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Study on Application of Element Technology for High Efficiency Recovery of Waste-to-Energy on Incineration Facilities in Korea

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Contents of Presentation

I. Research Overviews

Goal and Necessity

Contribution to climate change response and national energy source through waste-to-energy high efficiency recovery of incineration facilities

- Survey on the status of domestic and overseas policy and technology related to waste-to-energy recovery
- On-site surveys to improve energy recovery capability such as introduction of inverter and application of low temperature catalyst.
- Analysis of the improvement effect of power generation efficiency by application of element technologies
- Estimation of greenhouse gas reduction through high efficiency of waste energy

※ Element Technologies : Low-Temp. Economizer, Low Air Ratio Combustion, Low-Temp. Catalyst, Dry Type Emission Gas Treatment, De-Plumer, No Wastewater Close System, High Temp. & High Pressure Boiler

Paradigm shift trends

- The 21st century is the era of energy and climate concerns, and the paradigm is being dramatically shifted in all areas of human life

1960	1980	2000	the 21st
End-of-Pipe	**Precautionary Principle**	**Sustainable Development**	**Energy·Climate Era**
Regulation and post-management of pollutant emissions	Minimization of waste and prevention of pollution	Sustainable development and sustainable Earth Reinforcement of international cooperation	Green growth

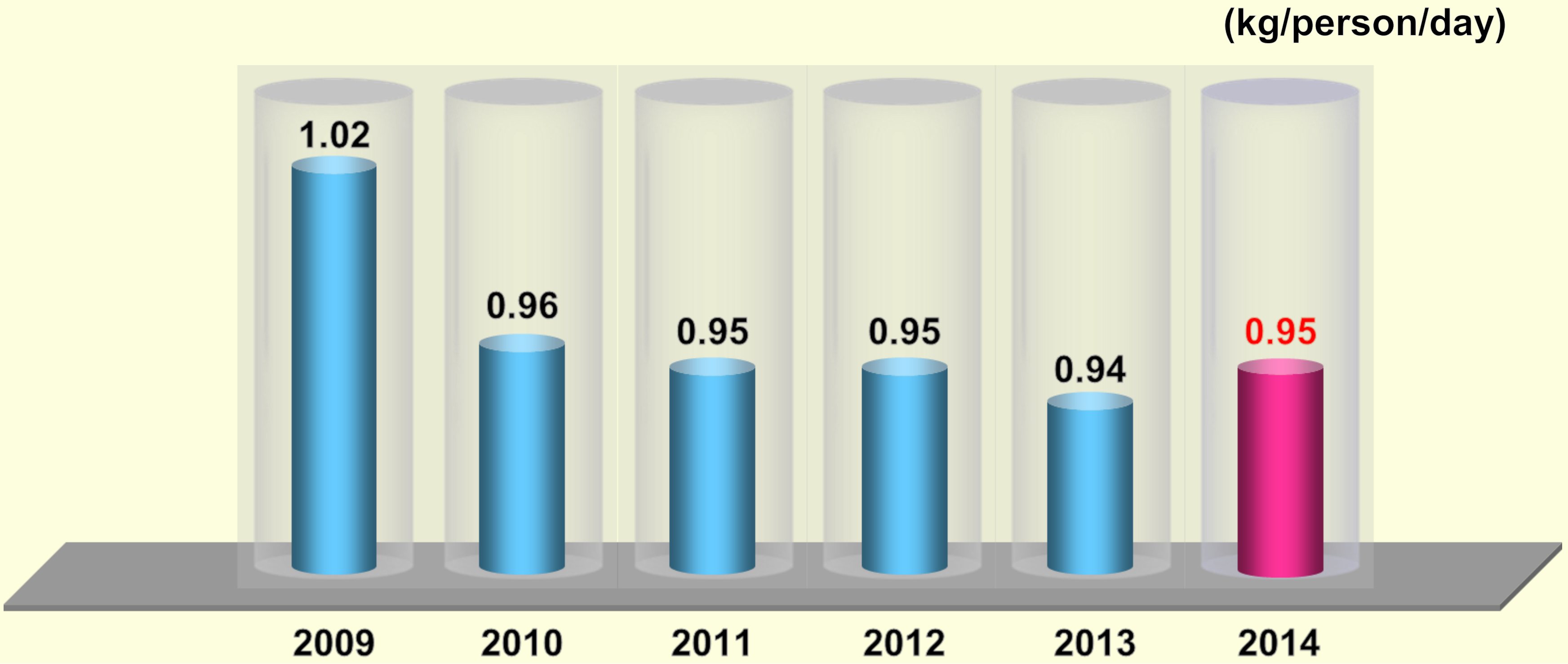
Progress of the Waste Policy in Korea

- Waste policy has been developed : **Safe treatment** (~1980s) → **Recycling** (90s~early 00s) → **Resource recirculation** (mid 00s~)
  - The Wastes Control Act has been divided and developed into five Acts incl. the Act on the Promotion of Saving and Recycling of Resources.

1980s	1990s ~ early 2000s	Mid 2000s ~
Safe treatment	Recycling	Resource recirculation
Wastes Control Act ('86)	Act on the Promotion of Saving and Recycling of Resources ('92) Act on the Control of Transboundary Movement of Hazardous Wastes ('94) Promotion of Installation Waste Disposal Facilities Act ('95) Construction Waste Recycling Promotion Act ('03)	Act on the Resource Circulation of Electrical and Electronic Equipment and Vehicles ('07)

Waste generation per person in Korea

- **In 1995, a volume-based garbage system was introduced in Korea**
  - Since the introduction, the amount of waste per capita has decreased by more than 10% from 1.05 in 1995 to 0.95 in 2014.

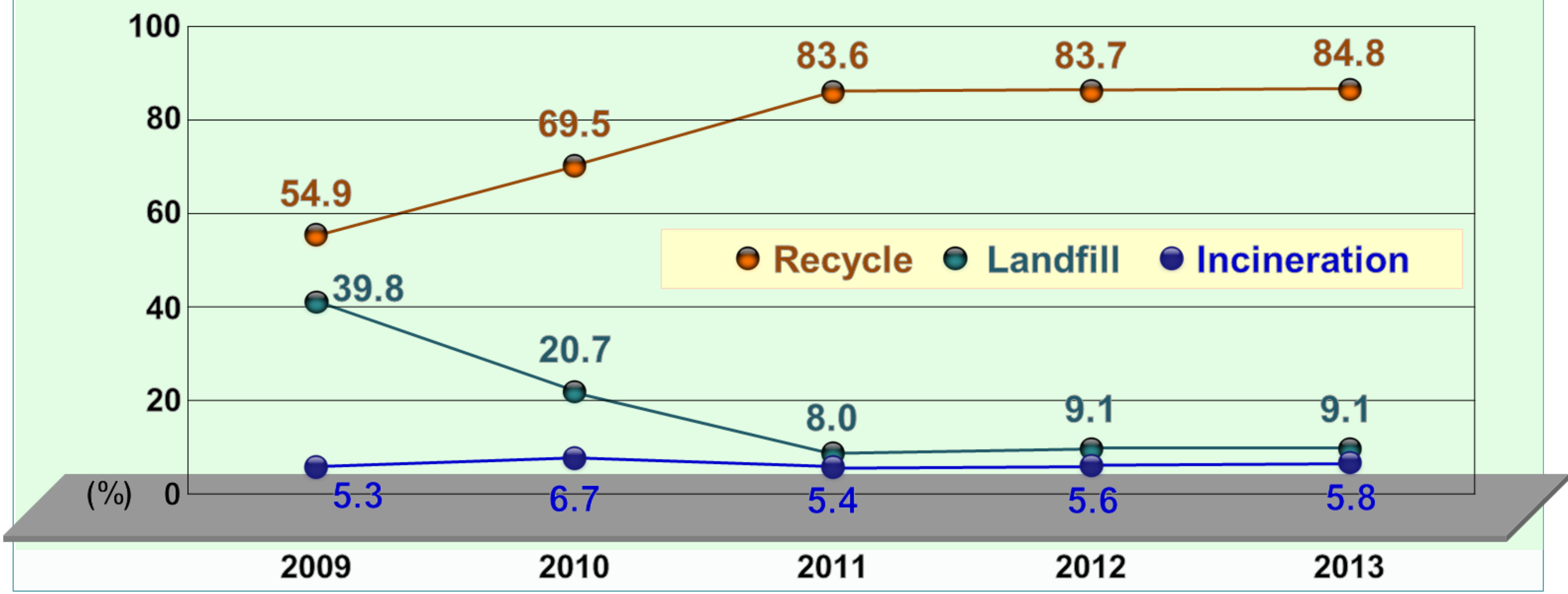


※ Advanced countries (kg/person/day, '12) : Germany 1.671, Japan 0.959, England 1.342

Status of waste disposal in Korea

- **Changes in waste treatment system (Landfill → Recycle)**
  - In 2009, landfill rate was very high at 39.8%, but in 2013, it was significantly reduced to 9.1%.

Landfill (39.8 → **9.1**), **Recycle** (54.9 → **84.8**), **Incineration** (5.3 → **5.8**)



New Incineration heat energy recovery standard in Korea

- **Establish the appropriate recovery standard to achieve policy and economic performance**

- The energy recovery formula is improved to accurately measure the energy recovered from incineration facilities based on the results of the NIER and expert opinions

- Improve energy recovery and use of waste incineration facilities by improving energy recovery rate calculation method

- Confirmation point of application factor and measuring instrument within the range that can improve data reliability

Incineration heat energy recovery formula in Korea

Definition of incineration heat energy recovery and utilization

- The ratio of energy used and converted to energy such as heat, steam, electricity, etc. from total potential energy of waste

Improve the current energy recovery & utilization rate calculation by EU method

Incineration heat energy recovery and utilization rate formula

Post	New(Current)
$\frac{\text{Recovered E} \times \text{Total amount}}{\text{Total amount of input E}} \times 100$	$\frac{Ep - (Ef + Ei)}{0.97 \times (Ew + Ef)} \times 100$

- E_p(Gcal/yr) : Annual external supply energy as heat or electricity. (2.6 for electricity, 1.1 for heat)
- E_f(Gcal/yr) : Annual external energy contributing to the production of steam. (2.6 for electricity, 1.1 for heat)
- E_w(Gcal/yr) : Annual energy contained in the treated waste.(estimated by the LHV)
- E_i(Gcal/yr) : Annual external energy not contributing to the production of steam. (2.6 for electricity, 1.1 for heat)
- 0.97 : A factor accounting for energy losses due to bottom ash and radiation.

