Life Cycle Assessment of the Environmental Emissions of Waste-to-Energy Facilities

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INTRODUCTION

Over the past ten years, environmental issues have become an increasing priority for both government and industry alike. In the U.S. as well as in Europe, the emphasis has gradually shifted from a site specific focus to a product specific focus. For this reason, tools are needed to scientifically assess the overall environmental performance of products and/or industrial systems. **Life Cycle Assessment (LCA)** belongs to that category of tools, and is used to perform this study.

In numerous industrial countries, LCA is now recognized, and is rapidly becoming the tool of preference, to successfully provide quantitative and scientific analyses of the environmental impacts of industrial systems. By providing an unbiased analysis of entire systems, LCA has shown that the reality behind widely held beliefs regarding "green" issues, such as reusable vs. one way products, and "natural" vs. synthetic products, were far more complex than expected, and sometimes not as "green" as assumed.

This paper describes the modeling and assumptions of an LCA, commissioned by the Integrated Waste Services Association (IWSA), that summarizes the environmental emissions of waste-to-energy facilities, and compares them to the environmental emissions generated by major combustible energy sources of the northeast part of the United States (NE). The geographical boundary for this study is, therefore, the NE US.

General Principle of Life Cycle Assessment

LCA is an analytical tool used to comprehensively quantify (with further option to interpret) the material and energy flows (flows to and from the environment, including air emissions, water effluents, solid waste, and the consumption/depletion of energy and other resources), over the entire life cycle of a product or process. The life cycle is meant to be studied comprehensively, including production and extraction of raw materials, intermediate products manufacturing, transportation, distribution, use, and final disposal. The general principle for extending system boundaries is illustrated in Figure 1.

All flows within the system are normalized to a unit summarizing the *function* of the system. This allows for the comparison of different industrial systems performing the same function. Once this shared function is defined, a unit has to be chosen in order to compare the systems on the same quantitative basis. The concept of the *function* is presented in the example of comparing milk bottles of different packaging materials (glass, plastic, etc.). The *function* of the comparison would be: *packaging of milk.* The *functional unit* would be: *the packaging of one gallon of milk.*

APPLICATION TO THIS STUDY: FUNCTIONAL UNIT AND SYSTEM BOUNDARIES

The Life Cycle Starting Point for MSW

In the Life Cycle approach, it is necessary to study the environmental and resource consequences of a product or process comprehensively. In the case of waste-to-energy, the commonly accepted starting is the generation of waste at the point of collection[1].

Functional Analysis

WTE is a process that performs two functions: MSW is being disposed of, and it is being reused in a beneficial way as a fuel source to generate electricity. In an LCA, when an additional function is introduced, it must be meaningfully compared in all of the options. Although the disposal of MSW is considered a meaningful function, it will not be studied in this LCA: following LCA reasoning, the function of disposing MSW in the WTE option would also have to be presented for all of the comparisons. However, the study of an alternate means of disposal on the other electricity options would entail the analysis of processes of landfilling, recycling, etc., and studying these large and complex processes would go beyond the scope of this study.

As a result, the remaining main function considered in this study is the production of electricity, comparing each electricity option on a per unit of electricity generated.

Figure 2 presents the three electricity comparisons in this study: the production of electricity from a waste-to-energy facility vs. the production of electricity from the major combustible sources electricity: coal, fuel oil, and natural gas.

Figures 2 shows each comparison as having only one function **(F1)**: producing electricity. Producing electricity, however, is not the only function that is associated with WTE. An additional function of WTE is recycling steel scraps. The WTE process recovers ferrous material from MSW and sends it off site to be recycled into usable steel (secondary steel), which displaces the production and use of steel from natural resources (primary steel).

Since none of the combustible electricity sources perform this same function, the production of primary steel must be subtracted out of only the WTE system. Figure 3 presents the two systems which contain the processes of each option and their respective functions. Note: only coal combustion is shown here, although WTE is compared to fuel oil and natural gas in the same way.

The Functional Unit Precisely Defined

The functional unit that will meaningfully compare the function of energy is a defined quantity of electricity produced, and has been chosen as 1 kilowatt-hour (kWh).

MODELING

This section describes all of the components modeled in the LCA. The entire waste-to-energy system and a general overview of the NE electricity grid contributors are discussed. Due to limited space in this paper, the detailed descriptions for modeling NE electricity grid components are not included. All data are modeled in Ecobalance's LCA software, TEAM^{TM2}.

Waste-To-Energy System

The waste-to-energy system includes the transportation of MSW to the waste-to-energy facility, combustion of MSW, including air emissions and water effluent control, disposal of the waste-to-energy ash residue, and production of steel with recovered ferrous materials.

Transportation of MSW to Waste-to-Energy Facility. Municipal solid waste is processed from the surrounding residential, commercial, and industrial facilities. The service area is assumed to be 50 miles in diameter with the average hauling distance of 25 miles. Approximately two-thirds of the waste stream is delivered by transfer trailer and one-third by roll-off containers and packer trucks. They return empty from the facility.

Residential MSW is typically collected with a 20- to 30- cubic yard packer truck. Since packer truck utilization is normally about 80 percent with a packing density of 750 pounds per cubic yard, a packer truck collects approximately 7.5 short tons of MSW per load. The average consumption of diesel oil per load is 13 gal/load which implies a fuel consumption of 1.8 gal per short ton of MSW[3]. Transfer trailers and roll-off containers will be modeled from Ecobalance's database, DEAM™[4], on standard heavy-duty diesel-powered trucks.

Air emissions generated from the collection vehicles are based on measured air emissions of a diesel oil heavy-duty truck[5], however, actual air emissions may be higher than considered, due to the high stop-start frequency.

Waste-to-Energy Facility. In order to use a representative waste-to-energy facility as a fair comparison to other NE electricity grid contributors, a typical facility was defined to produce average facility parameters. Figure 4 presents the five different areas of the waste-to-energy process for which typical data were obtained.

General Characteristics of the Waste-to-Energy Facility. The size of the waste-to-energy facility is assumed to be a 1500 ton-per-day (TPD), 5000 Btu/lb. refuse throughput. The facility has an annualized capacity factor of 92%, so it combusts an average of 1380 TPD of MSW. The facility consists of two 750 TPD mass burn waterwall furnaces, multi-pass boilers. Superheated steam is generated and used to drive a condensing steam turbine and generator set to produce electricity.

The facility includes an enclosed tipping hall for waste deliveries and a refuse storage bunker which holds up to 5000 short tons of MSW. Each boiler generates steam at 850 psig, 850°F, and operates continuously 24 hours per day, seven days per week, with the exception of power outages. The steam system includes a turbine generator, a water-cooled condenser, a wet cooling tower, condensate pumps, a low pressure heater, a deaerator, feedwater pumps, a boiler with an economizer, generating banks and superheater sections, and all ancillary equipment required to generate steam at the specified condition. Net power produced is 37.5 Megawatts (MW). 600 kilowatt-hours of electricity are produced per short ton of MSW combusted[6].

Auxiliary Burners. Auxiliary burners are provided for startup, shutdowns and any upset conditions. No auxiliary fuel is combusted other than for these conditions. The auxiliary fuel is assumed to be fuel oil, and on average 0.6 gallons per short ton of MSW fired is used for combustion (less than 1% of total heat release).

Water Systems. City water is demineralized in the water treatment system, and sulfuric acid (35% solution H_2SO_4) and caustic soda (50% solution NaOH) are used to regenerate the treatment system. In addition, small quantities of other chemicals are used for water treatment. The demineralized water is used for boiler makeup, and it is assumed that all process waste water is reused in the facility.

MSW Handling On-Site. Trucks carrying MSW enter the site, proceed to the weigh scales and remote scalehouse and continue on to the tipping floor. On the floor they back into bays to discharge their load into the refuse bunker. The trucks leave the tipping area and proceed to the facility scales to be weighed out before exiting the facility grounds.

Ancillary Materials. Besides MSW and the fuel oil used periodically in the auxiliary burners, there are additional materials that are consumed during the waste-to-energy process. The materials added to emissions control operations include powdered activated carbon (1.0 pounds per short ton of MSW), pebble lime (25 pounds per short ton of MSW), and aqueous ammonia (0.5 gallons per short ton of MSW). Materials used to regenerate the water treatment system are caustic soda (0.006 pounds per short ton of MSW), and sulfuric acid (0.004 pounds per short ton of MSW).

Air Emissions. The waste-to-energy facility contains emissions control equipment that complies with EPA's emissions guidelines. These include a selective non-catalytic reduction (SNCR) NOx control system, an activated dry carbon injection system, a lime-based spray dryer absorber system, and a fabric filter.

This facility uses technology that meets the Maximum Achievable Control Technology (MACT), as defined by the U.S. Environmental Protection Agency (EPA) for waste-to-energy facilities[7] for electricity production in the NE US. Table 1 presents average values for actual WTE emissions as reported by the U.S. EPA[8], per short ton of MSW combusted.

A fraction of the 2080 pounds of CO_2 emitted per short ton of MSW combusted comes from burning biomass. Paper and paperboard make up 25% of total MSW directed to WTE plants, yard trimmings make up 18%, and wood makes up 4%[9]. Organic carbon content by weight of biomass is assumed to be 41%[10]

Ash and Ferrous Scrap Management. After combustion of MSW, bottom ash falls off the grate into a quench basin and is combined with grate siftings. The bottom ash is conveyed to a ferrous recovery system. Fly ash and spent salts of reaction are conditioned with water and combined with the bottom ash for disposal. All ash handling occurs in buildings and enclosures so that no significant fugitive emissions occur. Ash and ferrous materials are stored separately in a grade level storage building, and then are sent to be disposed of or recycled in the ash residue monofill and the scrap metal recycling facility, respectively.

Ash Residue Monofill. The amount of combined fly ash residue and bottom ash that is generated at the facility is assumed to be 500 pounds per short ton of MSW. Ash is transported 50 miles to a double-lined monofill in payloads of 22.5 short tons. The typical truck used to transport ash residue is a tandem truck, filled based on weight of the material. Besides the emissions due to truck and transport of the material, it is assumed that no significant fugitive emissions come from the ash due to ash wetting, indoor loading, and covered transport.

The ash residue monofill is double-lined, consisting of a 24-inch clay layer and a 60-mils geosynthetic layer. Leachate from the landfill (40 pounds per short ton of MSW) is collected and discharged to a treatment works plant.

Scrap Metal Recycling Facility. Forty pounds of clean ferrous scrap metal per short ton of MSW are hauled fifty miles to a scrap metal recycling facility. Ferrous material is transported 50 miles to a scrap recycler in payloads of 22.5 short tons.

From an LCA modeling perspective,

- the burdens of the recycling of 40 pounds of ferrous scrap (secondary steel from an electric arc furnace) are added to the waste-to-energy system; and

- the burdens of producing that quantity of steel from primary means are subtracted out of the waste-to-energy system. This is because, since steel is being recycled and used for secondary steel production, the same quantity of steel that would have been produced by primary means is offset.

Electricity from Combustible Sources of Electricity

The combustible sources of electricity that are compared to waste-to-energy electricity production are coal, fuel oil, and natural gas.

Electricity from coal. The coal important to this study is eastern bituminous, since the vast majority of coal burned in the northeast is eastern bituminous coal. Modeling electricity production from coal includes materials, energy consumed, and emissions due to bituminous coal mining, preparation, transportation to facilities, combustion, emissions control technology such as flue gas desulfurization, and management of coal combustion byproducts at a landfill or storage pond.

Emissions due to coal combustion are figured for each type of firing configuration since firing configurations have different combustion requirements (coal burning temperatures, firing methods, and emissions control equipment, etc.) and emit varying amounts of pollutants.

Electricity from fuel oil

Heavy fuel oil, or residual oil, is the fuel oil used in power utilities. This type of oil is produced from the residue remaining after the lighter fractions of oils, such as gasoline, kerosene, and distillate oils have been removed from the crude oil. In general, the combustion of residual oils generates large quantities of ash, NOx, and SOx.

Modeled in this report includes energy, raw materials consumed, and emissions due to mining crude oil (including onshore production, offshore production, and thermal enhanced recovery methods), refining crude oil, and transportation from the mining site to the power generation plant.

Petroleum Administration for Defense Districts[11] (PADD's) were originally defined during WWII for purposes of administering oil allocation. The PADD region in the NE US that contains MACC and NPCC is PADD region I. Over 97% of the crude oil in PADD Region I comes from foreign crude oil sources. Therefore, transportation will take into account foreign oil brought into the US. It is assumed that foreign oil precombustion processes require the same energy and have the same environmental impacts as domestic oil processes, so figures for domestic oil precombustion processes are used in the model.

Electricity from natural gas. Raw natural gas is a mixture of hydrocarbons, N_2, CO_2, sulfur compounds, and water. It may have any range of compounds from mostly methane to inert gases, such as nitrogen, carbon dioxide, and helium, and smaller amounts of ethane, propane, and butane. Natural gas may be mined onshore, offshore, and in conjunction with petroleum processes.

Modeling natural gas includes taking into account the energy, raw materials, and emissions due to mining and cleaning natural gas, pipeline transportation, and combustion.

Modeling Software: TEAM™

All of the modeling for this LCA is performed on TEAM™, the LCA modeling tool developed and used by Ecobalance for the last 5 years. This tool, developed in C^{++}, efficiently performs complex Life Cycle Assessments, and models material and chemical flows through extended industrial process networks. This model contains an extensive database called DEAM™ of the basic Life Cycle Inventory of commodity materials, transportation means, energy sources and disposal options. This model strictly follows the LCA methodological framework developed by Society of Environmental Toxicology and Chemistry and adopted by the U.S. EPA. It also follows the recommendations developed in the ISO 14000 forum.

DISCUSSION ON WATER EFFLUENTS

Water effluents are not being taken into account for any of the electricity options for the following reasons:

Pre-electricity production: Water effluents coming from pre-electricity production processes are considered negligible for this study since the only effluents coming from precombustion are those from mining the fuels that are used to transport materials and refinery processes. Over the entire life cycle, these quantities are considered negligible.

Electricity Production: Water used during combustion of MSW includes demineralized water used for boiler makeup, for treatment of fumes, and for slag cooling. It is assumed that most of the water is recycled in the facility, so water effluents generated as a result of MSW combustion are negligible. The same applies for other combustible fuels.

Post-combustion waste management: The monofill that holds MSW ash residue is lined, and leachate is collected and transported to an offsite waste water treatment plant (WWTP). This collection of leachate is considered standard practice for typical waste-to-energy facilities in the U.S. Water discharged from the WWTP is considered safe enough to be released into the environment.

Leachate from coal combustion byproduct (CCB) monofills in the U.S. is generally not collected and taken off-site, so it is very difficult to quantify its actual amount per specified quantity of coal combusted. In terms of environmental impacts, leachate generated from coal ash at a monofill depends upon local conditions, such as precipitation, the leachability of the fly ash, and origin of the coal.

RESULTS

The results of this study will be presented at the conference. The comparisons between the electricity options are made to comparatively assess different impacts each option makes on the environment. Following is a brief overview of what the results will show.

Direct Comparison: Waste-to-Energy vs. Coal, Fuel Oil and Natural Gas

A direct comparison will be made between electricity produced from waste-to-energy and electricity produced by each of the combustible fuels. Actual quantities for each flow are directly compared. Examples of flows are as follows:

- **Raw materials** extracted from the earth and consumed: coal, natural gas, oil, uranium, and limestone;
- **Air pollutants** emitted: particulate matter, CO_2, NOx, SOx, and CO;
- **Energy** consumed: total renewable and non-renewable and feedstock and fuel energy.

Impact Analyses

Acidification potential, global warming potential, and natural resource depletion for each electricity option will be presented at the conference.

Acidification Potential. Potential acidic deposition (onto soil, vegetation, and water) can be expressed as potential H^+ equivalents. Potentially acidifying emissions of SO_2, NO_x and NH_x can be aggregated on the basis of their potential to form H^+, and the resulting value is the acidification potential.

Global Warming Potential. The "greenhouse effect" refers to the ability of some atmospheric gases to retain heat which is radiating from the earth. Global Warming Potentials (GWPs) have been calculated to compare the emission of different greenhouse gases. The emissions accounted for in this assessment are CO_2, N_2O, and CH_4., the pollutants recognized to potentially contribute to global warming.

Natural Resources Depletion Index. Resource depletion can be defined as the decreasing availability of natural resources. Resources considered in this impact are fossil and mineral resources, excluding biotic resources and associated impacts such as species extinction and loss of biodiversity. The fossil and mineral resources taken into account for this study are: coal, iron, natural gas, oil, and uranium. It is important to recognize that what is addressed in this index is the fact that some resources are depleted, not the fact that their extraction from the environment will generate impacts (e.g., methane emissions from coal mining).

TABLES

Table 1. MACT emissions limits and Waste-to-Energy facility emissions per short ton of MSW.

Pollutant[note 1]	MACT Rule (per dry std. m^3)	WTE Facility Emissions (lb./short ton MSW)
SOx	7.9 ppm	0.19
NOx	136 ppm[note 2]	2.4
CO	40 ppmv[note 3]	0.42
Particulate Matter	4.8 mg	0.099
HCl	9.7 ppm	0.13
Pb	0.006 mg	$5.4*10^{-5}$
Hg	0.022 mg	$1.9*10^{-4}$
Cd	0.00098 mg	$8.8*10^{-6}$
PCDD/PCDF	3.3 ng	$3.0*10^{-8}$
CO_2[note 4]	Unregulated	2080
CH_4	Unregulated	0.003
N_20	Unregulated	0.008

1 All pollutants are assumed to have O_2 at 7%.

2 Emissions from Mass Burn/Water Wall Furnace type of boiler, 200 ppm NOx.

3 Emissions from Mass Burn Waterwall, 100 ppmv CO.

4 The emissions values chosen for unregulated emissions such as CO2 (2080 lb./short ton of MSW), methane (0.003 lb./short ton of MSW) and N20 (0.008 lb./short ton of MSW), were supplied by IWSA engineers.

