Waste Conversion Technologies: Emergence of a New Option or the Same Old Story?

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New Technologies

Waste Conversion Technologies: Emergence of a New Option or the Same Old Story?

- Increasing interest and flow of information regarding Waste Conversion Technologies ("WCTs") for municipal solid waste ("MSW") processing.
- WCT systems may offer improvements over landfilling and combustion-based waste-to-energy ("WTE").
  - Emissions.
  - Efficient energy recovery.
  - Power generation applications.
  - Recovery of materials.
  - Reduced reliance on landfills.
  - Public acceptance.
- WCTs sometimes referred to as "emerging" technologies.
  - May be better described as re-emerging or technology refinements.
  - Some WCTs have been the subject of previous attempts at commercialization here.
  - Some WCTs integrate familiar processing systems in novel ways.
- Increased attention to WCTs arises from circumstances in other countries and localized interest in the United States.

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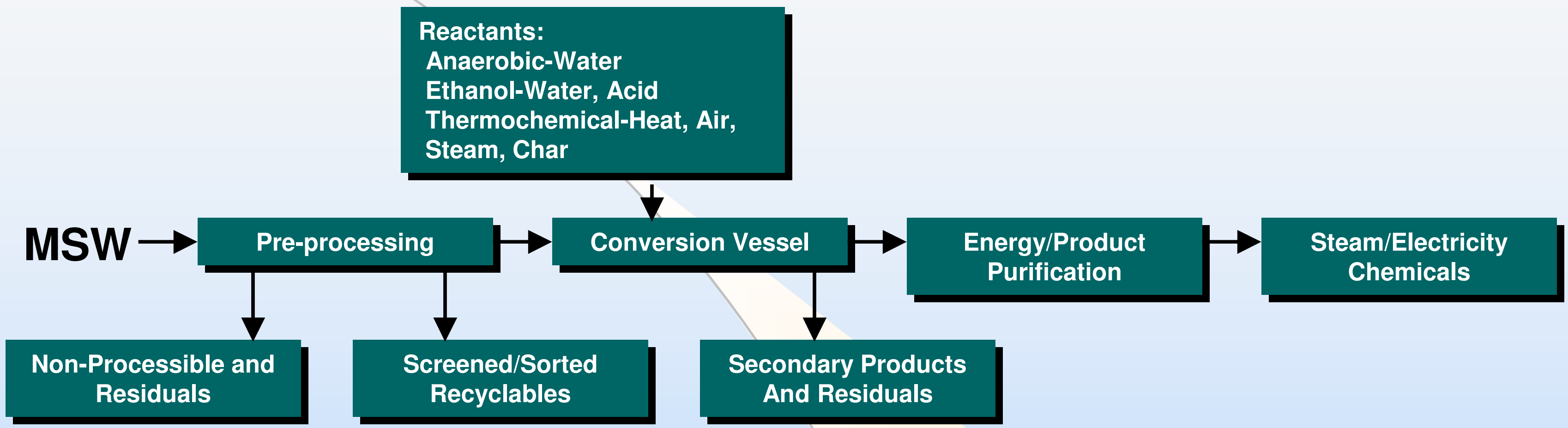
- Primary drivers have been the following:
  - The European Union's ("EU's") Landfill Directive that seeks to drastically reduce the amount of putrescible wastes landfilled by 2020.
  - Japan's chronic shortage of domestic energy resources and landfill space.
  - The desire to develop "sustainable" waste management programs in compliance with the Kyoto Protocol.
  - The reluctance to propose combustion-based WTE facilities.
- In the United States, we lack the nationwide regulatory impetus provided by the EU's Landfill Directive, the Kyoto Protocol, or a shortage of landfill space.
- However, some states and communities, motivated by similar goals, are investigating the feasibility of WCTs.
  - California legislation, requiring the California Integrated Waste Management Board ("CIWMB") to "research and evaluate new and emerging non-combustion thermal, chemical, and biological technologies."
  - Los Angeles County developing a demonstration Facility.
  - New York City's efforts to find viable non-export alternatives.
  - Most recently, energy cost inflation has spurred further interest in recovery of energy from wastes.

What are WCTs?

- Reports abound on the WCTs.
  - EU Landfill Directive requirement for compliance strategies from member nations.
  - Substantial amount of technology development in Japan.
  - CIWMB draft research report to the Legislature.
- Technologies being offered include biological, thermochemical, and hybrid systems.