Measures for High-Efficiency Waste-to-Energy Recovery

- ■ The high efficiency recovery of energy from waste incineration facility is possible through institutional improvements, technological improvements and application to activation policy

☞ Institutional strategies improvement, legislative regulations can force an improved energy recovery rate

☞ Technological improvement can be realized through improved heat recovery rate, efficient use of steam, and improved efficiency rate of steam turbines

☞ Giving support from government subsidies, providing incentives, developing energy recovery guidelines, and publishing a handbook to explain how to improve energy recovery rates

II. Survey of Domestic & Abroad Status

Waste Treatment Status in Korea

MSW and Industrial Waste Disposal Trend

- Municipal solid waste is 59% recycled, 25.3% incinerated and 15.7% landfilled
- Industrial waste is 77.3% recycled, 5.7% incinerated, and 16.1% landfilled
- The proportion of incineration part increased slightly in 2015 compared to 2014

Sort		'11		'12		'13		'14		'15	
		ton/d	%	ton/d	%	ton/d	%	ton/d	%	ton/d	%
MSW	Total	48,934	100	48,990	100	48,728	100	49,915	100	51,247	100
	Landfill	8,391	17.2	7,778	15.9	7,613	15.6	7,813	15.7	7,719	15.1 (▼0.6)
	Incineration	11,604	23.7	12,261	25.0	12,331	25.3	12,648	25.3	13,176	25.7 (▲0.4)
	Recycle	28,939	59.1	28,951	59.1	28,784	59.1	29,454	59.0	30,352	59.2 (▲0.2)
Industrial	Total	137,961	100.0	146,390	100.0	148,443	100.0	153,189	100.0	155,306	100.0
	Landfill	23,037	16.7	21,803	14.9	24,629	16.6	24,606	16.1	23,578	15.2 (▼0.9)
	Incineration	8,306	6.0	9,570	6.5	9,340	6.3	8,797	5.7	9,670	6.2 (▲0.5)
	Recycle	100,750	73.0	111,974	76.5	111,867	75.4	118,363	77.3	121,397	78.2 (▲0.9)

Energy Recovery Status in Korea

Energy Recovery Status for the MSW(Municipal Solid Waste)

Sort	Energy Production (Gcal)	Energy Use					
		Outside Supply(Gcal)			Facility Use(Gcal)		
		Subtotal	Heat	Electricity	Subtotal	Heat	Electricity
Whole Country	9,295,220	5,161,518	4,609,883	551,635	4,093,311	3,231,090	862,221

Heat	Electricity	Outside Supply	Facility Use
84.7 %	15.3 %	55.8 %	44.2 %

Sort	Facility	Facility Number (%)	Facility Capacity (ton/day)	Treatment Volume (ton)	Energy Production (Gcal)
MSW	Large (Above 2t/h)	67 (36.4 %)	15,682 (91.14%)	4,016,968 (92.61%)	8,283,592 (89.1%)
	Medium and Small (Below 2t/h)	117 (63.6%)	1,525 (8.86%)	320,600 (7.39%)	1,011,628 (10.9%)
Total		184	17,207	4,337,568	9,295,220

EU's Energy Recovery Policy for MSW

- In the past, European countries have approached the incineration facilities in terms of **waste disposal rather than energy recovery**. Therefore, older incinerators are not able to carry out energy recovery and only the incinerators built after the 1990s are able to do so.

- **The European Union (EU) established legislation** including Directive 2000/76/EC (about waste incineration), Directive 1999/31/EC (about waste reclamation), and Directive 2004/8/EC (about combined power generation) **in order to increase energy efficiency of related facilities as well as support recycling of municipal waste and energy recovery.**

EU's Energy Recovery Policy for MSW

- Facilities constructed after December 31, 2008 are recognized as renewable energy when the energy recovery rate is above 65%. Prior to 2008, facilities have applied energy recovery rate of more than 60%.

III. Technology for High Efficiency WtE

How to Improve Generating Efficiency of Waste Incineration Facilities

The power generation efficiency of waste incinerators has a functional relation with **heat recovery capability**, efficient use of steam **and** efficiency of generation systems

■ The following factors are necessary to improve the power generation efficiency by using waste-to-energy

- collecting more heat as steam
- providing steam turbines more steam by using collected steam
- converting collected steam into electricity more in efficient ways

Element Technology to Improve Power Generation Efficiency

- Power generation efficiency can be increased through heat recovery capability, efficient use of steam and improved steam turbine performance.

Technical Elements			Changing Conditions
High Heat Recovery ability	①	Low-Temp. Economizer	Exhaust Gas Temp. of Boiler Exit
	②	Low Air Ratio Combustion	Combustion Ratio
Use of Steam	①	Low-Temp. Catalyst	Catalyst Inlet Temp.:
	②	Dry Type Emission Gas Treatment	Wet Exhaust Gas Treatment→ Dry Type Exhaust Treatment
	③	De-plumer	Plume Prevention → No Plume Prevention
	④	No Wastewater Close System	Exhaust Gas Temp. of Boiler Exit
Steam Turbine System	①	High Temp. & High Pressure Boiler	Steam Condition
	②	Extraction Condensing Turbine	Heat Source of Deaerator Steam : Steam → Turbine Extraction
	③	Water Cooled Condenser	Turbine Exhaust Pressure

Ⅳ . Results and Discussions

Low-Temp. Economizer

❖ Initial Conditions

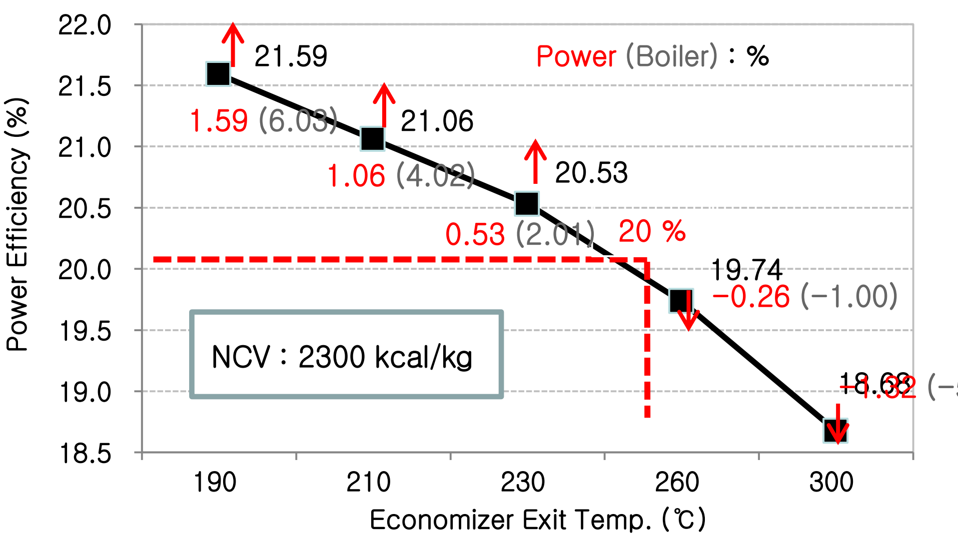
- Excess Air Ratio : 1.8
- Boiler Exhaust Gas Flow : 6500 m^3/ton
- Boiler Efficiency : 75.8 %
- Power Generation Efficiency : 20 %
- Exit Gas Temp. : 250 ℃

NCV (kcal/kg) / Exit Temp. (℃)	2300	2500	2700	3000
190	△ 1.59 (6.03)	△ 1.46 (5.54)	△ 1.35 (5.13)	△ 1.22 (4.62)
210	△ 1.06 (4.02)	△ 0.98 (3.70)	△ 0.90 (3.42)	△ 0.81 (3.08)
230	△ 0.53 (2.01)	△ 0.49 (1.85)	△ 0.45 (1.71)	△ 0.41 (1.54)
260	▼ (-) 0.26 (-1.00)	▼ (-) 0.24 (-0.92)	▼ (-) 0.23 (-0.86)	▼ (-) 0.20 (-0.77)
300	▼ (-) 1.32 (-5.02)	▼ (-) 1.22 (-4.62)	▼ (-) 1.13 (-4.28)	▼ (-) 1.02 (-3.85)

