Issues and Prospects of WTE for Better Efficiency

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Background

- Most people agree nowadays that it's time to use wastes as a useful energy source, if possible, in a better efficiency.
- Since oil price would remain high and even coal price has increased twice during the last few years, most countries have shown interests in WTE, mostly from wastes incineration plants.
- Waste-To-Energy(WTE) should remain as a key option among wastes treatment routes, especially when the energy price remains high and even sources are becoming limited. Although the direction to WTE is mostly agreed, detailed method has still many obstacles and limitations.
- There are many issues and related problems to WTE. Most prominent aspects are economics, application of high grade technologies, and government policies.
- Mostly disregarded aspect is the renewable energy definition of wastes. Wide inclusion of wastes in renewable category would be favorable in inducing favorable policy from government.

Issues in WTE

- **Issues on WTE :**
  - ✓ Adaptability of technologies to different characteristics of wastes
  - ✓ Waste-To-Energy in big cities
  - ✓ Definition of wastes in renewable energy
  - ✓ Government support to heat energy from wastes
  - ✓ Renewable Portfolio Standard (RPS) for energies from wastes in Korea

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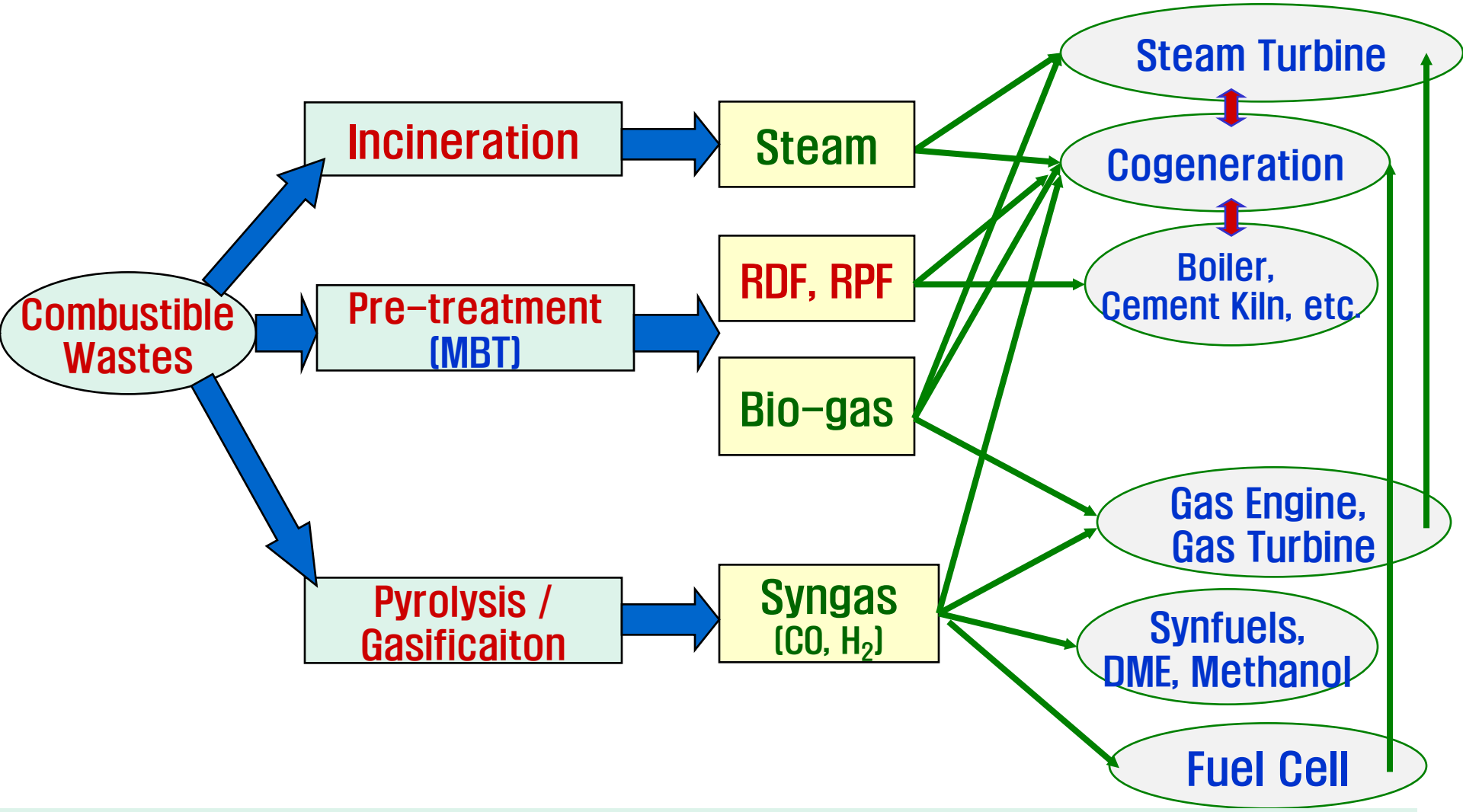
Typical Municipal Solid Wastes in Korea