What are WCTs?

Processing Stages of a Waste Conversion Technology

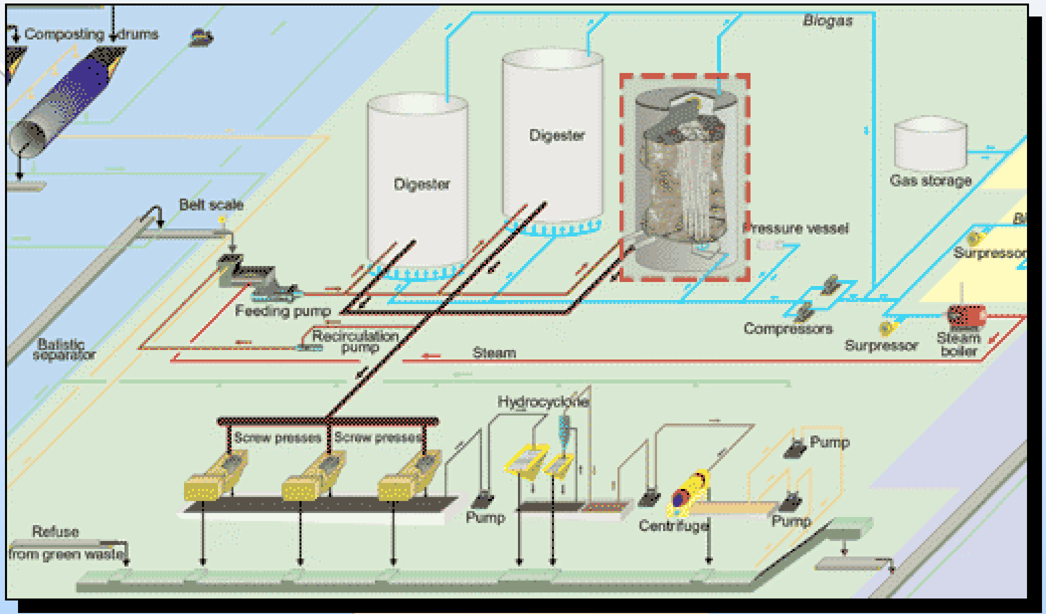


- WCTs produce intermediate products from MSW that may be utilized in energy generation or chemical manufacturing.
- Synthesis gas (syngas) or a fuel.
- In contrast, combustion-based WTE converts unprocessed or preprocessed MSW directly to energy.
- WCTs and WTE include the recovery of recyclable materials in their processes, and can operate successfully with residential, and commercial recycling programs in well-planned integrated systems.

Biological

Valorga Anaerobic Digestion Vessels And Materials/Gas Flows
Source: Valorga International Website (www.valorgainternational.com)

- Anaerobic Digestion
  - Anaerobic Digestion ("AD"), like composting, relies on a natural biological process of treating biodegradable waste by means of bacterial action, but in the absence of oxygen.
  - The process generates a biogas.



  - Mixture of principally CH_4 and CO_2, but with some H_2S, N_2, and NH_4, dependent on feedstock
  - Biogas can be used via a gas spark-ignition engine or fuel-diesel oil/biogas engine for electricity generation and heat export.
  - The process is limited to biodegradable waste.

Biological (cont.)