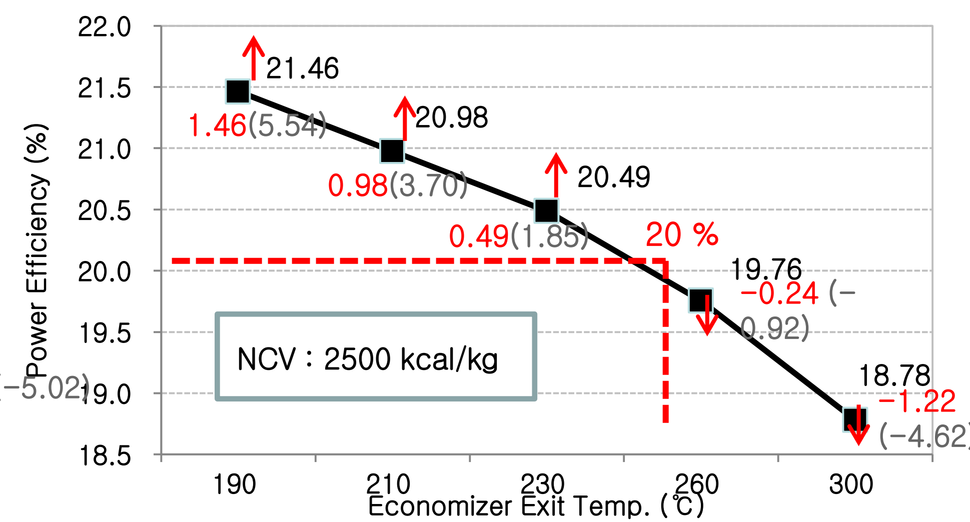
Low-Temp. Economizer

❖ Power Generation Efficiency according to NCV and Economizer Exit Temp. Changes

NCV : 2300 kcal/kg

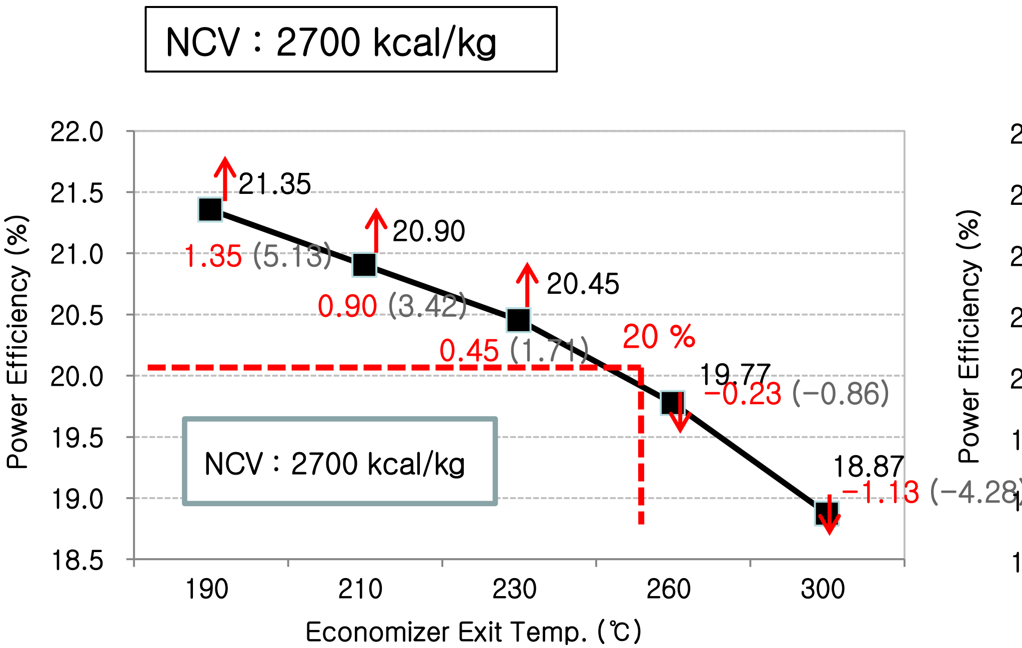


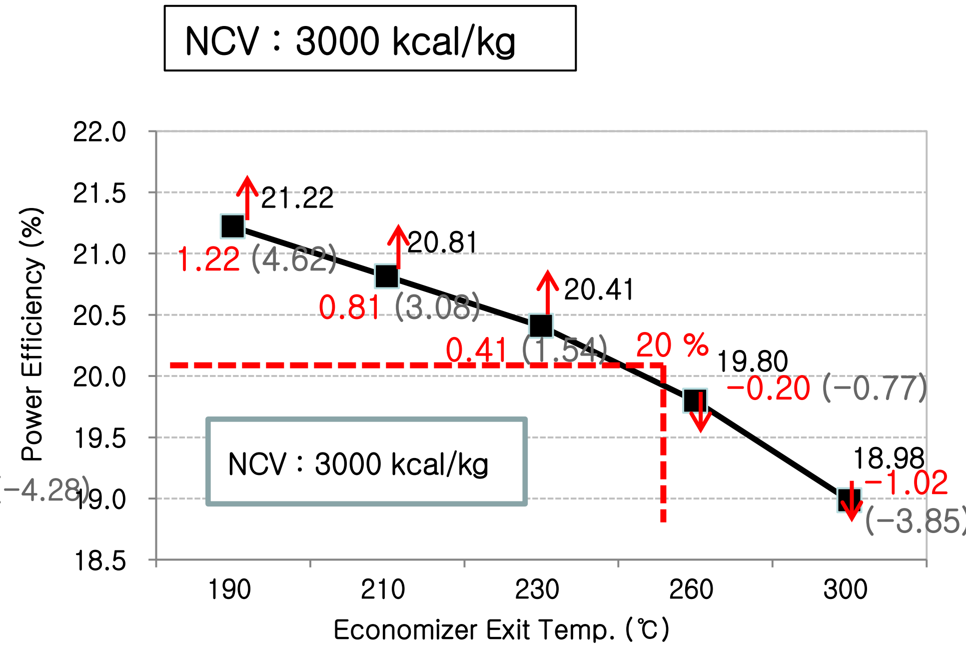
NCV : 2500 kcal/kg



Low-Temp. Economizer

❖ Power Generation Efficiency according to NCV and Economizer Exit Temp. Changes





Low-Temp. Economizer (Comprehensive Results)

- Applied Conditions : Economizer outlet temperature(190 - 300℃), Exhaust gas flow(5,000 - 7,000 m^3/ton), low calorific value(2,000 - 3,000 kcal/kg)
- Electricity production was increased as the economizer outlet temperature decreased.
- At the outlet temp. of 230, 210, 190℃, the power generation efficiency increase was shown by 0.45, 0.91 and 1.36 respectively.

Average (Min. ~ Max.)

NCV (kcal/kg) / Exit Temp. (℃)	2000	2300	2500	2700	3000
190	1.57 (1.31~1.83)	1.36 (1.14~1.59)	1.25 (1.04~1.46)	1.16 (0.97~1.35)	1.04 (0.87~1.22)
210	1.04 (0.87~1.22)	0.91 (0.76~1.06)	0.84 (0.70~0.98)	0.77 (0.64~0.90)	0.70 (0.58~0.81)
230	0.52 (0.44~0.61)	0.45 (0.38~0.53)	0.42 (0.35~0.49)	0.39 (0.32~0.45)	0.35 (0.29~0.41)
260	-0.26 (-0.22~-0.30)	-0.23 (-0.19~-0.26)	-0.21 (-0.17~-0.24)	-0.19 (-0.16~-0.23)	-0.17 (-0.15~-0.20)
300	-1.31 (-1.09~-1.52)	-1.14 (-0.95~-1.32)	-1.04 (-0.87~-1.22)	-0.97 (-0.81~-1.13)	-0.87 (-0.73~-1.02)

Excess Air Ratio Incineration

❖ Initial Conditions

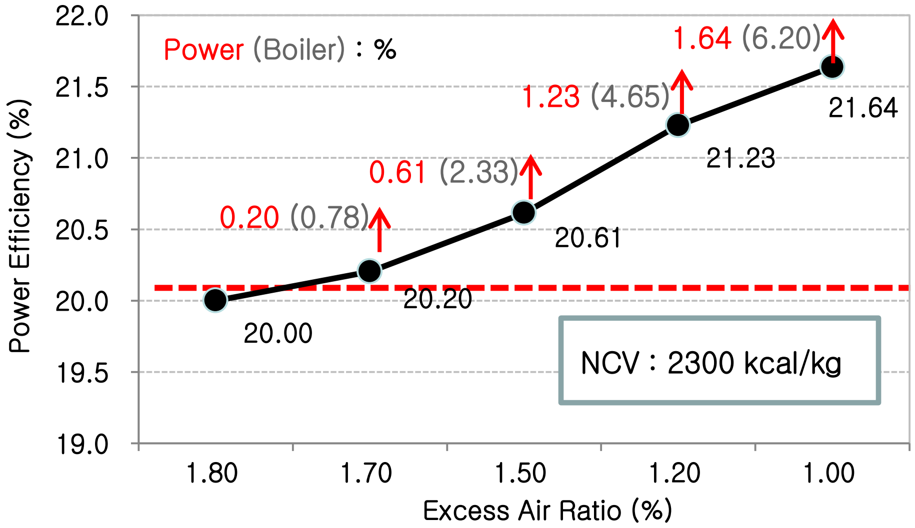
- Excess Air Ratio : 1.8
- Boiler Exhaust Gas Flow : 6500 m^3/ton
- Boiler Efficiency : 75.8 %
- Power Generation Efficiency : 20 %
- Exit Gas Temp. : 250 ℃

NCV (kcal/kg) / Excess Air Ratio (%)	2300	2500	2700	3000
1.80	0.00	0.00	0.00	0.00
1.70	0.20 (0.78)	0.19 (0.71)	0.17 (0.66)	0.16 (0.59)
1.50	0.61 (2.33)	0.56 (2.14)	0.52 (1.98)	0.47 (1.78)
1.20	1.23 (4.65)	1.13 (4.28)	1.05 (3.96)	0.94 (3.57)
1.00	1.64 (6.20)	1.51 (5.70)	1.39 (5.28)	1.25 (4.75)

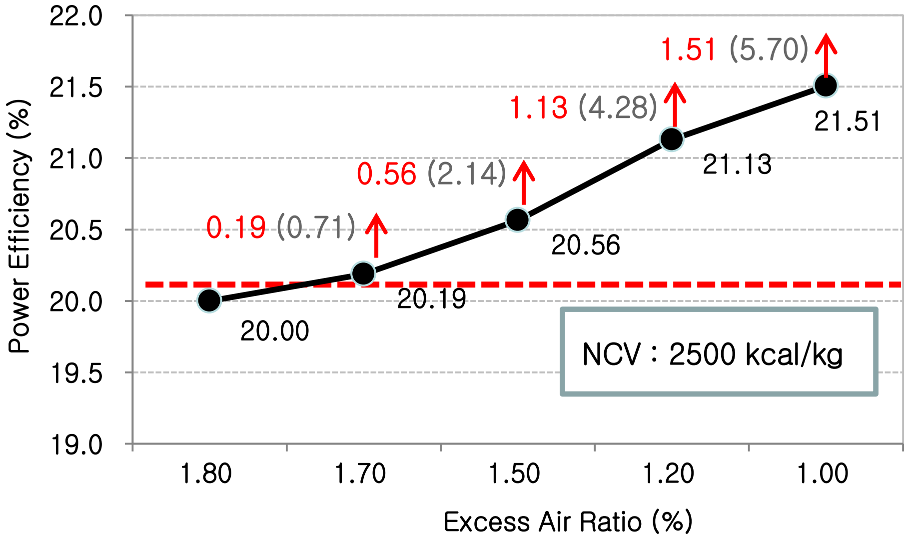
Excess Air Ratio Incineration

❖ Power Generation Efficiency according to NCV and Excess Air Ratio Temp. Changes