FIGURES

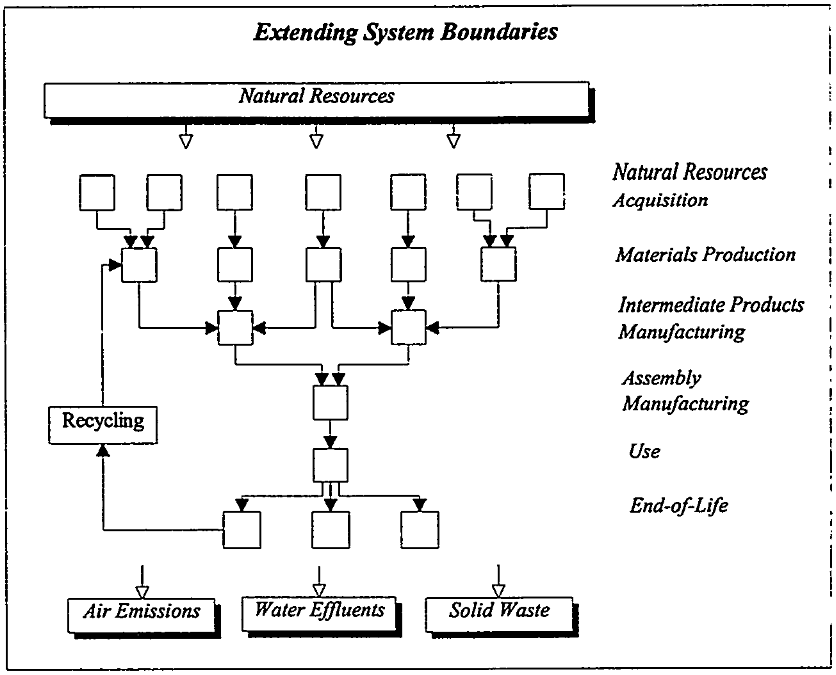

Figure 1 Extending system boundaries.

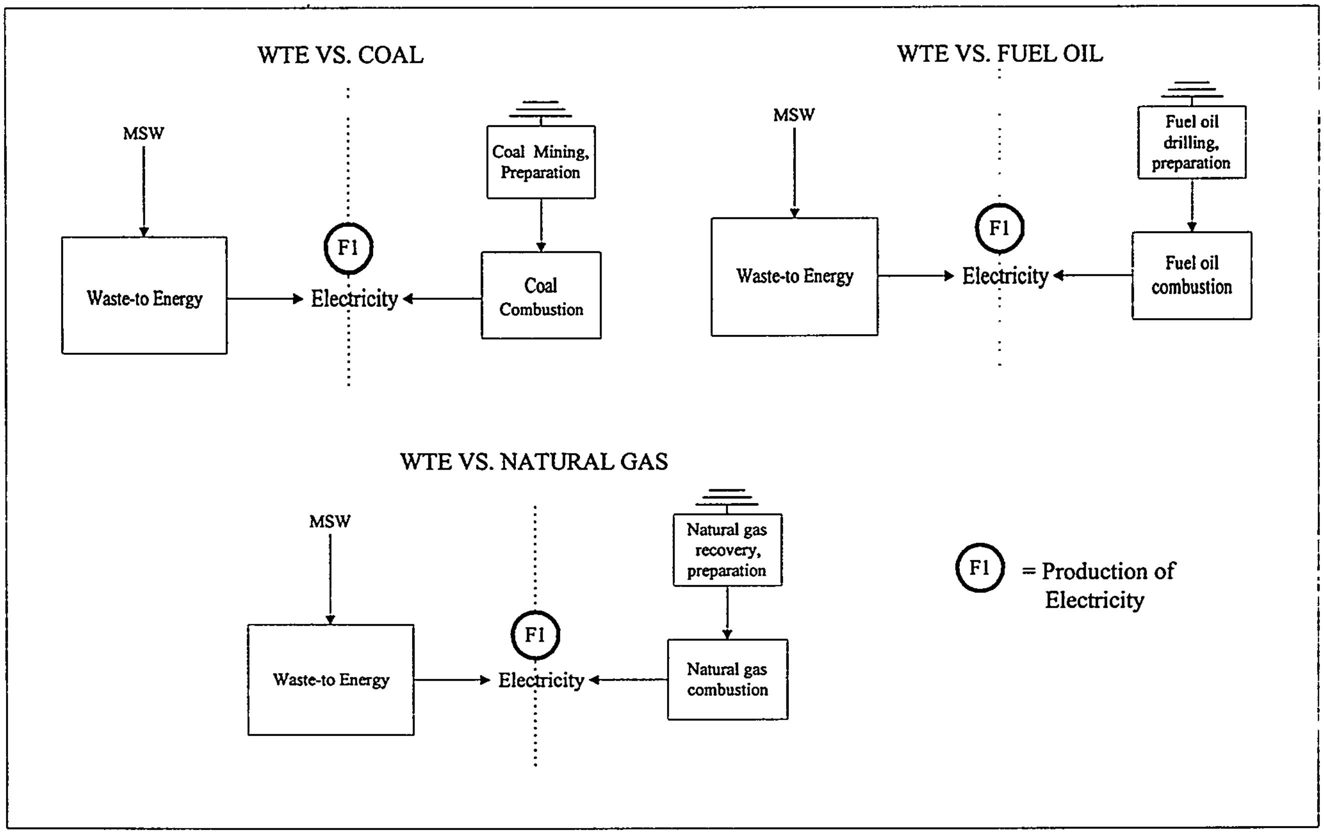

Figure 2 Production of electricity by a waste-to-energy facility and the combustible electricity sources.

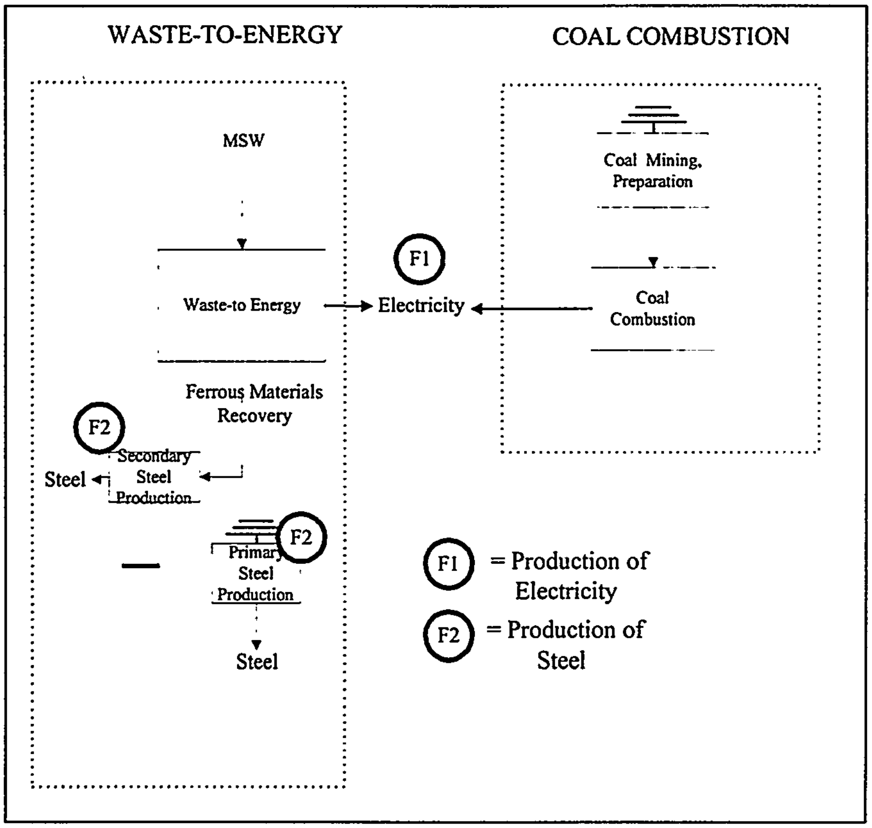

Figure 3 System boundaries for WTE vs. the combustible source of electricity.

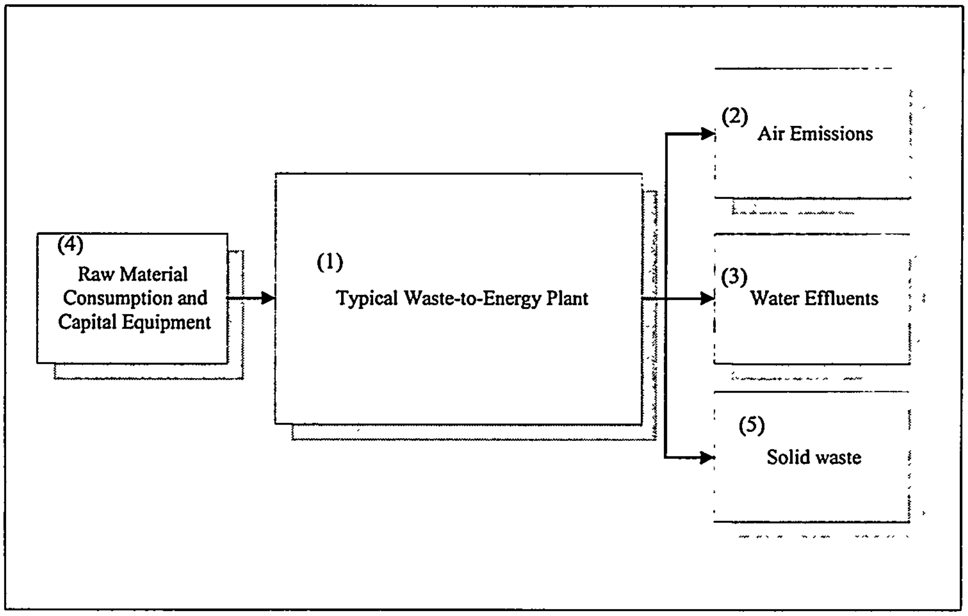

Figure 4 Schematic of the waste-to-energy facility.

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[5] EPA Emissions Laboratory, Ann Arbor, MI.

[6] IWSA, May 1996. 1996 IWSA Municipal Waste Combustion Directory.

[7] 60 Federal Register, p. 65387, December 19, 1995.

[8] US EPA Docket A-90-45, items IV-B-13, II-B-39, and IV-B-015.

[9] Derived from data provided in Franklin Associates, September 1994. "Summary: The Role of Recycling in Integrated Solid Waste Management to the Year 2000", Table 5.

[10] Carbon content percentage for paper and paperboard products from an unpublished LCA report by Ecobalance for American Forest and Paper Association on unbleached paper products, 1995.

[11] EIA Petroleum Supply Annual 1993, Vol. 1. 1993 data was used because that was the latest year for which information used to calculate transportation distances could be found (see Section 3.3.2).

Permitting and Siting Success Using the "I-Site" Approach

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INTRODUCTION

Growth in the waste-to-energy industry has fallen considerably since its hey day in the mid-1980s. Depending on the perspectives of various interests, many explanations for this decline are given. These include the effects of recycling mandates, lack of energy markets and citizen environmental concerns.

Two obstacles to successful siting—energy surpluses and overly ambitious recycling mandates—are being cleared away. Deregulation of the electric power industry promises to create new, competitive energy markets. Utilities are making plans to exit the so-called "merchant function," thus creating new opportunities for independent power producers and aggregators. Unreliable recycling markets present new demands for disposal capacity.

There appears, then, to be only one remaining hurdle that must be overcome for the industry to take advantage of the potential opportunities ahead. Not surprisingly, it is community perception. Driven by a fear of the unknown, the public—including news reporters and local politicians—challenges disposal methods they don't understand. And their protests persist even though these projects actually lessen many environmental threats. Fueling opponents are some personal injury lawyers and special interest groups that secure economic opportunity from the debate.

Each victory by waste-to-energy opponents has the effect of rocking investor and lender confidence, employee morale and customer and prospect resolve. Regulators and elected officials take cues from the public and either kill plans outright or impose expensive and unnecessary conditions that have the same effect. These individual battlefield victories by opponents makes their winning the war much more likely. One needs to look no further than the moribund nuclear power industry to see these results.

How can the waste-to-energy industry take advantage of new market opportunities, win permits with a minimum of delay, limit costly conditions, reduce unfounded objections and contain legal costs? The answer is letting down the traditional corporate guard and fully "involving" all constituent audiences in the siting process. The success of the involvement in siting—or the "I-Site"—approach also relies heavily on the adoption of a new, yet common sense, communications model. These conclusions are based on a comparison of siting successes and failures over the last 15 years, including lessons learned from other industries.

INVOLVEMENT AND COORDINATION

At the forefront of the I-Site approach is defining and coordinating messages to all of the constituent audiences. These audiences may include:

- Neighbors
- Elected officials
- Appointed officials (board of health, fire department, conservation commissions, zoning, etc.)
- Investors and lenders
- Employees
- Vendors and contractors
- Customers and prospects (host communities, purchasers of energy or disposal capacity, etc.)
- Business groups (chambers of commerce)
- Environmental and health organizations

None of these groups can be taken for granted.

Coordination of messages and targets is especially important today because a wide variety of information sources ensures all constituents will have access to data. Sometimes, these audiences receive information not directed to them, creating confusion and misunderstanding when taken out of context. Communicating concessions to host communities, for example, may alarm investors. Informing investors or lenders of cost-saving initiatives may concern employees or regulators. Each stakeholder's reaction depends on his or her vested interests, and these may appear at odds with other constituents. Traditionally, responsibility for dealing with each constituent often falls upon as many different people, departments or outside agencies—placing at risk controls that would otherwise consider the ramifications for other audiences.

Most progressive companies now realize the industrial assembly line model is out-dated because it fragments what should be a single process—that of delivering a product to consumers. Similarly, what should be a single process—communication aimed at reaching siting goals—has become artificially fragmented. The market conditions and customs of a century ago dictated separate and uncoordinated advertising, public relations and marketing efforts. Today, though, these present barriers to your success. Working independently, each department or outside vendor will interpret the plan differently and put their own "spin" on the message. This serves to dilute—if not completely undermine—messages aimed at others. The end result: audiences feel betrayed.

Companies must reassemble into a unified entity all marketing, government affairs, community relations, investor relations, advertising and internal communications efforts. Existing departments, individuals or outside vendors must be brought under a central command to ensure communications becomes a single process. This may require reorganizing departments so that sales and marketing, government affairs, investor relations, corporate communications, community relations, advertising, etc. are brought under one roof.

If you rely on outside vendors for any company communications, make sure they wholeheartedly endorse this philosophy and have skills in all areas—from advertising to the do's and don't of writing a press release. Watch for any biases or limitations they may have that might result in them using inappropriate communications vehicles. Re-engineering guru Michael Hammer says, "You cannot reengineer a process in isolation. Everything must be on the table. Any attempt to set limits, to preserve a piece of the old system, will doom your efforts to failure." Ironically, communicators frequently talk about re-engineering on behalf of their companies or clients while their departments or agencies have been largely overlooked as candidates for change.

PLAN A PROACTIVE PROGRAM

No matter what you've been told by proponents about overwhelming support for the project, plan a pro-active program—and the earlier the better. A proactive approach helps developer's build credibility, demonstrate an image of cooperation and nothing to hide. If you don't tell the story early and often, audiences will be blind sighted by legal notices or what they hear from so-called environmental "experts." They may even misinterpret what they are seeing out their kitchen windows. Steam may be mistaken for smoky pollutants, for example.

Those charged with coordination of the communications program often must assume the roles of devil's advocate and detective in their organizations. They should ask questions about potential "nuisance" concerns such as noise, odor, truck traffic and so on. When a potential problem area is discovered, find out what mitigating measures will be employed. This information should then be incorporated into the siting program.

KEEP MESSAGES AUDIENCE-CENTERED

All attention must be focused on the target audience. In practice, this means substituting complex jargon with easy-to-understand language. Further, your audience wants to know "what's in it for me"—WII-FM. Let them know what benefits they can expect, such as:

- Permanent and temporary jobs
- An improved environment (replaces older facility or landfill)
- Community royalties (PILOTs) or increased tax revenues
- Reduced tipping fees
- Other community involvement (cite past experiences with schools, Chambers, etc.)

Put yourself in the place of opponents. Of what are they afraid? Are there concerns valid? What can be done to mitigate these issues? Balance humane understanding with business goals. Learning from Union Carbide's Bhopal catastrophe, company spokesman Robert M. Berzok said recently, executives must "make an emotional connection" with audiences.

Take this a giant step forward, ask neighbors to get “involved.” Contrary to what your general counsel says, invite them to call or write with questions or comments. The nature of the legal profession is one of tight-lipped caution. Developers must find a middle ground between project attorneys and communicators. Most importantly, “listen” to what each audience has to say. Neighbors may not only have some good ideas, they may become supporters.

Health risk assessments are widely misunderstood. Be prepared to explain the inherently conservative nature of such studies and give constituents everyday equivalents. Driving in traffic, eating certain foods and other daily life needs expose humans to risks far greater than those being studied. During one lengthy and heated debate over the findings of a “worst case” health risk assessments, some project opponents clamored for a recess—for a cigarette break. Use opportunities such as these to compare relative risks.

If opponents argue that they choose to take certain risks, sensitively point out the risks from other disposal alternatives.

After the permits are granted, continue to inform all audiences. Tell neighbors and officials what they may see and hear during other project phases, such as:

- Site preparation (traffic, noise, relocation of buildings or utilities, etc.)
- Construction (pile driving, etc.)
- Start-up (steam blows)
- Commercial operation (traffic, noise, odor)

When talking with reporters, be sure to avoid use of technical jargon and, again, tell the facts loud, clear and often. In every conversation, emphasize your main points over and over. This is important because invalid arguments you thought you previously addressed have a way of re-entering the debate. When a problem occurs or a mistake is made, remember the truth is never to complicated to explain. There is a reason for everything, explain yours. If you don’t tell your side of the story, someone else will. If you don't have the answers yet, tell the reporter as much and promise to get back to them. Follow through on your promise as quickly as possible.

TIMING IS EVERYTHING

For best results, an orderly and well-timed flow of information is critical. In all cases, start by telling all employees. This remains true during any crisis—such as an accident or set back—that might take place. Be sure notifications are made through usual and customary channels. Project opponents look for inconsistencies in notification procedures as evidence of management flaws. Further, placing all employees on the same page helps prevent sending out mixed messages. If you don't have an employee notification procedure, create one.

Next, notify key political leaders, neighbors and the media—in that order and as soon as possible. If political leaders hear from you first, there is much less likelihood they will grandstand later. Ask them to withhold public comment until neighbors are notified of siting plans, progress or unforeseen events. They not only should understand this courtesy to their constituents, but will appreciate not being thrown in the middle.

Try to talk to key neighbors and community leaders in person. If it is impossible to talk to every neighbor, deliver or send personalized letters to all who might be impacted. If neighbors hear from the press first, they are much more likely to make misinformed comments and that may position them forever.

When delivering notifications, be sure not to put them in mail boxes. Such actions not only violate postal service rules (and could result in your communications being confiscated), it gives opponents additional weaponry.

Last in this timeline is the local media. If you are lucky enough not to receive a call from them first, proactively deliver your press release and facts to reporters and be prepared to answer their questions. If the reporter reaches you first, explain candidly that you have already begun notifying officials and neighbors. This open and honest approach demonstrates you have nothing to hide.