Trend of Heating Value in Korean MSW

Year	Heating Value (kcal/kg)		Composition (wt%)			No. of plant sites for data collection
	Average	Maximum	Moisture	Combustibles	Ash	
1997	1,496	2,001	54	35	11	10
1999	1,511	2,019	53	36	11	15
2001	1,578	2,981	50	40	10	27
2002	1,945	3,403	47	43	10	29
2003	2,243	3,892	42	46	12	33
2004	2,302	3,340	41	49	10	32
2005	2,541	3,611	38	52	10	33
2006	2,596	3,511	37	53	10	33
2007	2,456	3,492	35	54	11	35
2008	2,632	3,531	33	53	11	35
2009	2,794	3,571	34	54	11	37

- Clear trend in moisture, combustibles
- Mainly due to :
  - Lower moisture, food wastes
  - Higher content of vinyls, plastics, papers, woods/leaves, textiles

Key Technologies for WTE



- Recent trend in Korea is treating the wastes through pre-treatment in order to maximize the reuse of combustible and bio-digestible wastes similar to the policy that has been popular in Europe.

- DME : Di-methyl Ether

Key Technologies for WTE

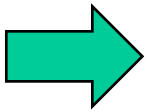
- Because of the recent high demand for RDF and RPF as a replacement fuel for cement kilns or for paper mills, technology route of MBT(Mechanical Biological Treatment) becomes an important option.
- Since food wastes are discarded separately from the household in Korea, pre-treatment by the mechanical separation is mostly employed.
- Pyrolysis/gasification route for WTE requires a high capital investment while providing the valuable syngas of carbon monoxide and hydrogen that is the basic ingredient for petrochemical industry. With high capital cost per unit wastes, at least 50-100 ton/day scale plant should be constructed to ensure the economic competitiveness. Syngas can go to gas engine, gas turbine, or fuel cell after gas cleaning. If enough waste amount can be gathered and guaranteed, even investment for converting to synthetic diesel or DME(di-methyl ether), methanol can be rationalized at the time of peak oil.
- Market and technology trend in Korea's case indicates that the WTE technology moves from incineration to pre-treatment and finally to pyrolysis/gasification. Key deciding factor in this direction appear to be the required capital cost to handle unit amount of wastes.

Issues in WTE : Adaptability of technologies to different local wastes

- There have been many cases of operational troubles while applying foreign WTE and MBT technologies in Korea. Most notable example is the lower product yield than the design value in RDF plants, which was caused by the wrong moisture content of local wastes.
- Typical differences in characteristics of wastes were moisture, salt, chloride contents, heating value, and the ash behavior at high temperature as well as the degree of pre-separation(existence of wires, etc.).
- Procedural checking of adaptability by pilot and demonstration plants with actual domestic wastes appears to be a key aspect although it requires a time and cost.