NCV : 2300 kcal/kg



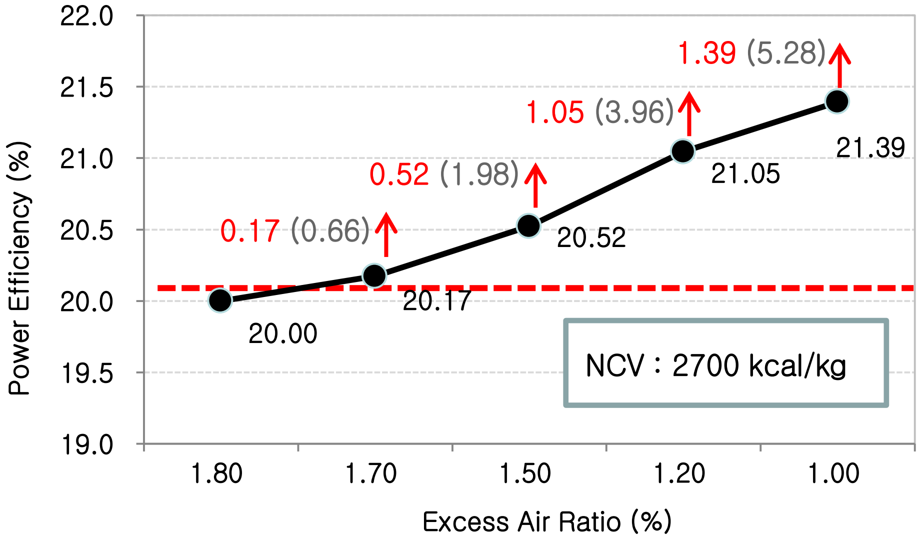
NCV : 2500 kcal/kg



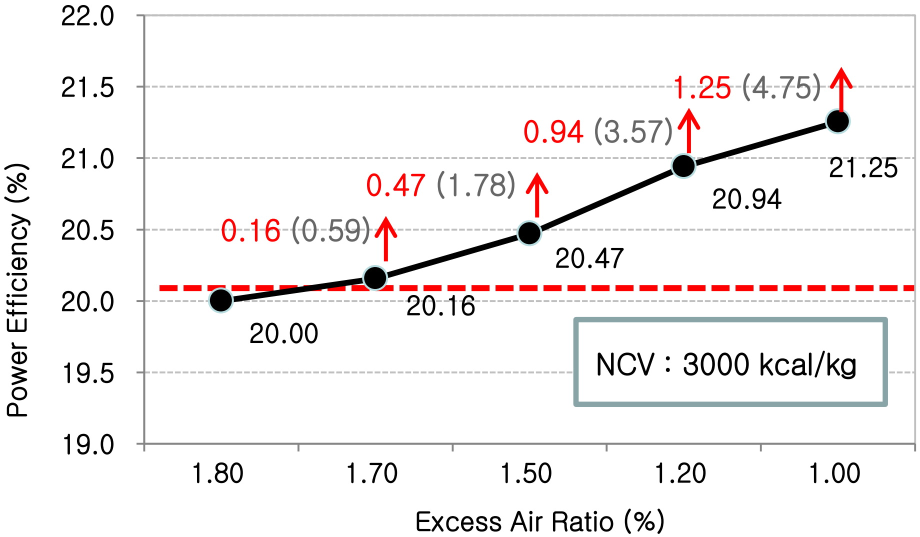
Excess Air Ratio Incineration

❖ Power Generation Efficiency according to NCV and Excess Air Ratio Temp. Changes

NCV : 2700 kcal/kg



NCV : 3000 kcal/kg



Excess Air Ratio Incineration(Comprehensive Results)

- Applied Conditions : Excess air ratio(1.0 – 2.0), Exhaust gas flow(5,000 - 7,000 m^3/ton), low calorific value(2,000 - 3,000 kcal/kg)
- The boiler efficiency can be increased by reducing the amount of combustion air flow to the incinerator to reduce the amount of heat exiting the boiler outlet.
- As the excess air ratio was reduced from 1.7 to 1.0, the power generation efficiency increased from 0.18 to 1.4% at 2,300 Kcal/kg of low calorific value.

Average (Min. ~ Max.)

NCV (kcal/kg) / Excess Air Ratio (%)	2000	2300	2500	2700	3000
2.0	**-0.40** (-0.34~-0.47)	-0.35 (-0.29~-0.41)	-0.32 (-0.27~-0.38)	-0.30 (-0.25~-0.35)	-0.27 (-0.22~-0.31)
1.8	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
1.7	0.20 (0.17~0.24)	0.18 (0.15~0.20)	0.16 (0.13~0.19)	0.15 (0.12~0.17)	0.13 (0.11~0.16)
1.5	0.60 (0.50~0.71)	0.53 (0.44~0.61)	0.48 (0.40~0.56)	0.45 (0.37~0.52)	0.40 (0.34~0.47)
1.2	1.21 (1.01~1.41)	1.05 (0.88~1.23)	0.97 (0.81~1.13)	0.90 (0.75~1.05)	0.81 (0.67~0.94)
1.0	**1.61** (1.34~1.88)	1.40 (1.17~1.64)	1.29 (1.08~1.51)	1.19 (1.00~1.39	1.08 (0.90~1.25)

Low Temp. Catalyst Denitrification

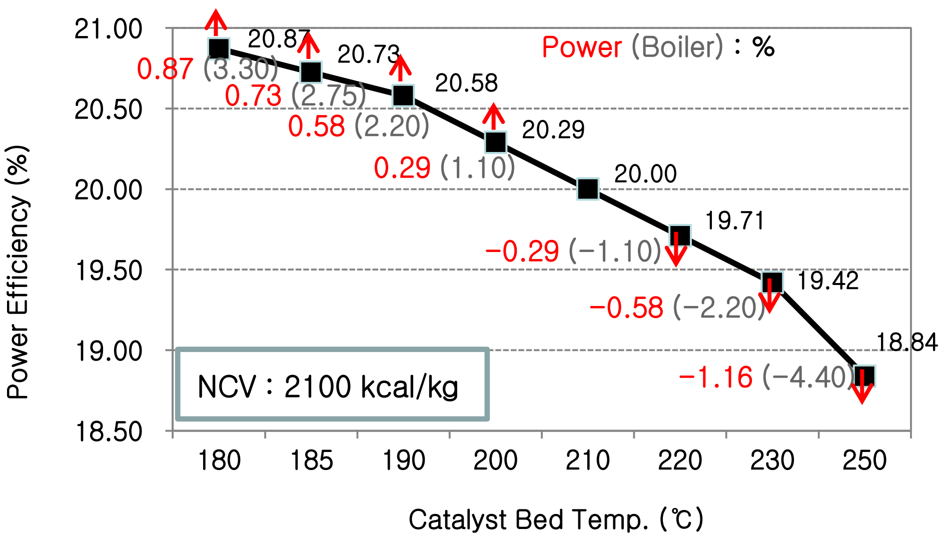
❖ Initial Conditions

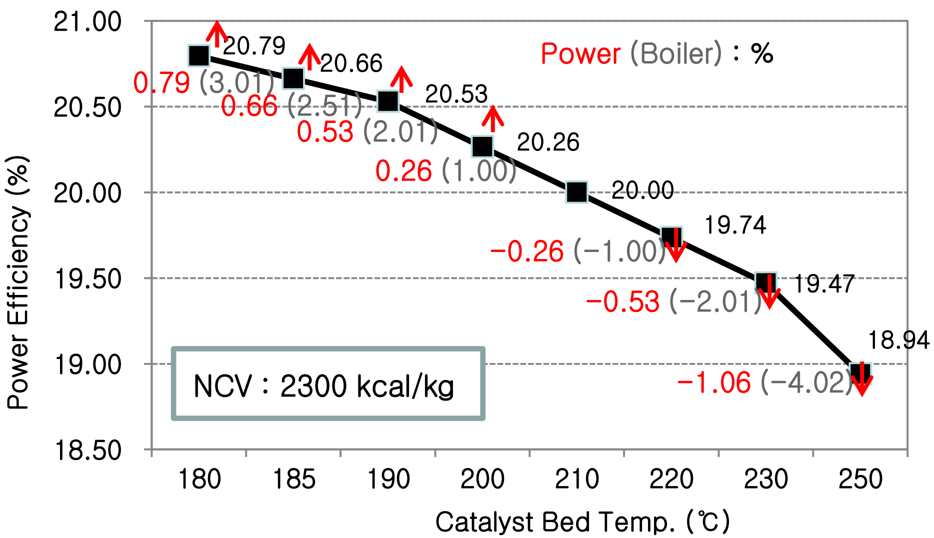
- Excess Air Ratio : 1.8
- Boiler Exhaust Gas Flow : 6500 m³/ton
- Boiler Efficiency : 75.8 %
- Power Efficiency : 20 %
- Catalyst Bed Temp. : 210 ℃

NCV (kcal/kg) / Cat. Bed Temp. (℃)	2100	2300	2500	2700	3000
180	0.20 (3.30)	0.19 (3.01)	0.17 (2.77)	0.16 (2.57)	0.16 (2.31)
190	0.20 (2.20)	0.19 (2.01)	0.17 (1.85)	0.16 (1.71)	0.16 (1.54)
210	0.00	0.00	0.00	0.00	0.00
230	1.23 (-2.20)	1.13 (-2.01)	1.05 (-1.85)	0.94 (-1.71)	0.94 (-1.54)
250	1.64 (-4.40)	1.51 (-4.02)	1.39 (-3.70)	1.25 (-3.42)	1.25 (-3.08)

Low Temp. Catalyst Denitrification

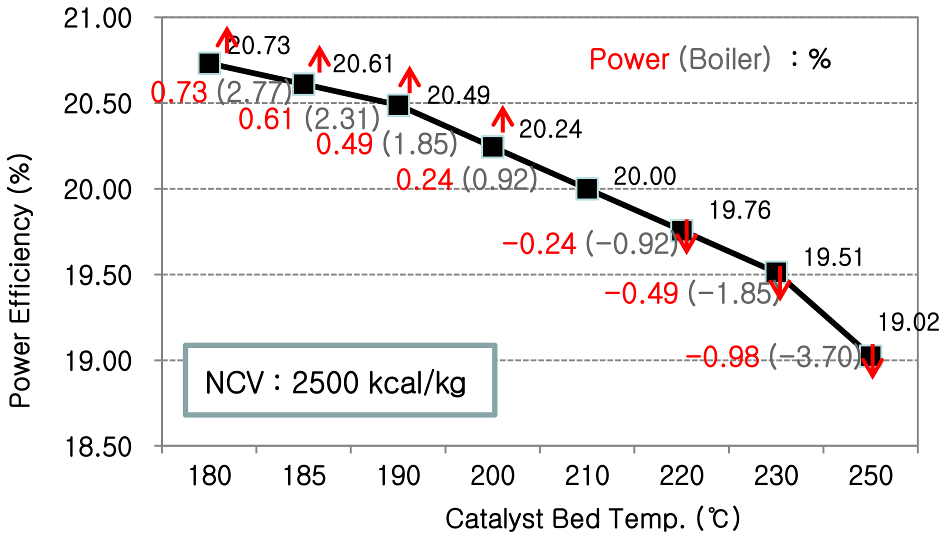
❖ Power Generation Efficiency according to NCV and Catalyst Bed Temp. Changes