It is vital that a reporter always reach someone at your company. There is only one thing worse than the words "unavailable for comment" appearing in print. And that is the words "no comment." The former sends the message that you may be hiding something and the latter confirms it. Additionally, never talk "off the record" with reporters. Even if the reporter invites an off the record response, you can bet your comments will be published if the editor hears about them.

Designate a contact person who can answer questions. Since some reporters may have early deadlines before your office opens, make sure they have a way of reaching someone during these hours. That may mean giving out a home telephone number. Make sure the company receptionist or secretary understands the importance of media calls and directs them to you or your designee. If you use voice mail, get in the habit of checking it often.

After these core groups are notified, create and take advantage of opportunities to share information with local business and economic development officials, neighborhood groups and influential people in the community. Arrange to speak before service clubs and the Chamber of Commerce. Continue to emphasize your key points.

At all times, remember to put yourself in the place of other constituents and consider their reactions to the planned message. They will want to know what you are doing to mitigate problems.

CONCLUSION

In summary, developers often either overestimate the public's ability to understand complex jargon or underestimate the impact of so-called "experts" who join opposition groups. Further, waste-to-energy developers frequently omit project details that seem too complicated to explain. However, executives who *pro-actively* and fully involve the public in an exchange of easily understood terms achieve success at the lowest cost. Successful public involvement means *interactive* communication—not only distributing information, but listening to comments and responding accordingly.

Further, the timing and types of notices to employees, supporters, politicians, neighbors and the media is much more critical than some would believe. Vital to success is a global view that gauges the impact of these communications on unintended audiences.

Giving reporters information clearly, concisely and in appropriate news style is critical. A company must tell its side of the story or someone else will. And, the story must be told loud, clear and often.

These findings appear to be supported by a 1994 study, Waste-to-Energy in the United States: A Social and Economic Assessment, organized by Oak Ridge National Laboratory (ORNL) researchers. The study concluded that "financial barriers were not the predominant reason for WTE project cancellations, and those barriers are not likely to be highly problematic in the coming decade. The case study portion of the study identified numerous complexities that community leaders and decision makers must address when considering WTE. After a WTE project has been initiated, the decision to proceed with or abandon the project appears to depend largely on the dynamics of the decision-making process and the interactions among concerned parties."

The emerging competitive electricity marketplace has the potential to create new opportunities for the waste-to-energy industry. However, a bright future will only be realized if the industry learns from its past mistakes and considers communications a single process that is well coordinated and audience-centered.

EVENING PLENARY SESSION

Assessment of Emission and Ash Management Regulations - A Global Report

Assessment of Emission and Ash Management Regulations
The European Perspective

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INTRODUCTION

To reduce the impact on the environment, the emission requirements on waste incineration have increased rapidly in Europe during the last 10 years. Priority has been laid on the reduction of gas emissions. It is important to state that the regulatory requirements on air emissions differ a lot between the European countries. The Directives, approved by the European Community, EC, in 1989 are still being implemented. But, the EC member states are free to impose more stringent requirements than the EC Directive and some countries in the Central Europe: the Netherlands, Germany, Austria and Switzerland have done so. The situation during 1989-1992 could be characterized as a race between these countries in tightening the emission standards. The most conspicious are the extremely strict requirements introduced in the Netherlands in 1989. Those standards have confused and worried the operators and other parties in other European countries because of the risk that it might serve as a model for a new EC Directive.

The misgivings soon turned out to be justified as the EC Commission started the preparation of a revised directive for waste incineration. The last draft proposal was presented in 1994. It is strongly influenced by the strict standards of the Central European countries, but not as far-reaching as the Dutch regulation. Anyhow, objections were raised by several countries to the frequent tightening up of the emission standards claiming that the financial consequences are unacceptable. The new EC Directive is still in the pipeline, but there is no fixed time for the approval.

Efficient gas control does not mean that the harmful compounds disappear. They are to also found in the residues from the gas cleaning. In Europe, we can observe a growing concern about the environmental consequences of ash disposal, especially the long term risk of leachate discharges. An increasing number of countries will no longer accept land disposal unless the residues are properly treated. The very strict standards on gas emissions in many countries will probably be followed by as strict requirements on the control of residues.

This paper reports on the emission and ash management regulatory requirements for waste incineration in Europe and reviews the level of emission controls, current technologies and enforcement practices. The development of emission standards in different European countries during the last 10-15 years is illustrated as background for the now actual situation. The proposed European Directive is discussed and compared with the American regulations under the Clean Air Act. The adopted objectives and strategies are discussed and other means of control exemplified.

GAS EMISSIONS

Emission standards (1, 2, 3, 4)
The emission standards for waste incineration in the European Community, EC, and in some of the memberstates are presented in **table 1**. The presentation does not comprise the complete conditions. The table is meant to illustrate the essential features of the different regulations. The consideration of more sophisticated discrepancies is not within the scope of this paper, but it is important to observe that the standards have different reference conditions in different countries. The following list comprises the most important differences.

- The average values must be met as over varying time periods, from 1/2 hour to 1 month.
- The values are related to differing O2- or CO2- levels.
- The sampling and analysis methods (hence what is actually measured) are different.
- There are differences regarding standard status: whether it is target values or limit values and the

measures and penalties that a transgression will lead to.

- The times for the given standards to be fulfilled are different.
- Whether they are valid for existing plants or only the new ones.
- The figures in the table are valid for big plants, for the small ones there are normally other, less strict requirements.

The selection of standards in the table is meant to illustrate the stepwise development of the standardised requirements on air emissions from waste incineration in Europe and reflect the different priorities concerning pollutants in the mentioned countries.

The background to the rapidly increased emission requirements in Europe during the last 10 years is to be found further back in the growing awareness of the threatening pollution of our society and its impact on the human health and the environment. But, the starting point for strongly sharpened requirements on waste incineration came with the Swedish standards of 1986, focusing on dioxins and mercury. The preparatory work for this regulation started in 1984-85 as a result of public concern in Sweden about dioxins and the uncertainty concerning the impact of dioxins on the human health. Dioxin had been detected in mothers milk and waste incineration was pointed out as one of the main sources of the emissions. The course of events in Sweden attracted special attention internationally since the Swedish Environmental Protection Board declared a temporary moratorium on the construction of new incineration facilities waiting for the result of a thorough investigation. In 1986 the result of the effort was published in the report "Energy from Waste". The overall conclusion of the study was that it is possible to reduce the emissions to the levels acceptable to human health and the environment by the implementing improved operation and gas cleaning. Consequently the moratorium for new plants was lifted in 1986. Dioxins and mercury were singled out as critical pollutants, whose high toxicity, resistance and accumulation in the eco systems required very strict control. The emission standards set down in 1986 as a consequence of the investigation were at that time much more strict regarding these two pollutants than in any other country. Total dust emissions were also strictly regulated because of the high correlation with the emissions of several hazardous pollutants as cadmium, lead etc. The acids were not prioritized, since the emissions of those compounds from waste incinerators were evaluated as being of minor importance to health and the environment. It is interesting to observe that the Swedish authorities have not followed the Netherlands and Germany regarding the later, fundamentally tightened standards for especially acids in those countries. The reason is most likely the study of 1986.

While Sweden in 1986 pointed out dioxins and mercury as critical pollutants, Germany gave during the early 80´s special attention to acids like HCl, HF and SO2. At the end of the 80´s, the real revolution concerning emission requirements came when other countries in Europe combined the two priorities into very strict requirements on all pollutants. In 1989, the Netherlands introduced extremely strict requirements and Austria was close behind. Germany took up the challenge by new stricter guidelines and so did Switzerland.

The European Community, EC, approved a directive on waste incineration in 1989, closely following the older, less strict standards of 1986 from Germany, without specified requirements on dioxins and with moderate requirements on mercury. As a consequence of the tightened standards in the Netherlands, Germany and other Central European countries, EC started the preparation of a revised directive for waste incineration in the beginning of the 90´s. The first draft editions were targets for strong criticism but gradually the proposal became much more balanced. The last draft directive was presented in August 1994. It is practically identical with the German Standards of 1990.There are still a few substantial objections, but as a whole the proposal seems to be acceptable. The most important objection, and that is a fundamental one, is the lack of a scientific risk assessment and a cost/benefit analysis as a basis for the emission requirements.

Since EC presented the proposal on tightened Waste Incineration Directives in 1994, we have not experienced any new official initiative in this field from the Commission. They are said to work on a cost/benefit analysis, for the new standards. That must be understood as a response to the critical reactions to the proposal. In December 1996 the European Council of Ministers adopted a Resolution on an updated Community Strategy for Waste Management. In that paper the Council "invites the Commission to consider the scope for the amendment of Community legislation in relation to the incineration of waste with energy recovery". That opens up for a prompt accomplishment of the revised European Directive, most likely very close to the draft proposal. Everything seems to indicate that most countries will approve the new Directive unchanged, but some countries will remain with their stricter requirements.

Glancing at the table, the Dutch standards seems to be fairly close to the draft EC standard. But there is a fundamental difference in the measuring period for the plants to comply with the requirements: 1 versus 24 hours. The difference is obvious when comparing the short-period requirements for the two standards. Apart from that the most salient discrepancy is the maximum emission level of 70 mg/m3 (see table 1) in the Dutch standards. As the low level has an obvious impact on the gas treatment cost, it has stressed the debate concerning the reasonableness of the figure. It is said that a cost analysishas been conducted in the Netherlands, but so far I have not heard about any changes of their standards.

Based on later evaluations it is questioned if the very strict requirement on dioxins (0.1 ng/m3) introduced by Sweden 1986 is scientificly justified.

Indirect measures on emission reduction (2, 4)
The European standards according to the draft EEC Directives or national regulations normally include operational measures in excess of the emission limits with the intention to achieve low emissions. Here are some examples on that type of measures:

- the oxygen level may not fall below 6%
- the combustion temperatures must always be at least 850°C
- the residence time at 850°C must exceed 2 seconds
- auxiliary burners must be installed and operated in the start-up phase

There has been a strong opposition from the operators to this type of restrictions, not least in Sweden. There are experiences telling us that auxiliary burners sometimes may lead to deterioration instead of improvement. For some types of incinerators it is not obvious that an oxygen level of at least 6%, a lowest temperature of 850°C or a minimum residence time is relevant. There is an obvious risk that this type of regulation puts a negative influence on the technical development and the optimization of plant operation.

Comments to the draft EC Directive (2, 4)
As mentioned above, the draft proposal of 1994 to a new EC Directive on waste incineration has caused substantial opposition to arise from several operators and other experts. The following list illustrates subjects of discussion in connection with official regulations.

- The frequent change of standards - the new proposal coming up before the previous has been implemented - leads to poor operation and increased costs. The standards must be long term, permanent, to make it possible to operate plants economically and technically optimal.
- The emission requirements must be based on consequence analysis regarding impact on the environment compared with cost expenditures. The margin effects of increased requirements must be carefully considered. Expenditures should correspond to environmental benefits.
- The emission standards should be based on accurate considerations of the alternatives for energy production and waste treatment. If the requirements are more strict than for the alternatives, the net result will be an unfavourable use of the society resources. There is also an obvious risk that incineration will be replaced by other methods, which may give more pollution to the environment while consuming a higher quantity of fossile fuels.
- The principle of BAT (Best Available Technology) is unrealistic since it does not consider the financial consequences. It means as well frequent changes, leading to unstable operating conditions and uncertancy, not to say action paralysis. BAT must be combined with cost restrictions, which means growing into the principle of BATNEC (Best Available Technology, No Excessive Costs).
- There are no reason at all to put standardized requirements on operating conditions, like process temperatures and auxiliary burners, in addition to the emission requirements. That holds back the technical development and limits the possibility to optimize the plant operation.
- Too frequent measuring of emissions are unwarranted. No expert can honestly concludethat there are acute toxicity or acidification risks at modern waste incinerators. It is only the long term average emissions, that are of interest. The frequency and type of measuring must be adapted to that fact.

Comparison of European and American Standards (4)

In april 1996, the ISWA Working Group on Thermal Treatment organized a specialized seminar in Copenhagen addressing "European requirements and its consequences". That session developed a comparison between the proposed EC Directive and the corresponding USA standard, according to the Clean Air Act (CAA). Coincidentally, the two documents were promulgated at about the same time. Since then, the administrative handling of the two standards has been different. The USA standard has been approved but so far not the European.

There are significant differences between the two directives. The American one focuses entirely on air quality standards. The European is more far-reaching, adressing as well pollution standards for emissions to soil, surface- and groundwater. A comparison between the two directives is no simple task. First of all they must be normalized regarding equivalent units. The EC Directive is referred to 11 % oxygen content, 0°C (32°F) and a pressure of 101,3 kilopascals (29,92 inches of mercury) whereas the US CAA Standards is referred to 7 % oxygen, 68°F (20°C) and the same pressure. The EEC Directive is based on the metric system where the US CAA Standards are based on the English system of weights and concentration (i.e. parts per million, grains per dry standard cubic foot etc.). The measurement periods, on which the emission values are based as average values, differ significantly between the two standards.

The European and the American standards are compared in **Table 2** with the American values converted to the European equivalent units. The differences in sampling methodsand averaging periods has been ignored. The conclusion is that the two standards are fairly close numerically to each other, but can be very different in actual stringency.

Comments to adopted objectives and strategies (4)

It stands to reason that the reduction of emissions from waste incinerators, as from other emitting activities, is to protect the human health and the environment. To stipulate the acceptable level of emission a risk assessment has to be accomplished. The European countries and EC have so far in general assumed an unresponsive attitude towards scientifically based risk assessments. The chosen approach is "technology oriented", which means that it is based on the principle that the best available technology (BAT) must be put into practice regardless of what is required to protect health and environment. The economic consequences and the requirements on competing waste treatment and energy production alternatives are not considered.

Here we find an interesting comparison between Europe and America, reflecting differences in the approach to the problem. The US Clean Air Act Standards have a more "objective oriented" approach, aiming at what is necessary for the protection of human health and the environment. That means the same assessment undependant of type of emittent and consequently equality between different waste treatment and energy production options. The result of the European approach is very rigorous restrictions for waste incinerators compared with other waste treatment and energy production alternatives. It is of course technically possible to apply gas control technology at waste incinerators capable of meeting every demand including unmeasurable emission. But it leads to very high investment and operation costs as well as reduced reliability as a consequence of increasingly complex technology.

Other means of control

There are other means of administrative control besides air emission standards that have influence on the emissions from waste incineration. Here are a few examples from Europe.

- Requirements on separate collection of hazardous wastes as batteries and chemical residues makes the feeded waste fuel cleaner and helps to reduce the pollution of the exhaust emissions. According to studies in Sweden, such measures have reduced the mercury load with the waste fuels heavily and thereby substantilly contributed to the reduced mercury emissions. Another similar measure is the ban on the use of cadmium in some European countries.
- Taxes and other economic means of control has been put into practice in some countries. In France a tax of 150 FFr (about 25 US dollar) per ton gas is imposed for HCl, SOx and NOx with further taxes being planned for particulates and organic compounds. Another example is the Swedish charge system on emission of nitrogen oxides from energy producing units, undependant type of fuel. The system is as a whole a zero-sum game, favourising low emissions. The charge is 40 SEK (about 5 US dollar) per kg NOx-emission with a refund proportional to produced amount of energy. That means incentive for continous improvements and technological development as long as it is inside the scope of the fee level.
- According to the applied solid waste management hierarchy, landfilling has the lowest priority. But recycling and recovery, not just modern energy-from-waste plants, have difficulties in competing financially with landfilling, especially with the very strict requirements in the Central European countries. A growing number of countries have inaugurated taxes or governmental charges on landfilling in order to support recycling and recovery. But the cost gap is too big to be bridged over by these loadings. Another means of cost equalization being introduced in several countries is the ban on landfilling of waste without pretreatment. Such a restrictions make incineration of unusable, unrecyclable organics a necessity independant the cost levels. But that type of restriction involves a risk that cost/benefit assessments of emissions reductions will be ignored.

AIR POLLUTION CONTROL

Control technologies and enforcement practices (2, 3, 4, 5, 6, 7, 8, 9, 10)

Since long time ago, at least since the beginning of the seventieth decade, it has been obvious that waste incineration plants must have gas cleaning equipment to avoid adverse impacts on the public health and the environment. The measures were at that time concentrated on dust reduction, normally by means of electrostatic precipitators. A changed attitude came with the eighties and a better understanding of the impact on the environment from all type of emissions. It started with acid gasses and different types of wet scrubbers were tested and introduced, especially in Germany. But the real break-through came with the Swedish alarm about dioxins in 1984-85. The Swedish investigation during 1985-86 represented in my opinion the ideal model for a target directed achievment. It was organized as an extensive, cooperative joint effort of regulatory authorities, plant operators and other experts. Everyone realized the gravity of the situation and was devoted to solution of the problem. That created a breeding ground for realistic conclusions about impact on human health and environment, required reduction of emissions, technological solutions and economic considerations. The importance of waste as fuel and energy supplier was emphasized and expressed through the title of the report: "Energy from waste". As a follow-up of the investigation, essential development was performed in Sweden during the rest of the eighties, not only about gas cleaning equipment, but as the other factors affecting the emissions: the quality of waste as fuel, the combustion process and the energy production. A typical design used cyclone or elctrostatic precipitator for primary cleaning followed by dry scrubber and bag filter for emission polishing.The result was rapid and impressive, which is shown in **table 3** as a summary for the total number of incineration plants in Sweden.

The introduction of the even more strict standards in the Netherlands in 1989 raised a question whether it was possible to find gas cleaning systems capable of coping with those standards, at least if the economic consequences are concidered. Anyhow, a new market opened for the manufacturers of gas cleaning equipment. The air pollution control systems became multistep, chemical factories.

A system for air pollution control capable of meeting the strict requirements of today can be designed in many different ways. The gas cleaning equipment must be an integrated part of the total plant, which means influence from such factors as fuel quality, combustion process, energy recovery, handling of residues, reliability and flexibility. In some countries in central Europe, as Germany and the Netherlands the systems for gas cleaning have become very complex and expensive during the nineties. A total net waste treatment cost of 1000 SEK/ton (about 130 US dollars) is not exceptional. A typical layout is as follows:

- dust removal by electrostatic precipitators, cyclones and fabric filters
- two stage wet flue gas cleaning with acid and basic stage
- deNOx stage with non-catalytic (SNCR) and/or catalytic (SCR) reduction system
- active carbon filter or catalytic oxidation.

It is obvious that the implementation of such a complex system threatens the reliability and safety of the plant operation, at least during a transitional period. It is also obvious that it is possible to apply technology capable of achieving these and even stricter standards as long as the economic factor is neglected. The question remains: is this a nessessary measure and the right priority to maximize protection of human health and environment.

