatically reduces noise during operation. The reduction of power consumption also contributes to the reduction of emission of greenhouse gasses during power generation.</td></tr>
</table>

<table>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>150 kWh/ton-product</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>Decomposition of dioxin, reducing dispersing dust, & noise</td></tr>
<tr><td>・Co-benefits</td><td>Low electrode consumption (0.8 - 1.0 kg/ton-product at AC)</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>JP Steel Plantech</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>SOACT 2nd Edition ("Ecological and Economical Arc Furnace"), Diagram from JP Steel Plantech</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

<table>
<tr><td rowspan="2">A-2</td><td>A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td>Medium temperature batch scrap preheating EAF</td></tr>
<tr><th colspan="1">Item</th><th>Content</th></tr>
<tr><td>1. Process Flow or Diagram</td><td></td></tr>
<tr><td>2. Technology Definition/Specification</td><td>- High melting efficiency batch charging type EAF with SPH.
- Preheated scrap temperature is about 250 - 300 degC.
- Fully enclosed automatic charging system to keep working floor clean.
- Minimize scrap oxidation by temperature controlling
- Material limitation free</td></tr>
<tr><td>3. Expected Effect of Technology Introduction — ・Electricity Saving</td><td>40 kWh/ton-product</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>Reduction of dioxin emission, dispersing dust & noise</td></tr>
<tr><td>・Co-benefits</td><td>No limit of material for high quality products as like stainless steel.</td></tr>
<tr><td>4. Japanese Main Supplier</td><td>Daido Steel</td></tr>
<tr><td>5. Technologies Reference</td><td>May contact to Daido Steel</td></tr>
<tr><td>6. Comments</td><td>-</td></tr>
</table>

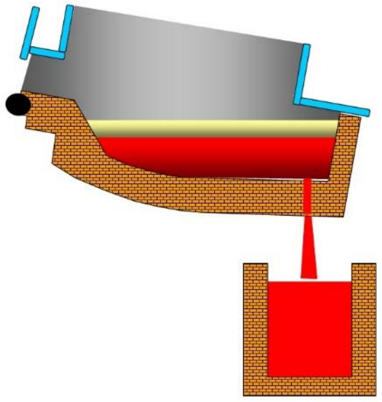
A-3		A. Energy Saving for Electric Arc Furnace (EAF) High efficiency oxy-fuel burner/lancing for EAF
Item		Content
1. Process Flow or Diagram		 New type of burner has been used to inject carbon and oxygen from side wall and closed slag door. The buener can realize evenly distributed slag-foaming and post-combustion without fully opening slag. door. Coherent buner can make long and sharp oxygen jet, which works instead of oxygen lance. Oxygen jet from the center hole is restricted to expand by the combustion around the jet, the combustion is generated by the fuel and oxygen from the peripherai nozzles 
2. Technology Definition/Specification		Conventional oxygen lances inserted through slag door causes; - Local oxygen input near the slag door - Uneven slag foaming through the bath - Uneven post-combustion of generated CO - Much hot gas escape caused by the cold air infiltration through the slag door
3. Expected Effect of Technology Introduction	・Electricity Saving	14.3 kWh/ton-product
	・Thermal Energy Savings	-
	・Environmental benefits	-
	・Co-benefits	Reduction of nitrogen in steel, quality improvement
4. Japanese Main Supplier		Nikko, JP Steel Plantech
5. Technologies Reference		SOACT 2nd edition (Add the word "High efficiency" to SOACT item for up-to-date oxygen use), Diagram from Nikko
6. Comments		<Source of "Electricity saving"> 0.14 GJ/ton in SOACT ---> 0.14 x 9.8/1000 = 14.3 kWh/ton

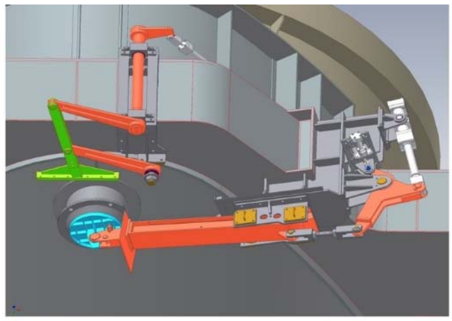
A-4

A. Energy Saving for Electric Arc Furnace (EAF)

Eccentric bottom tapping (EBT) on existing furnace

Item	Content
1. Process Flow or Diagram	see below





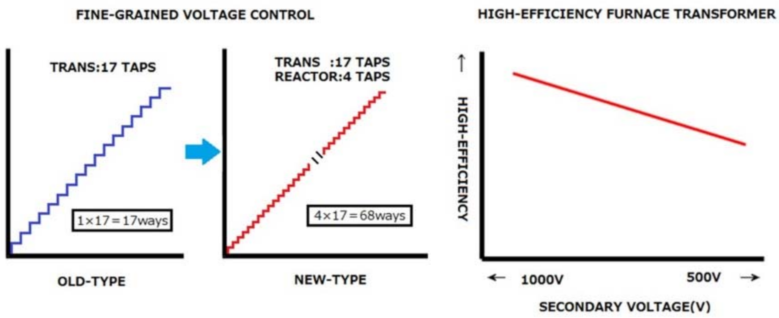
EBT concept and tapping mechanism

Effect of EBT

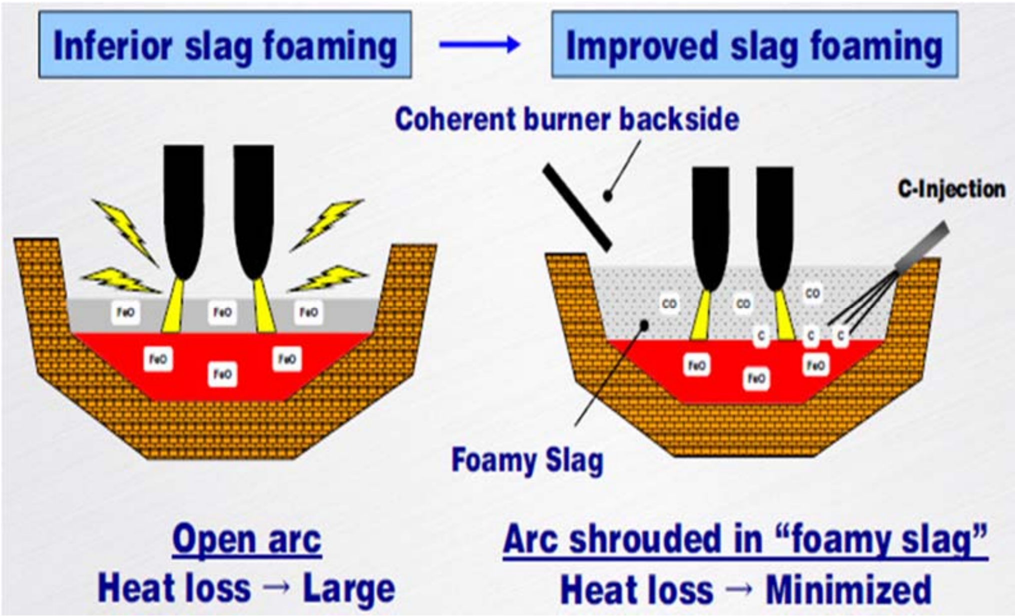
Effect of EBT			Main factors
Category	Item	Effect	
Cost	1. Yield of Alloys	Si : 15 - 100%↑	Slag free tapping
	2. Yield of Fe	Fe : 1.1%↑	Slag free tapping, Hot heel
	3. Electric power consumption	7 - 25 kWh/t↓	Hot heel
	4. Electrode consumption	0.2 - 0.4 kg/t↓	Hot heel → Decrease of Electric power → High power factor
	5. Refractory consumption	Wall: 23 - 64%↓ Ladle: 9 - 54%↓	- Increase of water cooled area - Slag free tapping
	6. Lime consumption	15 - 25%↓	Hot heel
Productivity	1. Tap - to - On 2. On - to - Tap	1.0 - 3.0 min.↓ 1.0 - 7.2 min.↓	Shortened Hot repair, Shortened Tilting for Tapping, Decrease of Electrode con.
Quality	1. Dephosphorus 2. Inclusion	16 - 28%↑ Total [O] 1 - 3ppm↓	Hot heel Slag free tapping

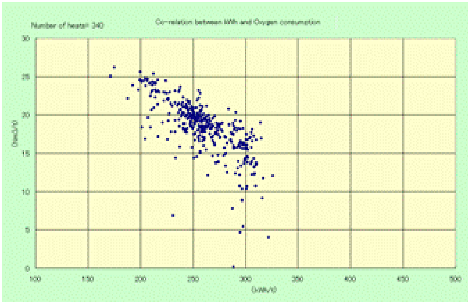
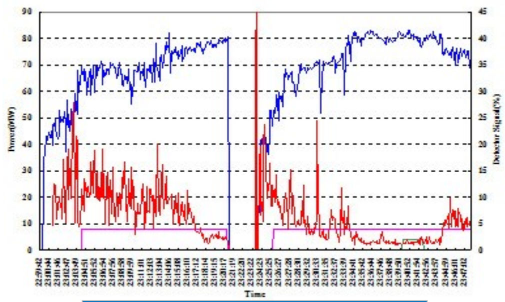
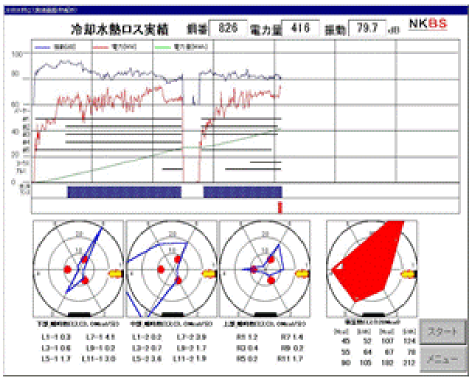
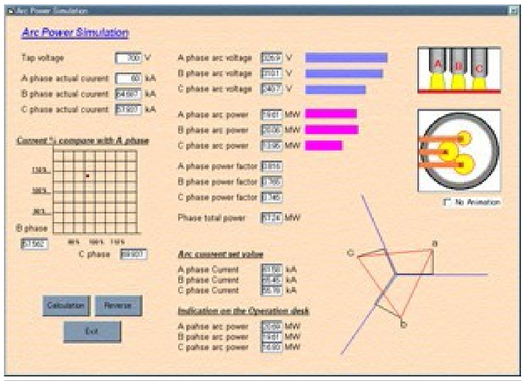
Item		Content
2. Technology Definition/Specification		- Molten steel is tapped through the hole at the furnace bottom. - Tilting angle for tapping is smaller than conventional spot tapping, and quick tapping and returning are possible. - Tapping hole is plugged with silicon sand after tapping, which is held by stopping mechanism. - Slag free tapping is possible - Reliable stopping and scraping mechanism to avoid leakage
3. Expected Effect of Technology Introduction	・Electricity Saving	15 kWh/ton-product
	・Thermal Energy Savings	-
	・Environmental benefits	-
	・Co-benefits	Increase in Fe & alloy yield, and productivity Improve steel quality
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel
5. Technologies Reference		EPA-BACT (Sep. 2014), Diagram from JP Steel Plantech
6. Comments		<Preconditions on calculating effects and investment costs> - Values of "Electricity saving" are based on the EPA-BACT (Sep. 2014) & equipment supplier's rough estimation - "Profit" does not include such other advantages than electricity saving

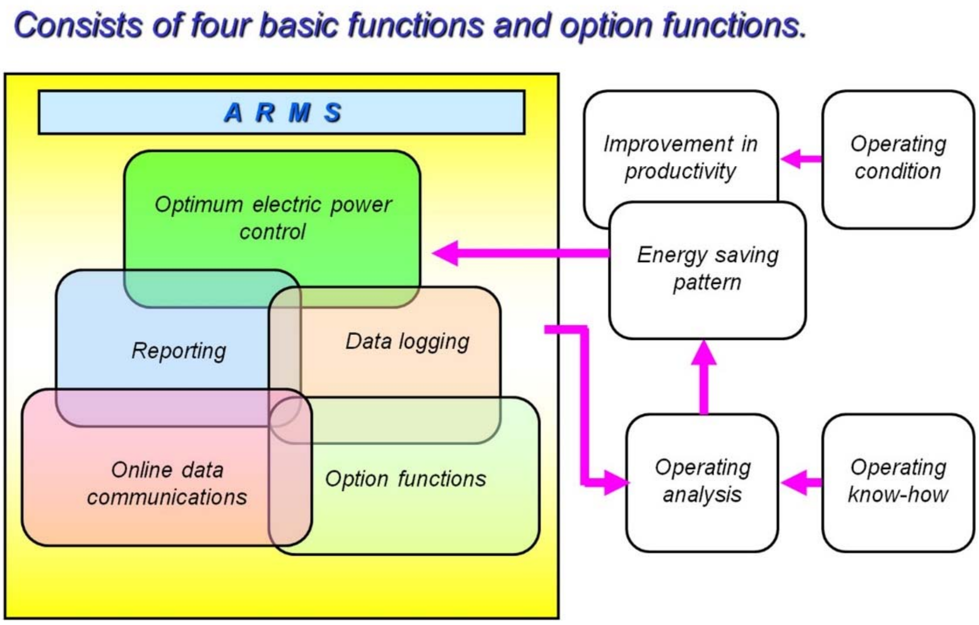
<table>
<tr><td rowspan="2" colspan="2">A-5</td><td>A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td>Ultra high-power transformer for EAF</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>

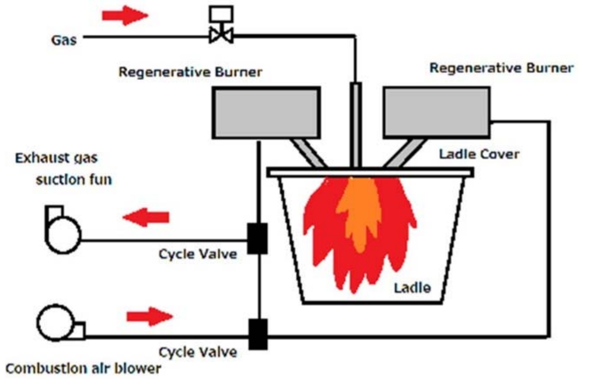


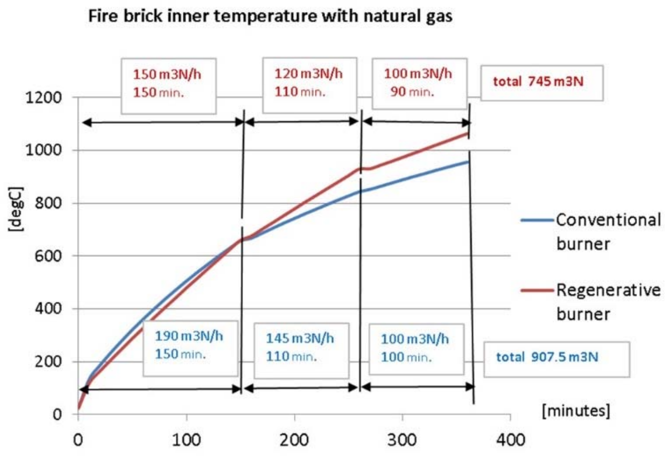
</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>In the conventional system, series reactor was used for the early melting stage in order to stabilize arc and control of a flicker.
Since High-Efficiency Furnace Transformer provides high impedance at early melting stage, series reactor is not required, though the same performance is achieved.
- Reduce electric power consumption
- Reduce electrode consumption
- Shorten tap to tap time
In addition, it will conduct a fine-grained control by adding a reactor.</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>15 kWh/ton-product</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>-</td></tr>
<tr><td>・Co-benefits</td><td>Increase productivity</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>JP Steel Plantech, Nikko</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>EPA-BACT ("Transformer efficiency - ultra-high power transformers"), Diagram from Nikko</td></tr>
<tr><td colspan="2">6. Comments</td><td><Preconditions on calculating effects>
- "Electricity saving" 15 kWh/ton-product comes from EPA-BACT,
assuming that 44 MVA transformer for 80 ton EAF is revamped to 55 MVA.</td></tr>
</table>

A-6	A. Energy Saving for Electric Arc Furnace (EAF)
	Optimizing slag foaming in EAF
Item	Content
1. Process Flow or Diagram	
2. Technology Definition/Specification	- Proper chemical ingredients of slag (Basicity 1.5 - 2.2, FeO 15 - 20 %) - High efficient burner and/or lance - Controlled O2 & C injection into EAF proper position - Keeping slag thickness with air-tight operation
3. Expected Effect of Technology Introduction ・Electricity Saving	6 kWh/ton-product
3. Expected Effect of Technology Introduction ・Thermal Energy Savings	-
3. Expected Effect of Technology Introduction ・Environmental benefits	Noise reduction & working floor cleaning
3. Expected Effect of Technology Introduction ・Co-benefits	-
4. Japanese Main Supplier	JP Steel Plantech, Daido Steel
5. Technologies Reference	SOACT 2nd Edition (Delete the word "Exchangeable Furnace and Injection Technology"), Diagram from JP Steel Plantech
6. Comments	<Source of "Electricity saving"> (1) 2.5 - 3 % energy saving in SOACT ---> 430 kWh/ton x 0.03 = 12.9 kWh/ton (2) The phenomenon is explained by several factors, 6 kWh/ton is reasonable (Japanese experts).