Issues in WTE : Waste-To-Energy in big cities

- Most big cities have installed enough incineration capacity. Incineration is the most reliable and cost-effective WTE option in most countries.
- Whether existing WTE plants should be revamped with the new plants using RDF or pyrolysis/gasification technologies remain as a big issue, especially when the mass collection across the several adjacent municipalities has finally reached a public consensus after enduring more than ten years of acute disputes.
- Problem is that since the larger amount of wastes can provide more economical advantage, the plants with new technology need to get wastes from the amount that should go to existing plants.
- Although the new technology like RDF or gasification might provide a higher efficiency or better recycling options, public acceptance and history to get a permission of the current plants should not be neglected.
- Incineration plants in Seoul combusted about 2,000 ton-MSW/day. In reality, however, gathering more than few hundreds of tons/day in one plant is not practical.



Use existing WTE facilities with higher efficiency

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Issues in WTE : Definition of wastes in renewable energy

	Energy Source		IEA	EU	USA	JAPAN	CHINA	KOREA	AUSTRALIA	FRANCE	S. AFRICA	UK
Renewable Energy	Hydro	Large Hydro	○	×	○	×	○	○	○	○	○	○
		Small Hydro	○	○	○	○	○	○	○	○	○	○
		Pumped Storage Power Generation	×	×	×			×				
	Geothermal	Power Generation	○	○	○	×	○	○	○	○		
		Heat Pump	×	×	×	○						
	Solar Energy	Photovoltaic	○	○	○	◎	◎	◎	○	○	○	○
		Solar Heating	○	○	○	○	○	○		○		
		Solar Heat Electricity Generation	○	○	○		○	○	○		○	
		Passive Solar	×	○	×	○	○	×				
	Sea Power		○	○	○	×	○	○	○		○	○
	Wind Power		○	◎	○	○	◎	◎	○		○	○
	Biomass	Soiid Biomass	○	○	○	○	○	○	○	○	○	○
		Biomass Gas	○	○	○	○	○	○	○	○	○	○
		Liquid Biomass	○	○	○		○	○		○		
		Black Liquor				○		×	○			
	Wastes	Renewable Municipal Wastes	○	○	○	○		○	○	○	○	○
		Non-renewable Municipal Wastes	×	×	×	○		○				○
		Industrial Wastes	×	×		○		○				○
		Non-specific Combustible Renewables	×	×		○		○				○
		Waste Heat from Wastes	×	×		○		○				○
		Food Wastes				○		×	○			
	Temperature Difference Energy		○	○	×	○		×				
New Energy	Fuel Cell							◎				
	Gasification/Liquefaction of Coal							○				
	Hydrogen				○			○				

- IEA defines that only the energy value of combusted biodegradable material is qualified as renewable energy. Thus, non-biodegradable parts of the waste is not considered renewable. The narrow definition might impede the legal government support at some countries like in Korea.

Definition Issue of wastes in renewable energy

- Purpose of developing renewable energy or similar energy lies in securing energy as a clean, environment-friendly way with affordable price to the society, not confining to the only bio-degradable, or only purely renewables like solar and wind.
- Each country has a unique feature regarding available domestic energy source, and thereby opts to define very differently for the best use of available energy source.
- Definition by IEA(International Energy Agency) on renewable energy has an indirect influence to the WTE industry.
- Many countries have a governmental incentives based upon the renewable energy policy. When many wastes such as industrial wastes are omitted in renewable energy category, government support has no or weak legal basis.
- In Korea's case, new and renewable energy law is a cornerstone of legal government subsidy for different energy forms. If WTE is not categorized as a renewable energy, all the new legislation should follow, which means no actual meaningful support for the near future.
- When considering the purpose of renewable energy is in reaching sustainable energy society, narrow definition on renewable energy for the wastes would not help to maximize as a useful energy source.
- Narrow definition by IEA on energy from wastes has influenced as a negative way on competing with other renewable energies.

Issues in WTE : Government support to heat energy from wastes

- Typically government subsidizes electricity from WTE. But, heat energy as steam from WTE plants is not supported by Government. Rather, steam from WTE is treated as a product from wastes of zero value and be paid far less than the identical steam from natural gas.
- Most steam from waste incineration plants in Korea goes for heating of nearby apartments, but steam price from WTE is at 20-25% level compared to the steam by natural gas. This low price in turn prevents capital investment for generating high grade steam.
- Even without government support, reasonable pricing policy to the steam from WTE plants is very critical in WTE industry.
- From 2011, some government support for innovating the existing WTE facility is available.