In other countries, as in Scandinavia, there has been a more pragmatic, cost-benefit characterized approach. The Swedish attitude has its origin in the investigation in the middle of the eighties. The chosen systems, dominated by dry scrubbers and bag filters, makes it possible to meet the now valid EC Standard and as well the dominating fraction of the proposed new Standard. A normal net waste treatment cost is about 300 SEK/ton waste (about 40 US dollars), significantly lower than in the Central

Europe. The difference reflects the very high additional costs that must be paid for a questioned benefit to the environment.

In this paper it is not possible to address technical descriptions on different systems and equipment for emission control. I do not think it is necessary either since the manufacturers serve the international market. I will mention one project, because it has a new technology under development in the SYSAV waste-to-energy plant in Malmö. A full size installation of a high dust (front end) catalyst has been in operation at the plant since 1996 to reduce NOx. Before that a selective non-catalytic reduction with urea injection has been in operation since several years ago resulting in a NOx-emission of about 100 mg/Nm3. It is well known that catalytic reduction of NOx with ammonia is very efficient if the catalyst is located after a fabric filter at the tail end. The problem is that this is a very expensive solution. A catalyst capabel to stand the conditions in the high dust position of an waste incineration plant would be much more cost effective. The full scale prototype in Malmö, which has been in operation since autumn 1995, was prepared by a 2-years promising test in a pilot plant. The full scale operation has so far been in accordance with the expectations with a further NOx-reduction of 40-50 % compared to the original SNCR installation.

THE HANDLING OF RESIDUES

The new challenge (11, 12)

As a result of efficient measures to reduce the gas emissions the hazardous pollutants are to be found concentrated in the residues: bottom ash (slag), fly ash (in this paper including boiler ash) and other gas cleaning products. The predominant ash management practice in Europe has been and is still disposal in landfills. But there is a growing concern about the environmental consequences of ash disposal, especially the long term risk of leachate emissions. Here we have a new challenge in taking care of the residues from the waste incinerators. Though the development of the residue management in Europe has been evolving for several years, the work is still in its start-up phase. The reason for that is the number of difficulties associated with the problem.

The ash residues produced in Europe makes a considerable amount to handle. The around 30 million tons of waste incineratad in Europe yearly will result in about 7-8 million tons of residues. Bottom ash is the dominating part, accounting for 80 to 95 % of the total, which means around 6-7 million tons. The rest is gas cleaning residues, around 1 million tons yearly. In Europe the bottom ash, the fly ash and the other gas cleaning products are normally managed separately.

The main objective of the handling of residues from waste incineration is, as for emission control, to protect human health and the environment. But there is as well another objective, attracting increased interest: the recovery of the residues. To meet both objectives the management of waste incineration residues in Europe gives priority to and even demands recycling. Economically and environmentally viable residue management alternatives are under development to meet the objectives. That means normally use of treated residues in construction, e.g. in roads. But there are other options as well. The residues contain concentrated substances from the waste and represents obviously a source of metallic raw material. The wet gas cleaning products are sources for the extraction of hydrogen chloride, sodium chloride and gypsum. Extraction of these valuables makes it possible to close resource cycles.

The residue management in Europe is generally aiming at
- reduced amount of residues,
- reduced content of hazardous pollutants in the residues

- maximized recycling of residues.

The quality of the waste, the type of incinerator and the efficiancy of operation is of the utmost importance for the possibility to comply with these objectives. It is normally a good strategy to design a waste incineration plant so that the toxic elements are concentrated in the fly ash and the gas cleaning products, leaving the bottom ash as "clean" as possible. An optimized operation will ensure minimal amounts of trace metals as cadmium and mercury, low content of organic constituents and high concentrations of stable mineral phases in the bottom ash. We have here an example on how important it is to look upon the total system of an incineration plant in order to optimize the total result, based on the prerequisite in the specific case concerning feeded waste, energy market, emission requirements, use of recycled slag, ash deposition etc. Several operators, manufacturers and other experts in Europe are acting in that direction.

Impact and regulations (11, 13)

As the dominating ash management practice in Europe still is landfilling the regulations for landfill disposal is of vital importance for the requirements on waste incineration residues. There are so far no approved EC Directive on landfilling, but a proposal is under final preparation. Current regulations are consequently national and differ a lot. An example of well developed landfill regulation is the German "TA Siedlungsabfall" which defines two different landfill classes with different demands on ash quality. Fly ash is classified as "hazardous waste" and consequently has the most demanding landfill requirements, normally in separate cells. As a consequence of a growing concern an increasing number of European countries will no more accept disposal unless the residues are properly treated.

For bottom ash the situation is different since the content of harmful pollutants are significantly lower than with the fly ash and there are obvious recycling options. The different countries have approved their own standards for the utilisation of slag, but these are stepwise being brought closer to each other as a result of exchanged experiences and extensive cooperation. In due time an EC standard will be approved but the memberstates will still have the possibility to require stricter standards.The requirements are under frequent alterations, based on new knowledge from research and development.

In the Central European countries (Germany, the Netherlands, France) the requirements have reached a quite strict level, considering especially the burnout and the leaching properties of the slag. The burnout is normally expressed by the loss on ignition (LOI) and/or the total organic carbon (TOC). Typical requirements are (weight percent):

• Loss on ignition	less than 3 %
• TOC	less than 1 %

The slag quality must comply with requirements on the maximum limits according to leaching tests (primarily trace elements and unorganic salts). As the limit values and the test methods are not harmonised for the different countries, a comparison is very difficult. As an example parts of the German standards according to "LAGA Merkblatt" is shown in **table 4.** The document is continuously revised.

Storage of the wet slag before use is normally a standardised requirement in order to transfer the strongly alcalic hydroxids into carbonates, thereby lowering the pH-value to 9.5 or lower, which also reduces the solubility of lead.

The treatment of residues (11, 12, 13, 14))

To develope treatment practices and management options for waste incineration residues it is necessary to thorougly consider the physical and chemical characteristics of the materia. Those residues are heterogenious materials, whose properties vary over time in response to waste feed as well as plant design and operating conditions of incinerator and air emission control equipment. In general the ash residues from a waste incineration plant amounts to about 15-35 % of the weight of the waste fed. Bottom ash (slag) is the dominating part, accounting for 80-95 % of the total solid residues. That means about 150-300 kg per ton waste.Typical ranges of gas cleaning residues produced per ton of feeded waste are 20-50 kg (dry process, including fly ash), 15-40 kg (semi-dry process including fly ash) and 1-3 kg (wet condensing process excusive of the fly ash). The amount of fly ash precollected in the wet condensing process is 10-30 kg/ton waste. Wet condensing processes also produce 0,3-0,5 m3 of saline wastewater per ton waste.

To meet the requirements on proper treatment of the residues various treatment methods are beeing considered and several equipment manufacturers in Europe are currently developing methods and systems to meet the requirements. There are several commercial ash treatment plants in operation or under construction and many examples on test and demonstration projects. The methods and systems of interest are in different levels of technical development and validation. A few methods can be viewed as nearly established technologies but as to the rest there are still a considerable amount of improvement work to be done. The efficiency of the different methods are questioned and has to be confirmed, especially when speaking about the long term liability of deposited treated residues. Anyhow there are methods promising a long term stable and harmless product, which sets aside the need of controlled deposition and opens up for reuse.

An obvious problem with most of the ash treatment methods is the very high investment and operation costs. Added to the heavy economic burden of very strict gas emission control these costs can turn aside the construction of urgent new incineration plants in favour of landfilling or other inferior waste treatment alternatives. That should be an impelling force for the development of cheaper ash treatment and gas cleaning alternatives. Here we face an important challange for the manufacturers and contractors. In my opinion, deposition in landfills or longterm storage (for instance in German salt mines) should be accepted as an alternative to advanced treatment practices if the storage site conditions can meet strict requirements.

The available treatment processes under development and implementation can be classified as follows:

- Separation
- Stabilization
- Solidification
- Thermal treatment

The most widespread form of separation in Europe, in commercial operation since the early eighties, is the screening and sorting of bottom ashes for the recycling of metals, especially ferrous, and the use of the screened ash in construction. This has been done to varying degrees for many years in different countries.

Ash stabilization and solidification are often combined. The dominant solidification agent is cement, often a tailor-made compound. Removal of soluble salts such as calcium chloride before stabilization and solidification is sometimes necessary to meet longterm stability requirements.. A promising process for stabilization without solidification seems to be adding soluble phosphates, which form low solubility phosphate minerals.

Thermal treatment involves melting or sintering of the residues at high temperatures of 1200 to 1500 °C to transform the ash into a harmless and very stable glass (vitrification). Dioxins and other organic compounds are also destroyed. Thermal treatment is the most expensive of the actual methods involving high energy consumption and exotic technology. The need of further development is obvious.

Liquid discharges from wet scrubbers have been traditionally discharged to the sewers after treatment and that is still the case for some plants. But, there is increasing pressure to eliminate such discharges. One possibility is to use dry or semidry scrubbers. In Germany, there is the general opinion that these methods are not able to comply with the strict requirements on acids. Another method put into practice in Germany, is vaporization of the csrubber blow-down to make the plant a zero-discharge facility. Filter cakes from wet scrubbing systems are normally disposed of in special landfills.

Utilisation of residues (11, 12, 13)
The bottom ash has been utilised in some countries in Europe for more than 20 years for civil engineering purposes, particularly as subbase at parking lots, bicycling paths and residential as well as major roads (paved and unpaved). As a subbase material, the bottom ash usually substitutes gravel, which is a limited resource in many countries in Europe. Therefore, there is an incentive for utilization of bottom ash from a natural resource conservation as well as an economic point of view. An important limiting factor for recycling of residues from waste incineration is the difficulties to guaranty an acceptable longterm quality of the utilized residues and a low longterm impact on the environment.

In Germany, France, the Netherlands, Denmark and Schwitzerland a considerable part of the produced slags and minor parts of the fly ash are recycled, **table 5** . Other countries report lower levels of recycling of different reasons.

Raw slag from a waste incineration plant can normally not be utilized without treatment. Two treatment steps are in general required:

- Storage of the wet slag (maturing process, normally a formal requirement).
- Mechanical treatment - especially sieving and multistage magnetic separation, which sometrimes may be followed by a washing step.

The quenching of bottom ash in water involves some negative effects for recycling since several metals are oxidized and the iron scrap contaminated by calciumproducts. Methods for dry discharge has been introduced in Europe in order to eliminate these disadvantages.

The data on treatment practices and utilization options for slags available in different reports are often very difficult to compare and evaluate because of the discrepancies. The reason to that is the different sampling and analythical methods, misinterpretation of reported data and other mistakes.

A typical result of the treatment of waste incineration slags in Europe is as follows (weight percent):

- 80-85 % secondary construction material
- 10 % secondary raw material, mainly ferrous metal
- 5-10 % coarce fraction for disposal or returned to processing

The fly ash and other gas cleaning products are of less interest as construction materials, mainly due to the higher contents of toxic inorganic (heavy metals) and organic (dioxins and furanes) compounds or water soluble salts. These residues can be utilized only after further conditioning or more sophisticated treatment. In the Netherlands fly ash is used as aggregate in asphalt and concrete. An interesting possibility practiced in Germany, requiring less treatment, is the use of such residues to fill underground salt mines. The extraction of high graded hydrochloric acid, gypsum etc for recycling is so far of less importance in Europe.

CONCLUSIONS

There is no doubt that the turbulence around the very restrictive requirements on waste incineration in Europe has given rise to impressive technical and operational progress. The operators have been much more target-directed and the contractors and manufacturers have met the increased demand for advanced equipment and methods. Waste incinerators complying with the new, strict emission standards are close to the zero-level of emissions. The rapid progress confirms that a drastic change in conditions sometimes is a driving force for the development.

The problem is that the costs associated with the measures have exploded. The new strict standards have in general been adopted politically with inadequate consequence conciderations. They are obviously not based on a scientific risk assessment concerning the impact on the human health and the environment. The environmental gains compared to the additional costs and operation difficulties have not been satisfactorily analyzed. That is of coarse a very serious consequence since there is an evident risk of mismanagement of society´s resources and the environment. Waste incineration runs the risk of beeing replaced by other, less favourable waste treatment methods not because it is bad, but because it costs too much to comply with the low benefit regulations.

It must be admitted that risk assessment in this case is difficult because of a lack of basic knowledge. The stringent requirements can be justified politically as being a precautionary measure. Today we have reached the level of knowledge and experience where we should try to define the point of reasonable emission levels and the prudent cost/benefit ratios for the emission control. That gives the opportunity to issue reasonable standards and offer the market stable long-term conditions.

The approach on waste incineration in Europe, not to say worldwide, seems to be based on the belief among the political decision makers that waste incineration is an extremely harmful **destruction** method, which must be hedged by very rigorous restrictions compared with most other activities in the society. The created atmosphere has a strong influence on public opinion and strengthens the negative attitude. The specific requirements on waste incineration stresses the public opinion that waste incinerators are very harmful. For the just acceptance of waste incineration and therefrom following fair requirements, it is in my opinion of utmost importance that the method be widely recognised as the environmentally friendly **energy production method** it really is.

It is possible that the future may bring such a changed attitude. The search for new energy sources, based on renewable fuels, is one possibility. Municipal and industrial wastes are to a large degree biofuels, which can reduce the need of fossile fuels. A broader adoption of the energy-from-waste concept is hopefully the key to a revised, more positive approach to waste incineration in Europe. Looking at the situation in the Nordic countries, where waste incinerators have been synonymous with energy production for many years gives at least a small hope for such an alteration in public attitude. Another balancing pressure is a better understanding of the problem with landfills, as beeing resource destructive and long-term risks to human health and the environment. The new waste management legislation under implementation in many countries bans deposition of waste without pretreatment, which opens up the arena for incineration.

Based on facts, the prospects for waste incineration with energy recovery should be very favourable.

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Table 1. European emission standards for waste incinerators

Pollutant (mg/m3)	Sweden 1986 1)	Germany 1986	Germany 1990 2)	EC 1989 3)	the Netherlands 1989 4)	EC (draft dir.) 1994 5)	 1994 5)
HCl	100	50	10	50	10	10	60
HF	-	2	1	2	1	1	4
SO2	-	100	50	300	40	50	200
NO2	-	500	200	-	70	200	400
TOC	-	20	10	20	10	10	20
CO	100	100	50	100	50	50	100
Dust	20	30	10	30	5	10	30
Cd + Hg	Hg=0.08(0.03)	0.2	0.05+0.05	0.2	0.05+0.05	0.05+0.05	0.05+0.05
PCDD+PCDF (ngTEQ/m3)	0.1	-	0.1	-	0.1	0.1	0.1
Related to dry gas	10%CO2	11%O2	11%O2	11%O2	11%O2	11%O2	11%O2
Sample average (with some exceptions)	1 month	24 hours	24 hours	1 month	1 hour	24 hour	0.5 hour

1) According to ENA 1986. Sweden has later adapted the EC Directive of 1989 regarding stricter requirements.
2) According to17. Decree to BlmSchG, Dec 1, 1990.
3) According to Directives 89/369 and 89/429, Dec 1, 1990.
4) According to BLA, Aug 15, 1990.
5) According to Draft Directive Incineration of waste, Aug.1994 (GH016).

Table 2. Comparison of European and American Standards (converted into European equivalents)

Pollutant mg/m3	European standard EEC draft Directive	American Standard	American State Standards
HCl	10	28 or 95 % removal	28 or 95 % removal
HF	1	-	2
SO2	50	61 or 80 % removal	61 or 85 % removal
NO2	200	219	205
NH3	10	-	11
TOC	10	-	15
CO	50	175	79
Dust	10	17	17
Cd	0.05	0.026	
Hg	0.05	0.10 or 85 % removal	
PCDD + PCDF (ng TEQ/m3)	0.1	(0.13)	

Table 3. Total reduction of air emissions from the Swedish waste incinerators 1985-1994

Pollutant		1985	1994	Reduction
HCl	ton/year	8400	290	96 %
SO2	ton/year	3400	820	76 %
NO2	ton/year	3400	1600	53 %
Dust	ton/year	420	40	90 %
Hg	kg/year	3300	100	97 %
Cd	kg/year	400	15	96 %
Pb	kg/year	25000	300	99 %
PCDD + PCDF	g/year	90	2	98 %
Basic data				Increase
Number of plants		21	21	
Waste load	Mton/year	1.53	1.68	10%
Energy prod.	TWh/year	3.4	4.3	25%

Table 4. German standards and outlines for deposition and utilization of slags.

Compound	Unit	Deposition by TA Siedlungsabfall Class 1	Deposition by TA Siedlungsabfall Class 2	Utilization LAGA Merkblatt
Unburnt, organic				
LOI	weight %	3	5	3
TOC	weight %	1	3	1
Elutant by DIN 38414				
pH		5.5-13	5.5-13	7-13
TOC	mg/kg	200	1000	-
Pb	mg/kg	2	10	1
Cd	mg/kg	0.5	1	0.05
Cr(6)	mg/kg	0.5	1	0.5
Cu	mg/kg	10	50	5
Ni	mg/kg	2	10	0.4
Hg	mg/kg	0.05	0.2	0.01
Zn	mg/kg	20	50	3
Cloride	mg/kg	-	-	2500
Nitrate	mg/kg	-	-	5000

Table 5. Utilisation of bottom ash in some European countries

Country	Amount utilized	Applications
Germany	About 50 % or 1.5 Mtons/year 1)	Road construction (ptimarily as granular base).
France	About 50 % or 1.2 Mtons/year	Road construction
the Netherlands	About 90 % or 1 Mtons/year	Road construction, embankments, noise and wind barriers. Aggregate in asphalt and concrete
Denmark	About 90 % or 0.4 Mtons/year	Construction works (roads, parking lots, bicycle roads etc)
Sweden	Limited, under developement	Construction works (roads, parking lots, etc)

1) 1 M ton = 1,000,000 kg

Incineration of Municipal Waste and Measures against Dioxin in Japan

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Introduction

It was in 1983 that dioxin was detected from fly ash emitted from municipal solid waste(MSW) incinerators in Japan. Since then, the Ministry of Health and Welfare has executed numerous researches on the generation mechanism and control of dioxin. Based upon the results of the researches, the Ministry entrusted a group of experts to conduct a study on measures to be taken against dioxin, and finally issued "the Guidelines for the Prevention of Dioxin Generation from MSW Incinerators" in December 1990.In June 1996,"The Conference for examining the measures to reduce dioxin in connection with waste disposal" was established ; and in January 1997,the Guidelines was amended

The present situation of MSW management in Japan

(1) Measures currently implemented in Japan

In Japan, we are reducing the volume of waste and promoting recycling along with incineration of combustible waste; in addition, we are promoting "recyclic treatment of waste " which involves the use of heat generated from incineration.