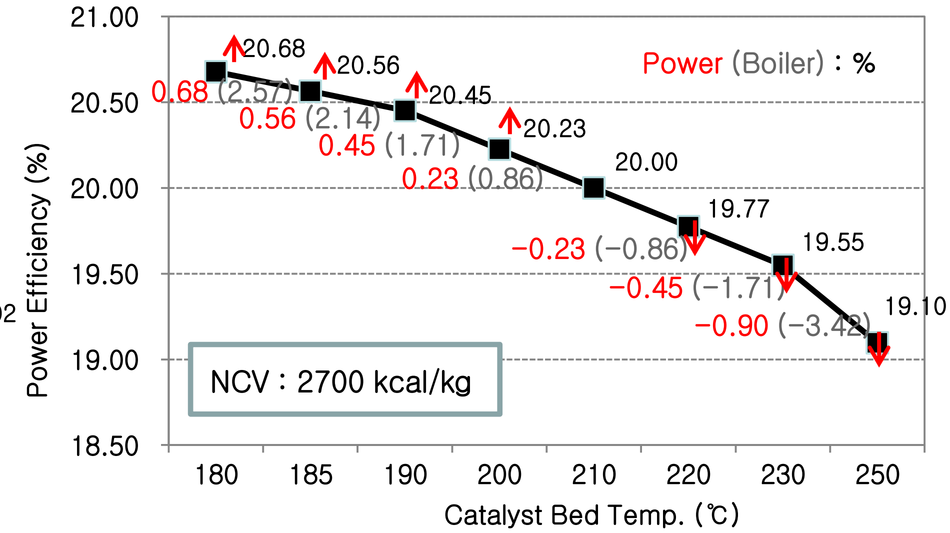




Low Temp. Catalyst Denitrification

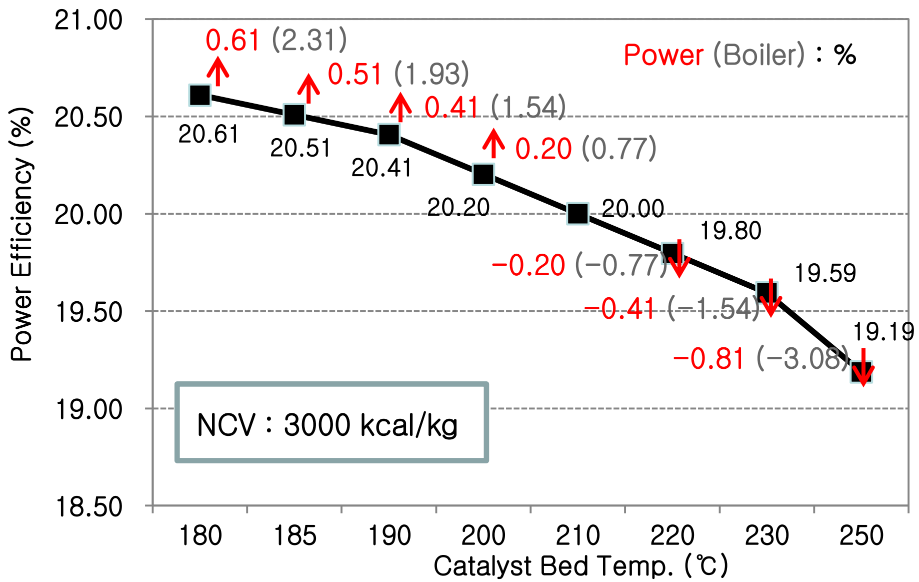
❖ Power Generation Efficiency according to NCV and Catalyst Bed Temp. Changes





Low Temp. Catalyst Denitrification

❖ Power Generation Efficiency according to NCV and Catalyst Bed Temp. Changes



Low Temp. Catalyst(Comprehensive Results)

- Applied Conditions : NCV(2000-3000 kcal/kg), Exhaust Gas Volume(5000-7000 m^3/ton), Catalyst Bed Inlet Temp.(180-250 ℃).
- The bag filter outlet temperature 165 ℃ should be raised to 210 ℃ for the catalytic reaction.
- By decreasing the catalyst bed temperature from 210 ℃ to 180 ℃, the electricity production could be increased from 0.17 to 0.78%.

Average (Min ~ Max)

Inlet Temp. (℃) \ NCV (kcal/kg)	2000	2300	2500	2700	3000
180	**0.78** (0.65~0.91)	0.68 (0.57~0.79)	0.63 (0.52~0.73)	0.58 (0.48~0.68)	**0.52** (0.44~0.61)
185	0.65 (0.54~0.76)	0.57 (0.47~0.66)	0.52 (0.44~0.61)	0.48 (0.40~0.56)	0.44 (0.36~0.51)
190	0.52 (0.44~0.61)	0.45 (0.38~0.53)	0.42 (0.35~0.49)	0.39 (0.32~0.45)	0.35 (0.29~0.41)
200	0.26 (0.22~0.30)	0.23 (0.19~0.26)	0.21 (0.17~0.24)	0.19 (0.16~0.23)	0.17 (0.15~0.20)
210	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
220	-0.26 (-0.22~-0.30)	-0.23 (-0.19~-0.26)	-0.21 (-0.17~-0.24)	-0.19 (-0.16~-0.23)	-0.17 (-0.15~-0.20)
230	-0.52 (-0.44~-0.61)	-0.45 (-0.38~-0.53)	-0.42 (-0.35~-0.49)	-0.39 (-0.32~-0.45)	-0.35 (-0.29~-0.41)
250	**-1.04** (-0.87~-1.22)	-0.91 (-0.76~-1.06)	-0.84 (-0.70~-0.98)	-0.77 (-0.64~-0.90)	-0.70 (-0.58~-0.81)

Dry Type Exhaust Gas Treatment

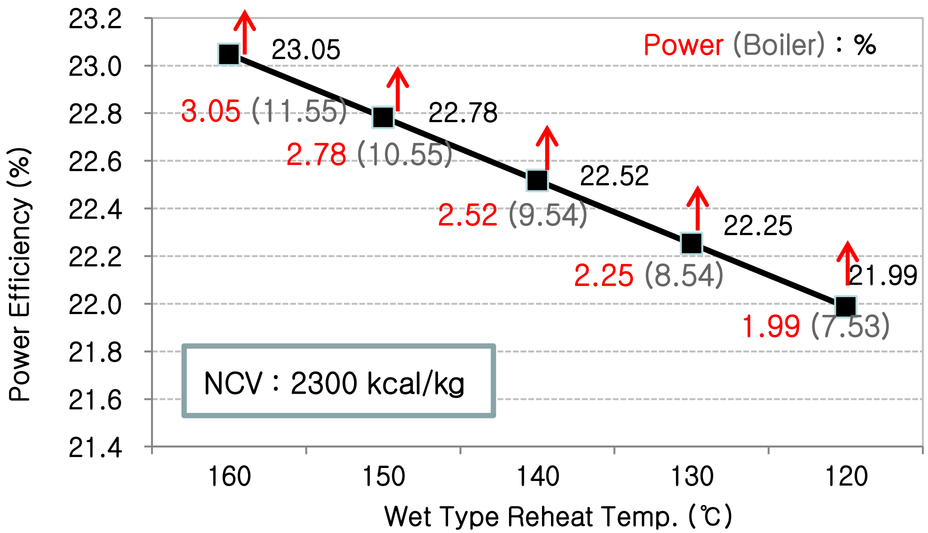
❖ Initial Conditions

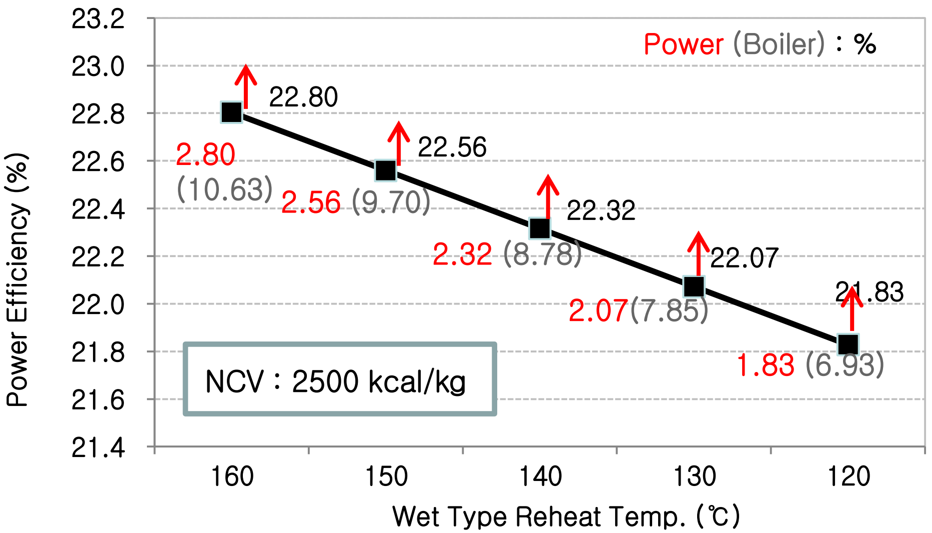
- Excess Air Ratio : 1.8
- Boiler Exhaust Gas Flow : 6500 m^3/ton
- Boiler Efficiency : 75.8 %
- Power Efficiency : 20 %
- Bag Filter Temp. : 165 °C, Wet Scrubber : 60 °C , Cat. Bed Inlet Temp.: 210 °C
- Reheating Temp. : Wet Type 150 °C, Dry Type 45 °C

