Issues and Prospects of WTE for Better Efficiency

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EXECUTUVE SUMMARY

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. Issues on WTE has discussed from several points of view. Adaptability of domestic wastes to the newly adopted technologies, WTE technology choice for the big city case, heat energy like WTE steam compared to the electricity that gets Governmental support, definition issue on renewable energy from wastes and its impact, RPS issues in Korea are chosen as the issues. Prospect of WTE for better efficiency is also discussed with the currently best available technology and with comparison by coal fired power plant cases.

INTRODUCTION

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.

Put simply, simple reclamation should be replaced with WTE methods in a more energy conscious society. But, there are many issues and related problems. Most prominent aspects are economics, application of high grade technologies, and government policies. 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. Coal industry has employed steam turbine systems of over 36% efficiency, with ultra supercritical technology, over 40%. Best available technology for waste incineration plant is 30% efficiency in Japan, which suggests that there are many rooms to reach higher efficiency in WTE.

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. When RPS(Renewable Portfolio Standard) is implemented from 2012 in Korea and most Governmental support for the energy is based on whether the energy source is included in the renewable energy category, the definition of produced energy from wastes for the renewable energy is critical for the more wide implementation of WTE. Probably this case is a local issue, but narrow definition by IEA on energy from wastes has influenced as a negative way on competing with other renewable energies.

Table 1 illustrates the recent trend of MSW heating values in Korea. Most of wastes incineration plants that were built during the 1990's in Korea were designed to treat MSW(Municipal Solid Waste) of less than 2,000 kcal/kg, which was the normal heating value at the construction time. But, mainly due to the separation of food wastes from household wastes prompted to increase the portion of high heating value materials like paper and plastics. With the increase in heating values to almost 3,000 kcal/kg, WTE is becoming a must option in many municipalities.

Table 1. 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

KEY TECHNOLOGIES FOR WASTE-TO-ENERGY

WTE is based on using the energy content of combustible organic wastes. Incineration and using the ensuing steam is the most common technology of 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. Food wastes, animal manure and wastewater sludge are pre-treated to produce bio-gas of methane that is utilized mostly in gas engines to generate electricity. Other combustible wastes can be further separated to increase the heat content as RDF(Refuse Derived Fuel) or RPF(Refuse Plastic Fuel). 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.

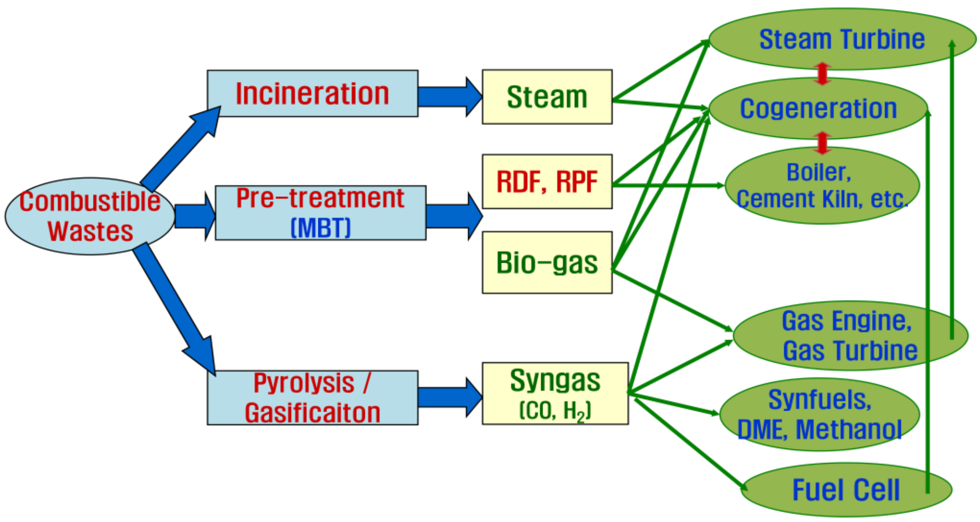

Figure 1. Key technologies in Waste-To-Energy.