The Ministry of Health and Welfare has been pursuing an initiative through a project which subsidizes the waste disposal facilities established by municipalities with public funds. In 1994, the project for creating a recyclid waste treatment infrastructure was started, in order to subsidize incineration facilities, which supply other facilities with electric power by power generators of their own, as well as RDF (refuse derived fuel) facilities and facilities related to recycling.

In "The 5-year Plan for Establishing Waste Disposal Facilities(8th)" started in 1996, the target for project by the year 2000 is given based on the assumption that the annual growth rate of waste volume per capita is 0.5%.

Moreover, under the Law for Promotion of Separate Collection and Recycling of Containers and Packages that will actually come into force in April 1997, recycling of containers and packages, which accounts for about 60% of the total volume of municipal waste, will be promoted by classifying the role of individuals as follows: (1) Consumers shall cooperate with separate collection of MSW; (2) Municipalities shall collect containers and packages by type; and (3)

Enterprises shall recycle containers and packages collected by municipalities by themselves or subcontract such operations to designated recycling corporations.

(2) Volume of waste and the situations of waste disposal

The total volume of municipal waste was 50.3 million tons in a year (up 0.2% from the previous year) and the daily volume of waste per capita was 1,103 g, both of which have leveled off in the last few years, as shown in Fig. 1.

The rate of intermediate treatment, which accounted for 85.6%(Fig.2), has been increasing steadily year by year. This shows that as the waste treatment facilities have been established, intermediate treatment has been actively implemented. On the other hand, the volume of waste directly landfilled was 7.12 million tons, accounting for 14.4%, which decreased from the previous year(Fig.3).

The volume of recycled waste through separate collection in each municipality totaled 2.2 million tons, showing an increase from the previous year. The volume of recycable waste collected by local residents' organizations was 1.92 million tons. Fig. 4 shows the rate of recycling through resource recovery and group collection in each municipality was 8.0%, increasing year by year.

(3) Waste disposal facilities

As Fig. 5 shows, the number of incineration facilities in 1993 was 1,854, remaining at the same level over the past few years. Table 1 shows a change in the number of facilities according to the type of incinerator. There were 433 continuous type incinerators, 324 semi-continuous type incinerators, 866 mechanical-grate batch type incinerators, and 231 fixed-grate batch type incinerators. Those numbers have hardly changed over the past few years.

There were 2,321 final disposal facilities with residual volume at 149.31 million m^3, showing a tendency to decrease(Fig.6).

In order to obtain understanding and cooperation from residents, it is essential to carry out any assessment. In a growing number of cases, it has become necessary to improve the environment around disposal facilities as well as facilities themselves.

Forming part of such efforts is the building of parks and green zones, swimming pools utilizing heat generated by incineration plants, tropical plant gardens, welfare for the elderly, rehabilitation facilities and city halls and supply of hot water and area-wide air conditioning.

(4) Significance of incineration as a method of intermediate disposal

The basic rule in waste disposal is to reduce waste through resource recovery and recycling, then treat waste with considerations for sanitary and environmental preservation. Since Japan is narrow country, it is difficult to keep sufficient landfill sites, it is common practice in Japan to incinerate waste then conduct final disposal with environmental considerations. Intermediate disposal is an effective and important process where waste can be reduced in terms of weight and volume, stabilized and made harmless. In particular, waste in terms of weight can be reduced to about 1/6 or 1/7 through incineration, thereby contributing significantly to environmental preservation in our daily life. Therefore, about 3/4 of the total waste is currently disposed through incineration.

(5)Use of heat from waste incineration

Heat generated by waste incineration plants is used in various ways; power generation, air conditioning and hot water supply, hot water swimming pools, hot water and energy supply to social welfare facilities like facilities for elderly, and energy supply to local air conditioning. Surplus heat is most widely used for air conditioning and water supply to facilities.

Waste power generation is an effective way of using surplus generated by waste incineration plants. Under the system, thermal energy from high-temperature exhaust gas generated from waste incineration is collected by boilers, which generate steam to rotate facilities.

It is at Nishiyodo Plant of Osaka City in 1965 that surplus heat was first used for power generation. The national government has since promoted power generation by surplus heat. For example, it has extended subsidies to local governments which have built facilities to use surplus heat when they built new waste incineration plants or renewed existing plants.

As of the end of fiscal 1994, power was produced at 135 waste incineration plants. Total power generation capacity stood at some 450,000 kW, equivalent to the power consumption of about 1.2 million households or Yokohama City. Moreover,50 to 60 incineration plants sell excess power to electric power companies, accounting for 40% of the plants with power generation(Fig. 7 and Fig.8)

Guidelines for preventing dioxin generation in MSW treatment

(1) Background

There seems to be diverse sources of dioxin (and the like), as it is generated during combustion of materials. In Japan, the volume of dioxin generated at incineration facilities accounts for 80% to 90% of total dioxin. Therefore, it is imperative that dioxin generated at incineration facilities be reduced.

The Ministry of Health and Welfare set out "Guidelines for preventing dioxin generation" (hereinafter referred to as "Old Guidelines") in 1990 to guide local governments. In response to a suggestion from the public welfare study group to use 10pg-TEQ/kg/day instead of TDI currently used, "The Conference for examining the measures to reduce dioxin in connection with waste disposal" was established in June 1996; and in January 1997, "Guidelines for preventing dioxin generation in connection with municipal waste disposal" (hereinafter referred to as "New Guidelines") were established.

(2) The salient points of the guidelines

New Guidelines, not only to reduce generated dioxin but also to prevent the generation itself as much as possible, aim at adopting the best available technology to prevent adverse effects on our health. In order to reduce dioxin at MSW incinerators established by municipalities, the New Guidelines require the following measures:

[1] Promotion of recycling and Reduction of waste. It is important to reduce the amount of waste to be incinerated by restricting waste discharge and promoting recycling.

[2] Measures adopted against emitted gas.

(i) New incinerators. Incinerators which will be constructed in the future, in principle, must be continuous type incinerators. By setting the standard of dioxin density at 0.1ng-TEQ/Nm^3, which is at the same level as western developed countries, the New Guidelines show some measures to achieve this standard.

The measures include homogenization of waste content, stabilization of operation load, good combustion practice, low temperature at the entrance of dust collectors, and exhaust gas disposal using advanced technology such as activated carbon absorption.

(ii) Existing incinerators. Measures will be adopted at the following two stages:

○ From the viewpoints of adverse effects on human health, the standard for judging whether emergency measures are necessary or not is given as 80ng-TEQ/Nm^3, based on TDI at 10pg-TEQ/kg/day. Emergency measures should be implemented immediately at the facilities where the emission density exceeds 80ng-TEQ/Nm^3. The measures include appropriate combustion management, changing from intermittent operation to continuous operation, improvement of facilities (such as changing from electric precipitators to fabric filter dust collectors), and suspension of operations or closure of facilities.

○ From the viewpoint of adopting the best available technology, even when the emission density is less than 80ng-TEQ/Nm^3, permanent measures will be adopted systematically, with an aim towards achieving the following standards through the similar measures adopted for new incinerators. Under the Old Guidelines standards for existing incinerators are: 0.5ng-TEQ/Nm^3 for continuous type incinerators, 1ng-TEQ/Nm^3 for semi-continuous type incinerators, and 5ng-TEQ/Nm^3 for intermittent operation incinerators.

[3] **Broader-based waste disposal.** As combustion in small-scale intermittent running incinerators is unstable, it is difficult to adopt measures against dioxin. Therefore, neighboring municipalities work in cooperation to put them together for combustion in large-scaled continuous type incinerators. In order to actualize this, each local government will establish the broader-based project for waste disposal; and based on the project, each municipality will promote broader-based waste disposal regardless of the municipal boundaries.

[4] Disposal of bottom ash and fly ash. In order to reduce dioxin from bottom ash and fly ash, the decomposition treatment, such as melting solidification method, should be promoted.

[5] Measures adopted at landfill sites. The measures, such as soil capping, and reduction of the SS of leachate from disposal facilities, will be implemented at final disposal facilities in order to prevent scattering of bottom ash and fly ash which may contain dioxin.

[6] Follow-up measures. In order to steadily, promote above-mentioned measures it is indispensable to adopt follow-up measures as well. In each municipality, density of dioxin generated at incineration facilities must be measured on a regular basis (once a year in principle), the results of the measurement must be announced publicly, and the measures adopt must be constantly reviewed.

The Ministry of Health and Welfare will provide guidance to local governments in promoting the measures to be adopted against dioxin based on the New Guidelines.

Measures adopted against dioxin, and waste disposal system in the future

(1) Broader-based waste disposal

Each municipality has responsibility for municipal waste disposal. Therefore, in general, disposal of waste was performed within each jurisdiction. However, due to the transition to recyclic waste treatment and the advanced technology in waste disposal, it is also necessary to discuss the broader-based waste disposal. In particular, in local areas, when pursuing the following measures such as (1) the promotion of recycling, (2) the promotion of incineration and the maximum utilization of the residual heat, and (3) the implementation of measures against dioxin.

In short, we are now entering a period of revolution of the waste disposal system. Therefore, as shown in Fig. 9, measures adopted against dioxin are closely related to the waste disposal system as a whole in the future.

(i) Promotion of recycling. Compared to the current situation where facilities are located in different areas, a broader-based system will facilitate recycling, as recyclable material can be collected at one place. This leads to a reduction in the volume of waste to be incinerated. Moreover, based on the Law for promotion of recycling of containers and packages, collection by type will be actively implemented; thus, it would be possible to recycle containers and packages on a broader basis.

(ii) Promotion of incineration and the maximum utilization of the residual heat. Combustible waste excluding material recycle waste should be incinerated as much as possible, thereby reducing the volume of waste for final disposal. The utilization of the residual heat results in the continuous operation of incinerators; in addition, thermal recycling enhances the conservation of primary fuel. This will eventually reduce the generation of greenhouse gases.

(iii) Measures adopted against dioxin. The New Guidelines state that incineration facilities, which will be constructed in the future, must be continuous type incinerators to reduce the quantity of dioxin. In order to employ continuous type incinerators, a certain volume of waste, in other words, a certain scale of population is required. Therefore, in a sparsely populated area, a broader-based system is necessary.

(2) Considerations for broader-based waste disposal

When broader-based waste disposal is carried out, a high cost as well as the measures beyond municipal boundaries will be often required. Therefore, each municipality must include the measures against dioxin in their respective waste disposal projects, adjust the measures between neighboring municipalities, and promote broader-based efforts toward systematically solving dioxin problems. For a well-balanced broader-based waste disposal, prefectural governments are required to adjust the measures between municipalities.

When examining broader-based waste disposal, it is necessary to consider the following matters: a scale for the broader-based waste disposal, timing for implementation, selection of a site where incineration facilities will be established, a combination with other facilities, preparation of various elements for implementation, effects of broader-based waste disposal and evaluation, and the methods for implementation.

(3) Broader-based waste disposal using RDF

When waste is disposed as proper RDF, it has a more stabilized quality than waste itself, thereby facilitating combustion control. Moreover, as RDF can be stored in a stable form over a relatively long period, RDF produced at each RDF facility can be collected at one place, used as fuel, and incinerated.

Therefore, because of these characteristics, the introduction of RDF facilities is highly recommended in the following cases:
(i) The case in which the transportation of waste is problematic since incineration facilities are located far away as a result of broader-based waste disposal;
(ii) The case in which the geographically condition make the implementation of broader-based incineration unfeasible (such as a solitary island); and
(iii) The case in which the utilization of RDF is widely promoted.

(4) Follow-up measures

In order to implement the above-mentioned measures steadily, follow-up measures must be adopted on a continuous basis. For this purpose, municipalities and prefectural governments must make concerted efforts; as a nation, it is necessary to review the state subsidy for waste disposal facilities with focusing on recycling, broader-based waste disposal, and disposal employing advanced technology.

Conclusion

In 1996, total discharge of dioxin from municipal waste incinerators is estimated about 4300g-TEQ/year. By taking measures against existing incinerators, constructing new full-continuous type incinerators, putting small-scaled facilities together, introducing RDF plants ,etc. It is possible to reduce most of discharge as Fig.10. Since it is said that discharge of dioxin from municipal waste incinerators occupies 80~90% of total, we expect that total concentration of dioxin in environment and our daily intake of dioxin will be greatly reduced.

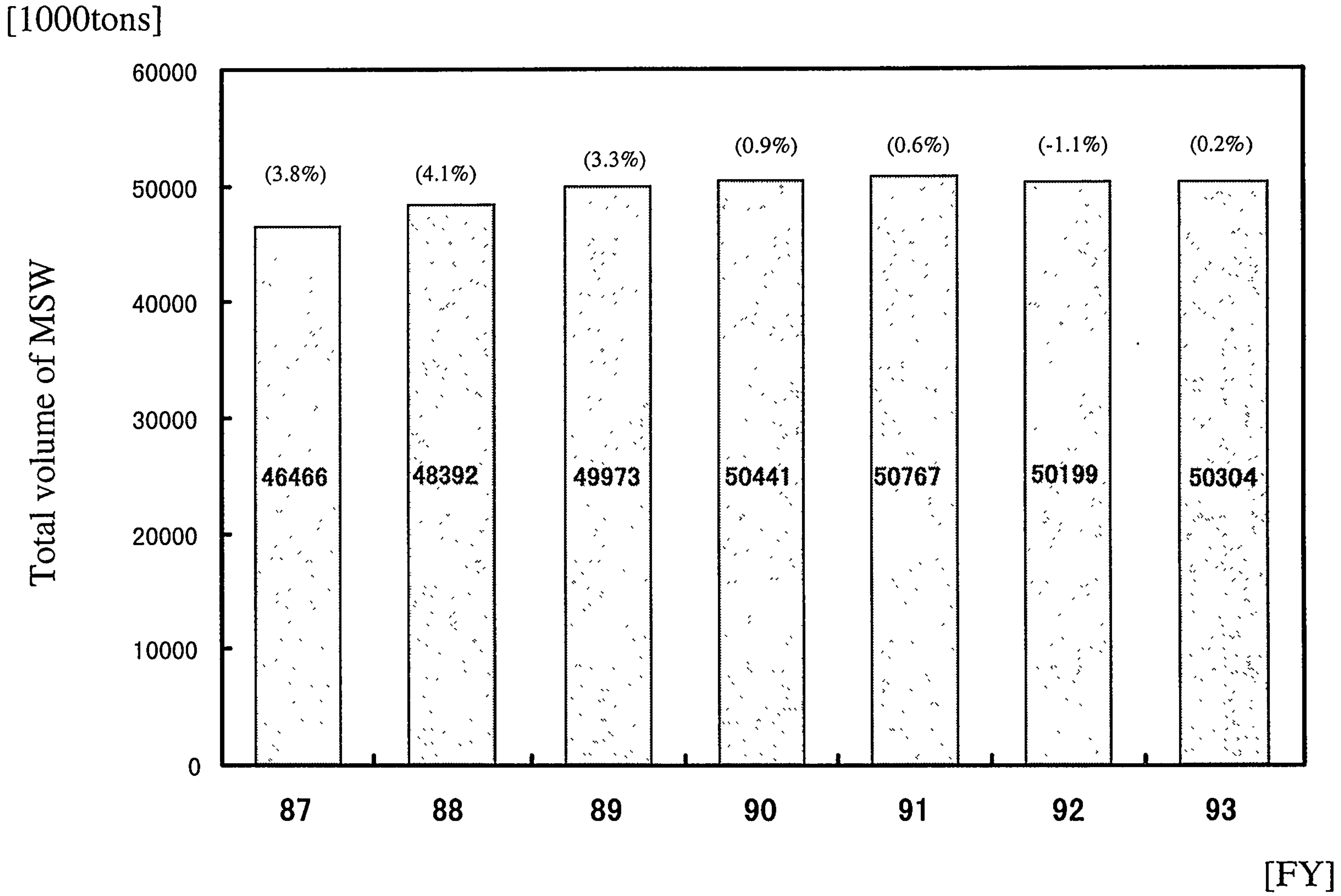


Figure 1. Change in total volume of MSW

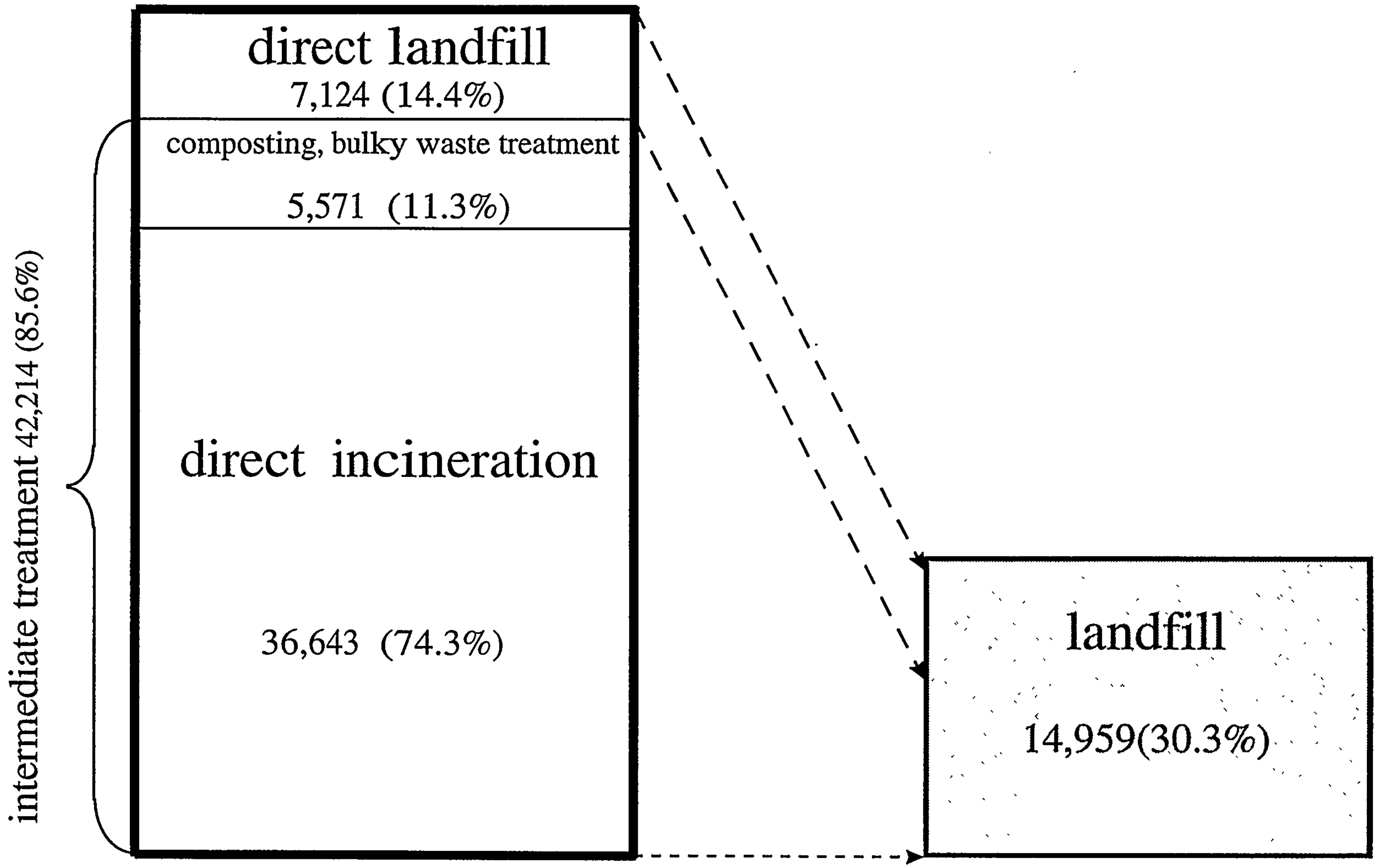


Figure 2. Situation of MSW treatment (FY1993)