NCV (kcal/kg) / Reheating Temp. (Wet-Dry) (°C)	2300	2500	2700	3000
120(75)	1.99 (7.53)	1.83 (6.93)	1.69 (6.42)	1.52 (5.78)
130(85)	2.25 (8.54)	2.07 (7.85)	1.92 (7.27)	1.73 (6.55)
140(95)	2.52 (9.54)	2.32 (8.78)	2.14 (8.13)	1.93 (7.32)
150(105)	2.78 (10.55)	2.56 (9.70)	2.37 (8.98)	2.13 (8.09)
160(115)	3.05 (11.55)	2.80 (10.63)	2.60 (9.84)	2.34 (8.86)

Dry Type Exhaust Gas Treatment

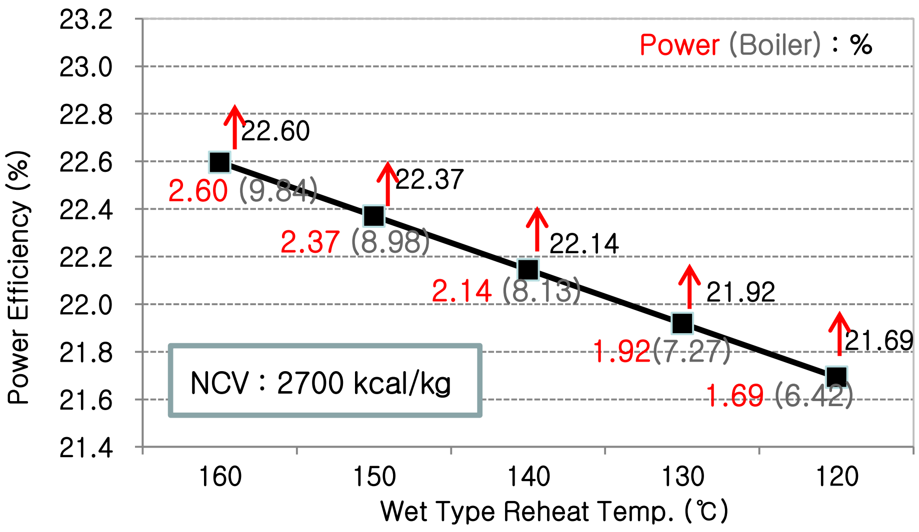
❖ Power Generation Efficiency according to NCV and Reheating Temp. Changes of Wet Process

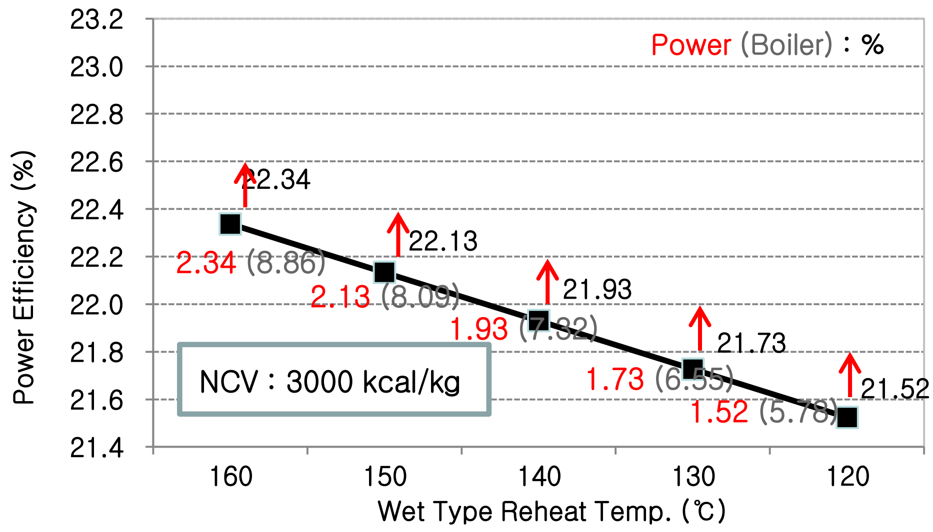




Dry Type Exhaust Gas Treatment

❖ Power Generation Efficiency according to NCV and Reheating Temp. Changes of Wet Process





Dry Type Exhaust Gas Treatment(Comprehensive Results)

- Applied Conditions : NCV(2000-3000 kcal/kg), Exhaust Gas Volume(5000-7000 m^3/ton) and), Wet Type Reheating Temp.(120-160℃)
- As the reheating temperature increased from 120C to 160C, the energy recovery rate also increased. The power generation efficiency can be increased by a max. of 3% from a min. of 1.31%.

Average (Min ~ Max)

Reheating Temp. (℃) \ NCV (kcal/kg)	2000	2300	2500	2700	3000
160	**3.00** (2.50~3.50)	2.61 (2.18~3.05)	2.40 (2.00~2.80)	2.23 (1.85~2.60)	2.00 (1.67~2.34)
150	2.74 (2.29~3.20)	2.38 (1.99~2.78)	2.19 (1.83~2.56)	2.03 (1.69~2.37)	1.83 (1.52~2.13)
140	2.48 (2.07~2.90)	2.16 (1.80~2.52)	1.99 (1.65~2.32)	1.84 (1.53~2.14)	1.65 (1.38~1.93)
130	2.22 (1.85~2.59)	1.93 (1.61~2.25)	1.78 (1.48~2.07)	1.64 (1.37~1.92)	1.48 (1.23~1.73)
120	1.96 (1.63~2.29)	1.70 (1.42~1.99)	1.57 (1.31~1.83)	1.45 (1.21~1.69)	**1.31** (1.09~1.52)

High Temp. & High Pressure Boiler

❖ Power Efficiency Improvement of Steam Turbine System(High Temp. & High Pressure Boiler)

- Using Model : Steam Turbine Calculator(US Department Energy)
- Turbine Properties

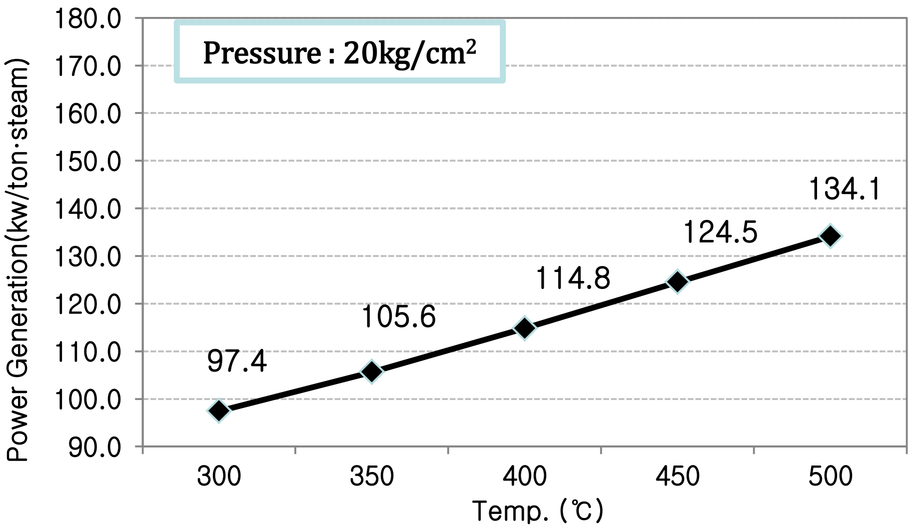
  - Isentropic efficiency : 70 % (commonly 55-80 %)

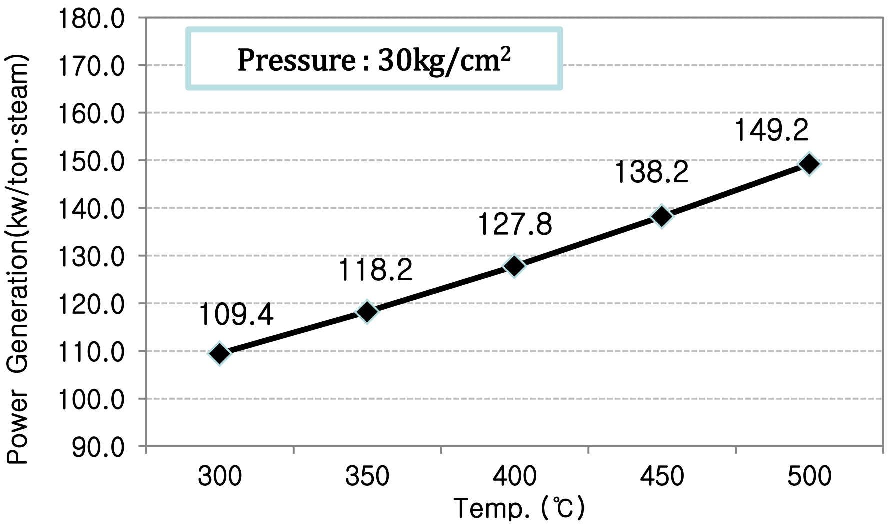
  - Generator efficiency : 95 % (commonly 95 %)