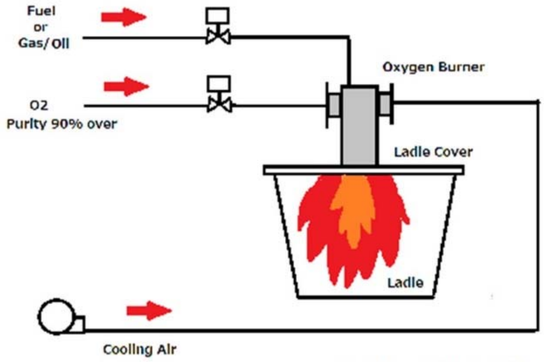
<table>
<tr><td colspan="2" rowspan="2">A-7</td><td>A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td>Optimized power control for EAF</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>
Statistical analysis

Slag foaming detection

Heat loss supervision

Power supply control for each phase</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>- Data logging and visualization of melting process
- Automatic meltdown and additional scrap charging judgement
- Automatic phase power independent control for well-balance melting</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>15 kWh/ton-product</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>Productivity increase
Manpower saving</td></tr>
<tr><td>・Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>JP Steel Plantech</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>SOACT 2nd Edition ("Improved Process Control (Neural Networks)"), Diagram from JP Steel Plantech</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

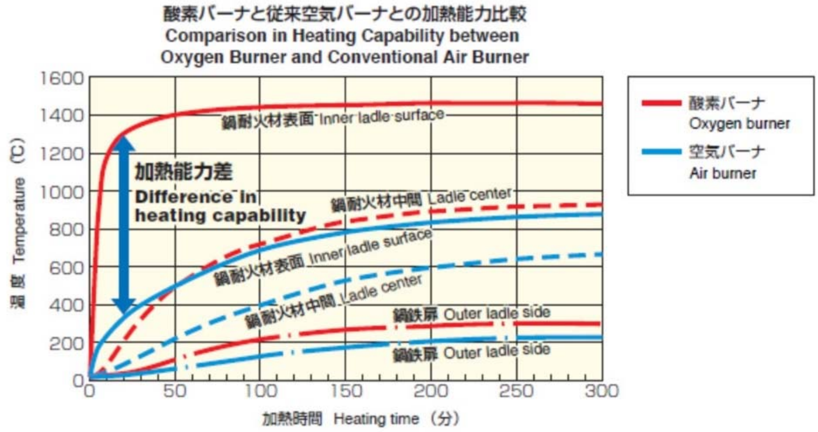
A-8	A. Energy Saving for Electric Arc Furnace (EAF)	
	Operation support system with EAF meltdown judgment	
Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		Automatic rapid melting system for EAF - Optimum electric power control - Reporting, Data logging and online data communications - Automatic meltdown Judgment - Power supply and electrode position control for each phase
3. Expected Effect of Technology Introduction	・Electricity Saving	6 kWh/ton-product
	・Thermal Energy Savings	-
	・Environmental benefits	-
	・Co-benefits	Productivity increase Manpower saving
4. Japanese Main Supplier		Daido Steel
5. Technologies Reference		May contact to Daido Steel
6. Comments		-

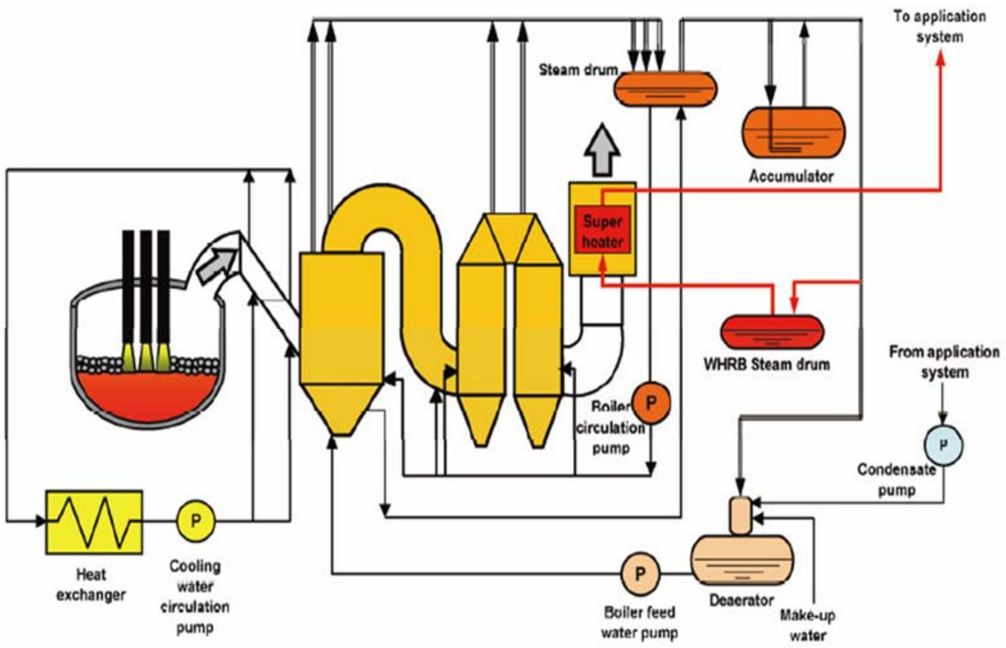
<table>
<tr><td rowspan="2">A-9</td><td>A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td>Low NOx regenerative burner system for ladle preheating</td></tr>
<tr><td>Item</td><td>Content</td></tr>
<tr><td>1. Process Flow or Diagram</td><td>


</td></tr>
<tr><td>2. Technology Definition/Specification</td><td>While one of the burners is burning, the other burner will work as an exhaust outlet. The exhaust gas is discharged from the system after the waste heat of the gas is recovered so that the temperature of the gas will be lowered to the extent that there will be no condensation in the regenerator. The combustion air receives heat from the regenerator. Therefore, the combustion air will be preheated to a super-high temperature (i.e., 90% of the temperature of the exhaust gas or over) before the combustion air is supplied to the burner. When the preset cycle time elapses, the burners exchange their roles of combustion and exhaustion.</td></tr>
</table>

<table>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>-</td></tr>
<tr><td>・Thermal Energy Savings</td><td>40 % fuel saving is expected comparing to existing preheater with conventional burner.
900 m3N natural gas in 6 hour burning for 80 ton ladle consumes about 40 GJ ---> 0.5 GJ/ton-steel x 40 % = 0.2 GJ/ton-steel save.</td></tr>
<tr><td>・Environmental benefits</td><td>Low NOx</td></tr>
<tr><td>・Co-benefits</td><td>Higher brick temperature can allow lower tapping temperature for energy saving at EAF.
Improving meltshop atmosphere by reducing hot gas which disturbs dirty gas suction at the canopy.</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai-Ro, Nippon Furnace</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>-</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

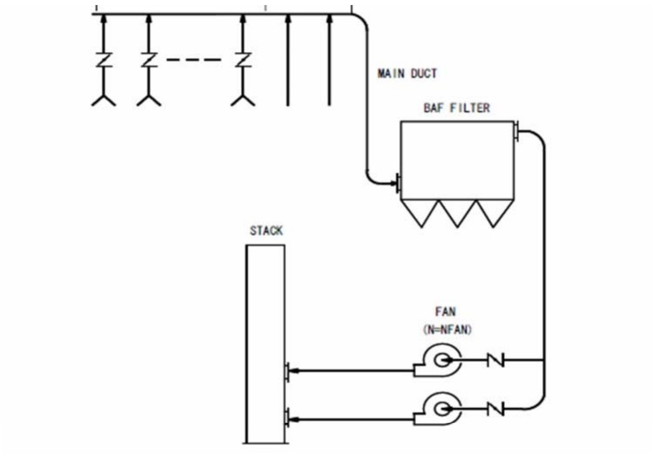
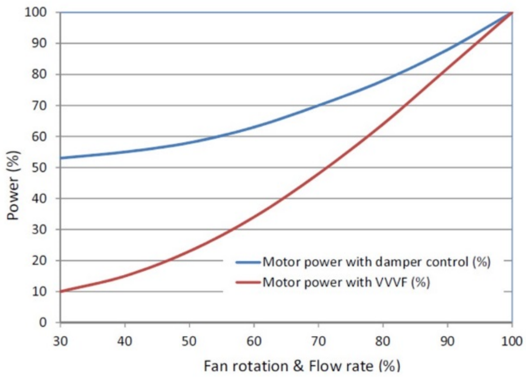
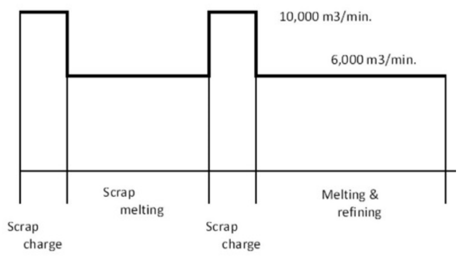
<table>
<tr><td rowspan="2" colspan="2">A-10</td><td>A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td>Oxygen burner system for ladle preheating</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>

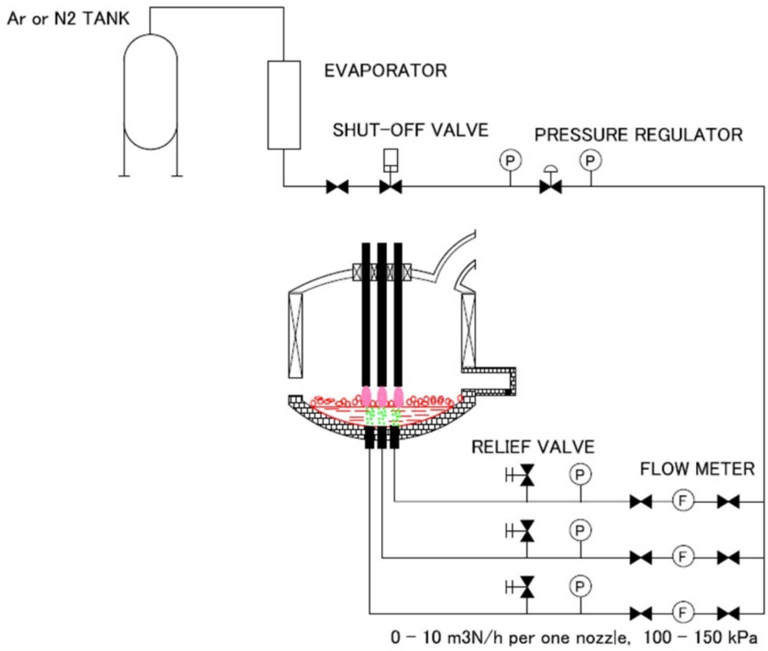

</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>Oxygen combustion achieve rapid heating by high flame temperature. High flame temperature achieve high wall temperature, therefore it can be possible low temperature feeding of melted metal in to the ladle.</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>-</td></tr>
<tr><td>・Thermal Energy Savings</td><td>40% fuel saving is expected comparing to existing preheater</td></tr>
<tr><td>・Environmental benefits</td><td>Low NOx</td></tr>
<tr><td>・Co-benefits</td><td>Higher brick temperature can allow lower tapping temperature for energy saving at EAF.</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai-Ro, JP Steel Plantech</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>Diagram from Chugai Ro, May contact to suppliers</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

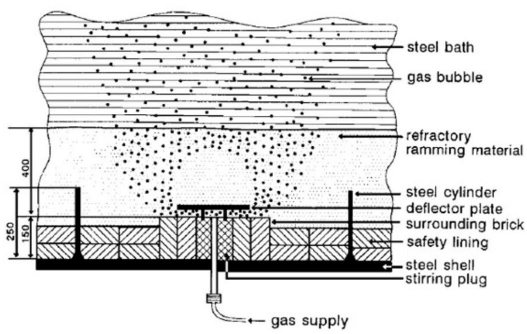
<table>
<tr><td colspan="2" rowspan="2">A-11</td><td>A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td>Waste heat recovery from EAF</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>
</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>- Waste heat boiler based on the OG boiler technology
- Specified for splash and dust containing
- Main boiler is radiative type, and convective type super heater is located at the downstream of boiler to avoid clogging.</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>132 kWh/ton-product</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>-</td></tr>
<tr><td>・Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>JP Steel Plantech</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>Diagram from JP Steel Plantech, May contact to JP Steel Plantech</td></tr>
<tr><td colspan="2">6. Comments</td><td><Preconditions on calculating effects>
- Power generation is 248,000 MWh/year with two 150 ton EAFs for DRI
- Assumed annual production by two 150 ton EAF
= 500,000 / 80 x 150 x 2 = 1,875,000 ton/y
- Unit power generation = 248,000 x 1,000 / 1,875,000 = 132 kWh/ton-product
- Suited to DRI continuous charging EAF, not scrap EAF</td></tr>
</table>

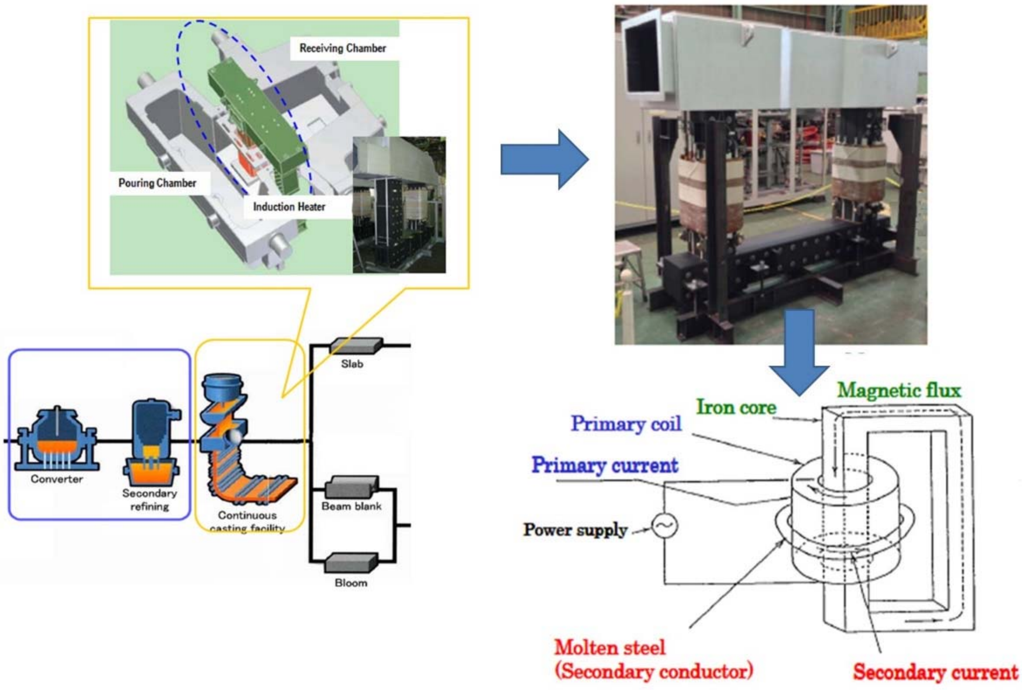
A-12

A-12	A. Energy Saving for Electric Arc Furnace (EAF)
	Energy saving for dedusting system in EAF meltshop

Item		Content
1. Process Flow or Diagram		   EAF operation and controlled flow rate for house-dedusting
2. Technology Definition/Specification		- Damper openings and exhaust fan rotation are controlled in consonance with the furnace operation pattern - Reducing fan rotation with VVVF system enables to save motor power, comparing to the simple damper control system.
3. Expected Effect of Technology Introduction	・Electricity Saving	6kWh/ton-product (25 % of assumed unit power consumption)
	・Thermal Energy Savings	-
	・Environmental benefits	Better working floor and atmosphere
	・Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel
5. Technologies Reference		Diagram from JP Steel Plantech
6. Comments		<Preconditions on calculating effects> Assumed electricity consumption for building dedusting is 24 kWh/ton-product, and 25 % power saving is expected.