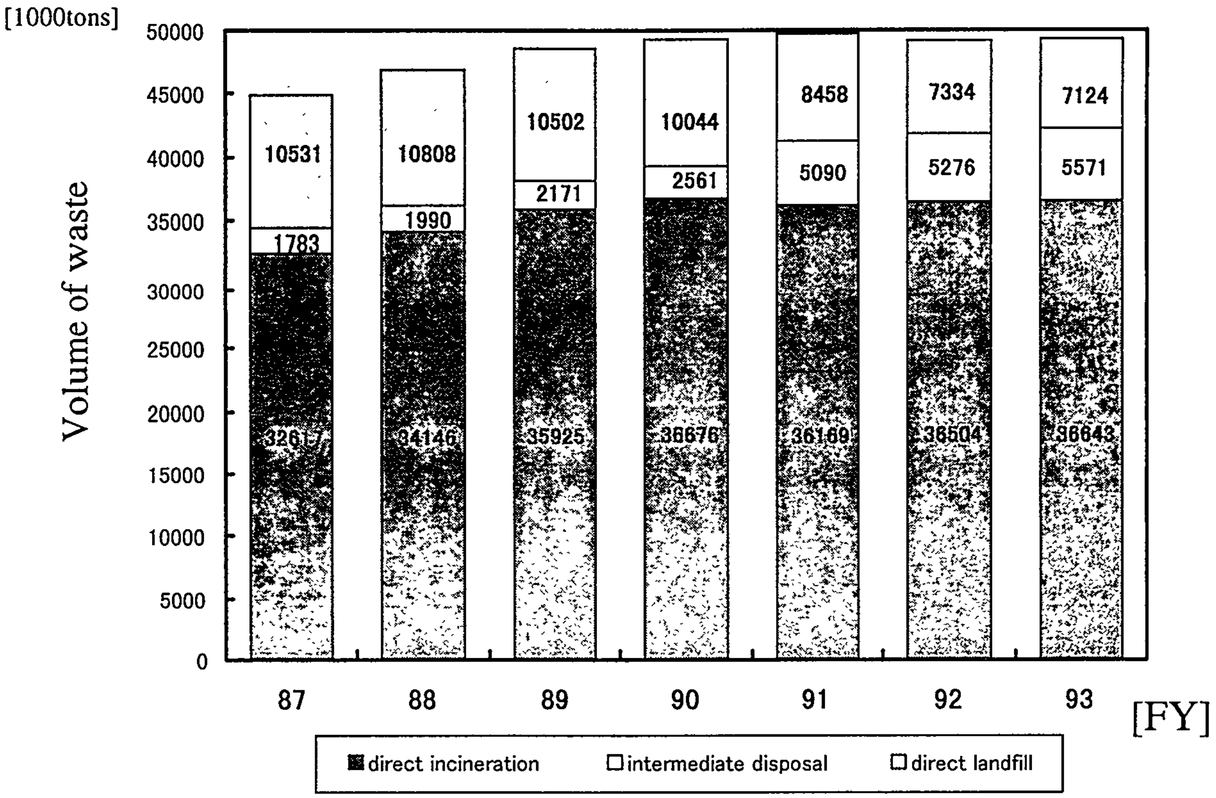


Figure 3. Change in method of waste treatment

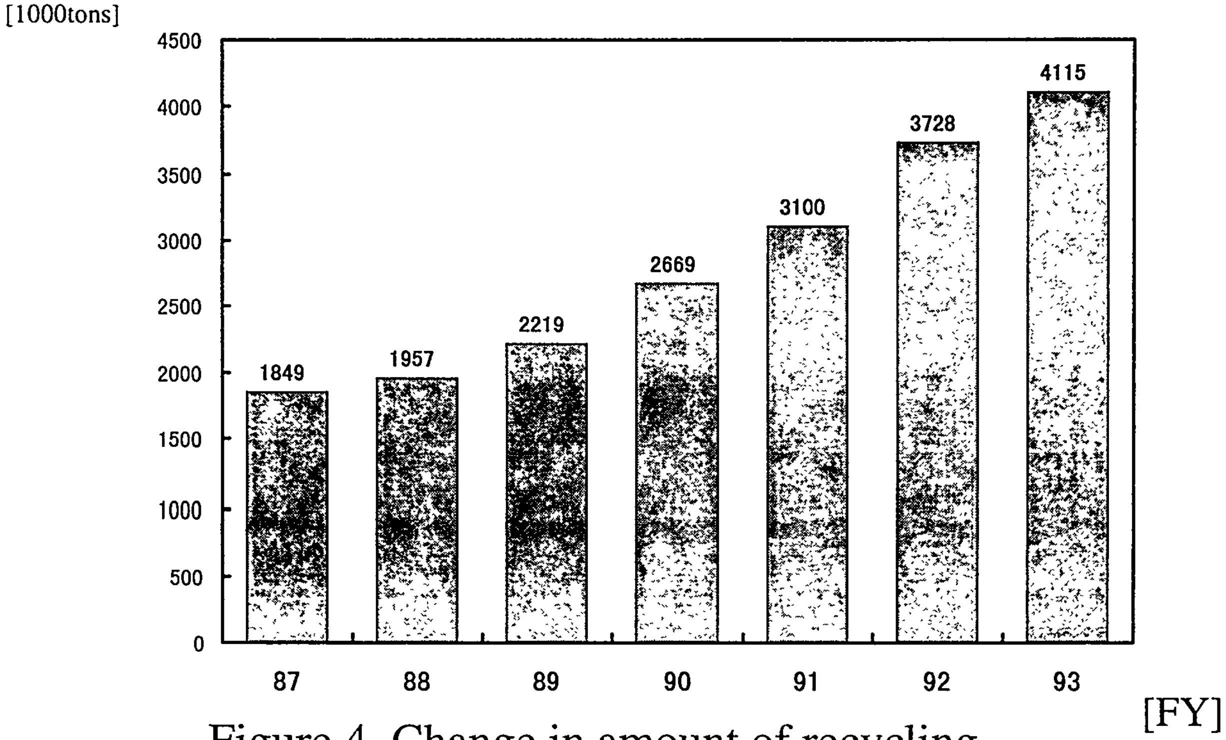


Figure 4. Change in amount of recycling

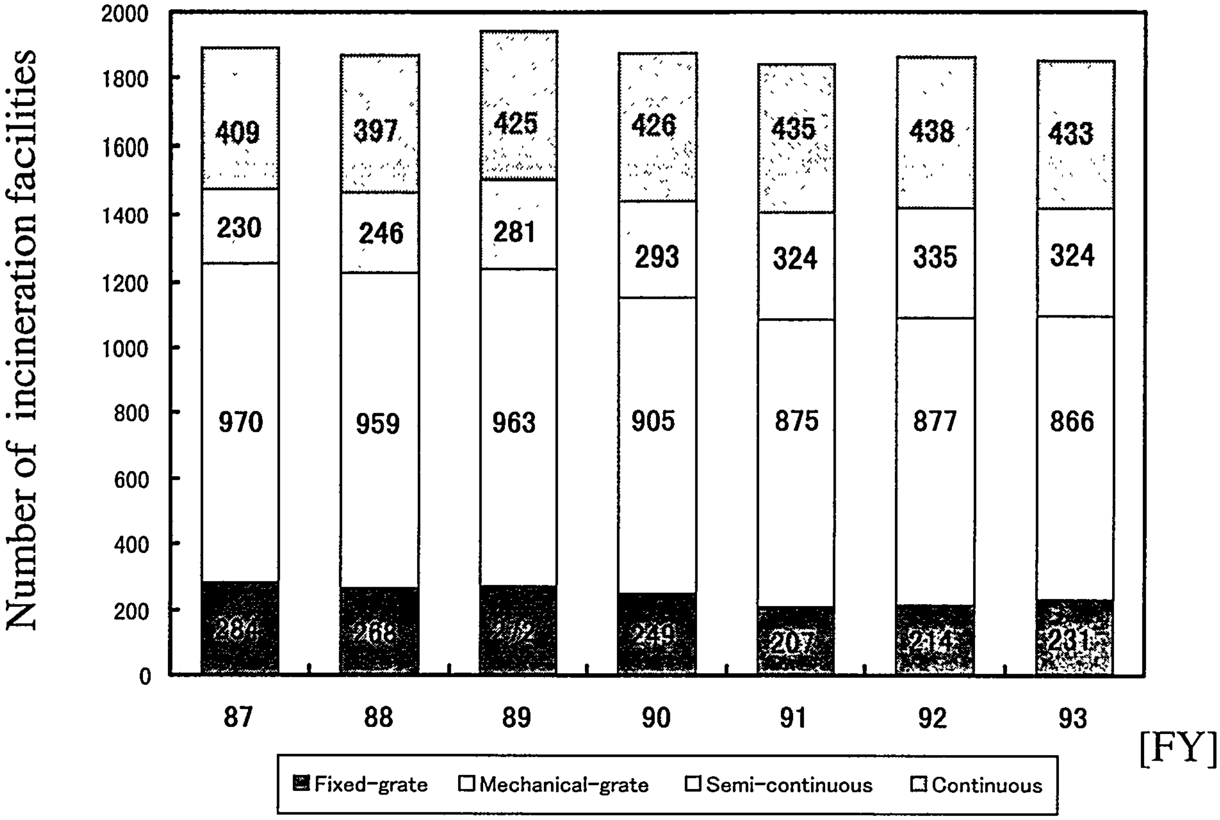


Figure 5. Change in number of incineration facilities

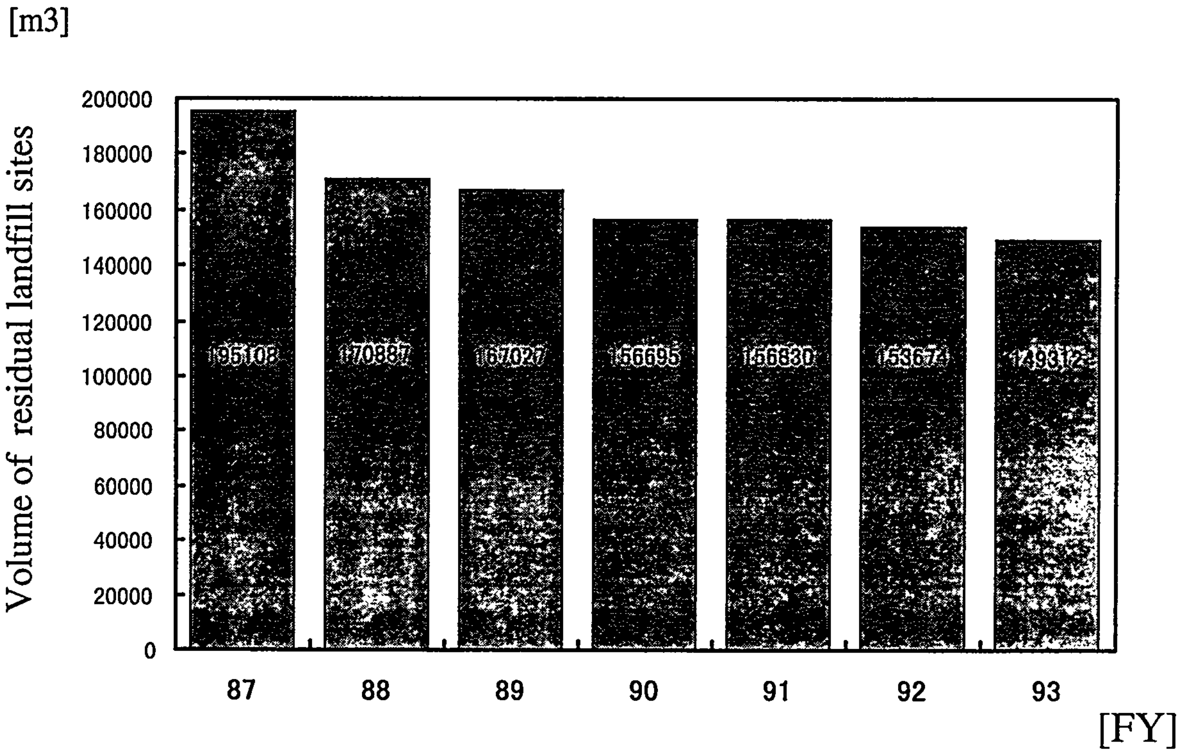


Figure6. Change in residual volume of landfill sites

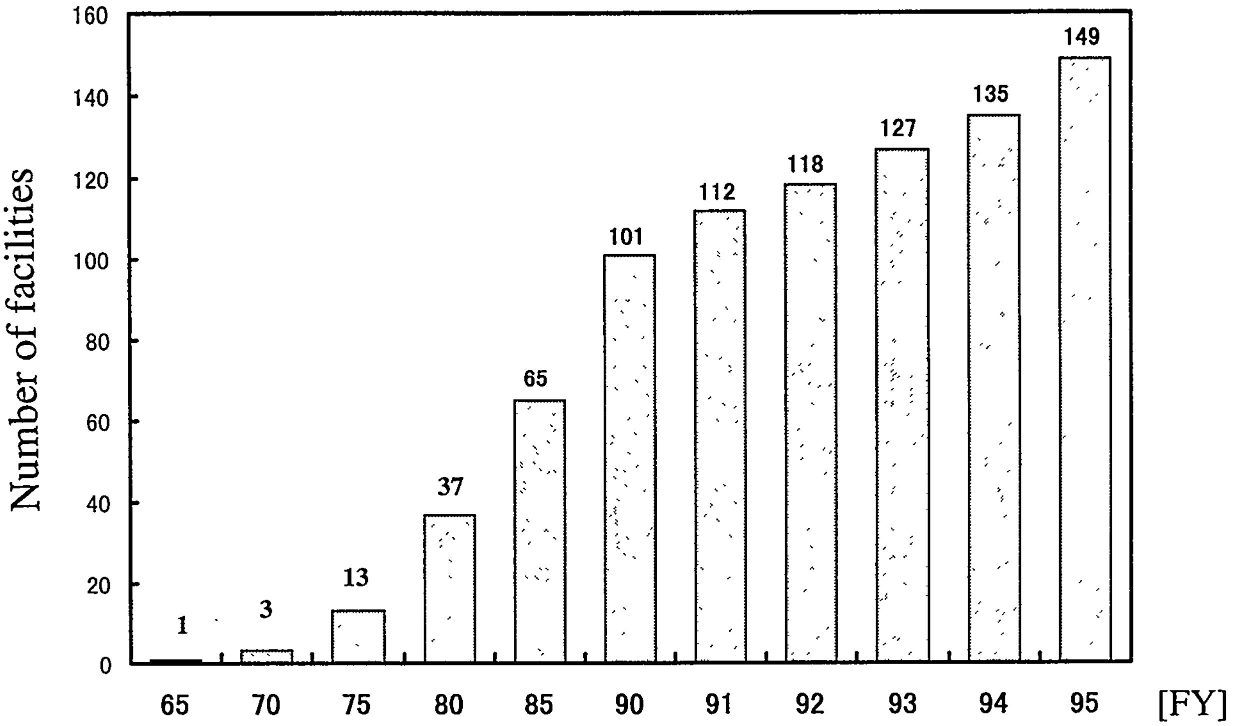


Figure 7. Change in number of facilities with Power Generation Equipment

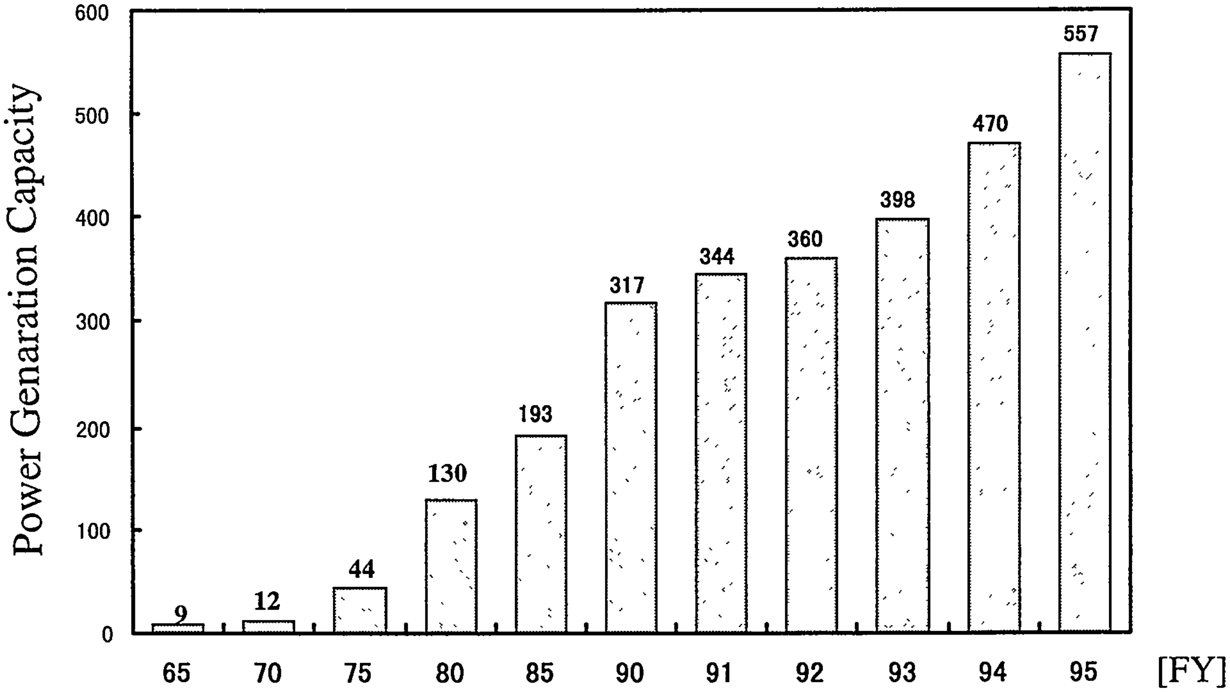
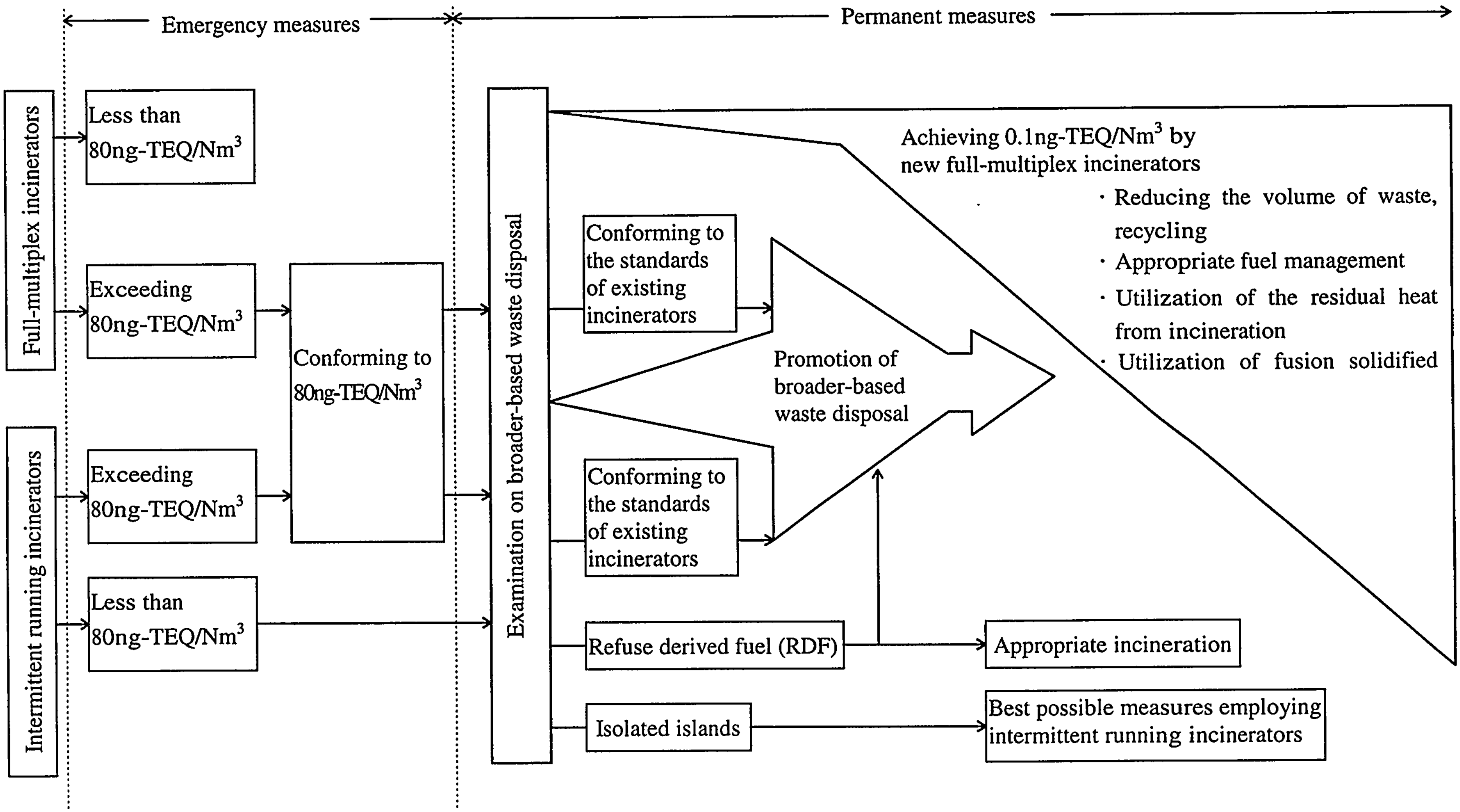


Figure 8. Change in Power Generation Capacity of waste incineration facilities

Fig. 9 Waste disposal system in the future (Promotion of measures to be adopted against dioxin at incineration facilities)



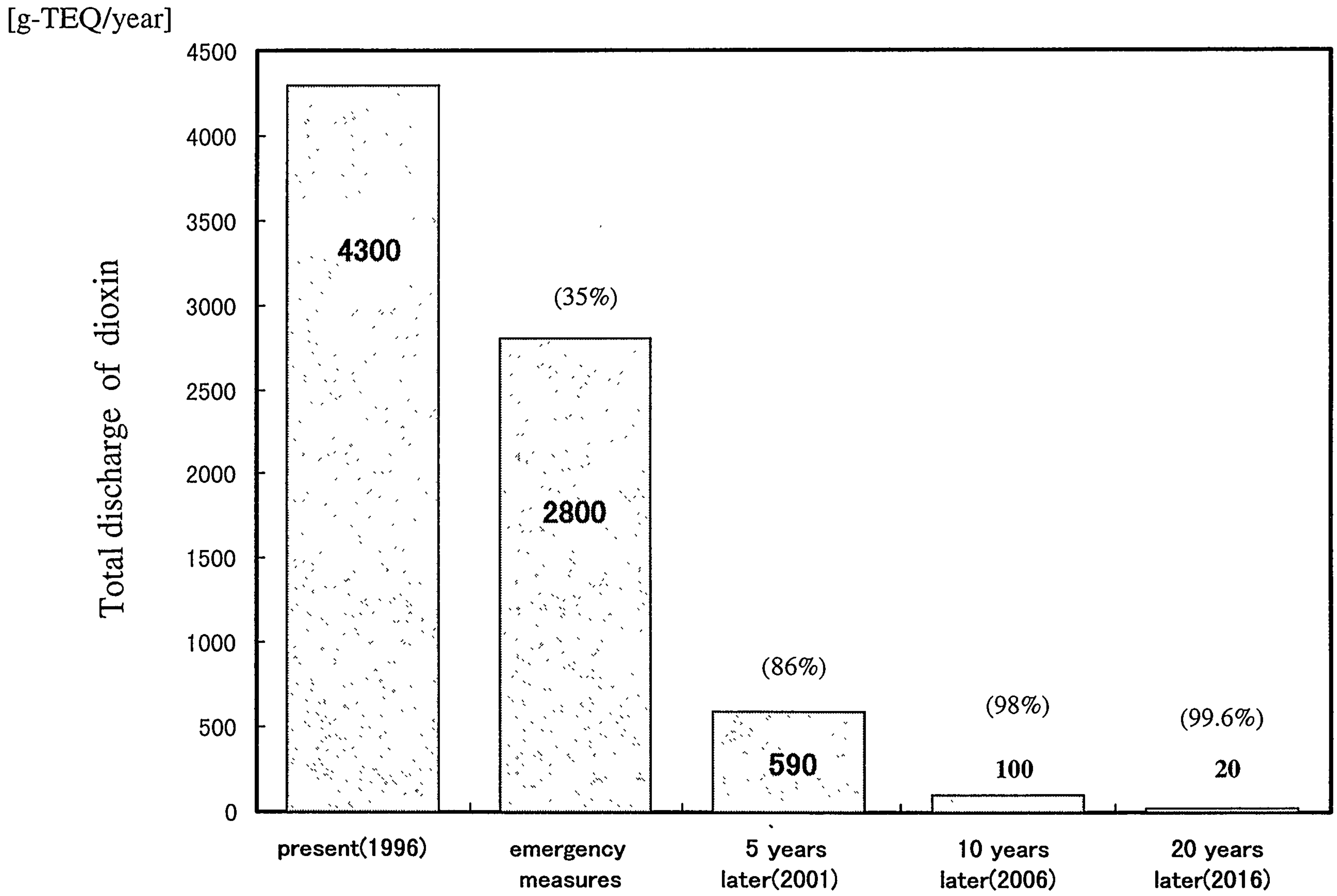


Figure 10. Total discharge and reduction rate of dioxin

TECHNICAL SESSION II

Emerging Issues & Technologies

How Big Should a New Energy Recovery Facility Be?

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INTRODUCTION

Careful attention must be paid to characterizing the municipal waste stream, both now and in the future, if the capacity (size) of waste management facilities are to be optimized for economic and environmental benefits. This is particularly important for municipal waste combustion facilities where significant capital expenditures are required before any waste can be handled. Too large a facility can bring undue financial strain; too small a facility will create a need for more landfill capacity reducing the potential benefits of energy recovery and increasing the long-term release of methane, a potent greenhouse gas, from these materials.

Modern waste management systems seek to obtain a least cost solution while maintaining environmental objectives. To meet these requirements, modern systems include elements of reduction; diversion through recycling or reuse; and disposal, including energy recovery and landfilling. The exact proportion of materials handled by each of these alternatives is a function of the characteristics of a community's waste stream and the economics of applying the various alternatives. Managers need to evaluate the concerns of local citizens to arrive at the best solution for their community. More and more, these managers are coming to appreciate that waste is like any other commodity in our society—it creates a monetary dynamic that influences management decisions.

As more waste is generated, municipalities can move to modify the system by raising tipping fees or taxes, but this can have undesired effects. For example, several years ago Metropolitan Toronto increased landfill tipping fees for commercial users. In response, these users simply transported more waste to the United States. Local revenues dropped and the overall public cost of waste disposal increased because commercial revenues no longer offset comparatively expensive local recycling programs. In addition, the reduced rate of landfilling delayed closing of some landfills because materials were no longer available to complete the closure plan.

Other examples of unexpected results from interventions in waste management systems can be cited. The German "green-dot" system sought to separate consumer packaging from the waste stream by requiring that manufacturers deal with these materials. This did not reduce the cost to society—it merely shifted the point of payment. The "green-dot" system led to a glut of material on the recycling market. In October 1996, Germany enacted the Closed Cycle Economy Law. This law put material recycling and waste combustion with energy recovery on an equal footing. The recycling industries that grew over the past few years in response to the artificially created need to recycle materials irrespective of cost or true societal benefit may now face economic ruin as waste flows to the most cost effective management alternative.

Different waste management alternatives can also be selected to address environmental concerns, but these selections can also effect the ultimate mix of waste disposal options. For instance, European countries are moving towards limiting the level of carbon in waste deposited in landfills to minimize both future ground water pollution and greenhouse gas emissions. In turn, this is increasing the demand for waste combustion with energy recovery.

The suggestion that municipal waste combustion (MWC) with energy recovery might become part of a community's solid waste management system usually draws negative response. Some of the criticisms originate from genuine concerns about the effects such projects might have on the environment and human health. Other criticisms are based on the belief that incinerators, a major capital expense, will become a financial burden to an unwary community. Some even suggest that incineration will encourage a sense of complacency among those who should be striving to reduce the volume of the waste stream. Since the MWC must have enough fuel for economic operation, this last argument goes, MWCs discourage 3-R activities--reduction, reuse and recycling--by requiring all the available MSW to feed its insatiable appetite.

Many of these concerns have a basis in fact. Comparatively higher emissions characterized many older MWCs; however, state-of-the-art facilities now have such low emissions that conventional stack testing methods must be modified to even detect emitted compounds. Excessive costs characterize facilities built on unreasonable expectations (i.e., future waste growth, explosive energy price increases, or technically impossible performance). Creative analysis of the amount of waste that can be diverted through innovative 3-R initiatives are frequently used to support the theory that there is not enough material for all management options to co-exist. This argument falsely presumes that no prudent amount of MWC capacity can co-exist with 3-R activities in a given waste shed.

While most people would like to select the optimal set of waste management alternatives for their community, they are faced with the problem of determining the highest or best use of the materials in their waste stream. There are, unfortunately, no universally acceptable standards for making this decision. This evaluation uses a responsible and prudent guideline — build MWCs to handle what is likely to be left after application of the 3-R's — to reach the conclusion that MWCs and the 3-R's are compatible as long as the materials and resources which have a higher and better use are reduced, reused, or recycled instead of being recovered (incinerated at an energy recovery facility). This paradigm leads to the conclusion that it is certainly safe to build MWC capacity equal to half a waste shed's current disposal needs and it is probably justified to equal today's disposal requirements.

MUNICIPAL SOLID WASTE CHARACTERISTICS

The starting point for estimating future effects of various 3-R strategies is a comprehensive picture of today's waste stream. The amount and nature of solid waste generated in a community depends not only on population, season and business economic cycle, but also the demographics of the community. The 1991 Gore & Storrie study[1] of MSW composition and generation rates in different Ontario communities clearly shows these effects.

Not only is it necessary to know what is in the waste stream, but it is also necessary to know how much material is already being removed. Projections of waste and composition over the planning cycle must account for these factors, especially since they form the basis for evaluating management options. The potential effects of reduction, reuse and recycling initiatives must be combined with the future quantity estimates to establish the amount and characteristics of the residual (post 3-R) waste requiring management.

Composition