Issues in WTE : RPS for WTE in Korea

Amount, portion of WTE in new/renewable energy in Korea

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total Amount	2,453.2	2,917.3	4,436.4	4,582.4	4,879.2	5,225.2	5,608.8	5,858.5	6,086.2
(portion,%)	1.5	1.8	2.1	2.1	2.1	2.2	2.4	2.4	2.5
Solar Heating	37.1	34.8	32.9	36.1	34.7	33	29.4	28	30.7
Photovoltaic	1.5	1.8	1.9	2.5	3.6	7.8	15.3	61.1	121.7
Biomass	82.5	116.8	131.1	135	181.3	274.5	370.2	426.8	580.4
Wastes (% of Total Amount)	2,308.0 (94.1%)	2,732.5 (93.7%)	3,039.3 (68.5%)	3,313.2 (72.3%)	3,705.5 (75.9%)	3,975.3 (76.1%)	4,319.3 (77.0%)	4,568.6 (78.0%)	4,558.1 (74.9%)
Hydro	20.9	27.6	1,225.6	1,082.3	918.5	867.1	780.9	660.1	606.6
Wind	3.1	3.7	5.2	11.9	32.5	59.7	80.8	93.7	147.4
Geothermal	-	0.1	0.4	1.4	2.6	6.2	11.1	15.7	22.1
Hydrogen, Fuel Cell	-	-	-	-	0.5	1.7	1.8	4.4	19.2

- Energy from wastes comprises a large proportion of new/renewable energy in Korea. While a large sums of investment has poured into solar and wind industry and for their related R&D, almost no government incentives were given to WTE. That is going to change from 2012 by RPS(Renewable Portfolio Standard) application.
- From 2012 in Korea, six electric power companies, five major independent power producers, and two public utilities should buy a portion of electricity from new/renewable energy sources.

RPS in Korea Applicable from 2012

Only applicable for electricity, not for steam.

Weighting Factor	Energy Source
0.25	IGCC, Process Waste Gas
0.5	Wastes LFG
1.0	RDF Electricity Generation Wastes Gasification Electricity Generation Bio-energy Hydro Tidal (with Tide Embankment) Wind Power (Land-based)
1.5	Wood-based Biomass Electricity Generation Wind Power (Sea-based, < 5 km from land)
2.0	Fuel Cell Wind Power (Sea-based, > 5 km from land) Tidal (w/o Tide Embankment)

RPS Issue in WTE

- RPS will hopefully vitalize WTE. Since the WTE can produce, if properly invested and maintained, clean electricity with reasonable cost, companies that has a quota to fulfill the new/renewable energy have an incentive to choose WTE as a reliable option. However, RPS weighting factor, that is the ratio of saleable portion out of total produced electricity, remains at a disappointing value of 0.25-0.5.
- RDF and gasification routes of wastes are entitled weighting factor 1.0. All these values from wastes should be increased to the level as the wood-based biomass case, 1.5.
- Opponents argue that incentives should go to the less-economical energy source to stimulate the technology quantum jump, instead of already well-proven areas like WTE. Even many NGO groups insist that energy from WTE should not be included in the renewable energy category and any government incentives should not be given.
- Regardless of the inclusion of WTE in renewable energy, MSW is an available energy source that should be utilized in a clean and efficient way. Installing more efficient WTE technologies demand a new capital investment or sometimes a higher capital cost per unit volume of wastes. RPS system with appropriate weighting factor for wastes can provide a ground to that direction, and can give a healthy signal to the industry.