<table>
<tr><td rowspan="2">A-13</td><td colspan="2">A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td colspan="2">Bottom stirring/stirring gas injection</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>

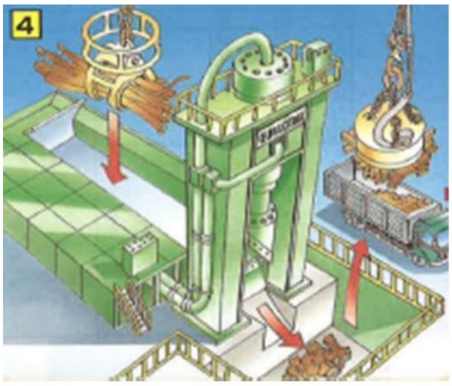

</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>Inject inert gas (Ar or N2) into the bottom of EAF to agitate steel bath
Expected effects:
- homogenize chemical composition and temperature in steel bath
- accelerate chemical reaction between steel and slag
- shorten tap-tap-time
- save electrical energy
- increase yields of iron and alloys</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>18 kWh/ton-product</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>-</td></tr>
<tr><td>・Co-benefits</td><td>Fe yield increase 0.5 %</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>-</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>1) EPA-BACT
2) Bottom-stirring in an electric-arc furnace: Performance results at ISCOR Vereeniging Works
(The Journal of The South African Institute of Mining and Metallurgy, January 1994</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

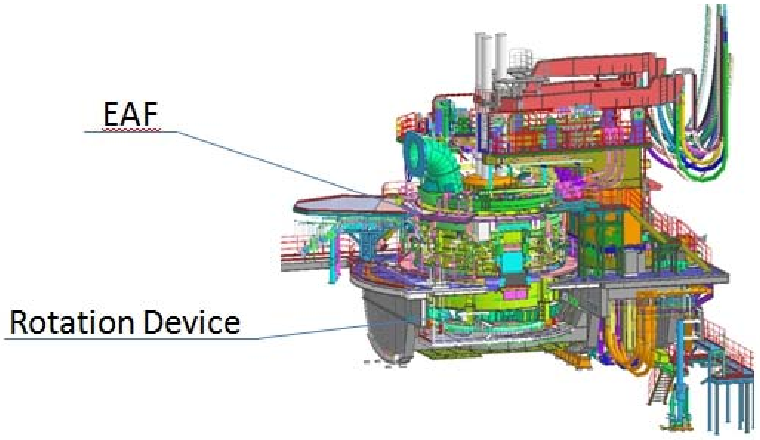
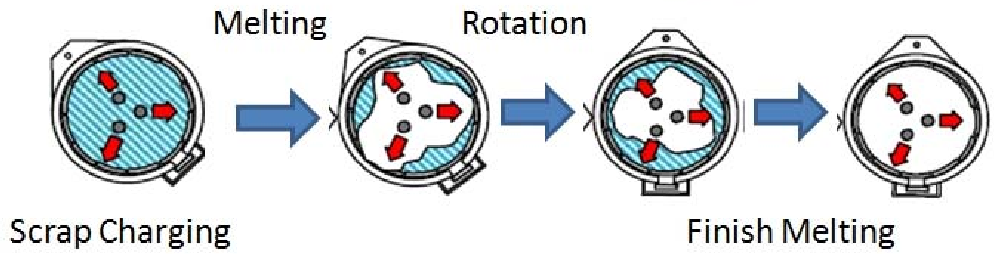
<table>
<tr><td colspan="2" rowspan="2">A-14</td><td>A. Energy Saving for Electric Arc Furnace (EAF)</td></tr>
<tr><td>Induction type tundish heater</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>
</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>＜Features for Induction Tundish heater＞
1. Uniformity of Element of Molten Steel: Agitation effect by electromagnetic force.
2. High Precision Temperature Control: Target Temp.±2.5degree.
3. High Heating Efficiency: More than 90% by channel type inductor.
4. Ease of maintenance: Water cooled feeder with quick connector. Self-cooled type Induction coil and so on.</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>3 kWh / ton-product (Effect is calculated comparing to electricity consumption of plasma type heater)</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>-</td></tr>
<tr><td>・Co-benefits</td><td>Productivity increase
Quality improvement</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Fuji Electric</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>May contact to Fuji Electric</td></tr>
<tr><td colspan="2">6. Comments</td><td><Preconditions on calculating effects>
- Assumed plasma type tundish heater is installed
- Ladle capacity: 200 ton
- Operated days: 30 days/month
- Electricity intensity of heater: 13.7 kWh/ton
- Heat efficiency: 70%
- Pouring amount: 2.5 ton/min
- Dissolution time: 80 min/charge
- Raised temperature: 40 degree C
- Number of charges: 8 charges/day
- Monthly production: 48,000 ton
- Annual production: 576, 000 ton</td></tr>
</table>

A-15

A. Energy Saving for Electric Arc Furnace (EAF)

Scrap pretreatment with scrap shear

Item		Content
1. Process Flow or Diagram		   Before scrap pretreatment (0.3 ton/m3)  After scrap pretreatment (0.6 ton/m3)
2. Technology Definition/Specification		- Long size or low bulk-density scrap is shredded and packed - For example, bulk density of 0.3 m^3/ton can be increased to 0.6 m^3/ton with 1250 ton shear x 2 for 80 ton EAF - Scrap pretreatment decreases the scrap-charging frequency, which will lead to energy saving
3. Expected Effect of Technology Introduction	･Electricity Saving	20 kWh/ton-product (reported by Non-integrated steel producers' association of Japan)
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	Fe yield increase in 1.5 %, TTT shortening
4. Japanese Main Supplier		Fuji Car Manufacturing
5. Technologies Reference		-
6. Comments		-

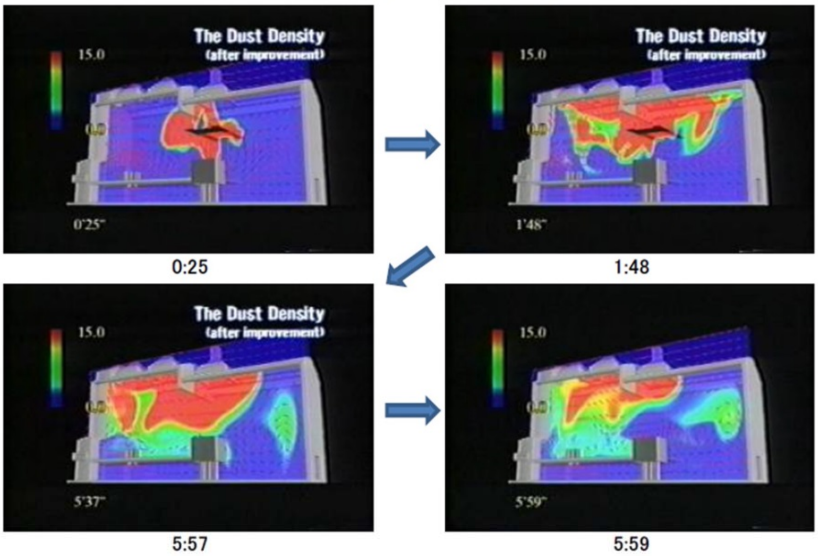
A-16	A. Energy Saving for Electric Arc Furnace (EAF) Arc furnace with shell rotation drive
Item	Content
1. Process Flow or Diagram	 
2. Technology Definition/Specification	Furnace shell is rotated 50 degree back-and-force Uniform scrap melting with furnace shell rotation - Shortening power-on time - Reduction in cooling water energy loss - Reduction in scrap cutting oxygen - Reduction in refractory repairing materials
3. Expected Effect of Technology Introduction ・Electricity Saving	32 kWh/ton-product
・Thermal Energy Savings	-
・Environmental benefits	-
・Co-benefits	- No limit of material for high quality products - Reduction of refractory consumption
4. Japanese Main Supplier	Daido Steel
5. Technologies Reference	May contact to Daido Steel
6. Comments	-

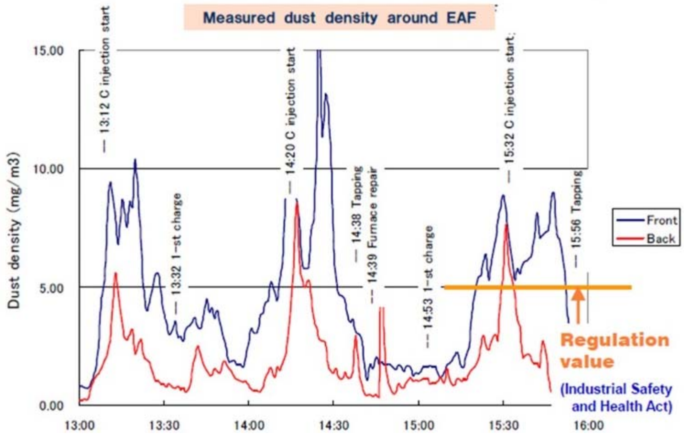
B-1

B. Environmental Protection for Electric Arc Furnace

Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		- Improved design configuration of the direct evacuation for treating hot unburned gas from much fuel use - Minimize dust and gas dispersion from EAF with enough capacity and suitable control - Much fossil fuel use becomes possible to save electricity
3. Expected Effect of Technology Introduction	･Electricity Saving	- When capacity increase is applied to the standard size EAF (30 m3N-O2/ton-steel, 20 m3N-natural gas/ton-steel, and 15 kg-carbon/ton-steel), expected electrical energy saving becomes as: 4 - 5 kWh/m3N-O2 8 - 9 kWh/m3N-natural gas 8 - 9 kWh/kg-carbon - Decrease in yield is assumed as 1 - 2 % per 10 m3N-O2/ton-steel.
	･Thermal Energy Savings	-
	･Environmental benefits	Better work floor environment
	･Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel
5. Technologies Reference		SOACT 2nd Edition Diagram from Daido Steel Recent Progress of Steelmaking Technology in Electric Arc Furnace (1993, JISF)
6. Comments		-

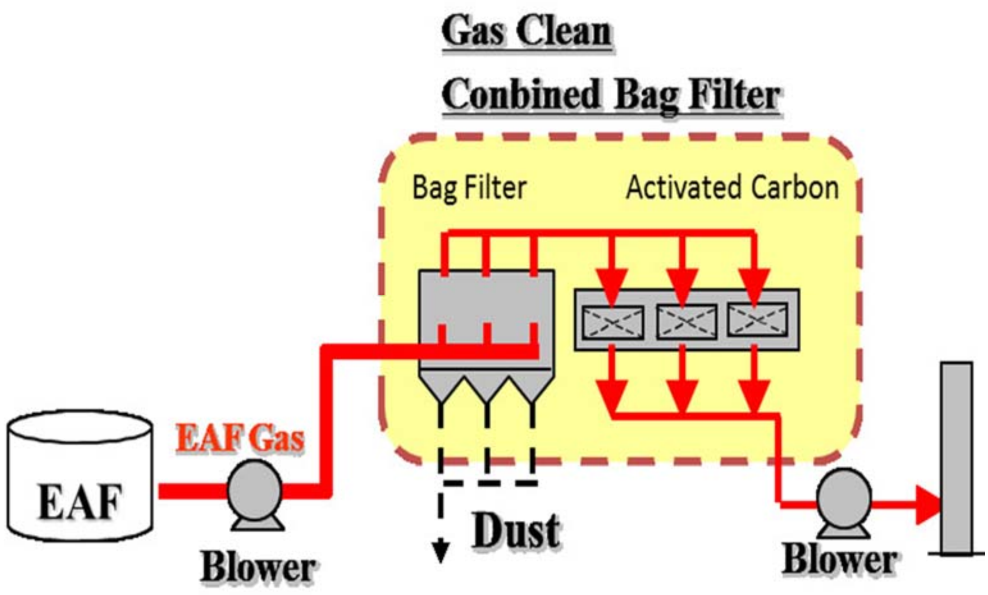
<table>
<tr><td colspan="2">B-2</td><td>B. Environmental Protection for Electric Arc Furnace
Floating dust control in EAF meltshop</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>Transient analysis of flow and dust density in meltshop builiding
Simulated dust density after scrap charge to EAF


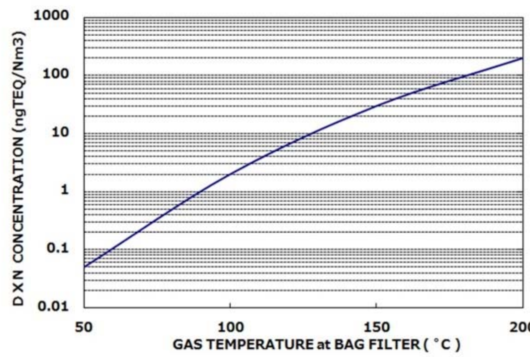
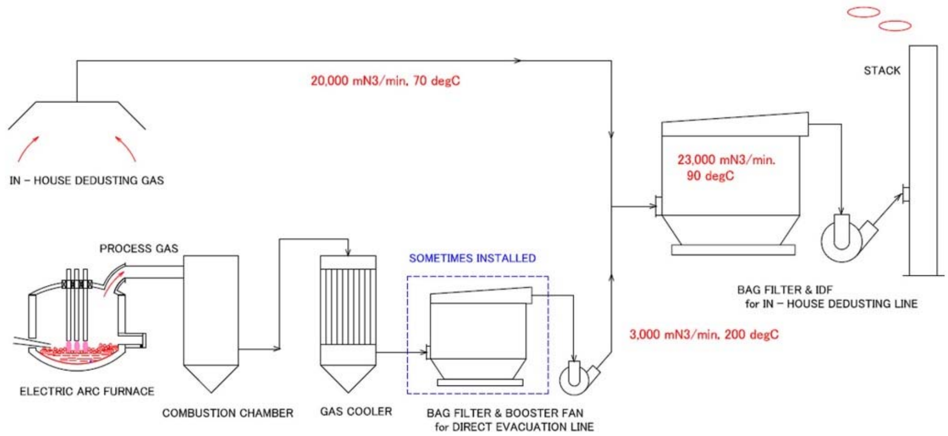
Floating dust density around EAF (by laser-scattering dust indicator)

</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>- In modern EAF meltshop, fully enclosed building is required to avoid dust dispersion to the outside, but enclosed building raises work floor pollution which affects workers health.
- Proper design and operation of dedusting system based on the flow analysis and real dust data are essential.
- Building and suction system revamping shall be executed based on the flow analysis.
- Target value of dust loading on working floor should be less than 5 mg/me, for example, specified in Industrial Safety and Health Act.</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>-</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>Restrict dust loading on working floor to less than 5 mg/m3</td></tr>
<tr><td>・Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>JP Steel Plantech, Daido Steel</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>Diagram from JP Steel Plantech, May contact to suppliers</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

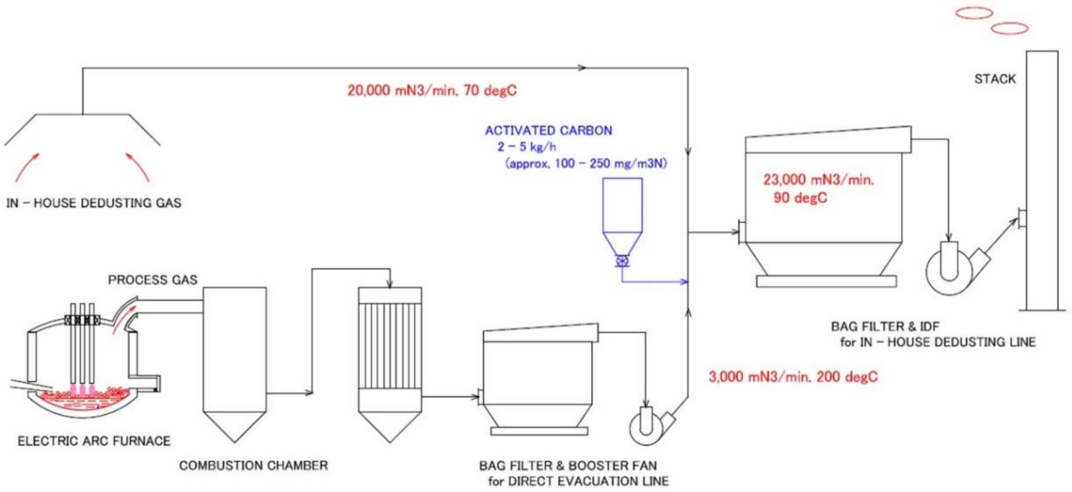
B-3

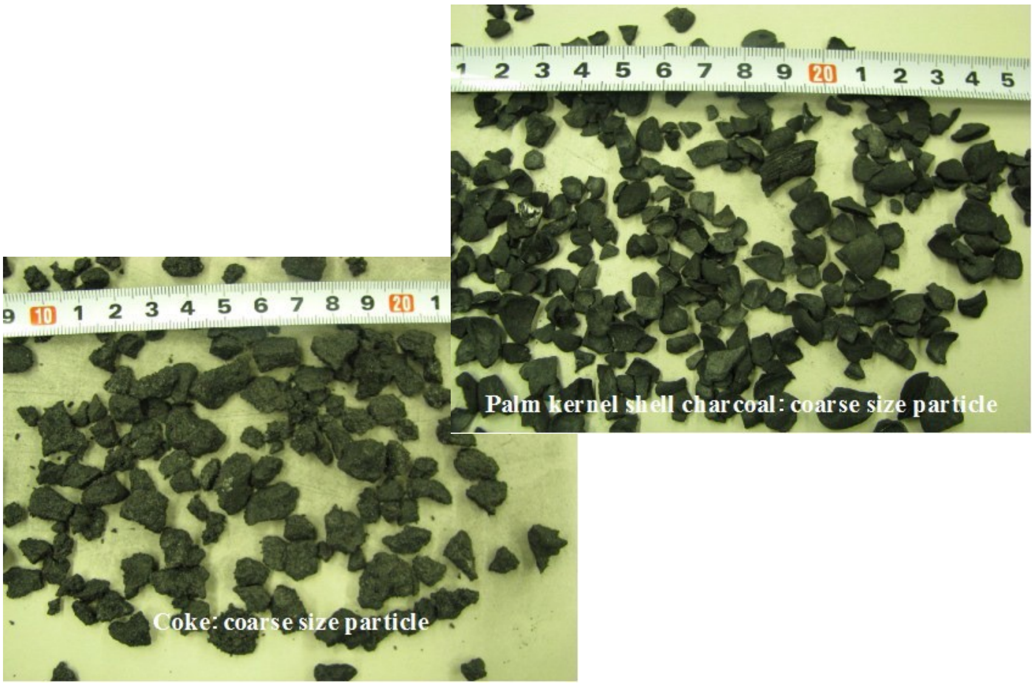
B. Environmental Protection for Electric Arc Furnace

Dioxin adsorption by activated carbon for EAF exhaust gas

<table>
<tr><th colspan="2">Item</th><th>Content</th></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>
</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>A new dioxin-removal system passes exhaust gas through a layer of granular activated carbon with outstanding adsorption performance. High-performance activated carbon was developed exclusively for the system. Packaged cartridges with a unique structure allowing the system to adsorb and remove dioxins and heavy metals to an extremely low levels. A cartridge with a unique structure ensures improved contact efficiency between activated carbon and exhaust gas. Consequently, the filled quantity of activated carbon is considerably reduced allowing unparalleled compact size. In addition, amount of consumed activated carbon would be substantially reduced comparing to previous Activated Carbon Adsorption Tower. Furthermore, it would save electricity consumption of blower since its pressure loss would be lower than 0.5kPa (Approx. 50 mmAq) per a cartridge comparing to previous equipment.</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>-</td></tr>
<tr><td>・Thermal Energy Savings</td><td>-</td></tr>
<tr><td>・Environmental benefits</td><td>Dioxin will be lower than 0.1 ng TEQ/m3N</td></tr>
<tr><td>・Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>JFE Engineering</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>Diagram from JFE Engineering, May contact to JFE Engineering</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