  - Mass flow : 30 ton/h

High Temp. & High Pressure Boiler

❖ Temp. Condition : 300 – 500 ℃, Pressure 20 – 60 kg/cm^2

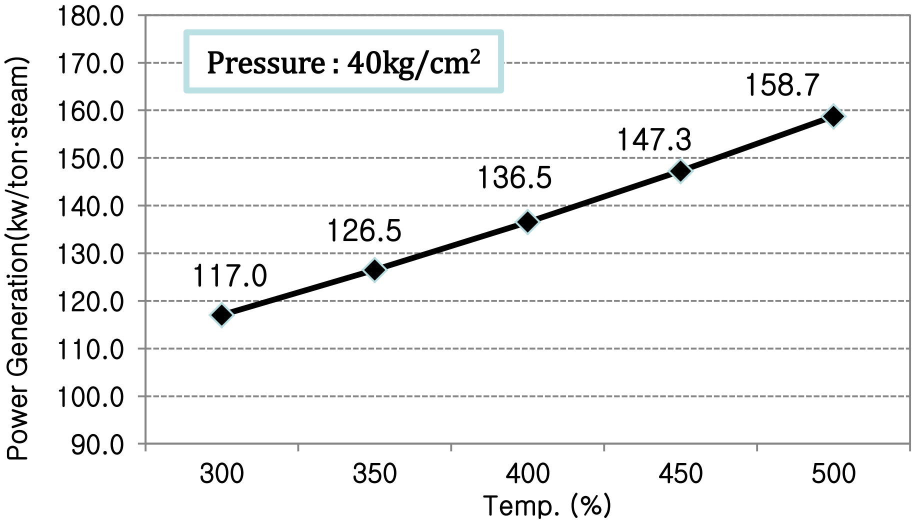


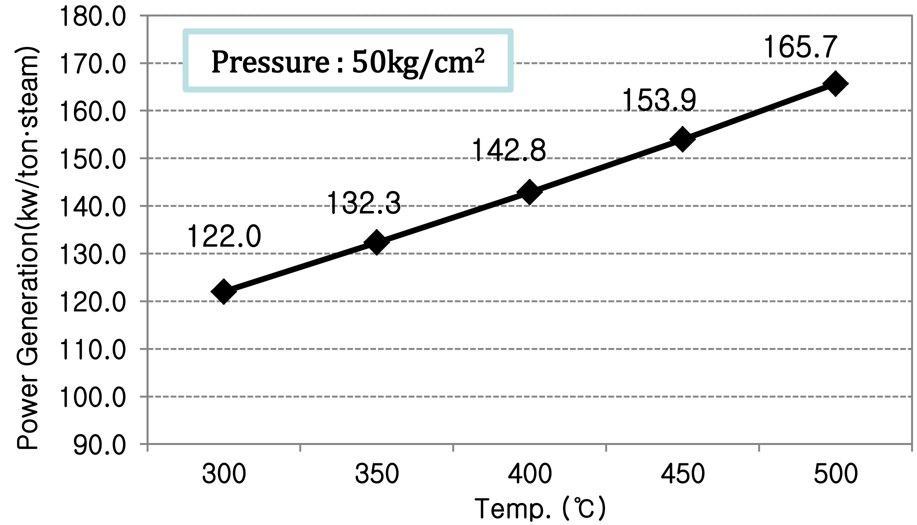


- 20kg/cm^2 x 300℃ : 97.4 kW/ton
- 20kg/cm^2 x 350℃ : 105.6 kW/ton
- 20kg/cm^2 x 400℃ : 114.8 kW/ton
- 20kg/cm^2 x 450℃ : 124.5 kW/ton
- 20kg/cm^2 x 500℃ : 134.1 kW/ton

- 30kg/cm^2 x 300℃ : 109.4 kW/ton
- 30kg/cm^2 x 350℃ : 118.2 kW/ton
- 30kg/cm^2 x 400℃ : 127.8 kW/ton
- 30kg/cm^2 x 450℃ : 138.2 kW/ton
- 30kg/cm^2 x 500℃ : 149.2 kW/ton

High Temp. & High Pressure Boiler





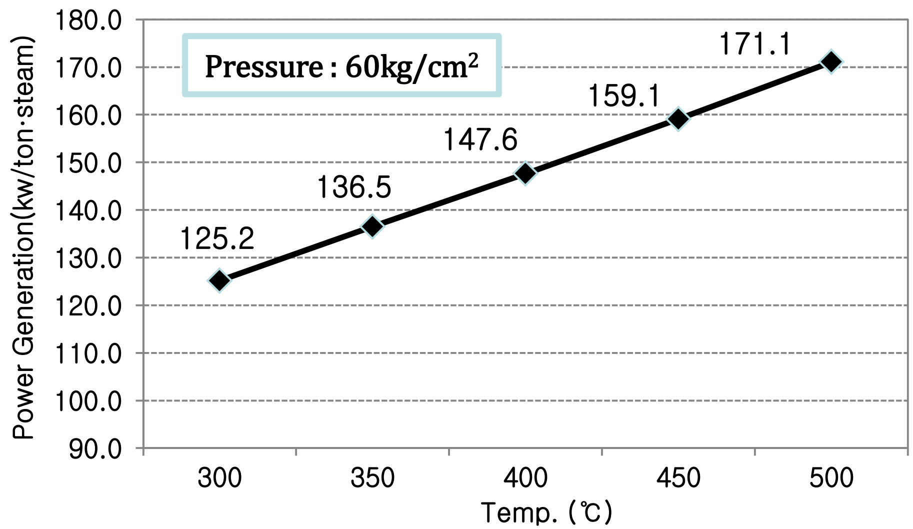
Pressure
$40kg/cm^2$

- $40kg/cm^2$ x 300℃ : 117.0 kW/ton
- $40kg/cm^2$ x 350℃ : 126.5 kW/ton
- $40kg/cm^2$ x 400℃ : 136.5 kW/ton
- $40kg/cm^2$ x 450℃ : 147.3 kW/ton
- $40kg/cm^2$ x 500℃ : 158.7 kW/ton

Pressure
$50kg/cm^2$

- $50kg/cm^2$ x 500℃ : 122.0 kW/ton
- $50kg/cm^2$ x 500℃ : 132.3 kW/ton
- $50kg/cm^2$ x 500℃ : 142.8 kW/ton
- $50kg/cm^2$ x 500℃ : 153.9 kW/ton
- $50kg/cm^2$ x 500℃ : 165.7 kW/ton

High Temp. & High Pressure Boiler

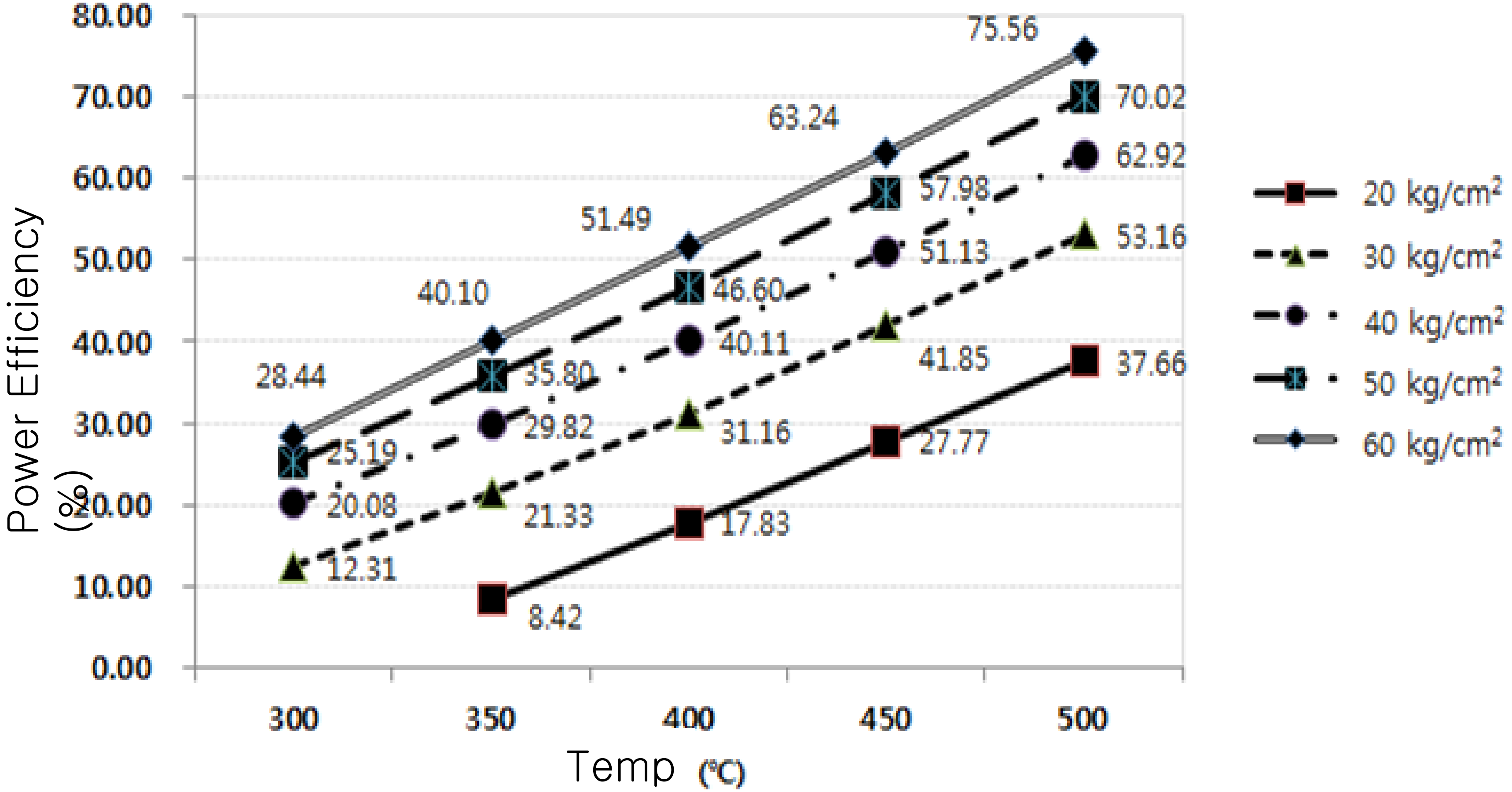


Pressure

60kg/cm²

- $60 kg/cm^2$ x 300℃ : 125.2 kW/ton
- $60 kg/cm^2$ x 350℃ : 136.5 kW/ton
- $60 kg/cm^2$ x 400℃ : 147.6 kW/ton
- $60 kg/cm^2$ x 450℃ : 159.1 kW/ton
- $60 kg/cm^2$ x 500℃ : 171.1 kW/ton

High Temp. & High Pressure Boiler



High Temp. & High Pressure Boiler

- Comparison Criteria : Temp. 300 ℃, Pressure 20 kg/㎠
- Power generation efficiency was calculated by increasing steam temperature every 50℃(300-500℃) and pressure every 10kg/㎠(20-60kg/㎠)
- Power generation increases 40.11% at pressure 40kg/㎠ and temperature 400℃ and 75.56% at pressure 60kg/㎠ temperature 500℃ compared to the standard condition of 20 kg/㎠ × 300 ℃.