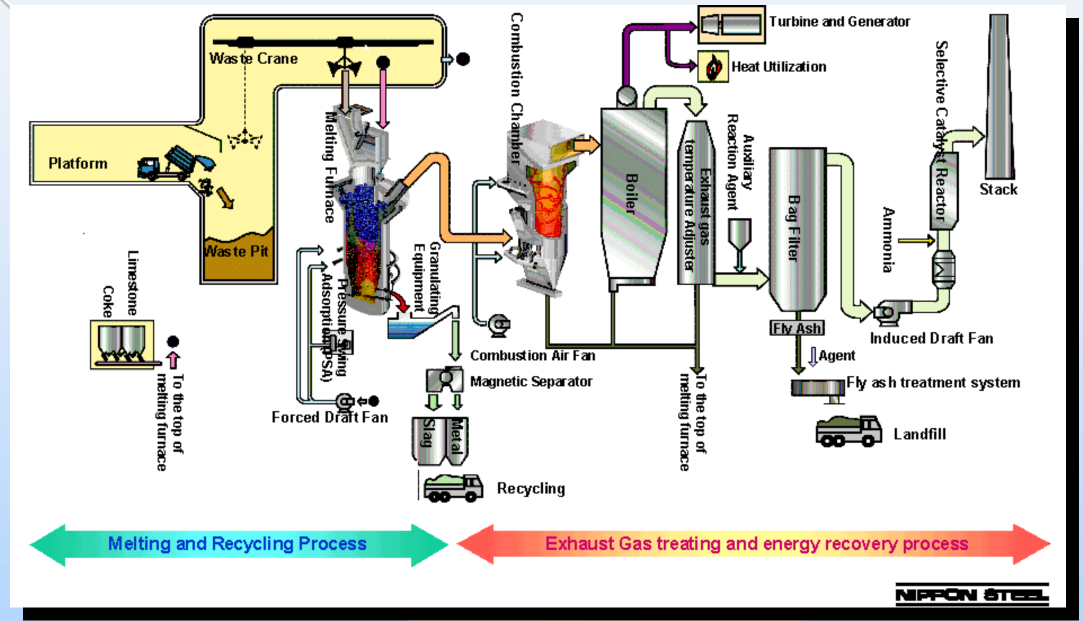
- Ethanol Production
  - Ethanol Production from cellulosic feedstocks occurs via fermentation – Anaerobic process.
  - Ethanol Production, like anaerobic digestion relies upon fermentation, but designed to produce different products.
  - Cellulosic feedstocks undergo a pre-treatment step to break down cellulose and hemicellulose to simple sugars.
  - No facilities converting MSW to ethanol are operating in the United States or the world.
- Europe leading in anaerobic digestion.
  - More than two (2) million tons per year of installed capacity.

Thermochemical

Nippon Steel – MSW Gasification System

Source: NEDO – 3r Technologies (www.nedo3r.com)

- **Gasification**
  - A thermochemical process involving the conversion of a solid or liquid feedstock into a gas via partial oxidation (using oxygen-rich air or oxygen) under the application of heat.



  - Process optimized to produce a fuel gas with a minimum of liquids and solids.
  - Convert carbonaceous feedstock into gaseous products at high temperature and elevated pressure in the presence of oxygen and steam.

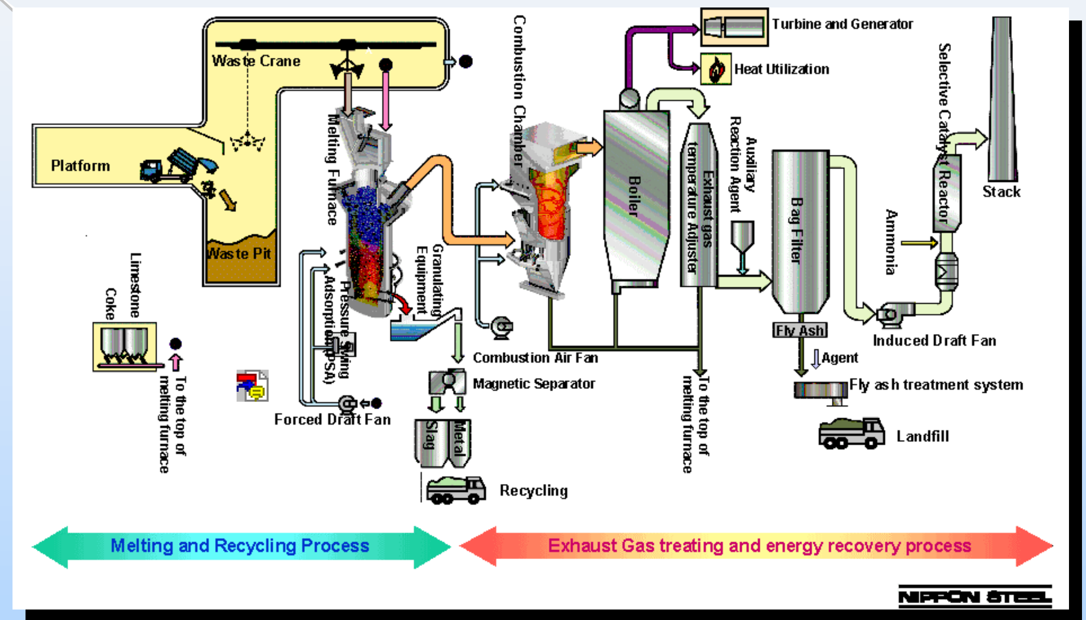
Thermochemical (cont.)