B-4		B. Environmental Protection for Electric Arc Furnace Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas
Item		Content
1. Process Flow or Diagram		 
2. Technology Definition/Specification		- Dioxin concentration in the EAF exhaust gas at the exit of bag filter is strongly susceptible to the gas temperature. - In order to comply with the regulated value of 5.0 ngTEQ/m^3N (applied to the existing EAF in JAPN), common technology is to mix the hot process gas with the in-house dedusting gas to cool down the gas through the bag filter. - Dioxin seems to be captured by the oily dust which is accumulated on the surface of filter. - When gas temperature at the bag filter ascends up to about 110 degC, where oil is vaporised, dioxin concentration rapidly increases even in a short time. - Collected duct at bag filter should be carefully treated, as it contains much dioxin. - This phenomenon is different from the case of incinerators, where the dust does not contains oily substances.
3. Expected Effect of Technology Introduction	・Electricity Saving	-
	・Thermal Energy Savings	-
	・Environmental benefits	Dioxin will be lower than 5.0 ng TEQ/m^3N
	・Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel
5. Technologies Reference		Diagram from Daido Steel, May contact to suppliers
6. Comments		-

B-5	B. Environmental Protection for Electric Arc Furnace	
	Dioxin adsorption by 2 step bagfilter technology for EAF exhaust gas	
Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		- In order to comply with the more stringent regulation of 0.5 ngTEQ/m3N (applied to the new EAF in JAPN), two-step bag filter system is applied with the careful temperature control. - When 0.1 ngTEQ/m3N is requested from the authorities, for the cases of installation at dense-population are or industrial wastes treatment, activated carbon injection into the exhaust gas line is effective. - Dust loading in the process gas is much higher than that of in-house dedusting gas, therefore, activated carbon is injected into the gas which is dedusted with the primary bag filter. This activated carbon powder is accumulated on the filters of secondary bag filter and adsorbs dioxin.
3. Expected Effect of Technology Introduction	・Electricity Saving	-
	・Thermal Energy Savings	-
	・Environmental benefits	Dioxin will be lower than 0.5 ng TEQ/m^{3}N
	・Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel
5. Technologies Reference		Diagram from Daido Steel
6. Comments		-

B-6		B. Environmental Protection for Electric Arc Furnace PKS charcoal use for EAF
Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		- Charcoal made from PKS (Palm Kernel Shell) has similar quality with coke commonly used for carbon injection into EAF - Higher heating value, lower sulfur content than fossil fuel coke - CO_2 generated from charcoal is not counted as GHG (Green House Gas) - PKS charcoal is produced for the production of activated carbon in a small scale - Equipment is very simple and can be constructed by local technology - Japanese supplier will provide with know-how
3. Expected Effect of Technology Introduction	･Electricity Saving	-
	･Thermal Energy Savings	-
	･Environmental benefits	39,000 ton-CO_2/y GHG reduction from 500,000 ton/y EAF plant
	･Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech
5. Technologies Reference		Diagram from JP Steel Plantech, May contact to JP Steel Plantech
6. Comments		<Preconditions on calculating effects> Replaced coke at EAF : 25 kg/ton-steel C content in coke : 85 % CO_2 generation from coke = 0.85 x 44 / 12 = 3.12 ton-CO_2/ton-coke GHG reduction = 500,000 ton-steel/y x 0.025 x 3.12 = 39,000 ton-CO_2/y

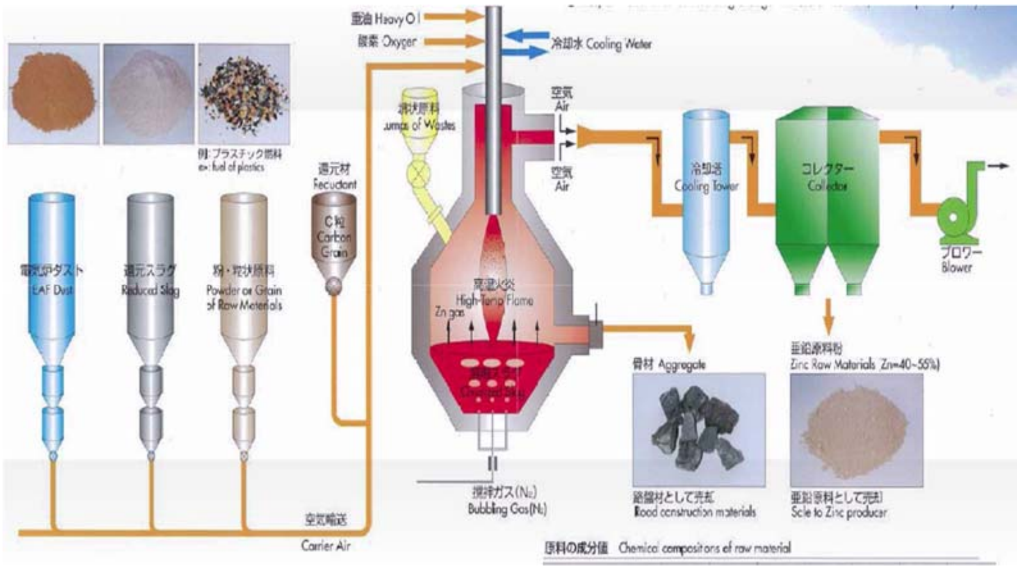
C-1

C. Material Recycle for Electric Arc Furnace

EAF dust and slag recycling system by oxygen-fuel burner

Item	Content

1. Process Flow or Diagram



2. Technology Definition/Specification

As dust and slag are melted down completely at high temperature, it is very effective against dioxin.
Produced valuable substances are completely harmless and can meet all environmental standards.
More than 99% of dioxin can be removed by high temperature treatment in the furnace and strong rapid cooling mechanism.
Besides electrical furnace dust and reduced slag, it is expected that this system will be applied to other waste treatments.
The equipment is simple and compact because of unnecessary pretreatment such as dust granulation and so forth.
Through simple design, excels in operability and suitable for on-site processing.

3. Expected Effect of Technology Introduction

・Electricity Saving: -

・Thermal Energy Savings: -

・Environmental benefits:

Example of the Leaching test result of Aggregate (Notice 46 by ME, Japan)

mg/l	Pb	Cd	Cr^{+6}	As	Hg	Se
Aggregate	<0.006	<0.001	<0.005	<0.005	<0.0005	<0.004
Regulation	0.01	0.01	0.05	0.01	0.0005	0.01

・Co-benefits:

Zn material can be gained from EAF dust
Concrete aggregate can be gained from EAF dust

4. Japanese Main Supplier

Daido Steel

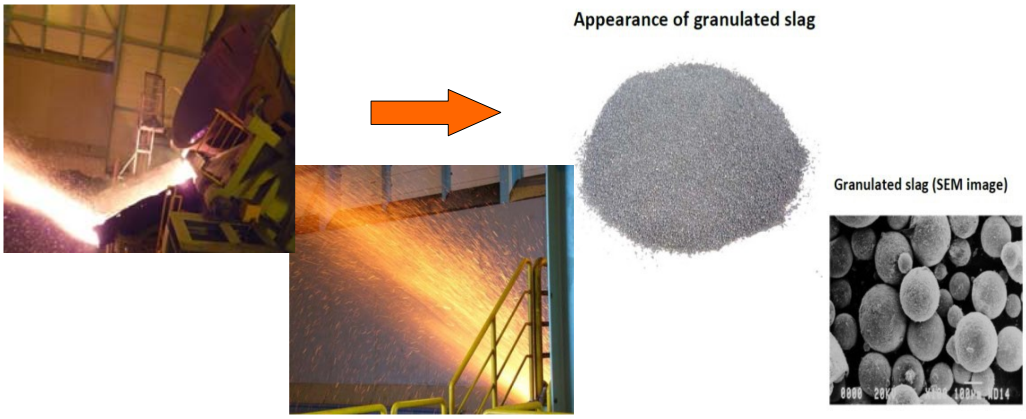
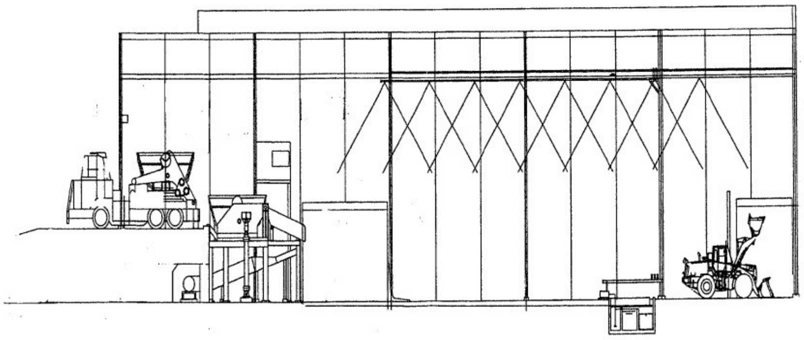
5. Technologies Reference

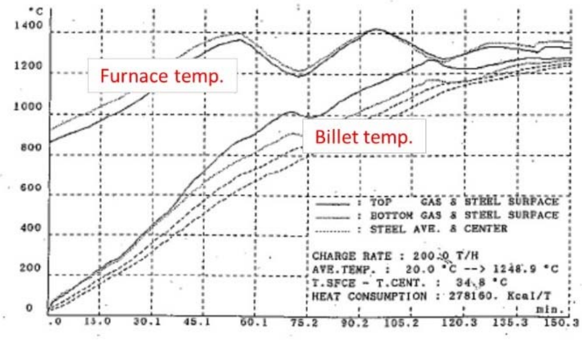
Diagram from Daido Steel, May contact to Daido Steel

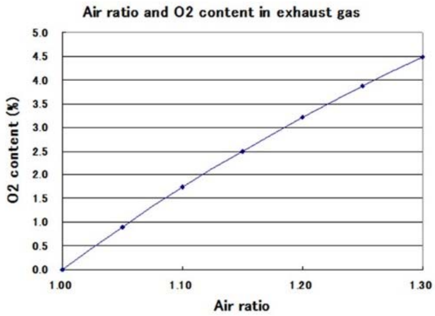
6. Comments

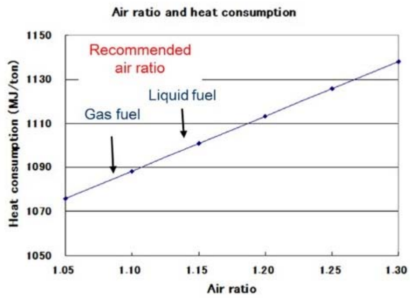
Example of the chemical composition of raw material

(wt%)	T-Fe	CaO	SiO_2	Zn	Pb	Cl	F
Zn raw material	6.5	2.5	0.9	52.3	8.5	7.7	1.4
Aggregate	40.1	17.8	10.2	2.1	<0.01	0.4	0.3

C-2		C. Material Recycle for Electric Arc Furnace **EAF slag agglomeration for aggregate use**
Item		Content
1. Process Flow or Diagram		 *Treatment Process for Electric Arc Furnace Slag Air* 
2. Technology Definition/Specification		Molten slag is rapidly cooled by jet air, and becomes 0.3-5mm size of spherical structure, -Create strong & heavy fine aggregate material for concrete -Environmental friendly material -Suitable & meet with JIS A 5011-4 for Electric arc furnace oxidizing slag aggregate. -Require smaller space than normal slag treatment area.
3. Expected Effect of Technology Introduction	・Electricity Saving	-
	・Thermal Energy Savings	-
	・Environmental benefits	-
	・Co-benefits	Reduce disposal cost of industrial waste Processing time for one heat of EAF : 10 minutes
4. Japanese Main Supplier		Nikko
5. Technologies Reference		Diagram from Nikko, May contact to Nikko
6. Comments		<Notice> When using this technology, slag analysis data should be confirmed to meet the environmental regulation <Preconditions on calculating effects> - Slag generation : 80 kg/ton-product - Yield of granulated slag with this process : 60-70 %

<table>
<tr><td rowspan="2">D-1</td><td>D. Energy Saving for Reheating Furnace</td></tr>
<tr><td>Process control for reheating furnace</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>




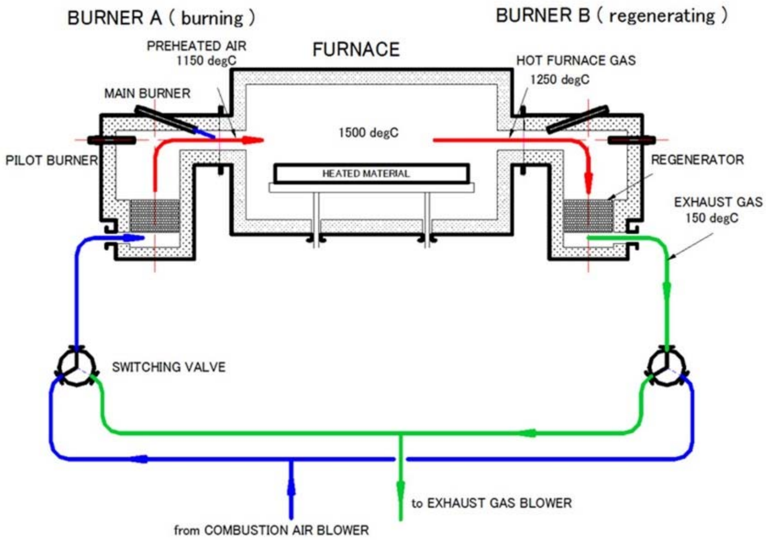
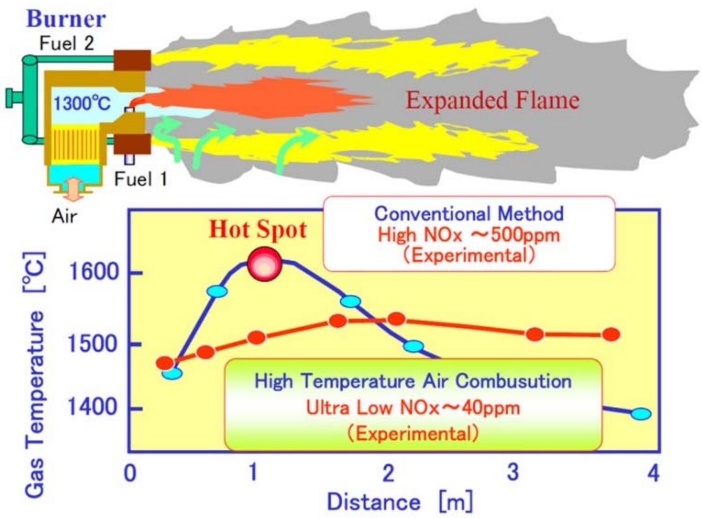


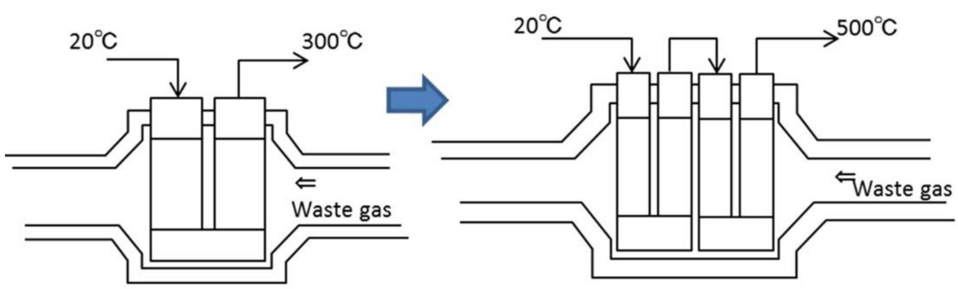
</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>- Setting furnace temperature by targeted billet temperature curve
- Precise air ratio control and O2 analysis in exhaust gas</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>-</td></tr>
<tr><td>・Thermal Energy Savings</td><td>0.015 GJ/ton-product (1 % fuel saving from the base line of 1,450 MJ/ton)</td></tr>
<tr><td>・Environmental benefits</td><td>-</td></tr>
<tr><td>・Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai-Ro</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>May contact to Chugai-Ro</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

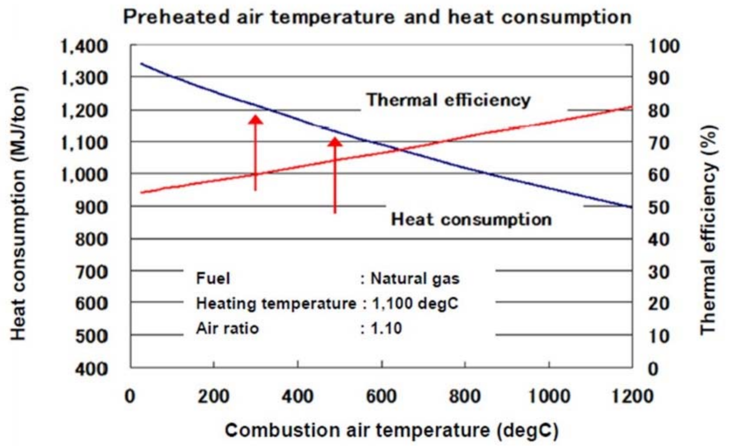
D-2

D. Energy Saving for Reheating Furnace

Low NOx regenerative burner total system for reheating furnace

Item		Content
1. Process Flow or Diagram		 
2. Technology Definition/Specification		While one of the burners is burning, the other burner will work as an exhaust outlet. The exhaust gas is discharged from the system after the waste heat of the gas is recovered so that the temperature of the gas will be lowered to the extent that there will be no condensation in the regenerator. The combustion air receives heat from the regenerator. Therefore, the combustion air will be preheated to a superhigh temperature (i.e., 90% of the temperature of the exhaust gas or over) before the combustion air is supplied the burner. When the preset cycle time elapses, the burners exchange their roles of combustion and exhaustion.
3. Expected Effect of Technology Introduction	・Electricity Saving	-
	・Thermal Energy Savings	0.189 GJ/t (about -13%)
	・Environmental benefits	CO_2 & NOx Reduction
	・Co-benefits	-
4. Japanese Main Supplier		Chugai-Ro, Nippon Furnace
5. Technologies Reference		Diagram from Chugai Ro, May contact to suppliers
6. Comments		-

<table>
<tr><td rowspan="2">D-3</td><td colspan="2">D. Energy Saving for Reheating Furnace</td></tr>
<tr><td colspan="2">High temperature recuperator for reheating furnace</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>

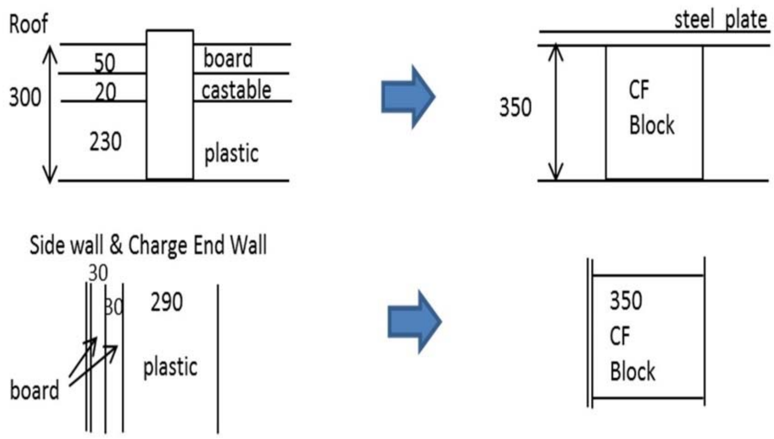
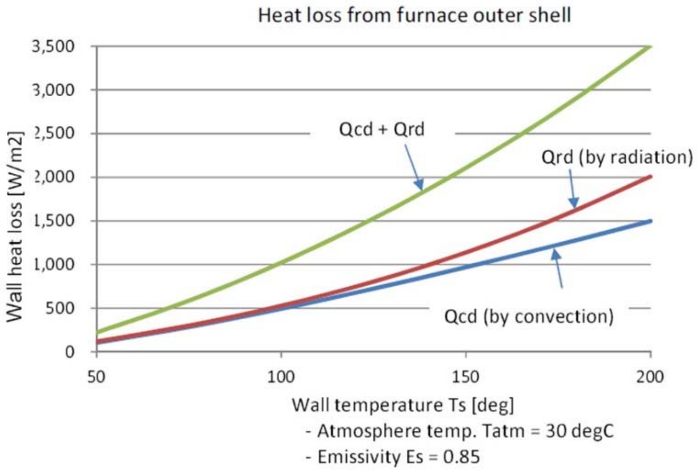

</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>Heat transfer area of the existing recuperator shall be increased (for example, by changing two-pass to four-pass) in order to raise the preheated combustion air temperature.