Prospect for Better Efficiency in WTE

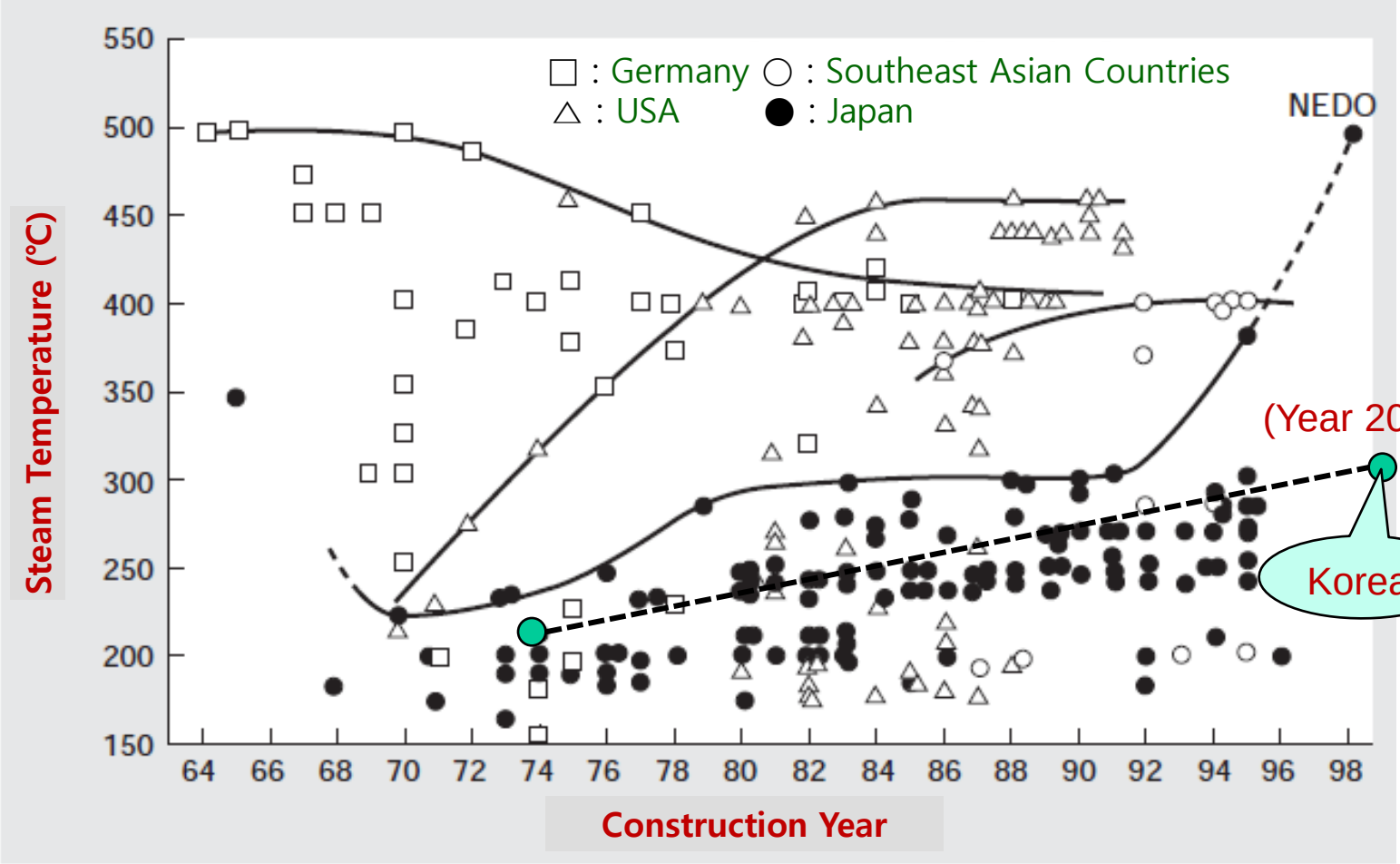
- Most WTE plants using MSW in Korea had built during the 1990's and at this time focus was on the safe treatment of wastes rather than the energy recovery. Steam from WTE was regarded as an extra product that could be beneficial to use for any purpose compared to just venting away. Steam quality from WTE plants was just a saturated one of steam pressure at the 20 bar level.
- By simple number, the rate of utilization out of the produced waste heat reached 87% in Korea. For MSW, the utilized rate was even over 90%. But, when looking into steam quality in terms of energy recovery from the raw wastes, the high number in the rate of waste heat utilization is misleading. Real energy recovery rate is well below the 30%, the level that can reach with the current available WTE technology
- The steam quality from WTE should reach the 400^{o}C level which was the worldwide trend after the mid-1980's.
- In Korea, WTE facilities producing 400^{o}C and 40 bar steam have been constructed only from the 2000's. It was because of the insufficiently allocated construction cost for the WTE of high efficiency. Steam price from WTE was unreasonably low compared to the identical steam that was made from natural gas or oil, and thus yielded a low return on investment.