Nippon Steel – MSW Gasification System

Source: NEDO – 3r Technologies (www.nedo3r.com)

Gasification (cont.)

- Partial oxidation of feedstock provides heat.
- Typically occurs at temperatures of between 760℃ – 1,650℃.
- Produce synthesis gas or "syngas."



- Predominantly CO and H_2.
- Lesser amounts of CO_2, H_2O, N, and small amounts of higher hydrocarbons.
- More than 50 gasification and pyrolysis Facilities worldwide, primarily in Japan.
- Capacities generally from 100 to 500 tons per day.

Thermochemical (cont.)
Commercially Active Gasification Facilities Using MSW

Location	Company	Began Operation	MSW Capacity
SVZ, Germany	Envirotherm	2001	275,000 TPY
Ibaraki, Japan	Nippon Steel	1980	500 TPD
Aomori, Japan	Ebara	2001	500 TPD (ASR)
Kawaguchi, Japan	Ebara	2002	475 TPD
Akita, Japan	Nippon Steel	2002	440 TPD
Oita, Japan	Nippon Steel	2003	428 TPD
Chiba, Japan	Thermoselect/JFE	2001	330 TPD
Ibaraki #2, Japan	Nippon Steel	1996	332 TPD
Utashinai City, Japan	Hitachi Metals	X	300 TPD
Kagawa, Japan	Hitachi Zosen	2004	300 TPD
Nagareyama, Japan	Ebara	2004	229 TPD
Narashino City, Japan	Nippon Steel	2002	222 TPD
Itoshima-Kumiai, Japan	Nippon Steel	2000	220 TPD
Kazusa, Japan	Nippon Steel	2002	220 TPD
Ube City, Japan	Ebara	2002	218 TPD
Sakata, Japan	Ebara	2002	217 TPD
Kagawatobu-Kumiai, Japan	Nippon Steel	1997	216 TPD
Lizuka City, Japan	Nippon Steel	1998	198 TPD
Tajimi City, Japan	Nippon Steel	2003	188 TPD

Thermochemical (cont.)

Commercially Active Gasification Facilities Using MSW

Location	Company	Began Operation	MSW Capacity
Chuno Union, Japan	Ebara	2003	186 TPD
Genkai Envir. Union, Japan	Nippon Steel	2003	176 TPD
Iabarki #3, Japan	Nippon Steel	1999	166 TPD
Ishikawa, Japan	Hitachi-Zosen	2003	160 TPD
Kocki West Envir., Japan	Nippon Steel	2002	154 TPD
Nara, Japan	Hitachi-Zosen	2001	150 TPD
Toyokama Union, Japan	Nippon Steel	2003	144 TPD
Mutsu, Japan	Thermoselect/JFE	2003	140 TPD
Minami-Shinshu, Japan	Ebara	2003	155 TPD
Iryu-Kumiai, Japan	Nippon Steel	1997	132 TPD
Maki-Machi-Kumiai, Japan	Nippon Steel	2002	132 TPD
Kamaishi, Japan	Nippon Steel	1979	110 TPD
Takizawa, Japan	Nippon Steel	2002	110 TPD
Seino Waste, Japan	Nippon Steel	2004	99 TPD
Kameyama, Japan	Nippon Steel	2000	88 TPD
Nagasaki, Japan	Hitachi Zosen	2003	58 TPD
Aalen, Germany	PKA	2001	27,000 TPY
Gifu, Japan	Hitachi Zosen	1998	33 TPD
Bristol, UK	Compact Power	2002	9,000 TPY

Thermochemical (cont.)

Mitsui Pyrolysis Drum
Source: MES Bulletin 31, August 2000

- <u>Pyrolysis</u>
  - Endothermic process in the complete absence of an oxidizing agent (i.e., air or oxygen).
  - Carbon-based matter chemically decomposed.
  - Typically occurs at temperatures of between 400°C – 800°C.

  - Typically occurs at temperatures of between 400°C – 800°C.
  - Three (3) main pyrolysis systems exist:
    - Slow (or carbonization).
    - Conventional.
    - Fast/flash (vacuum, fluidized-bed).