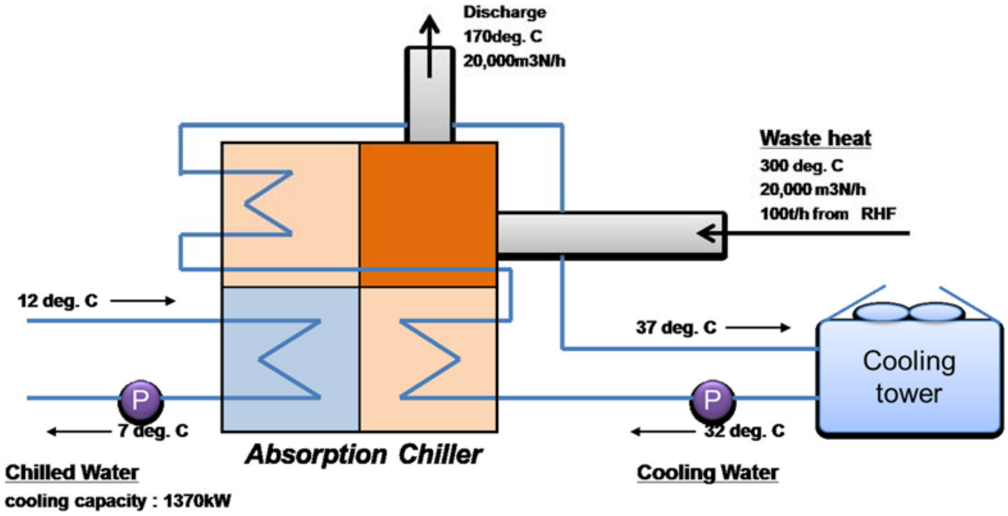
For this purpose, the following shall be needed.
- Modification of Recuperator room
- Change of air duct
- Increase of discharge pressure of blower
- High efficiency recuperator</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>-</td></tr>
<tr><td>・Thermal Energy Savings</td><td>0.100 GJ/t (about -7%)</td></tr>
<tr><td>・Environmental benefits</td><td>CO2 Reduction</td></tr>
<tr><td>・Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai-Ro, Rozai Kogyo</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>Diagram from Chugai Ro</td></tr>
<tr><td colspan="2">6. Comments</td><td><Preconditions on calculating effects>
When 300 degC air temperature is raised to 500 degC</td></tr>
</table>

D-4

D. Energy Saving for Reheating Furnace

Fiber block for insulation of reheating furnace

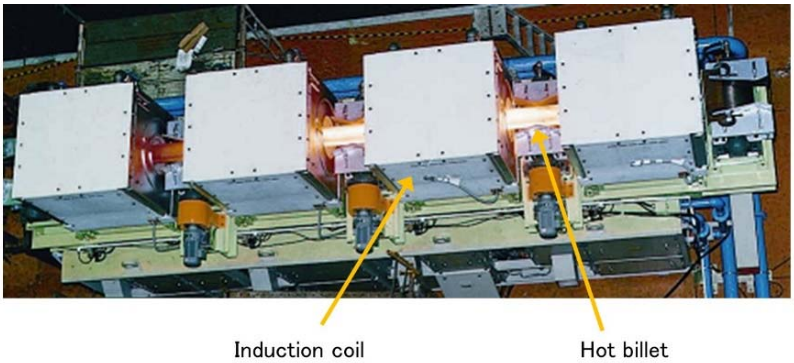
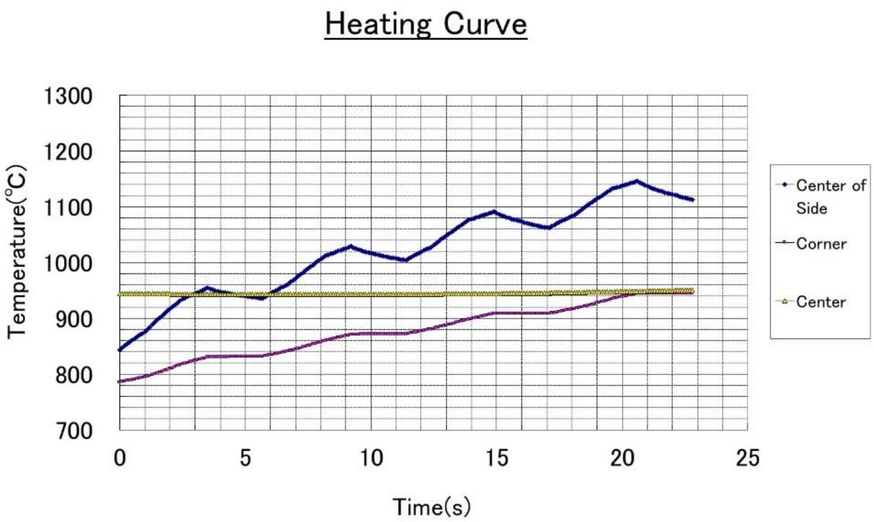
Item		Content
1. Process Flow or Diagram		  $Qs = 2.44\times(Ts-Tatm)^{1.25} + 5.674/10^8 \times \varepsilon_s \times ((Ts+273.15)^4 - (Tatm+273.15)^4)$ [W/m2] (1 [kcal/h・m2] = 0.86 x 1 [W/m2])
2. Technology Definition/Specification		Ceramic fiber is lighter in weight and has the lower thermal conductivity than conventional brick or castable. Ceramic fiber can be used for the insulation of furnace roof and side wall.
3. Expected Effect of Technology Introduction	・Electricity Saving	-
	・Thermal Energy Savings	0.039 GJ/t (about 2.7 %)
	・Environmental benefits	Reduction of Heat accumulation
	・Co-benefits	Quick heat-up and cool-down of the furnace temperature for smooth and energy-saving operation
4. Japanese Main Supplier		Chugai-Ro
5. Technologies Reference		Diagram from Chugai Ro and JP Steel Plantech
6. Comments		<Preconditions on calculating effects> assumed surface area of 100 ton/h furnace : 1350 m2 atmosphere temperature : 30 degC surface temp. and heat loss of brick lining case : 130 degC, 7.96 GJ/h surface temp. and heat loss of brick lining case : 90 degC, 4.08 GJ/h (7.96 - 4.08) /100 (ton/h) = 0.0388 GJ/ton ---> 0.039 GJ/ton saving

D-5	D. Energy Saving for Reheating Furnace	
	Air conditioning by absorption type refrigerating by using reheating furnace exhaust gas	
Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		This is a waste heat recovery system by using the absorption chiller. If there is a waste heat more than 200 deg. C, it can utilize for the double effect absorption chiller and can generate chilled water for air conditioning, etc. This chiller efficiency is about COP*:1.45 and it can reduce electrical type chiller power consumption. It requires close attention in case the exhaust gas contains corrosive components. *COP(Coefficient Of Performance) : Heat supplied(W) / Power consumption(W)
3. Expected Effect of Technology Introduction	･Electricity Saving	3.0 kWh/ton-product (compared to the air cooled electric chiller COP:3.5 / considering the auxiliaries consumption as 90kWh)
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	-
4. Japanese Main Supplier		HITACHI Infrastructure Systems Co.
5. Technologies Reference		Diagram from HITACHI Infrastructure Systems Co., May contact to HITACHI Infrastructure Systems Co.
6. Comments		<Preconditions on calculating effects> - compared to the air cooled electric chiller COP:3.5/ consider the auxiliaries consumption as 90kWh

D-6

D. Energy Saving for Reheating Furnace

Induction type billet heater for direct rolling

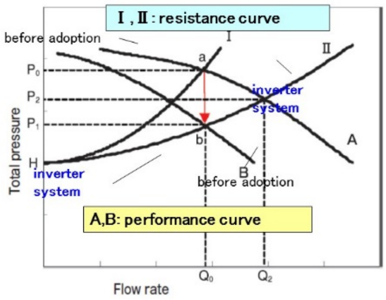
Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		Compensate temperature drop of billets transferred from CC to rolling mill (from 950 degC to 1050 degC). Advantages: - Automatic control - Less exhaust gas (without reheating furnace)
3. Expected Effect of Technology Introduction	・Electricity Saving	40 kWh/ton-product increase (electrical energy for billet heating)
	・Thermal Energy Savings	1.45 GJ/ton-product (Cold charge to reheating furnace is replaced.)
	・Environmental benefits	Better working floor and atmosphere
	・Co-benefits	-
4. Japanese Main Supplier		MES Power-Electronics Industry Co., Ltd.
5. Technologies Reference		-
6. Comments		-

E-1

E. Common systems and General Energy Savings

Inverter (VFD; Variable Frequency Drive) drive for motors

Item		Content
1. Process Flow or Diagram		(see figures below)



- Pumps are running at point " a" in the current situation, and will be running at point " b" after adoption of an inverter system.
- Power for pumps is proportional to" flow rate × total pressure", and motor input ratio before and after installation is the ratio of Q0 × P1 and Q0 × P0.

Fig.1 Relationship between flow rate and total pressure before/after adoption of an inverter system. *1

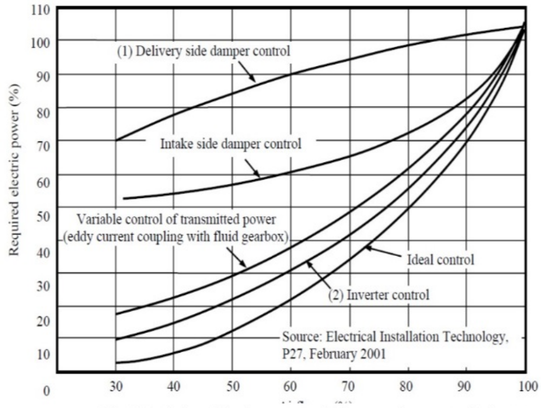
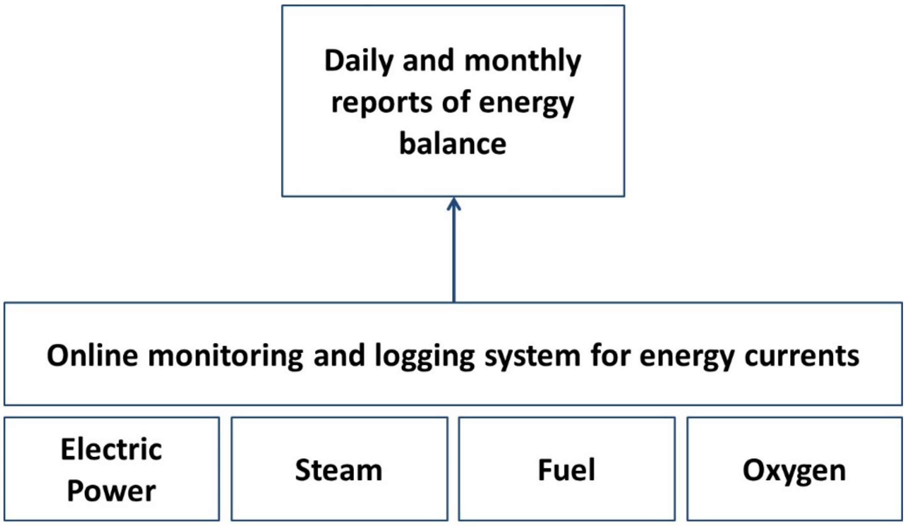
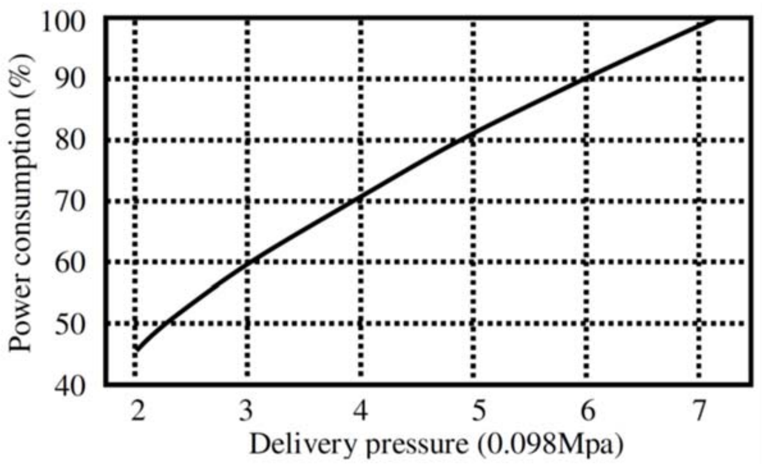


Fig.2 Relationship between airflow and required electric power relating to the type of control *2

Item		Content
2. Technology Definition/Specification		- Eco-Friendly Total efficiency of 97% is achieved. 20-30% of energy can be saved with fans and pumps. Separated installation is available for Transformer section. - Power Source Friendly Current harmonic at the power source conforms to IEEE519-1992 guidelines. - Less Maintenance Reliable, available and serviceable of maintenance tool are widely arranged. - Motor Friendly Series connected IGBT produce sinusoidal waveform of output voltage and current. It is best for to retrofit with existing motors.
3. Expected Effect of Technology Introduction	・Electricity Saving	13% (Depending on the country and conditions of the facility)
	・Thermal Energy Savings	-
	・Environmental benefits	CO2 Reduction
	・Co-benefits	-
4. Japanese Main Supplier		Hitachi, Ltd., Major electric equipment companies
5. Technologies Reference		*1 Guidebook on Energy Conservation for Factories (2010/2011), ed. by The Energy Conservation Center, Japan *2 Energy savings Diagnosis Examples-Common Equipment Volume', Energy conservation Center, Japan
6. Comments		<Preconditions on calculating effects> - Annual operation : 3,600 h/y - Unit cost of power : 0.145 US$/kWh

E-2	E. Common systems and General Energy Savings
	Energy monitoring and management systems
Item	Content
1. Process Flow or Diagram	
2. Technology Definition/Specification	This measure includes site energy management systems for optimal energy consumption in the plant. - Online monitoring: This is often used for the most important energy flows at the site. The data are stored for a long time so that typical situations may be analyzed. It is very important to monitor for all energy sources on online. It is the main technique used to avoid energy losses. - Continuous monitoring systems: Since all energy-related process parameters are used to optimize process control and to enable instant maintenance, undisrupted production process could be achieved. - Reporting and analyzing tools: Reporting tools are often used to check the average energy consumption of each process. In connection with cost controlling, controlling energy is the basis for optimizing energy consumption and cost savings. An energy controlling system enables to compare actual data with historical data (e.g. charts)
3. Expected Effect of Technology Introduction ・Electricity Saving	-
・Thermal Energy Savings	Energy saving effect depends on the local conditions, therefore, quantitative estimation is difficult.
・Environmental benefits	-
・Co-benefits	-
4. Japanese Main Supplier	Major electric equipment suppliers
5. Technologies Reference	-
6. Comments	-