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 WASTE-TO-ENERGY

Adaptability of technologies to different characteristics of wastes

There have been many cases of operational troubles while applying WTE and MBT technologies which were developed in foreign countries with their own indigenous wastes. Typical differences in characteristics were moisture, salt, chloride contents, heating value, and the ash behavior at high temperature as well as the degree of pre-separation.

WTE technologies are based on the heat treatment and biological treatment. Inorganic components, if they are under high temperature over 1,000^{o}C, all the time cause fouling and slagging operational troubles. Salt also influences the degree and speed in biodegradation and in ash fouling behavior. Salt content is critical especially in using as compost for agriculture. 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.

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. In Korea, most incineration plants that were built during the 1990's generate steam at 16-30 bar, 200-300^{o}C. Even 30% efficiency for electricity generation is possible in incineration plants when generating the steam at 500^{o}C, 100 bar. But, efficiencies in most incineration WTE plants are quite lower than 30%.

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. WTE technology shift in big cities has more subtle factors than in other cases. 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.

Big cities generate enough wastes to operate WTE plants of any kind of WTE technologies if the wastes can be gathered in a big plant. Even DME plants would be possible if more than 1,000 ton/day wastes can be processed at one spot. DME can be used as a replacement for LPG or diesel. 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.

Definition of wastes in renewable energy

Definition by IEA(International Energy Agency) on renewable energy has a big influence to the WTE industry. IEA defines renewable energy from wastes as in a dictionary. Only the energy value of combusted biodegradable material is qualified as renewable energy according to the IEA's definition, which means that the non-biodegradable part of the waste is not considered renewable. The narrow definition might impede the legal government support at some countries like in Korea.

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.

Table 2. Different definition of renewable energy in countries

	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	Solid 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				○			○				

Table 2 exhibits how countries define the renewable energy and in some countries as a new energy category. 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 as in Table 2. 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. When even the waste heat from wastes is not categorized as renewable, most of WTE energy would be dealt as a surplus from zero-value feedstock and in turn resulting in cheap steam price.

Government support to heat energy from wastes

Government support for WTE has many forms. 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. Electricity can be metered precisely whereas the steam value depends on variables like pressure and temperature which can vary quickly with time. Therefore, it’s not easy to make a clear value quantification to support heat energy from WTE. Industry should make an easy and cheap way in the quantification of heat energy for the variation of steam pressure and temperature.

Renewable Portfolio Standard (RPS) for energies from wastes in Korea

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. That portion will start from 2% in 2012 to the final 10% level after 2022. Energy from wastes comprises a large proportion of new/renewable energy in Korea as shown in Table 3. The proportion has reduced to 75% level in 2009, but still would act as a major portion till 2020. 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 application.

Table 3. Amount and portion of WTE in Korea’s new/renewable energy

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

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 as illustrated in Table 4. 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.

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.

Sometimes many people forget the underlying starting point. 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 or municipality can decide which is right for them, but nowadays too many so-called pure-renewable believers appear to influence and obscure the original purpose.

Table 4. Renewable Portfolio Standard(RPS) in Korea applicable from 2012

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

PROPSPECT FOR BETTER EFFICIENCY

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.

Table 5 illustrates how much of the WTE heat energy was utilized in Korea at the period of 2008. By simple number, the rate of utilization out of the produced waste heat reached 87%. 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. As shown in Figure 2, the steam quality should reach the 400^{o}C level which was the worldwide trend after the mid-1980's.

Actually, as shown in Figure 2, the steam temperature of 500^{o}C had been applied in Germany during the 1960's. Due to the cheap available oil and related cheap steam price, technologies at the WTE facilities in generating steam had deteriorated to the low-tech. Then, from the 1990's when more people were concerned about the environment and energy recovery, it became a trend in most countries including the far-east Asian countries to employ the WTE technology in that steam is produced around 400^{o}C.