Thermochemical (cont.)

- Pyrolysis (cont.)
  - Always produces gas, liquid, and solid char, the relative proportions of which depend upon the process type employed.
  - Main controlling determinants being temperature and the exposure time at that temperature.
  - Long exposure – Low temperatures – Char.
  - “Flash” pyrolysis (short exposure <1 second) – Eighty (80) percent by weight liquid.

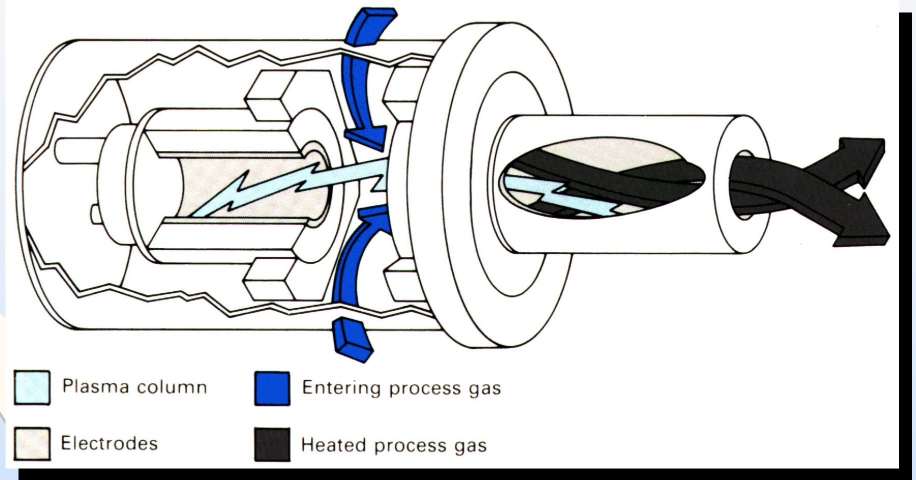
Thermochemical (cont.)

Commercially Active Pyrolysis Facilities Using MSW

Location	Company	Began Operation	MSW Capacity
Toyohashi City, Japan Aichi Prefecture	Mitsui Babcock	March 2002	2 x 220 tons per day (“TPD”) 77 TPD bulky waste facility
Hamm, Germany	Techtrade	2002	353 TPD
Koga Seibu, Japan Fukuoka Prefecture	Mitsui Babcock	January 2003	2 x 143 TPD No bulky waste facility
Yame Seibu, Japan Fukuoka Prefecture	Mitsui Babcock	March 2000	2 x 121 TPD 55 TPD bulky waste facility
Izumo, Japan	Thidde/Hitachi	2003	70,000 tons per year (“TPY”)
Nishi Iburi, Japan Hokkaido Japan	Mitsui Babcock	March 2003	2 x 115 TPD 63 TPD bulky waste facility
Kokubu, Japan	Takuma	2003	2 x 89 TPD
Kyouhoki, Japan Prefecture	Mitsui Babcock	January 2003	2 x 88 TPD No bulky waste facility
Ebetsu City, Japan Hokkaido Prefecture	Mitsui Babcock	November 2002	2 x 77 TPD 38 TPD bulky waste facility
Oshima, Hokkaido Island, Japan	Takuma		2 x 66 TPD
Burgau, Germany	Technip/Waste Gen	1987	40,000 TPY
Itoigawa, Japan	Thidde/Hitachi	2002	25,000 TPY

Thermochemical (cont.)

- <u>Plasma Torch</u>
  - Plasma arc technology – Heating method that can be used in both pyrolysis and gasification systems.
  - Also has application in treating WTE flyash.
  - Uses very high temperatures to break down the feedstock into elemental by-products.



    - Plasma – Collection of free-moving electrons and ions.
    - Typically formed by applying a large voltage across a gas volume at reduced or atmospheric pressure.
    - This is the same phenomenon that creates lightning.
    - Temperatures of 3,900℃ and above, the non-ionized gases in the reactor chamber can reach 930℃ to 1,200℃.
  - Molten slag is typically 1,600℃.
  - Intense heat breaks up the molecular structure of the organic material to produce simpler gaseous molecules, such as carbon monoxide (CO), hydrogen (H_2), and carbon dioxide (CO_2).
  - Inorganic material vitrified to form a glassy residue.
  - A large fraction of the generated electricity is required to operate the plasma torches, which reduces net electrical output of the facility.