E-3	E. Common systems and General Energy Savings
	Management of compressed air delivery pressure optimization
Item	Content
1. Process Flow or Diagram	 Relationship Between Delivery Pressure and Power consumption (with fixed delivery capacity)
2. Technology Definition/Specification	Energy saving in compressors requires consideration of the following points. * Selection of the appropriate capacity * Reduction in delivery pressure by keeping the required working power Since the required motive power increases with increased delivery pressure, appropriate delivery pressure should be selected in consideration of the items below. * Prevention of leakage * Reduction in temperature of the compressed air * Reduction in intake air resistance Intake air resistance increases with intake filters, silencers, and valves in piping etc., and will increase the required motive power if excessive. Care is required to reduce pressure losses in the intake air system through periodic cleaning of filters to eliminate clogging. * Reduction in piping resistance From the figure above, when delivery pressure is reduced to 0.098MPa, load on the electric motor can be reduced by approximately 10 %. When low pressure air is sufficient, low pressure unit should be additionally adopted instead of pressure reducing valves.
3. Expected Effect of Technology Introduction: ・Electricity Saving	285 MWh/y (=823 kW x 60 % x 10 % x 24 h/d x 241 days/y)
・Thermal Energy Savings	-
・Environmental benefits	-
・Co-benefits	-
4. Japanese Main Supplier	Major electric equipment suppliers
5. Technologies Reference	Japanese Technologies for Energy Savings/GHG Emissions Reduction 《2008 Revised Edition》, edited by NEDO
6. Comments	<Preconditions on calculating effects> - Number of compressors; Total of 17, *Delivery pressure; 0.8MPa, - Equipment capacity; 823 kW, *On-load operation load; 60%, - Daily operation; 24 h/d, *Annual operation; 241 days'

Contact Points of Supplier Companies

Company	Contact Points	Technology
Chugai Ro Co., Ltd.	***Akira SHINOZUKA*** Overseas Sales Section, Sales Dept, Plant Division Address: Sakai Works, 2-4 Chikko Shinmachi, Nishi-Ku, Sakai 592-8331, JAPAN Email: Akira_Shinozuka@n.chugai.co.jp Tel: +81-72-247-2108	A-9. Low NOx regenerative burner system for ladle preheating A-10. Oxygen burner system for ladle preheating D-1. Process control for reheating furnace D-2. Low NOx regenerative burner total system for reheating furnace D-3. High temperature recuperator for reheating furnace D-4. Fiber block for insulation of reheating furnace
Daido Steel Co., Ltd	***Kunio MATSUO*** General Manager, Machinery Engineering Dept., Machinery Division Address: 9 Takiharu-cho, Minami-Ku, Nagoya, JAPAN, 457-8712 Email: k-matsuo@ac.daido.co.jp Tel: +81-52-613-6819 ***Katsunari HASHIMOTO*** Export Sales Manager (Asean Area Manager), Machinery Division Adress: 1-6-35 Kounan, Minato, Tokyo, JAPAN, 108-8478 Email; k-hashimoto@bw.daido.co.jp Tel: +81-3-5495-1282	A-2. Medium temperature batch scrap preheating EAF A-4. Eccentric bottom tapping (EBT) on existing furnace A-6. Optimizing slag foaming in EAF A-8. Operation support system with EAF meltdown judgment A-12. Energy saving for dedusting system in EAF meltshop A-16. Arc furnace with shell rotation drive B-1. Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF B-2. Floating dust control in EAF meltshop B-4. Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas B-5. Dioxin absorption by 2 step bagfilter technology for EAF exhaust gas C-1. EAF dust and slag recycling system by oxygen-fuel burner
Fuji Car Manufacturing Co. Ltd.	***Mr. Satoshi MATSUMURA*** Environmental Plant & Equipment Sales Division 1 Address: Shibapark Bldg. A-10F, 2-4-1, Shibakouen, Minato-ku, Tokyo, 105-0011, Japan Email: s-matsumura@fujicar.co.jp Tel: +81-3-6402-4184 Fax: +81-3-6402-4185	A-15. Scrap pretreatment with scrap shear
Fuji Electric Co., Ltd.	***Masato IDE*** Assistant General Manager, Sales Dept. IV, Global Plant Sales Div., Sales Group Address: Gate City Ohsaki, East Tower 11-2, Osaki 1- Chome, Shinagawa-Ku, Tokyo 141-0032, JAPAN Email: ide-masato@fujielectric.co.jp Tel: +81-3-5435-7062	A-14. Induction type tundish heater
Hitachi, Ltd. Hitachi Infrastructure Systems Company	***Taisuke SHIMAZAKI*** Assistant Manager, Industrial Systems and Solutions Division, Heavy Industry Dept., Tokyo Head Office Email: taisuke.shimazaki.xz@hitachi.com TEL: +81-90-1690-4507 FAX: +81-3-5928-8745	D-4. Air conditioning by absorption type refrigerating by using reheating furnace exhaust gas E-1. Inverter (VFD; Variable Frequency Drive) drive for motors
JFE Engineering Corporation	***Nagayoshi SUZUKI*** Manager, Environmental Plant Section, Engineering Department, Overseas Business Sector Address: 2-1, Suehiro-cho, Tsurumi-ku, Yokohama, 230-8611 JAPAN Email: suzuki-nagayoshi@jfe-eng.co.jp Tel: +81(45)505-7821 Fax: +81(45)505-7833	B-3. Dioxin adsorption by activated carbon for EAF exhaust gas
JP Steel Plantech Co.	***Masao MIKI*** General Manager, Section 1, Overseas Sales & Marketing Dept. Address: 2-6-23, Shinyokohama, Kohoku-ku,Yokohama 222-0033 JAPAN Email: mikim@steelplantech.co.jp Tel: +81-(0)45-471-3917 Fax: +81-(0)45-471-4002	A-1. High temperature continuous scrap preheating EAF A-3. High efficiency oxy-fuel burner/lancing for EAF A-4. Eccentric bottom tapping (EBT) on existing furnace A-5. Ultra-high-power transformer for EAF A-6. Optimizing slag foaming in EAF A-7. Optimized power control for EAF A-10. Oxygen burner system for ladle preheating A-11. Waste heat recovery from EAF A-12. Energy saving for dedusting system in EAF meltshop A-13. Bottom stirring/stirring gas injection B-1. Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF B-2. Floating dust control in EAF meltshop B-3. Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas B-4. Dioxin absorption by 2 step bagfilter technology for EAF exhaust gas B-5. PKS charcoal use for EAF
MES Power-Electronics Industry Co., Ltd.	***Takahiro AO*** Manager, Design Sect. Engineering Dept. Address: 1-1,Tama 3-chome, Tamano, Okayama 706-8651, Japan Email: tao@mes.co.jp Tel: +81-863-23-2439 Fax: +81-863-23-2784	D-6. Induction type billet heater for direct rolling
Nikko Industry Co., Ltd.	***Akiyoshi OKAMOTO*** Director, Engineering and Marketing Division Address: 4-10, 2-chome, Nunobiki-cho, Chuo-ku, Kobe, 651-0097, JAPAN Email: a-okamoto@nikko-japan.co.jp Tel: +81-78-222-1688	A-3. High efficiency oxy-fuel burner/lancing for EAF A-5. Ultra high-power transformer for EAF C-2. EAF slag agglomeration for aggregate use
Nippon Furnace Co., Ltd.	***Susumu MOCHIDA*** Director, General Manager, Technology & Engineering Division Address: 1-53, Shitte 2-Chome, Tsurumi-ku, Yokohama 230-8666, JAPAN Email: s_mochida@furnace.co.jp Tel: +81-45-575-8008	A-9. Low NOx regenerative burner system for ladle preheating D-2. Low NOx regenerative burner total system for reheating furnace

ANNEX 1.

FULL LIST OF TECHNOLOGIES

136 energy saving, environment and recycle technologies of steel industry

Table　Full List of Technologies for CO2 Emission Reduction and Energy Saving in World Steel Industry

No	Title of Technology (SOACT base）[*1]	Technologies Reference[*2]				Expected Effect of Technologies Introduction [*3]		
		SOACT	NEDO	EU-BAT	EPA-BACT	CO2 Reduction kg- CO2/t of product	Energy Savings (Electricity/ Fuel) GJ/t of product	Co-benefits (Reduction of Water, Dust, SOx, etc.)
	Sintering	○						
1	Sinter Plant Heat Recovery (Steam Recovery from Sinter Cooler Waste Heat)	○	○	○	○	23.8(N)	/0.55, 0.25（N）	SOx, NOx, Dust
2	Sinter Plant Heat Recovery (Power Generation from Sinter Cooler Waste Heat)					16.9	22.1kWh/t /0.245	
3	District Heating Using Waste Heat	○					/800TJ/y(S)	
4	Dust Emissions Control	○						Dust
5	Exhaust Gas Treatment through Denitrification, Desulfurization, and Activated Coke Packed Bed Absorption	○						NOx, DXN, Hg
6	Exhaust Gas Treatment through Selective Catalytic Reduction	○						SOx
7	Exhaust Gas Treatment through Low-Temperature Plasma	○						DXN
8	High Efficient (COG) Burner in Ignition Furnace for Sinter Plant [*4]	○				0.46(N)	/0.01(S), 30%(S)	
9	Exhaust Gas Treatment Through Additive Injection and Bagfilter Dedusting	○						
10	Sintering machine ignition oven burner (NEDO)		○				/0.01[30%] (N)	
11	Partial recycling of waste gas (EU-BAT)			○				SOx, NOx, Dust
	Coke making	○						
12	Coke Dry Quenching	○	○	○	○	97.5(S)	1.47(N) /1.2(S)	
13	Coal Moisture Control	○	○		○	27.5(S)	/0.3(S)	
14	High Pressure Ammonia Liquor Aspiration System	○		○				Fume
15	Stripping of ammonia from the waste water (EU-BAT)			○				Water
16	Waste water treatment (EU-BAT)			○				Water
17	Modern Leak-proof Door	○		○				Fume
18	Cleaning of oven doors and frame seals (EU-BAT)			○				Fume
19	Reduction of SO2 by coke oven gas desulphurisation (EU-BAT)			○				SOx
20	Land Based Pushing Emission Control System	○		○				Fume (Dust)
21	Variable pressure regulation of ovens during the coking process (EU-BAT)			○				
22	VSD COG compressor (EPA-BACT)				○			
23	Coke Plant – Automation and Process Control System	○		○	○	3.8	/0.17	
24	COG-non-recovery Coke Battery [*4]	○		○	○		630-700KWh/t(S)/	
25	Waste Plastics Recycling Process Using Coke Ovens	-						
	Ironmaking	○						
26	Top Pressure Recovery Turbine	○	○	○	○	25(S)	0.49(S)/	
27	Pulverized Coal Injection (PCI) System	○	○	○	○	212(N)	/2.33(N: 200 kg inj.)	
28	Pulverized coal injection to 225 kg/ton iron (EPA-BACT)				○			
29	Oxy-oil injection (EU-BAT)			○	○	34.7	/0.57	
30	Gas injection (EU-BAT)			○	○			
31	Injection of COG and BOF gas (EPA-BACT)				○	54.9		
32	Plastic injection (EU-BAT)			○				
33	Direct injection of used oils, fats and emulsions as reducing agents and of solid iron residues (EU-BAT)			○				
34	Improve Blast Furnace Charge Distribution	○						
35	Use of high quality ores (EU-BAT)			○				
36	Charging carbon composite agglomerates (EPA-BACT)				○			
37	Blast Furnace Gas and Cast House Dedusting	○		○			/9tWater/t-iron	Water
38	Blast furnace gas recycling (EPA-BACT)				○			
39	B-gas（fueling）Regenerative Reheating Furnace	-						
40	B-gas（fueling）Ignition Burner of Sinter	-						
41	Direct injection of used oils, fats and emulsions as reducing agents and of solid iron residues (EU-BAT)			○	○	19.5	/0.18	
42	Cast House Dust Suppression	○		○				
43	Treatment and reuse of scrubbing water (EU-BAT)			○				
44	Hydrocyclonage of blast furnace sludge (EU-BAT)			○				
45	Slag Odor Control	○		○				Odor

Table Full List of Technologies for CO_2 Emission Reduction and Energy Saving in World Steel Industry

No	Title of Technology (SOACT base) [*1]	Technologies Reference[*2]				Expected Effect of Technologies Introduction [*3]		
		SOACT	NEDO	EU-BAT	EPA-BACT	CO2 Reduction kg- CO2/t of product	Energy Savings (Electricity/ Fuel) GJ/t of product	Co-benefits (Reduction of Water, Dust, SOx, etc.)
46	Slag heat recovery (EPA-BACT)				○			
47	Blast Furnace – Increase Hot Blast Temperature (>1100 Deg C)	○						
48	Blast Furnace – Increase Blast Furnace Top Pressure (>0.5 Bar Gauge)	○						
49	Improvement of combustion in hot stove (EPA-BACT)				○			
50	Blast Furnace Heat Recuperation	○	○	○	○	7.8(S)	/0.08, 0.08(S), 0.126(N)	
51	Optimized Blast Furnace Process Control with Expert System	○			○	24.4	/0.4	
52	Alternative Ironmaking: Direct Reduction (DRI/HBI) and Direct Smelting	○						
53	Smelting Reduction Processes	○						
54	Direct Reduction Processes	○						
55	Coal Based Rotary Hearth Furnace Type Ironmaking Process [*4]	○						
56	Paired Straight Hearth Furnace	○						
57	Coal and Lump Ore Based Smelting-Reduction Type Ironmaking Process [*4]	○		○				
58	Finex Process	○						
59	Rotary Kiln Direct Reduction	○		○				
60	Coal and Fine Ore Based DRI/HBI Production Process [*5]	○						
61	Natural Gas Based Zero-Reforming DRI/HBI Production Process using Fine Ore [*4]	○						
62	Coal Synthesis Gas and Lump Ore/Pellet Based Shaft Furnace Type DRI/HBI Production Process [*4]	○						
63	Natural Gas and Lump Ore/Pellet Based Shaft Furnace Type DRI/HBI Production Process with CO2 Removal System [*4]	○						
64	High-efficiency cupola (NEDO)		○					
	Steelmaking	○						
65	On-line Feedback Analyzer for Efficient Combustion [*4]	○		○				
66	ProVision Lance-based Camera System for Vacuum Degasser - Real-time Melt Temperature Measurement	○						
67	Hot Metal Pretreatment	○						
68	Programmed and efficient ladle heating (EPA-BACT)				○			
69	Increase Thermal Efficiency by Using BOF Exhaust Gas as Fuel	○						
70	Use Enclosures for BOF	○		○				
71	Control and Automization of Converter Operation	○		○	○			
72	OG-boiler System (Non-combustion)/Dry-type Cyclone Dust Catcher	○				12.0(N)	/0.13(N)	
73	Exhaust Gas Cooling System (Combustion System)	○		○	○	46	/0.92	
74	Converter gas recovery device (NEDO)		○			79.8(N)	/0.84(N)	
75	Laser Contouring System to Extend the Lifetime of BOF Refractory Lining	○						
76	BOF Bottom Stirring	○						
77	VSD on ventilation fans (EPA-BACT)				○	0.51	0.003/	
78	Dust hot briquetting and recycling with recovery of high zinc concentrated pellets for external reuse (EU-BAT)			○				
79	Elimination of Radiation Sources in EAF Charge Scrap	○						
80	Improved Process Control (Neural Networks)	○			○	17.6	0.11/	
81	Hot DRI/HBI Charging to the EAF	○						
82	Oxy-fuel Burners/Lancing	○			○	23.5	0.14/	
83	Scrap Preheating	○	○	○	○	35.2	0.22, 0.126(N)/	
84	New scrap-based steelmaking process predominantly using primary energy	○			○	35.3	0.44/-0.7	
85	Twin-shell DC with scrap preheating (EPA-BACT)				○	11.1	0.07/	
86	Bottom stirring/stirring gas injection (EPA-BACT)				○	11.7	0.07/	
87	Eccentric bottom tapping on existing furnace (EPA-BACT)				○	8.8	0.05/	
88	Post-combustion of the flue gases (EPA-BACT)				○			
89	Engineered refractories (EPA-BACT)				○		0.036/	
90	Adjustable speed drives (ASDs) (EPA-BACT)				○		0.05/	
91	Transformer efficiency—ultra-high power transformers (EPA-BACT)				○	10	0.06/	
92	Control and Automation for EAF Optimization	○		○				

Table Full List of Technologies for CO2 Emission Reduction and Energy Saving in World Steel Industry