Table 5. Utilization of WTE heat energy from municipal and industrial wastes 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%

In Korea's case, WTE facilities in that the 400^{o}C and 40 bar steam is generated have been constructed only after the 2000's. It was because of the insufficiently allocated construction cost for the WTE of high efficiency and also because of the poor understanding on the WTE itself. 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. Situation has dramatically changed nowadays in Korea. Just three years of return on investment is even possible in WTE plants when using industrial wastes and supply steam to the paper manufacturing plants. This trend has aroused new interest for the facilities producing a high grade steam and maximizing the steam amount.

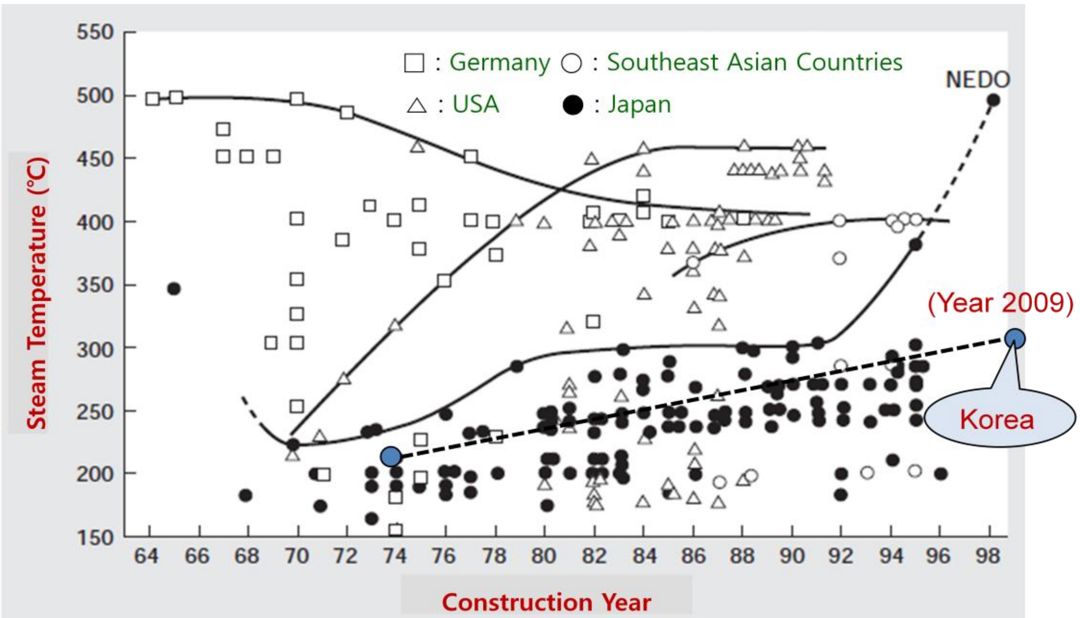

Figure 2. Trend of steam temperature in WTE plants in different countries.

Future technical direction for the production of high grade steam in WTE can be seen in the current trend of coal fired power plants. Coal fired power plants in Korea already employ a steam-producing technology at 241 bar and 538^{o}C, and newly built power plants are producing a supercritical steam at 250 bar, 600^{o}C. Currently best available technology in WTE generates steam at 100 bar, 500^{o}C, where overall efficiency can reach 30%. 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.

CONCLUSION

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. Although the new technology 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.

Pyrolysis/gasification plants for WTE would be better to build the scale of over 100 ton/day if possible to ensure the economic competitiveness. If enough waste amount can be gathered at the scale of over 500-1,000 ton/day, converting wastes to synthetic diesel, DME(di-methyl ether), or methanol might be rationalized.

There are many obstacles in wider application of WTE. Most prominent one is that steam from WTE is in most cases 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 for most traditional energy 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. In Korea’s case, if WTE is not categorized as a renewable energy Government support can be limited because it is based on the renewable energy law.

Future technical direction for WTE can be seen in the coal fired power plants. 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.

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