(%)

Pressure(kg/cm^2) \ Temp.(℃)		300	350	400	450	500
Model 1	20	Basis	8.42	17.83	27.77	37.66
Model 2	30	12.31	21.33	31.16	41.85	53.16
Model 3	40	20.08	29.82	40.11	51.13	62.92
Model 4	50	25.19	35.80	46.60	57.98	70.02
Model 5	60	28.44	40.10	51.49	63.24	75.56

Power Generation Efficiency by Element Technologies for MSW Facilities

- The increase in electricity production was achieved by increasing the heat recovery rate.
- The effect of increasing electricity production rate was about 0.5% to 35.8%.

Technical Elements			Improved Effects(%)	Changing Conditions
High Heat Recovery ability	①	Low-Temp. Economizer	0.9(0.3-1.8)	NCV:2,000-3000kcal/kg, flow rate:5,000-7000m³/ton Exhaust Gas Temp. of Boiler Exit.:250℃→230,210,190 ℃
	②	Low Air Ratio Combustion	0.7(0.2-1.9)	Combustion Ratio 1.8→(1.7, 1.5, 1.2, 1.0)
Use of Steam	①	Low-Temp. Catalyst	0.5(0.2-0.9)	Catalyst Inlet Temp.: 210℃→(200, 190, 185, 180℃)
	②	Dry Type Emission Gas Treatment	2.0(1.1-3.5)	Wet Process Reheating Temp.: 120, 130, 140, 150, 160 ℃
	③	De-plumer	0.7(0.5-1.3)	Main Steam Reduction:2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0%
	④	No Wastewater Close System	0.9(0.3-1.8)	Exhaust Gas Temp. of Boiler Exit: 250℃→ 230, 220, 210, 200, 190℃
Steam Turbine System	①	High Temp. & High Pressure Boiler	35.8 (0.0~71.3)	Steam Condition : 2MPaG x 300℃→ 6MPaG x 600℃
	②	Extraction Condensing Turbine	1.7	Steam Heat Source of Deaerator Heating : Average Extraction Steam Rate 9%
	③	Water Cooled Condenser	1.6	Turbine Exhaust Pressure:-76KPaG → -86KPaG

Power Generation Efficiency by Element Technologies for Industrial Waste Facilities

- The increase in electricity production was achieved by increasing the heat recovery rate.
- The effect of increasing electricity production rate was about 0.5% to 48.8%.

Technical Elements			Improved Effects(%)	Changing Conditions
High Heat Recovery ability	①	Low-Temp. Economizer	1.0(0.4-1.8)	NCV:3,300-4,100kcal/kg, flow rate:9,500-11,500 m³/ton Exhaust Gas Temp. of Boiler Exit. : 250℃→230,210,190℃
	②	Low Air Ratio Combustion	0.9(0.2-1.9)	Combustion Ratio 1.8→(1.7, 1.5, 1.2, 1.0)
Use of Steam	①	Low-Temp. Catalyst	0.5(0.2-0.9)	Catalyst Inlet Temp.: 210℃→(200, 190, 185, 180℃)
	②	Dry Type Emission Gas Treatment	2.4(1.5-3.5)	Wet Process Reheating Temp.: 120, 130, 140, 150, 160 ℃
	③	De-plumer	0.7(0.4-1.0)	Main Steam Reduction:2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0%
	④	No Wastewater Close System	1.0(0.4-1.8)	Exhaust Gas Temp. of Boiler Exit: 250℃→ 230, 220, 210, 200, 190℃
Steam Turbine System	①	High Temp. & High Pressure Boiler	48.8 (8.0~89.1)	Steam Condition : 2MPaG x 300℃→ 6MPaG x 600℃
	②	Extraction Condensing Turbine	1.7	Steam Heat Source of Deaerator Heating : Average Extraction Steam Rate 9%
	③	Water Cooled Condenser	1.6	Turbine Exhaust Pressure:-76KPaG → -86KPaG

Economic Analysis by Applying Element Technologies in MSW Incineration facilities

- According to the application of unit technologies, it was predicted that average CO_2, CH_4 and N_2O could be reduced by 223,362 tons, 9,203 kg, 1,305 kg respectively
- Reduction of CO_2 and improvement of power generation efficiency, it was predicted that the average economic benefit would be 4.69 and 38.47 million dollars, respectively

Technical Elements		Energy reduction (Mcal/ton)	Increment of electricity production (MWh/ton)	CO_2 reduction* ($tonCO_2$/yr)	CH_4 reduction* ($kgCH_4$/yr)	N_2O reduction* (kgN_2O/yr)	GHG reduction effect (million $)**	Electricity production increase effect (million $)***
Enhancement of heat recovery ability	Low-temp. economizer	79.2 (33.0~138.6)	0.09 (0.04~0.16)	206,072 (85,863~360,627)	2,392 (996~4,185)	1,196 (498~2,093)	4.33	34.63
	Low air ratio combustion	68.8 (12.7~142.6)	0.08 (0.01~0.17)	178,892 (33,128~371,034)	2,076 (384~4,306)	1,038 (192~2,153)	3.76	30.78
Effective use of steam	Low-temp. catalyst	42.1 (16.5~69.3)	0.05 (0.02~0.08)	109,476 (42,932~180,313)	1,165 (249~2,093)	635 (249~1,046)	2.30	19.24
	Dry type emission gas treatment	188.1 (123.8~265.7)	0.22 (0.14~0.31)	489,422 (321,988~691,201)	5,680 (3,737~8,022)	2,840 (1,868~4,011)	10.28	84.64
	De-plumer	61.0 (34.9~87.2)	0.07 (0.04~0.10)	158,821 (90,755~226,888)	1,843 (1,053~2,633)	922 (527~1,317)	3.33	26.93
	No wastewater close system	75.9 (33.0~128.7)	0.09 (0.04~0.15)	197,486 (85,863~334,868)	42,063 (996~360,627)	1,196 (498~2,093)	4.15	34.63
Average		85.9 (12.7~265.7)	0.10 (0.01~0.31)	223,362 (33,128~691,201)	9,203 (249~360,627)	1,305 (192~4,011)	4.69	38.47

- National specific power emission factor (GHG emission calculation methods article 6 clause 2, Average of 2007~2008) CO_2 (ton-CO_2/MWh) : 0.4653, CH_4 (kg-CH_4/MWh) : 0.0054, N_2O (kg-N_2O/MWh) : 0.0027, ** CO_2 reduction costs were applied GHG emission trading price(KAU17) as 21,000KRW/ton-CO_2 which suggested by KRX. *** Incineration amounts of municipal solid waste(2015) : 4,809,240ton/yr, Unit price of industrial electricity : 80KRW/kWh

Economic Analysis by Applying Element Technologies in Industrial Incineration facilities

Technical Elements		Energy reduction (Mcal/ton)	Increment of electricity production (MWh/ton)	CO_2 reduction* ($tonCO_2$/yr)	CH_4 reduction* ($kgCH_4$/yr)	N_2O reduction* (kgN_2O/yr)	GHG reduction effect (million $)**	Electricity production increase effect (million $)***
Enhancement of heat recovery ability	Low-temp. economizer	75.9 (33.0~128.7)	0.09 (0.04~0.15)	189,579 (82,426~321,461)	2,200 (957~3,731)	1,100 (478~1,865)	3.98	25.41
	Low air ratio combustion	65.9 (12.7~132.4)	0.08 (0.01~0.15)	164,574 (31,802~330,738)	1,827 (369~3,543)	955 (184~1,919)	3.46	22.59
Effective use of steam	Low-temp. catalyst	42.1 (16.5~69.3)	0.05 (0.02~0.08)	105,093 (41,213~173,094)	1,220 (478~2,009)	610 (239~1,004)	2.21	14.12
	Dry type emission gas treatment	188.1 (123.8~265.7)	0.22 (0.14~0.31)	469,827 (309,097~663,528)	5,453 (3,587~7,701)	2,726 (1,794~3,850)	9.87	62.12
	De-plumer	61.0 (34.9~87.2)	0.07 (0.04~0.10)	152,463 (87,122~217,804)	1,769 (1,011~2,528)	885 (506~1,264)	3.20	19.77
	No wastewater close system	79.2 (33.0~138.6)	0.09 (0.04~0.16)	197,822 (82,426~346,188)	2,296 (957~4,018)	1,148 (478~2,009)	4.15	25.41
Average		85.4 (12.7~265.7)	0.10 (0.01~0.31)	213,226 (31,802~663,528)	2,461 (369~7,701)	1,237 (184~3,850)	4.48	28.24

- National specific power emission factor (GHG emission calculation methods article 6 clause 2, Average of 2007~2008) CO_2 (ton-CO_2/MWh) : 0.4653, CH_4 (kg-CH_4/MWh) : 0.0054, N_2O (kg-N_2O/MWh) : 0.0027, ** CO_2 reduction costs were applied GHG emission trading price(KAU17) as 21,000KRW/ton-CO_2 which suggested by KRX. *** Incineration amounts of industrial waste(2015) : 3,529,550ton/yr, Unit price of industrial electricity : 80KRW/kWh

Conclusions

- The energy saving and GHG reduction effect determined with applying element technologies(low temperature economizer, low air ratio combustion etc.) in this tudy.

- When applying low-temperature catalysts for denitrification, power generation efficiency increased by minimum 0.19% to maximum 0.79% if the inlet catalyst bed temperature changes every 10℃ from 200℃ to 180℃ while maintaining the NCV level of 2,300kcal/kg.

Conclusions

- In the case of high efficiency dry flue gas treatment, the power generation efficiency increased from 1.09% to 3.5%.
- For high-temperature and high-pressure boilers, the electricity production increased with increasing temperature and pressure.
- The electricity production increased by 40.11% at 40 kg/㎠ × 400 ℃ and 75.16% at 60 kg/㎠ × 500 ℃ compared to the standard condition of 20 kg/㎠ × 300 ℃.

Conclusions

- The average power generation efficiency were 1.0 %(0.2~3.5 %) as municipal WTE facilities and 1.1 %(0.2~3.5 %) as industrial WTE facilities.

- Results of energy saving and economic evaluation were 85.9 Mcal/ton(38.47 million dollar) as municipal WTE facilities and 85.4 Mcal/ton(28.24 million dollar) as industrial WTE facilities.

Conclusions

- The GHG reduction effect on applying 6 kinds of element technologies were 223,362 ton-CO2/ton(4.7 million dollar) as municipal WTE facilities and 213,226 ton-CO2/ton(4.5 million dollar) as industrial WTE facilities.

Thank You !