Utilization of WTE heat energy in Korea, 2008

Item	Facilities		Amount of produced Waste Heat (Gcal/yr)	Utilized Amount of Waste Heat(Gcal/yr)			Rate of Waste Heat Utilization from WTE, %
	ea	Capacity (ton/day)		Total	Electricity	Heat Supply	
Total	78	17,501	9,644,311	8,353,441	1,320,871	7,032,570	86.6%
Municipal Wastes	45	13,016	6,976,727	6,330,363	1,253,112	5,077,251	90.7%
Industrial Wastes	33	4,485	2,667,584	2,023,078	67,759	1,955,319	75.8%

Trend of Steam Temperature in WTE plants

Boiler generating the 40 bar, 400°C steam is a general trend.



Source: Takuma Masao et. al., "Contribution to climate change by electricity generation through waste incineration", MHI report, 41, 212-215, 2004.

Future Technical Direction in WTE

- Future technical direction for the production of high grade steam in WTE can be seen in the current trend of coal fired power plants.
- Currently best available technology in WTE generates steam at 100 bar, 500^{o}C, where overall efficiency can reach 30%.
- Coal industry has employed steam turbine systems of over 36% efficiency, with ultra supercritical technology, over 40%. Compared to the coal fired plants, WTE still retains a large room in improvement for the steam quality and thus overall plant efficiency.
- Considering that the size of WTE plants is much smaller than that of coal fired plants and a large capital cost would be involved, WTE plants of 100 bar, 500^{o}C appear to be the best technical level that is practically attainable for the time being.
- In order to accelerate investment for the WTE plants of high efficiency, reasonable pricing policy for the WTE steam and the proper allotment for construction cost are most important factors that should be resolved.

Conclusions

- Recent trend in Korea is treating the wastes through pre-treatment like MBT and RDF. But, many cases of operational troubles have observed when applying with different characteristics of domestic wastes. Procedural checking of adaptability by pilot and demonstration plants with actual domestic wastes appears to be a key aspect although it requires a time and additional cost.
- Whether revamping the existing WTE plants to the plants using RDF should be considered carefully in a big city when the mass collection across the adjacent municipalities has reached a public consensus and passed the agonizing permission procedures.
- Steam from WTE is treated as a product from wastes of zero value and be paid far less than the identical steam from other fuels. Also, RPS weighting factor from wastes remains at 0.25-0.5, which should be increased to the level as the wood-based biomass case.
- Many countries have a governmental incentives based upon the renewable energy policy. Narrow definition as in IEA can give a negative impact on WTE.
- WTE still retains a large room in improvement for the steam quality and thus overall plant efficiency. In order to accelerate WTE plants of high efficiency, price for the WTE steam and the proper construction cost are most important factors that should be resolved.

References

Baumgartner, R. (2006): *Advanced coal technology to power the world*. World Bank Energy Week. March 7.

Masao T. (2004): *Contribution to climate change by power generation through waste incineration*. MHI Report 41, 212-215 (in Japanes).

Yun, Y. (2011): *Policies and technology development trend in WTE*. KISTEP Technical Trend Report (in Korean).

Yun, Y. (2007): *Current Status and Future Direction for Thermal Treatment of Wastes in Korea*. 26th Annual International Conference on Incineration and Thermal Treatment Technologies. Phoenix, USA.

Yun, Y., Sung, H.J. (2009): *Current utilization status and technology direction for waste heat*. J. of Environmental Hi-technology. 9(17). 2-9 (in Korean).

Yun, Y., Sung, H.J., Park, J.J. (2010): *Appropriateness study on designating wastes from industrial incineration facilities according to the re-classification of new and renewable energy*. Final Report to Korea Industrial Waste Resources Mutual-Aid Association (in Korean).

Thank you for your attention.