Hybrid

- <u>Bio-Mechanical Treatment</u>

  - Bio-Mechanical Waste Treatment ("BMT") – Generic name for a range of processes. Simplest form, bio-stabilizes the mass of waste followed by landfill.

  - More complex designs – Bio-stabilization followed by the recovery of valuable components from residual waste for:

    - Recycling.
    - Anaerobic digestion.
    - Composting.
    - Energy recovery – RDF – Production for WCT or WTE process.
    - Landfilling of the stabilized residue.

Hybrid (cont.)

- <u>Mechanical – Biological Treatment</u>
  - Dry or wet processes used for removal of metals, glass, and contaminants, leaving an organic fraction for the next stage (dirty MRF).
  - Organic fraction can be composted or utilized in anaerobic digestion.

Hybrid (cont.)

Primary factors governing the potential commercialization of WCTs in the United States are Reliability, Emissions, and Cost.

Reliability

- Most WCTs characterized by:
  - Short operating histories.
  - Low annual processing capacities.
  - Restricted waste inputs (plastics, biomass, shredder fluff, or medical wastes).
  - Cannot be considered commercially proven for large scale MSW processing.
- Existing WCTs handling mixed MSW require pre-processing in order to create a feed compatible with requirements of the process.
  - Experience with pre-processing of MSW in the United States is extensive in connection with WTE systems that utilize RDF technology and refuse composting facilities.
  - It is difficult to produce a pre-processed feed material that consistently meets a strict set of sizing and contaminant (inorganics) removal criteria, particularly in large-scale facilities.

Reliability (cont.)

  - CIWMB Draft Report says, "technological risks remain when using alternative thermochemical conversion technologies to process heterogeneous and highly variable feedstocks, such as post–recycled MSW. For this reason, the importance of feedstock preparation and pre-processing is vital to the success of thermochemical technologies."
- System scale-up is also a concern.
  - Some WCTs in Japan are operating at the 150,000 ton per year level.
  - A facility in Germany operates at 275,000 tons per year.
  - WCTs will have to attain reliable and economic operation at throughputs of 500,000 tons per year (~1,400 tons per day) and above in order to meet the needs of United States metropolitan areas.
  - Not clear whether the pre-processing systems and particularly the vessels in which the WCT processes occur can be scaled up beyond their current sizes.
  - Multiple, units at current capacities may be required in order to meet higher throughput requirements.
  - If the pre-processing and processing modules cannot be scaled-up, significant economies of scale may not be achievable for higher throughputs.

Emissions

- WCTs do not eliminate stack emissions.
- Types of pollutants emitted by pyrolysis and gasification systems are similar in content to WTE emissions.
- Reported emissions for specific pollutants vary among the WCTs.
- WTE emissions lie within the range of WCT values, except for dioxins and furans.
  - Dioxin and furan emissions reported by the WCT vendors are at least two (2) orders of magnitude lower than the WTE.
  - Although the WTE emissions are well below USEPA limits.

Emissions

Emission Results For Various Pyrolysis/Gasification Facilities (mg/Nm^3 unless noted)

Source: CIWMB, 2005

	PM	NO	CO	VOC	SQ_2	Dioxins/ Furan (ng/Nm^3)	HCl	HF	Cd	Pb	Hg
Brightstar	1.6-10	40-96	440-625	0.05	<0.1	0.0331	<1.0	0.59	<0.0002	0.0051	-
Compact Power	0.11	26.49	7.13	0.49	3.37	-	0.17	-	-	-	-
GEM	3	262	8	6	79	0.02	4	ND	ND	-	ND
Mitsui Babcock	-	75 ppm	5 ppm	-	8 ppm	0.016	9 ppm	-	-	-	-
Mitsui Babcock	-	<35 ppm	-	-	<10 ppm	<0.005	<31 ppm	-	-	-	-
PKA	2.3	54	38	-	7.7	0.2	2.3	0.15	0.002	-	0.002
Pyromex	1	135	38	-	20	0.005	1	0.03	-	-	-
Serpac	4.2-5.2	61-189	0.5-2.5	-	0.0-5.6	0.002	1.7-5	<0.1	-	-	0.05
Technip	3	180	10	-	5	0.001	5	ND	0.02	-	0.02
Thermoselect	0.84	21.76	2.95	-	0.16	0.0007-0.0011	-	-	0.001	0.013	0.0018
Thide-Eddith	-	470	50	-	<200	-	30	<1	-	-	-
Thide	<3	-	<20	-	<4	<0.01	<10	-	-	-	-
TPS	3-7	200-300	2.5-5	-	5-15	0.013	0.6-2	<0.1	<0.004	0.005	0.008-0.05
3,000 TPD Stack Test Results	1.48	194 ppm	6 ppm	-	6 ppm	1.4	7.5 ppm	-	.00027	.00217	.0017
U.S. Mass Burn Permit Limit:	27	205 ppm	100 ppm	-	29 ppm	30	29 ppm	-	0.040	0.44	0.080
German Limits	10	200	50	-	50	0.10	10	-	0.03	0.50	0.03