No	Title of Technology (SOACT base) [*1]	Technologies Reference[*2]				Expected Effect of Technologies Introduction [*3]		
		SOACT	NEDO	EU-BAT	EPA-BACT	CO2 Reduction kg- CO2/t of product	Energy Savings (Electricity/ Fuel) GJ/t of product	Co-benefits (Reduction of Water, Dust, SOx, etc.)
93	Slag Foaming, Exchangeable Furnace and Injection Technology	○			○	10.6	0.07/	
94	Airtight operation (EPA-BACT)				○		0.36/	
95	Exhaust Gas Treatment Through Gas Cooling, Carbon Injection and Bagfilter Dedusting	○		○				DXN, Dust
96	Ecological and Economical Arc Furnace [*4]	○				77	1.5	DXN, Dust, Noise
97	Waste Heat Recovery from EAF					70.1	0.86/t-steel	
98	DC arc furnace (NEDO)		○		○	52.9	0.32, 0.11(N)/	
99	Shaft-type Continuous EAF [*4] (EPA-BACT)				○		0.72/	
	Ladle Refining and Casting	○						
100	Efficient caster ladle/tundish heating (EPA-BACT)				○	1.1	0.02/	
	Casting	○						
101	Strip Casting Technology [*4]	○						
102	Thin Slab Casting and Hot Rolling	○	○					
103	Hot Charging to Reheat Furnace of Rolling Mills	○	○					
104	Near net shape strip casting (EU-BAT)			○	○	728.8	0.64/3.5	
105	Near net shape casting - strip (EPA-BACT)				○			
	Recycling and Waste Reduction	○						
106	Reducing Fresh Water Use	○		○			/20MLwater/day(S)	Water
107	Slag Recycling	○						Dust
108	Pressurization-type Steam Aging Equipment for Steel Slag	○						
109	EAF slag processing (EU-BAT)			○				Dust
110	Treatment of high alloyed and stainless steel EAF slags (EU-BAT)			○				Dust
111	Rotary Hearth Furnace Dust Recycling System	○				22.8(S)	/1400TJ/y(S)	Dust
112	Bag filter – combined or integrated reduction of solid and gaseous pollutants (EU-BAT)			○				SOx
	Common Systems	○						
113	Auditing Rotary Machines for Pump Efficiency	○					20-30%(S) /	
114	AIRMaster+ Software Tool – Improved Compressed Air System Performance	○				55,069t/y(S) (assessments 139)	993TJ/y(S) (assessments 139)/	Air leak
115	Combined Heat and Power Tool – Improved Overall Plant Efficiency and Fuel Use	○						
116	Fan System Assessment Tool – Efficiency Enhancement for Industrial Fan Systems	○				3,022t/y(S) (assessments 36)	53TJ/y(S) (assessments 36) /	
117	MotorMaster+ International – Cost-Effective Motor System Efficiency Improvement	○						
118	NOx and Energy Assessment Tool – Reduced NOx Emissions and Improved Energy Efficiency	○			○			
119	Process Heating Assessment and Survey Tool – Identify Heat Efficiency Improvement Opportunities	○				273,638t/y(S) (assessments 225)	5375TJ/y(S) (assessments 225)/22%(S)	
120	Quick Plant Energy Profiler – First Step to Identify Opportunities for Energy Savings	○						
121	Steam System Tools – Tools to Boost Steam System Efficiency	○				1,472,115t/y(S) (assessments 306)	20148TJ/y(S) (assessments 306)/	
122	Inverter (VVVF; Variable Voltage Variable Frequency) Drive for Motors [*4]	○	○	○	○	1.5	42%(S) , 0.02/	
123	Regenerative Burner Total System for reheating furnace [*5]	○	○		○	16.2-20(N)	/20-50%(S) ,0.17-0.21(N)	NOx
124	Techniques to improve heat recovery (EU-BAT)			○				

Table Full List of Technologies for CO2 Emission Reduction and Energy Saving in World Steel Industry

No	Title of Technology (SOACT base) [*1]	Technologies Reference[*2]				Expected Effect of Technologies Introduction [*3]		
		SOACT	NEDO	EU-BAT	EPA-BACT	CO2 Reduction kg- CO2/t of product	Energy Savings (Electricity/ Fuel) GJ/t of product	Co-benefits (Reduction of Water, Dust, SOx, etc.)
	General Energy Savings & Environmental Measures	○						
125	Energy Monitoring and Management Systems	○		○	○	11.4(S)	0.01/0.12[0.5%](S), 0.11	
126	Cogeneration (include Gas Turbine Combined Cycle (GTCC))	○	○		○	56.1(S)	1.1(S), 0.35/0.03	
127	Technology for Effective Use of Slag	○		○		340(S)		
128	Hydrogen Production	○	○					
129	Carbonation of Steel Slag	○				1-7%(S)		
130	By-product generator set (NEDO)		○	○				
131	Ironworks by-product gas, single-fuel-firing, high-efficiency, combined generator set (NEDO)		○					
132	Management of steam traps in steam piping and drain water recovery (NEDO)		○				1.5GJ/y(N) /1.5tWater/h](N)	Water
133	Power recovery by installation of steam turbine in steam pressure reducing line (NEDO)		○				47,652GJ/y(N) /0.8t-steam/h(N)	Steam
134	Management of Compressed Air Delivery Pressure Optimization [*4] (NEDO)		○				285MW/h/y(N) /	
135	Improving thermal insulation in industrial furnace (NEDO)		○				/840GJ/y(N)	
136	Preventive Maintenance (EPA-BACT)				○	35.7	0..02/0.43	

[*1] Description within ( ) indicates the technologies reference name. The title without ( ) refers to SOACT.

[*2] SOACT; The State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook (2nd Edition, 2010)
NEDO; Japanese Technologies for Energy Savings/GHG Emissions Reduction《2008 Revised Edition》
EU-BAT; Best Available Techniques (BAT) Reference Document for Iron and Steel Production (Draft version, 24 June 2011)
EPA-BACT; Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from the Iron and Steel Industry (2010)

[*3] Referred to EPA-BACT (pp.9-12), SOACT (S), and NEDO (N). In the case of EPA-BACT, there is no "( )" at the end of the value.

[*4] Arranged title after replacing trademark or trade name with technical terms

[*5] Arranged in a comprehensible title

ANNEX 2.

TECHNOLOGIES FOR BLAST FURNACE

Technologies for Blast Furnace

No	Title of Technology	Technology Description	Expected Effect of Introduction			
			CO2 Reduction kg- CO2/t of product	Electricity Savings GJ/t of product	Fuel Savings GJ/t of product	Co-benefits (Reduction of Water, Dust, SOx, etc.)
Sintering						
1	Sinter Plant Heat Recovery (Steam Recovery from Sinter Cooler Waste Heat)	This device recovers the sensible heat in the hot air with temperature of 250℃ to 450℃ from a sinter cooler. The sensitive heat can be recovered by one or more of the following ways: ・steam generation in a waste heat boiler ・hot water generation for local heating ・preheating combustion air in the ignition furnace ・power generation	23.8	—	0.25	SOx, NOx, Dust
2	Sinter Plant Heat Recovery (Power Generation from Sinter Cooler Waste Heat)	This is a waste gas sensible heat recovery system from sinter cooler to generate electric energy. The system is composed of dust collector, waste heat recovery boiler as steam, circulation fan and power generator by steam turbine.	16.9	22.1 kWh/t-sinter	0.245	—
3	High Efficient (COG) Burner in Ignition Furnace for Sinter Plant	The multi-slit burner is designed to form a successive and uniform frame along a pallet width direction in the ignition furnace. It consists of fuel exhaust nozzles and a slit-like burner tile containing these nozzles. The fuel, coke oven gas, supplied from the fuel exhaust nozzles reacts with the primary air inside the burner tile, then with the secondary air supplied to the periphery area of the frame. By lining up the burner block, the frame can cover the whole surface of the bed along the width direction. By controlling the primary/secondary air ratio, the length of the frame can be controlled to minimize the energy consumption for ignition.	0.46	—	0.010	—
Cokemaking						
4	Coke Dry Quenching	The heat recovered by inert gas is used to produce steam, which may be used on-site or to generate electricity. Hot coke from the coke oven is cooled in specially designed refractory lined steel cooling chambers by counter-currently circulating an inert gas media in a closed circuit consisting of 1) cooling chamber 2) dust collecting bunker 3) waste heat boiler 4) dust cyclones 5) mill fan 6) blowing device (to introduce the cold air from the bottom) 7) circulating ducts 8) Capacity ;The nominal capacity of a typical CDQ plant is less than 100 t/h/chamber.(EU-BAT) 260t/h(China/Shougang Jingtang/NSC-ENG)	97.5/t-coke	1.47/t-coke	1.2/t-coke	—
5	Coal Moisture Control	Coal moisture control uses the waste heat from the coke oven gas to dry the coal used for coke making. The moisture content of coal varies, but it is generally around 8-9% for good coking coal. Drying further reduces the coal moisture content to a constant 3-5%, which in turn reduces fuel consumption in the coke oven. The coal can be dried using the heat content of the coke oven gas or other waste heat sources.[SOACT]Generally, low-pressure steam is used as the humidity control heat source.[NEDO]	27.5/t-coke	—	0.3/t-coke	—
Ironmaking						
6	Top Pressure Recovery Turbine	This system generates electric power by employing blast furnace top gas to drive a turbinegenerator. After the blast furnace gas is used in power generation, it is used as a fuel in iron and steel manufacturing processes. This technology is a method of generating power by employing this heat and pressure to drive a turbinegenerator. The system comprises dust collecting equipment, a gas turbine, and a generator. Generating methods are classified as (1) wet or (2) dry depending on the B-gas purification method. Dust is removed by Venturi scrubbers in the wet method and by a dry-type dust collector in the dry method.	25.0/t-PI	0.49/t-PI	—	—
7	Pulverized Coal Injection (PCI) System	This system comprises a technology and equipment for injecting pulverized coal directly through the blast furnace tuyeres as a partial substitute for the coke used in the blast furnace. Because pulverized coal is injected directly, the corresponding amount of coke is unnecessary, making it possible to reduce energy consumption for coke making (coke dry distillation energy).	212/t-PI	—	2.33/t-PI (at 200kg coal inj.)	—
8	Hot Stove Waste Heat Recovery	This device recovers the sensible heat of the flue gas generated in heating the hot stoves which supply hot blast to the blast furnace and uses this heat in preheating fuel and combustion air for the hot stoves. Installation of this device improves the combustion efficiency of the hot stoves, thereby saving energy.	7.8/t-PI	—	0.08/t-PI	—
Steelmaking						
9	Converter Gas Recovery device	Molten steel is produced by the converter process. This device recovers and uses the high temperature waste gas generated in large quantity during blowing in the converter (basic oxygen furnace: equipment used to produce crude steel from pig iron, steel scrap, etc.)	79.8/t-CS	—	0.84/t-CS	—
General Energy Savings & Environmental Measures						
10	Cogeneration (include Gas Turbine Combined Cycle (GTCC))	This equipment is a high-efficiency (47.5%, HHV Base) combined generator set using the by-product gas produced during iron and steel manufacturing process as the fuel. This equipment is an iron and steel by-product gas fired combined generator set, in which the gas turbine is operated by high-temperature gas (1,300℃) generated by mixing the blast furnace gas with the coke oven gas to be gas with a heat amount of 4,400kJ/m3N and burning it after the pressure is increased to about 1.4MPa. At the same time the steam turbine is operated by the steam generated by directing the high-temperature (approx. 550℃) gas discharged from the gas turbine to the exhaust heat recovery boiler.	56.1/t-CS	1.1/t-CS	—	—
Recycling and Waste Reduction						
11	Rotary Hearth Furnace Dust Recycling System	Dust recycling in the rotary hearth furnace (RHF) was applied at Nippon Steel's Kimitsu Works in 2000. The dust and sludge, along with iron oxide and carbon, are agglomerated into shaped articles and the iron oxide is reduced at high temperatures. Zinc and other impurities in the dust and sludge are expelled and exhausted once into off-gas. The exhaust gas containing zinc is cooled using a boiler and recuperator and then, the secondary dust containing condensed zinc is collected in a precipitator.	22.8/t-PI	—	0.21/t-PI	Dust

ANNEX 3.

FINANCIAL SUPPORT SCHEME OF JAPAN

Introduction

Japan is offering various financial support programs aiming at promoting diffusion of Japanese superior technologies and products in other countries, especially in the area where difficulties of securing funds exist. The financial support offered by Japan includes:

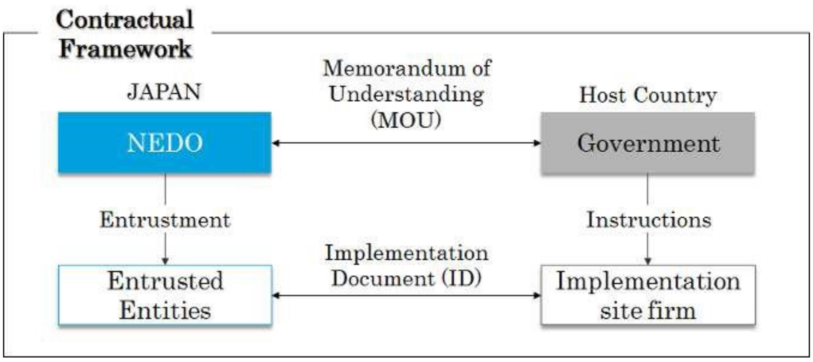
- Demonstration Project (NEDO)
- Export Loans (JBIC)
- GREEN (JBIC) and etc.

Though it is expected that by mobilizing those financial support programs, in order to contribute further diffusion of energy saving, environmental protection and recycling technologies in steel industry, detailed policies are currently under discussion.

Demonstration Project (NEDO)

The purpose of New Energy and Industrial Technology Development Organization (NEDO)'s "*Demonstration Projects*" is to demonstrate the effectiveness of advanced Japanese clean energy and environmental technologies through the introduction of such technologies in overseas countries.

Under the *Demonstration Project* scheme, costs are shared between Japan and the host country. In executing the Demonstration Project, with focus on technologies and systems in which Japan is strong, roles are shared with government of host country and related organization considering needs of government and industry of host country.



Demonstration Project consists of three projects namely "Feasibility Study (F/S)", "Model Project" and "Follow-up Activities".

Feasibility Study (F/S)

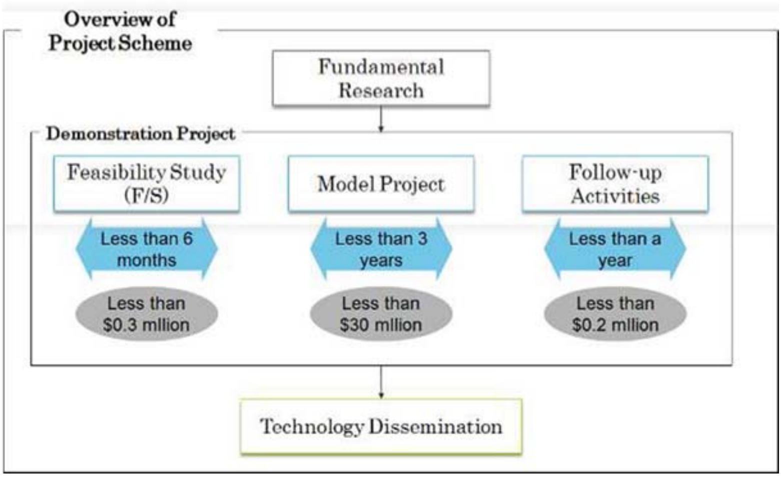
- Verifying feasibility of the project.

Model Project

- Actually bringing in Japanese technologies and systems and verifying effect of those technologies and systems as well as verifying new business model.

Follow-up Activities

– Promoting diffusion of verified technologies and systems and collecting information for formation of new projects.



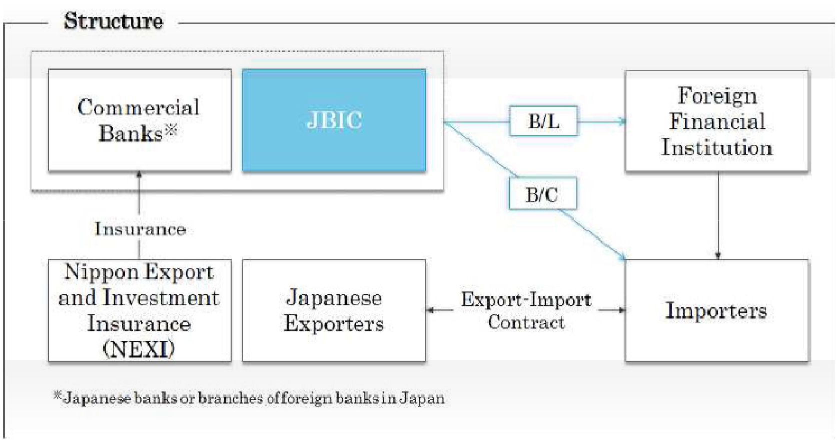
Export Loans (JBIC)

Japan Bank for International Cooperation (JBIC)'s "*Export Loans*" is provided to overseas importers and financial institutions to support finance exports of Japanese machinery, equipment and technology mainly to developing countries.

In particular, products such as marine vessels, power generation facilities and other types of plant equipment incorporate a large amount of advanced technology, and their export contributes to enhancing the technological base of Japanese industries. Further, Japanese shipbuilding and plant facilities industries have a broad range of supporting industries including SMEs producing parts and components. Export loans are also available to developed countries in eligible sectors.

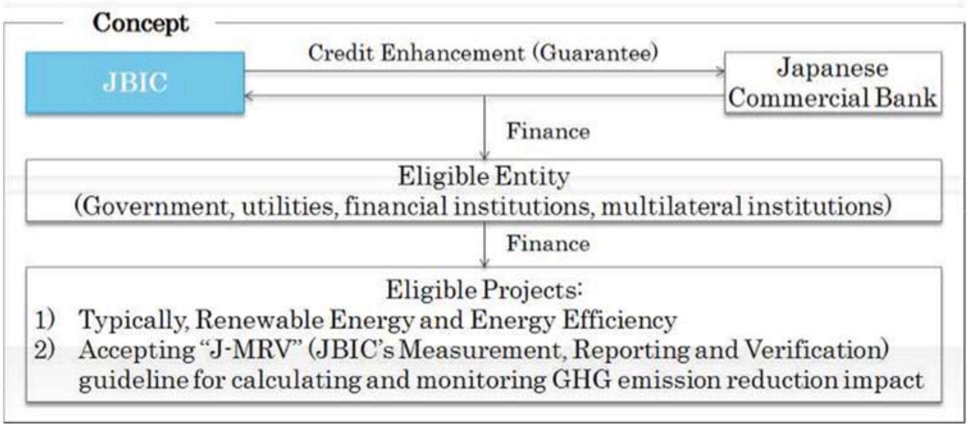
Overview

【Purpose】
Promoting exports of technology in the renewable energy sector
【Types of loans】
B/C: Buyers' Credit (Direct Loans)
B/L: Bank-to-Bank Loans(Two-Step Loans)
【Loan amount】
JBIC portion up to 60% (Based on the OECD Arrangement on Export Credits)
【Interest rates】
Commercial Interest Reference Rates(CIRRs)
【Loan term】
Up to 18 years



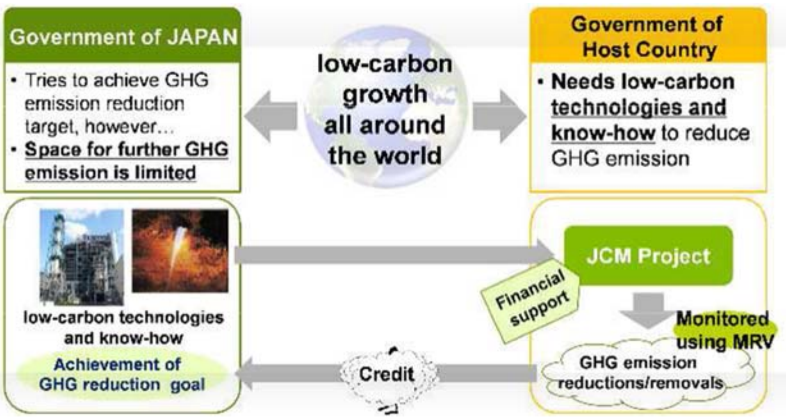
GREEN (JBIC)

Japan Bank for International Cooperation (JBIC)'s "*GREEN*" (Global action for Reconciling Economic growth and ENvironmental preservation) is a scheme which allows JBIC to support for projects undertaken in developing countries that are having a favorable impact on the preservation of the global environment. Under the GREEN scheme JBIC finances projects aimed at preserving the global environment, such as projects that significantly reduce greenhouse gas (GHG) emissions.