Most people associate MSW with the materials discarded directly by households. However, in actual practice, it also includes the employment related solid wastes discarded by industrial, commercial and institutional (ICI) sources. Such material resembles the residential waste stream because it contains newspapers and magazines, beverage cans, and food wastes. Process waste streams coming from industrial sources like foundry sand, prompt (in-house) steel making scrap and chemicals, etc. are not usually considered to be MSW. Construction and demolition debris (C&D) is MSW only in a very general sense, since the characteristics of the debris are so different from household wastes. Consistent with the pioneering work done by Bird and Hale[2] to characterize municipal discards in Canada, in this paper we consider only the residential and ICI wastes that would be targeted for reduction, reuse, recycling and, lastly, recovery.

Only limited field data exists for Ontario waste composition; there have been few published reports of detailed waste stream evaluations in Ontario after 1980. As a starting point in this evaluation, Ontario based data were modified using information from various other studies that characterized 3-R materials to account for changes that have occurred since the base data were gathered. Incidentally, since most of Canada and the United States share a generally common heritage and have many common expectations, the MSW streams are generally similar.

The Bird and Hale baseline data represents the composition of MSW in the late 1970s. Recognizing that changes in the economy and the use of different materials leads to a changing mix in the waste, it is necessary to adjust the 1980 figures for both effects. Using the sectorial generation rates from Franklin Associates[3], the 1980 levels were escalated to 1990. These were then adjusted using The WASTE Program[4] data, a sampling and analysis program undertaken in suburban Vancouver, British Columbia in 1991 which developed a comprehensive picture of waste received at an MWC. However, since The WASTE Program's data include the effect of Vancouver's successful blue-box program, this influence was factored out. Next, using the results of the year-long 1990 multi-borough sorting study in New York City[5], the Vancouver composition information was adjusted to reflect gross discard levels. The resulting estimated 1990 municipal solid waste composition for Ontario is shown in Table 1. The projected distribution of materials in Ontario's 1990 MSW stream shown in Table 1 are generally consistent with the 1991 Gore & Storrie results for the residential solid waste sampled in southern Ontario.

Table 1 contains projections of the waste stream composition for both the years 2000 and 2010. The waste mix changes over the years due to differences in sectorial generation rates. A good example of the effects of the sectorial generation rate shifts is the increased amount of plastic in the 1991 waste stream compared to that present in 1980. This has been matched by a decline in glass and ferrous metal packaging over the same time period.

The analysis in this report deals solely with changes that will occur in the composition and quantity of 100 kg of waste placed at curbside in 1990 as compared to that present in 2000 and 2010. It assumes that trends in waste generation seen over the past decades will continue; however, it also reflects changes in society's willingness to divert material from the disposal alternative.

The percentages in Table 1 represent the proportion of the individual components present in either the Gross or Net Discards. To calculate the Net Discards, the Gross Discards level outlined in the preceding paragraphs was adjusted to reflect recycling rates. The Gross Discard rates were adjusted for each of the subsequent periods to develop the basis for estimating waste composition at those times. An additional factor, population growth, has been disregarded in the present analysis. The Gross Discards in 1990 would have been 114 kg for every 100 kg of solid waste placed at the curb. By 2000, the Gross Discards are projected to grow to 128 kg and by 2010 to 145 kg of solid waste. The Net Discards for these periods will vary as a function of the success of diversion programs.

Impacts of Reduction, Reuse and Recycling

Reduction, reuse and recycling all conserve resources and minimize the amount of material left over for ultimate disposal. Various strategies exist to accomplish high diversion rates. For example, Table 2 includes British Columbian data which suggest that high deposits on containers result in excellent recovery rates. We have assumed that recycling could expand to look more like the British Columbia situation.

We have also assumed that recycling will increase from today's level. Present recycling rates can be characterized as the median rates from the 1991 Gore & Storrie study in Ontario. Estimates of the potential extent of recycling extend to between the low and the high recycling estimates for the year 2000 prepared by the USEPA and used in their Report to Congress, but could be further extended to include those identified by the Center for the Biology of Natural Systems (CBNS) that suggests higher rates are possible by 2010.

If entire communities are as motivated as true believers, and cost is not a consideration in an era of competing demands on public funds, the major difference between the high and low estimates is the inclusion of more types of recycled materials in later years. By 2010, 25% of the books, boxboard, diapers and mixed paper and 37% of the assorted plastics in categories 3 to 7 might be recycled. Also, half the wood and lumber and food wastes are assumed to be diverted by 2010. Achieving these recycling rates is dependent upon many things, not the least of which is the technical and economic feasibility of recycling some of these materials. Some of these considerations are contained in the following section.

Recycling Combustibles. Combustibles are the part of the municipal solid waste stream. They are broadly classified as:

- forest products (paper, cardboard and boxboard),
- derived from fossil fuels (plastics and waxes),
- yard and garden waste (grass, leaves, brush, stumps, etc.),
- food preparation waste (garbage for want of a better word), and
- textiles.

Paper Products. As may be expected, each time paper is recycled, some of the fibre is lost because it becomes too short to be recovered. The remaining fibre is somewhat oxidized causing it to lose some of its strength and become more brittle. Consequently, there is a limit to both the number of times fibre can be recycled and the amount of recycled fibre that can be used in new paper products without seriously degrading the product's properties. It is estimated that 15 to 25% of the recycled paper volume will end up as waste from the process[6]. This reality implies that it is not necessary to worry about recovering 100% of the paper products; only a certain amount, albeit a large fraction, of recycled fibre can be utilized even after worldwide fibre recovery capacity is fully expanded.

Plastics. Plastics are also recyclable combustibles. While research is underway to develop processes which can dissolve mixed plastics and recover their individual resins, the current method of recycling is to physically separate the recovered items by plastic type and colour for reuse. Thus, today's recycling methods address the relatively pure plastics used in packaging and food service applications, but they do not manage engineered plastics used in housewares and toys. They also do not address the special plastics found in video tapes, records, disks and diskettes. Current initiatives will likely lead to new technologies; but for the foreseeable future, a residual, not readily recyclable, plastics stream is likely to remain.