Cost

- Costs to construct and operate a WCT in the United States cannot be estimated with the same level of accuracy as for WTEs or landfills.
- The most reliable information available indicates that construction and operating costs for pyrolysis and gasification are much higher than those for WTE and landfilling.
- Costs for anaerobic digestion are competitive.
- One known instance, in which binding cost proposals have been submitted for a WCT in the United States – Collier County, Florida.
  - Collier County – Gasification technology proposed by a firm utilizing the Thermoselect process.
  - Project did not proceed because the system was "cost prohibitive."
- Cost estimates are available from studies conducted by the City of Los Angeles in 2005 and by Columbia University.
  - Los Angeles study presented cost estimates on fourteen (14) WCTs obtained from detailed quotations provided by the system suppliers.
  - Estimated breakeven tipping fees for two (2) gasification technology vendors who possess significant European and Japanese operating experience.
    - Thermoselect – $185 per ton.
    - Ebara – $289 per ton.

Cost (cont.)

- Estimated cost for anaerobic digestion process utilizing the Valorga system (possessing significant operating experience in Europe) – $67 per ton.
- Columbia University researchers estimated the net operating cost for a gasification facility operated by Nippon Steel in Akita City, Japan – $145 per ton.

- Appears that the more actual operating experience possessed by the vendor, and the more detailed and binding the cost information provided, the higher is the estimated cost for WCT facilities using gasification or pyrolysis technologies.
- Higher costs from experienced vendors may indicate a linkage between risk, reliability, and cost.
  - Pricing may indicate that attaining operating results (from pyrolysis and gasification) and acceptable risk necessitate high equipment investment, personnel, and maintenance costs.
- Conclusion of a study on the first attempt at developing a pyrolysis facility in the United States.
  - Early 1970s, Monsanto constructed a 1,000 ton per day facility in Baltimore.
  - Facility closed in 1977 without reaching design capacity or sustained operations.
  - Estimates prepared by William F. Cosulich Associates, P.C. (parent company of Dvirka & Bartilucci Consulting Engineers) at that time for upgrading the pyrolysis facility to correct design defects.
  - Total construction and operating costs fifty-three (53) percent and sixty-seven (67) percent greater, respectively, than an equal sized mass burn WTE.

William F. Cosulich Assoc., P.C.
Environmental Engineers
Woodbury, New York

City of Baltimore Maryland
Pyrolysis Plant Rehabilitation—Conversion
Feasibility Study

November, 1980

Outlook

- Can we expect WCT's to become a part of the MSW management landscape in the United States?
- Even at current costs, some communities will look beyond higher tipping fees to the benefits of the efficient energy recovery and additional material recycling.
- Energy prices may also assist WCTs and WTE toward increased affordability and interest from local government.

Yame Seibu Clean Center – Mitsui Engineering

- Costs will have to come down for a large number of facilities to arise here.
- Convince skeptical public and private sector solid waste management professionals that:
  - The pre-processing systems will be reliable.
  - The WCT systems can be scaled up.
- Can WCTs avoid the opposition that confronts WTE?
- The progress in Japan and Europe would indicate that WCTs may come here.
- Remember that combustion based WTE still dominates in both places.
  - Approximately 40.5 million annual tons of installed WTE capacity in Europe alone.
  - Three (3) million tons daily for the WCTs in Europe and Japan combined.
  - New WTE units are being installed at least at the same rate as WCTs.

THANK YOU!