Joint Crediting Mechanism (JCM)

The JCM is possible win-win scheme for both of Japan and host country in terms of low-carbon technologies transfer and GHG emission reduction. The JCM facilitates diffusion of leading low carbon technologies, products, systems, services, and infrastructure as well as implementation of mitigation actions, and contributing to sustainable development of developing countries. The JCM scheme appropriately evaluate contributions to GHG emission reductions or removals from Japan in a quantitative manner, by applying measurement, reporting and verification (MRV) methodologies, and use them to achieve Japan's emission reduction target. The JCM contributes to the ultimate objective of the UNFCCC by facilitating global actions for GHG emission reductions or removals, complementing the CDM.



ANNEX 4.

EXPECTED EFFECTS IN EACH ASEAN COUNRY

Pre-Conditions for Calculations of Effects

- As the plant costs and energy prices may change country to country, the differences are shown in the list of "Energy price, plant cost, and CO2 emission factor in ASEAN countries".
- Plant cost in each country is calculated by multiplying "plant cost index" to the cost in Japan.
- By using plant costs and energy prices, profit of operation and simple pay-back time are calculated for each ASEAN country in the sheet of "Expected effects in each ASEAN country". This calculation suggests that when energy price is high, energy saving project is profitable even though the plant cost is expensive.
- CO2 emission reduction is also calculated for each country by using emission factor of electricity in each country and the common value of CO2 emission rate from fuel (63.1 kg-CO2/GJ).

Energy price, plant cost, and CO2 emission factor in ASEAN countries

Country	Electricity price for industry use[1] (US$/kWh)	Fuel gas price for industry use[1] (US$/GJ)	Plant cost index[2] (Japan = 100.0)	CO2 emission factor[3] (ton-CO2/MWh)
Thailand	0.097	14.37	82.2	0.5472
Indonesia	0.090	7.17	76.3	0.7577
Vietnam	0.064	23.81	69.9	0.5638
Philippines	0.130	25.79	77.4	0.5109
Malaysia	0.100	5.67	85.9	0.6681
Singapore	0.147	50.00	111.6	0.4862
Japan	0.113	20.22	100.0	0.4960

1) JETRO website (2016), fuel gas is assumed as LPG
2) Japan Machinery Center for Trade and Investment (2016.3)
3) Average of combined margin from CDM projects, IGES website (2016.3.28)

Expected effects in Thailand, Indonesia and Vietnam

No.	ID	Title of technology	Thailand				Indonesia				Vietnam			
			Preconditions				Preconditions				Preconditions			
			CO2 emission factor (ton-CO2/MWh) 1)			0.5472	CO2 emission factor (ton-CO2/MWh) 1)			0.7577	CO2 emission factor (ton-CO2/MWh) 1)			0.5638
			Electricity price (US$/kWh) 2)			0.097	Electricity price (US$/kWh) 2)			0.090	Electricity price (US$/kWh) 2)			0.064
			Fuel gas price (US$/GJ) (LPG) 2)			14.37	Fuel gas price (US$/GJ) (NG) 2)			7.17	Fuel gas price (US$/GJ) (LPG) 2)			23.81
			CO2 reduction	Profit or Operation cost 3)	Assumed investment cost 4)	Pay back time	CO2 reduction	Profit or Operation cost 3)	Assumed investment cost 4)	Pay back time	CO2 reduction	Profit or Operation cost 3)	Assumed investment cost 4)	Pay back time
			(kg-CO2/ ton-product)	(US$/ton-product)	(million US$)	(year)	(kg-CO2/ ton-product)	(US$/ton-product)	(million US$)	(year)	(kg-CO2/ ton-product)	(US$/ton-product)	(million US$)	(year)
A. Energy Saving for Electric Arc Furnace (EAF)														
1	A-1	High temperature continuous scrap preheating EAF	82.08	14.55	31.24	4.3	113.66	13.50	28.99	4.3	84.57	9.60	26.56	5.5
2	A-2	Medium temperature batch scrap preheating EAF	21.89	3.88	8.22	4.2	30.31	3.60	7.63	4.2	22.55	2.56	6.99	5.5
3	A-3	High efficiency oxy-fuel burner/lancing for EAF	7.82	1.39	1.69	2.4	10.84	1.29	1.56	2.4	8.06	0.92	1.43	3.1
4	A-4	Eccentric bottom tapping (EBT) on existing furnace	8.21	1.46	3.29	4.5	11.37	1.35	3.05	4.5	8.46	0.96	2.80	5.8
5	A-5	Ultra high-power transformer for EAF	8.21	1.46	4.65	6.4	11.37	1.35	4.32	6.4	8.46	0.96	3.96	8.2
6	A-6	Optimizing slag foaming in EAF	3.28	0.58	1.23	4.2	4.55	0.54	1.14	4.2	3.38	0.38	1.05	5.5
7	A-7	Optimized power control for EAF	8.21	1.46	2.06	2.8	11.37	1.35	1.91	2.8	8.46	0.96	1.75	3.6
8	A-8	Operation support system with EAF meltdown judgment	3.28	0.58	2.06	7.1	4.55	0.54	1.91	7.1	3.38	0.38	1.75	9.1
9	A-9	Low NOx regenerative burner system for ladle preheating	12.62	2.87	0.33	0.2	12.62	1.43	0.31	0.4	12.62	4.76	0.28	0.1
10	A-10	Oxygen burner system for ladle preheating	12.62	2.87	0.25	0.2	12.62	1.43	0.23	0.3	12.62	4.76	0.21	0.1
11	A-11	Waste heat recovery from EAF	72.23	12.80	49.32	7.7	100.02	11.88	45.78	7.7	74.42	8.45	41.94	9.9
12	A-12	Energy saving for dedusting system in EAF meltshop	3.28	0.58	0.66	2.3	4.55	0.54	0.61	2.3	3.38	0.38	0.56	2.9
13	A-13	Bottom stirring/stirring gas injection	9.85	1.75	0.21	0.2	13.64	1.62	0.20	0.2	10.15	1.15	0.18	0.3
14	A-14	Induction type tundish heater	1.64	0.29	0.82	5.6	2.27	0.27	0.76	5.7	1.69	0.19	0.70	7.3
15	A-15	Scrap pretreatment with scrap shear	10.94	1.94	3.12	3.2	15.15	1.80	2.90	3.2	11.28	1.28	2.66	4.2
16	A-16	Arc furnace with shell rotation drive	17.51	1.94	4.93	5.1	24.25	1.80	4.58	5.1	18.04	1.28	4.19	6.6
B. Environmental Protection for Electric Arc Furnace														
17	B-1	Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF	-	-	-	-	-	-	-	-	-	-	-	-
18	B-2	Floating dust control in EAF meltshop	-	-	-	-	-	-	-	-	-	-	-	-
19	B-3	Dioxin adsorption by activated carbon for EAF exhaust gas	-	-	-	-	-	-	-	-	-	-	-	-
20	B-4	Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas	-	-	-	-	-	-	-	-	-	-	-	-
21	B-5	Dioxin absorption by 2 step bagfilter technology for EAF exhaust gas	-	-	-	-	-	-	-	-	-	-	-	-
22	B-6	PKS charcoal use for EAF	-	-	-	-	-	-	-	-	-	-	-	-
C. Material Recycle for Electric Arc Furnace														
23	C-1	EAF dust and slag recycling system by oxygen-fuel burner	-	-	-	-	-	-	-	-	-	-	-	-
24	C-2	EAF slag agglomeration for aggregate use	-	-	-	-	-	-	-	-	-	-	-	-
D. Energy Saving for Reheating Furnace														
25	D-1	Process control for reheating furnace	3.16	0.72	2.06	5.7	3.16	0.36	1.91	10.6	3.16	1.19	1.75	2.9
26	D-2	Low NOx regenerative burner total system for reheating furnace	11.93	2.72	6.58	4.8	11.93	1.36	6.10	9.0	11.93	4.50	5.59	2.5
27	D-3	High temperature recuperator for reheating furnace	6.31	1.44	1.23	1.7	6.31	0.72	1.14	3.2	6.31	2.38	1.05	0.9
28	D-4	Fiber block for insulation of reheating furnace	2.46	0.56	1.23	4.4	2.46	0.28	1.14	8.2	2.46	0.93	1.05	2.3
29	D-5	Air conditioning by absorption type refrigerating by using reheating furnace exhaust gas	1.64	0.29	0.74	5.1	2.27	0.27	0.69	5.1	1.69	0.19	0.63	6.6
30	D-6	Induction type billet heater for direct rolling	113.38	16.96	0.82	0.10	121.80	6.80	0.76	0.2	114.05	31.96	0.70	0.04
E. Common systems and General Energy Savings														
31	E-1	Inverter (VFD; Variable Frequency Drive) drive for motors	-	-	-	-	-	-	-	-	-	-	-	-
32	E-2	Energy monitoring and management systems	-	-	-	-	-	-	-	-	-	-	-	-
33	E-3	Management of compressed air delivery pressure optimization	-	-	-	-	-	-	-	-	-	-	-	-

Expected effects in Philippines, Malaysia and Singapore

No.	ID	Title of technology	Philippines				Malaysia				Singapore			
			Preconditions				Preconditions				Preconditions			
			CO_2 emission factor (ton-CO_2/MWh) 1)			0.5109	CO_2 emission factor (ton-CO_2/MWh) 1)			0.6681	CO_2 emission factor (ton-CO_2/MWh) 1)			0.4862
			Electricity price (US$/kWh) 2)			0.130	Electricity price (US$/kWh) 2)			0.100	Electricity price (US$/kWh) 2)			0.147
			Fuel gas price (US$/GJ) (LPG) 2)			25.79	Fuel gas price (US$/GJ) (NG) 2)			5.67	Fuel gas price (US$/GJ) (NG) 2)			50.00
			CO_2 reduction	Profit or Operation cost 3)	Assumed investment cost 4)	Pay back time	CO_2 reduction	Profit or Operation cost 3)	Assumed investment cost 4)	Pay back time	CO_2 reduction	Profit or Operation cost 3)	Assumed investment cost 4)	Pay back time
			(kg-CO_2/ ton-product)	(US$/ton-product)	(million US$)	(year)	(kg-CO_2/ ton-product)	(US$/ton-product)	(million US$)	(year)	(kg-CO_2/ ton-product)	(US$/ton-product)	(million US$)	(year)
A. Energy Saving for Electric Arc Furnace (EAF)														
1	A-1	High temperature continuous scrap preheating EAF	76.64	19.50	29.41	3.0	100.22	15.00	32.64	4.4	72.93	22.05	42.41	3.8
2	A-2	Medium temperature batch scrap preheating EAF	20.44	5.20	7.74	3.0	26.72	4.00	8.59	4.3	19.45	5.88	11.16	3.8
3	A-3	High efficiency oxy-fuel burner/lancing for EAF	7.31	1.86	1.59	1.7	9.55	1.43	1.76	2.5	6.95	2.10	2.29	2.2
4	A-4	Eccentric bottom tapping (EBT) on existing furnace	7.66	1.95	3.10	3.2	10.02	1.50	3.44	4.6	7.29	2.21	4.46	4.0
5	A-5	Ultra high-power transformer for EAF	7.66	1.95	4.38	4.5	10.02	1.50	4.86	6.5	7.29	2.21	6.32	5.7
6	A-6	Optimizing slag foaming in EAF	3.07	0.78	1.16	3.0	4.01	0.60	1.29	4.3	2.92	0.88	1.67	3.8
7	A-7	Optimized power control for EAF	7.66	1.95	1.94	2.0	10.02	1.50	2.15	2.9	7.29	2.21	2.79	2.5
8	A-8	Operation support system with EAF meltdown judgment	3.07	0.78	1.94	5.0	4.01	0.60	2.15	7.2	2.92	0.88	2.79	6.3
9	A-9	Low NOx regenerative burner system for ladle preheating	12.62	5.16	0.31	0.1	12.62	1.13	0.34	0.6	12.62	10.00	0.45	0.1
10	A-10	Oxygen burner system for ladle preheating	12.62	5.16	0.23	0.1	12.62	1.13	0.26	0.5	12.62	10.00	0.33	0.1
11	A-11	Waste heat recovery from EAF	67.44	17.16	46.44	5.4	88.19	13.20	51.54	7.8	64.18	19.40	66.96	6.9
12	A-12	Energy saving for dedusting system in EAF meltshop	3.07	0.78	0.62	1.6	4.01	0.60	0.69	2.3	2.92	0.88	0.89	2.0
13	A-13	Bottom stirring/stirring gas injection	9.20	2.34	0.20	0.2	12.03	1.80	0.22	0.2	8.75	2.65	0.29	0.2
14	A-14	Induction type tundish heater	1.53	0.39	0.77	4.0	2.00	0.30	0.86	5.7	1.46	0.44	1.12	5.1
15	A-15	Scrap pretreatment with scrap shear	10.22	2.60	2.94	2.3	13.36	2.00	3.26	3.3	9.72	2.94	4.24	2.9
16	A-16	Arc furnace with shell rotation drive	16.35	2.60	4.64	3.6	21.38	2.00	5.15	5.2	15.56	2.94	6.70	4.6
B. Environmental Protection for Electric Arc Furnace														
17	B-1	Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF	-	-	-	-	-	-	-	-	-	-	-	-
18	B-2	Floating dust control in EAF meltshop	-	-	-	-	-	-	-	-	-	-	-	-
19	B-3	Dioxin adsorption by activated carbon for EAF exhaust gas	-	-	-	-	-	-	-	-	-	-	-	-
20	B-4	Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas	-	-	-	-	-	-	-	-	-	-	-	-
21	B-5	Dioxin absorption by 2 step bagfilter technology for EAF exhaust gas	-	-	-	-	-	-	-	-	-	-	-	-
22	B-6	PKS charcoal use for EAF	-	-	-	-	-	-	-	-	-	-	-	-
C. Material Recycle for Electric Arc Furnace														
23	C-1	EAF dust and slag recycling system by oxygen-fuel burner	-	-	-	-	-	-	-	-	-	-	-	-
24	C-2	EAF slag agglomeration for aggregate use	-	-	-	-	-	-	-	-	-	-	-	-
D. Energy Saving for Reheating Furnace														
25	D-1	Process control for reheating furnace	3.16	1.29	1.94	3.0	3.16	0.28	2.15	15.1	3.16	2.50	2.79	2.2
26	D-2	Low NOx regenerative burner total system for reheating furnace	11.93	4.87	6.19	2.5	11.93	1.07	6.87	12.8	11.93	9.45	8.93	1.9
27	D-3	High temperature recuperator for reheating furnace	6.31	2.58	1.16	0.9	6.31	0.57	1.29	4.5	6.31	5.00	1.67	0.7
28	D-4	Fiber block for insulation of reheating furnace	2.46	1.01	1.16	2.3	2.46	0.22	1.29	11.7	2.46	1.95	1.67	1.7
29	D-5	Air conditioning by absorption type refrigerating by using reheating furnace exhaust gas	1.53	0.39	0.70	3.6	2.00	0.30	0.77	5.2	1.46	0.44	1.00	4.6
30	D-6	Induction type billet heater for direct rolling	111.93	32.20	0.774	0.05	118.22	4.22	0.86	0.41	110.94	66.62	1.12	0.03
E. Common systems and General Energy Savings														
31	E-1	Inverter (VFD; Variable Frequency Drive) drive for motors	-	-	-	-	-	-	-	-	-	-	-	-
32	E-2	Energy monitoring and management systems	-	-	-	-	-	-	-	-	-	-	-	-
33	E-3	Management of compressed air delivery pressure optimization	-	-	-	-	-	-	-	-	-	-	-	-

Comments

1) Average of combined margin from CDQ projects (source : IGEA website 2016.3)

2) Source : JETRO website " http://www.jetro.go.jp/world/search/cost/ "

3) Operation cost for Environment Protection or Material Recycle is described as minas (-)

4) Investent cost is assumed by multipying following factors to the assumed cost in Japan. (source : Japan Mac

Thailand	0.822
Indonesia	0.763
Vietnam	0.699
Philippines	0.774
Malaysia	0.859
Singapore	1.116

5) Assumed annual production to calculate pay-back time is 500,000 ton/y (refer to sheet"TCL_all")

6) LPG is assumed to calculate CO_2 emission from fuel combustion as:

47.3 GJ/ton-LPG & 2,985 kg-CO_2/ton-LPG --- 63.1 kg-CO_2/GJ

Technologies Customized List Version 2.0

For Technology Transfer to ASEAN Iron and Steel Industry
With regard to Energy-Saving, Environmental Protection, and Recycling