Textiles. This category is made up of textiles, rubber and shoes. The amount of rubber is small and includes tires, inner tubes, hockey pucks and soccer ball bladders. There is a ready market for used natural and synthetic textiles, so much of this category can be recycled. We are unaware of any use for worn-out shoes and know that they do not readily compost.

Yard and Garden Waste. The grass component is made up of grass and leaves and the simple expedient of using a mulching mower or having a back-yard compost heap (provided they are legal and properly operated to avoid nuisances) will eliminate much of this category. The brush category includes stumps, trunks and branches. While these may be usable in fireplaces, a substantial chipper is needed to convert this material into mulch or bulking agent for composting so collection is the most likely alternative for most of this material. The wood category can be similarly chipped and used if it is not impregnated with fungicides or coated with lead based paints.

Recycling Noncombustibles. Metals and glass are readily recyclable provided they are separated into marketable categories. Aluminum and tin cans are very high grade feed stock for making new aluminum and steel products. Other metals, like copper wiring and brass plumbing fixtures, are also recyclable once any organic coatings are removed.

While there are limited uses for mixed colour cullet in glass making, colour sorted glass has a much wider use. The market for coloured glass is limited. It is not used as much in North American packaging as it is in Europe and importing products in green and brown glass containers to North America leads to an accumulation of these materials.

Projections of Waste Composition and Quantity

As the foregoing shows, there is a wide potential for employing various techniques to reduce the MSW stream. Forecasting the characteristics and quantities of future MSW streams is not an exact science. Indeed, for the purposes of this assessment, precisely defining the future is unnecessary. Rather, we should use the estimated extremes to bracket future reality. Thus, the results presented here represent reasonable bounds for levels of reduction, reuse and recycling likely to be achieved by the years indicated.

The recycling rates shown in Table 3 include an allowance for both contaminated materials which become dirty through reuse and are not suitable for recycling and for the proportion of people who, after any amount of education and inducement, simply will not or do not comply with the recycling guidelines. Figure 1 estimates MWC composition and the changes in discard quantity over time:

- In 1990, every 100 kg of MSW at the curb would represented an average of 114 kg of waste generated.

- By 2000, the Gross Discards will be 128 kg. Depending upon the level of recycling achieved, between 92 and 61 kg will remain to be set out at the curb.

- By 2010, Gross Discards will rise to 145 kg. Again, depending upon the level of reduction, reuse and recycling achieved, between 103 and 53 kg will remain for ultimate disposal.

Because the estimates bracket the range of anticipated diversion effectiveness, we would not expect to have more post 3-R waste than is shown in Figure 1 under the low recycling (high net disposal) scenario. Nor would we expect to have less post 3-R waste than is shown under the high recycling (low net disposal) scenario.

Figure 2 shows the composition of municipal solid waste in 2010. Extensive 3-R management activities are expected to remove between 35 and 70 kg of paper for every 100 kg of waste currently discarded. The amount of food waste will be cut in half, to some extent as the result of less spoilage and wastage due to improved packaging, and the balance due to composting and in-sink garbage grinders. Material that is not diverted does not lend itself to alternative disposal. Either it should not be composted in residential settings (meat scraps and fat attract vectors and scavengers and create a public health problem) or it is bones and the like which do not compost well. Glass recycling is projected to increase as is the recycling of plastic containers and films. Yard waste is expected to be substantially reduced through the use of mulching lawn mowers, backyard composting and separate municipal collection of yard waste. Textiles will be recycled as well.

Having developed a description of the MSW stream in 2010, the issue of using MWC technology can be addressed.

INCINERATION'S PERCEIVED EFFECTS ON THE PUBLIC'S MOTIVATION TO CONSERVE

Incineration, whether in an energy recovery facility or in a mass destruction box, can be viewed as a simple solution to solid waste disposal. With an MWC available, people may feel that they do not have to participate in recycling programs because their waste is being volume-reduced prior to landfilling. Also, if an incinerator is available, the public is aware that existing landfill capacity can be extended by a factor of 5 to 10. As a consequence of this perception, many 3-R supporters feel that if incineration is encouraged, a moral incentive to reduce, reuse, and recycle is removed.

Incinerators are also perceived as insatiable monsters. This historical perception is the result of the method of financing prevalent in the United States. Many, if not most, U.S. incinerators are industrial revenue bond financed. As part of the financing package, the users pledge to deliver enough waste to the facility to keep it full. This pledge, when coupled with an energy purchase contract and technical (performance) guarantees, provides, in effect, a revenue guarantee that secures the debt. Thus, the basis for the argument, "If the 3-Rs are promoted, these communities face financial ruin because the anticipated revenues are not realized".

While the existence of these perceptions cannot be disputed, the reality is that as long as the MWC is properly sized, there is no conflict. The facility cannot process waste beyond its capacity, so 3-Rs are needed to extend landfills to the greatest extent. Also, in a comprehensive waste management system, the MWC recovers energy that would otherwise be lost and acts as a final hurdle for solid waste to clear before burial. Properly sized, incinerators ensure maximum recovery of materials and energy and minimum depletion of the landfill resource.

Effect of Changed Solid Waste Composition and Fuel Properties

Table 3 is a summary of the post 3-R discards fuel properties. These were estimated by combining individual component properties in proportion to the amount of each present. As diversion strategies are implemented, the first impact is to remove non-combustible recyclables. This has the effect of reducing fuel ash content and increasing the heating value. As diversion implementation continues, combustibles like paper and are targeted. These remove energy content and also reduce ash levels so the net impact is only a slight decrease in heating value. Assuming an extensive, CBNS type intensive diversion effort is put in place, the projected heating value actually rises because a relatively greater percentage of the waste is engineered and other plastics which do not presently have technically viable recycling options.

As the fuel properties change, so does the sustainable capacity of the incinerator facility in tonnes per day. The energy recovery capacity is fixed by the boiler design and physical installation, only so many joules of energy can be fed to the system within a given time frame. Changes in waste composition and waste chemistry result in changes in daily throughput capacity. In terms of tonne per day nameplate capacity, an incinerator built for today's waste will only handle 91-95 percent of the designed tonnage if it is being fed the year 2000 waste mix and 90-98 percent of design tonnage when fed the year 2010 mix. The residues produced, including moisture added for dust control and lime from the acid gas control system, will decrease 8 to 10 percent with low levels of recycling and increase 15 to 40 percent with high recycling rates compared to the residue generated in 1990.

COMPATIBILITY ASSESSMENT

As the 3-Rs are implemented, less material remains to be incinerated. The bottom line is that even if we can afford and induce the general public to reduce, reuse and recycle waste to the extent contemplated by advocates of CBNS, we will only reduce the amount requiring ultimate disposal to 1/3 to 2/3 of the amount generated before application of the 3-Rs. That is, an MWC designed to recover the energy content and recycle the residual metals and ash from about half of today's collections will likely still be needed in 2000 and 2010 under the most aggressive scenario analyzed. In reality, a capacity equal to today's net discards may actually be needed to accommodate the residual waste stream after reasonable diversion efforts.

Another way to look at prudent capacity is to ask how much of the residual solid waste collections (not picked up as a part of a 3-R program) will be needed to support a plant designed to handle today's solid waste stream. Answering this question requires considering the changes in waste fuel properties as a result of 3-R implementation and changes in waste characteristics over time.

The fuel properties govern how much solid waste can be burned in an incinerator because these systems are not tonnage devices, they are usable energy devices. An energy recovery incinerator cannot consume more waste than its energy recovery equipment is capable of removing. While contrary to convention, EFW's should be rated in kg/h of steam raised or mWe generated, not tonnes per day.

Figure 3 illustrates the effect of recycling and changing fuel characteristics on heating value. Note that, regardless of the level of recycling accomplished, the energy value increases between 1990 and 2010. Municipal solid waste has been changing. In the early 1980s, 10,500 kJ/kg (4,500 Btu/lb) was considered a typical heating value for as-discarded MSW. Today, we believe that MSW typically displays a heating value around 12,800 kJ/kg (5,500 Btu/lb). As 3-Rs are implemented, the heating value is expected to continue to rise. The increase in heating value, however, is from around 12,800 kJ/kg (5,500 Btu/lb) to around 14,000 kJ/kg (6,000 Btu/lb) — an increase that is much less than that already successfully handled by operating MWCs. At the same time, the ash content of as-discarded MSW will rise or fall depending on the effectiveness of 3-R programs with increasing effectiveness resulting in more ash which translates to more residue.

Figure 4 shows that a plant designed to process 100 TPD of as-collected municipal solid waste today will be able to process between 90 and 95 TPD of as-collected MSW in 2000. The exact value depends upon the extent of 3-R implementation and its impact on the final fuel properties. That same plant will be able to process between 90 and 98 TPD of as-collected MSW in 2010.

CONCLUSION

This paper provides a projection for the amount and composition of waste likely to be available in future years from a fixed population. The projection shows that under the low recycling scenario, if incinerator capacity equal to today's generation rate were built, recycling would accommodate the growth in waste production. If we take the high recycling rate projection, a need will remain for managing about half the waste that is currently being put out at the curb.

These projections do not account for widening the waste shed area, nor do they account for increases in population between now and 2010. The projections suggest that reasonably sized incinerator facilities can co-exist with even the most intensive recycling, reduction and reuse activities.

If we were to build enough capacity to recover the energy in half the waste collected today, that capacity should remain full into the foreseeable future. Even with maximum 3-R implementation, some waste will still go to the landfill without energy recovery and unrecycled metals will be lost to the disposal site. With minimum expected 3-R implementation, incinerator capacity equal to today's disposal will be needed instead of the half indicated under the maximum 3-R scenario.

Certainly reasonable amounts of energy recovery capacity, say equal to half of today's discards, will be needed, regardless of the success of 3-R programs.

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Table 1. Estimated MSW composition for Ontario in 1990 and subsequent years.

	1990 DISCARDS		2000 DISCARDS			2010 DISCARDS		
PARTITIONED CATEGORIES	GROSS	NET	GROSS	HIGH NET	LOW NET	GROSS	HIGH NET	LOW NET
Paper	63.23	53.88	76.56	46.18	19.35	92.06	55.28	21.10
Kraft & Corrugate	19.13	19.13	23.05	11.98	2.30	27.91	14.51	2.79
Newsprint	13.82	4.47	15.51	8.07	1.55	17.34	9.01	1.73
Fine Paper	14.26	14.26	19.92	10.36	1.99	25.57	13.30	2.56
Magazines & Glossy	2.13	2.13	2.45	1.27	0.24	2.94	1.53	0.29
Books & Phonebooks	1.31	1.31	1.50	1.50	1.50	1.80	1.80	1.35
Boxboard	2.00	2.00	2.30	2.30	2.30	2.75	2.75	2.07
Diapers	2.31	2.31	2.31	2.31	2.31	2.31	2.31	1.74
Mixed Paper	8.28	8.28	9.52	8.38	7.14	11.43	10.06	8.57
Glass	5.21	4.10	4.29	2.61	1.84	3.84	2.39	1.73
Beer Bottles	0.06	0.00	0.04	0.00	0.00	0.04	0.00	0.00
Softdrink--Refillable	0.65	0.65	0.49	0.01	0.00	0.42	0.00	0.00
Softdrink--Non-refillable	0.75	0.75	0.57	0.07	0.01	0.49	0.06	0.01
Liquor & Wine	0.87	0.31	0.66	0.37	0.07	0.56	0.32	0.06
Containers--Food	1.12	0.62	0.85	0.48	0.08	0.73	0.42	0.07
Containers--Other	0.37	0.37	0.35	0.35	0.35	0.33	0.33	0.33
Flat & Cullet	1.40	1.40	1.33	1.33	1.33	1.26	1.26	1.26
Ferrous Metals	4.13	3.66	3.84	3.30	3.05	3.63	3.22	3.03
Beer Cans	0.06	0.01	0.05	0.01	0.00	0.04	0.00	0.00
Softdrink Cans	0.04	0.03	0.03	0.01	0.00	0.02	0.00	0.00
Food Cans	1.22	0.82	0.95	0.48	0.24	0.73	0.37	0.18
Other	2.81	2.81	2.81	2.81	2.81	2.84	2.84	2.84
Non-ferrous Metals	1.19	0.85	1.44	0.78	0.43	1.44	0.75	0.42
Beer Cans	0.38	0.04	0.41	0.05	0.00	0.46	0.05	0.00
Food Containers & Foil	0.36	0.36	0.46	0.23	0.00	0.44	0.22	0.00
Manufactured Aluminum	0.42	0.42	0.53	0.47	0.40	0.50	0.44	0.38
Other Non-ferrous	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.03
Plastics	8.47	7.36	11.00	9.31	9.20	12.81	10.82	9.43
Container--1(PETE)	0.09	0.01	0.16	0.01	0.00	0.17	0.02	0.00
Container--2(HDPE)	1.14	0.11	1.62	0.08	0.00	1.92	0.10	0.00
Container--3(PVC)	0.04	0.04	0.06	0.05	0.03	0.08	0.06	0.04
Container--4(LDPE)	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.03
Container--5(PP)	0.16	0.16	0.22	0.22	0.22	0.26	0.26	0.17
Container--6(PS)	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.03
Container--7(other) & Unidentified	0.10	0.10	0.14	0.14	0.14	0.16	0.16	0.10
Film & Bags	1.95	1.95	2.47	2.47	2.47	2.87	2.87	1.81
Housewares	4.24	4.24	5.37	5.37	5.37	6.24	6.24	6.24
Toys	0.69	0.69	0.87	0.87	0.87	1.01	1.01	1.01
Tapes & Films	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Ceramics & Rubble	1.65	1.65	1.56	1.56	1.56	1.59	1.59	1.59
Wood (lumber)	3.34	3.34	3.95	3.95	3.95	4.58	4.58	2.29
Food Wastes	16.65	16.65	15.88	15.88	15.88	15.49	15.49	7.75
Textiles/leather/rubber	4.42	4.42	4.61	4.61	4.61	4.58	4.58	2.55
Textiles	3.94	3.94	4.09	4.09	4.09	4.06	4.06	2.03
Rubber	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Footwear	0.41	0.41	0.44	0.44	0.44	0.45	0.45	0.45
Yard Wastes	4.03	3.00	4.03	3.06	0.64	4.03	3.06	0.64
Grass & Leaves	3.43	2.40	3.43	2.61	0.34	3.43	2.61	0.34
Brush & Stumps	0.60	0.60	0.60	0.46	0.30	0.60	0.46	0.30
Fines	0.85	0.85	0.80	0.80	0.80	0.81	0.81	0.81
Petrolleum & Chemicals	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.12
GRAND TOTAL	113.42	100.00	128.18	92.25	61.53	145.10	102.82	51.46
GRAND TOTAL W/O YARD	109 38	97.00	124.15	89.19	60.89	141.07	99.75	50 82

Table 2. Comparison of present and future recycling levels in various jurisdictions.

	PROGRAM ELEMENT EFFICIENCY				
		——BLUE-BOX——			
	B.C. TYPE	MEDIAN			
PARTITIONED CATEGORIES	DEPOSIT LAWS	1991 ONTARIO	USEPA MINIMUM	MAXIMUM	CBNS TYPE INTENSIVE
Paper					
Kraft & Corrugate			48%	90%	90%
Newsprint		68%	48%	90%	90%
Fine Paper			48%	90%	90%
Magazines & Glossy			48%	90%	90%
Books & Phonebooks					25%
Boxboard					25%
Diapers					25%
Mixed Paper			12%	25%	25%
Glass					
Beer Bottles	96%		43%	90%	90%
Softdrink--Refillable	98%		43%	90%	90%
Softdrink--Non-refillable	79%		43%	90%	90%
Liquor & Wine		64%	43%	90%	90%
Containers--Food		45%	43%	90%	90%
Containers--Other					
Flat & Cullet					
Ferrous Metals					
Beer Cans	77%	57%	50%	75%	75%
Softdrink Cans	59%	34%	50%	75%	75%
Food Cans		32%	50%	75%	75%
Other					
Non-ferrous Metals					
Beer Cans	77%	57%	50%	99%	99%
Food Containers & Foil		0%	50%	99%	99%
Manufactured Aluminum			12%	25%	25%
Other Non-ferrous			12%	25%	25%
Plastics					
Container--1(PETE)	83%	61%	48%	99%	99%
Container--2(HDPE)	90%		48%	99%	99%
Container--3(PVC)			24%	50%	50%
Container--4(LDPE)					37%
Container--5(PP)					37%
Container--6(PS)					37%
Container--7(other) & Unidentified					37%
Film & Bags					37%
Housewares					
Toys					
Tapes & Films					
Ceramics & Rubble					
Wood (lumber)					50%
Food Wastes					50%
Textiles/leather/rubber					
Textiles					50%
Rubber					
Footwear					
Yard Wastes					
Grass & Leaves		30%	24%	90%	90%
Brush & Stumps			24%	50%	50%
Fines					
Petrolleum & Chemicals					50%

Table 3. Post 3-Rs residue fuel quality.

year	gross generation	low recycling	high recycling	gross generation	low recycling	high recycling	gross generation	low recycling	high recycling
	Discards			Relative Plant Capacity			Total Residue--% of feed		
1990	113.6	100.0		97.5%	100.0%		21.7%	21.6%	
2000	128.4	92.2	61.5	91.0%	94.5%	97.5%	19.1%	19.9%	23.6%
2010	145.4	102.8	51.5	87.8%	90.8%	89.5%	17.4%	18.5%	27.5%
	Higher Heating Value -- Btu/lb			Lower Heating Value -- Btu/lb			%--Carbon		
1990	5,537	5,416		4,876	4,752		30.7	30.1	
2000	5,863	5,688	5,586	5,193	5,006	4,885	32.3	31.2	29.7
2010	6,044	5,878	5,982	5,370	5,194	5,302	33.3	32.2	32.0
	%--Hydrogen			%--Oxygen			%--Nitrogen		
1990	4.18	4.12		24.5	24.4		0.37	0.40	
2000	4.41	4.24	4.07	25.6	23.8	19.4	0.35	0.42	0.52
2010	4.54	4.38	4.42	26.6	24.7	19.7	0.34	0.40	0.04
	%--Sulfur			%--Chlorine			%--Moisture		
1990	0.095	0.098		0.14	0.16		26.0	26.7	
2000	0.097	0.099	0.096	0.16	0.22	0.32	24.8	27.4	30.8
2010	0.099	0.100	0.098	0.17	0.23	0.64	23.9	26.3	25.6
	%--Ash								
1990	14.1	14.0							
2000	12.3	12.7	15.1						
2010	11.1	11.7	17.1						

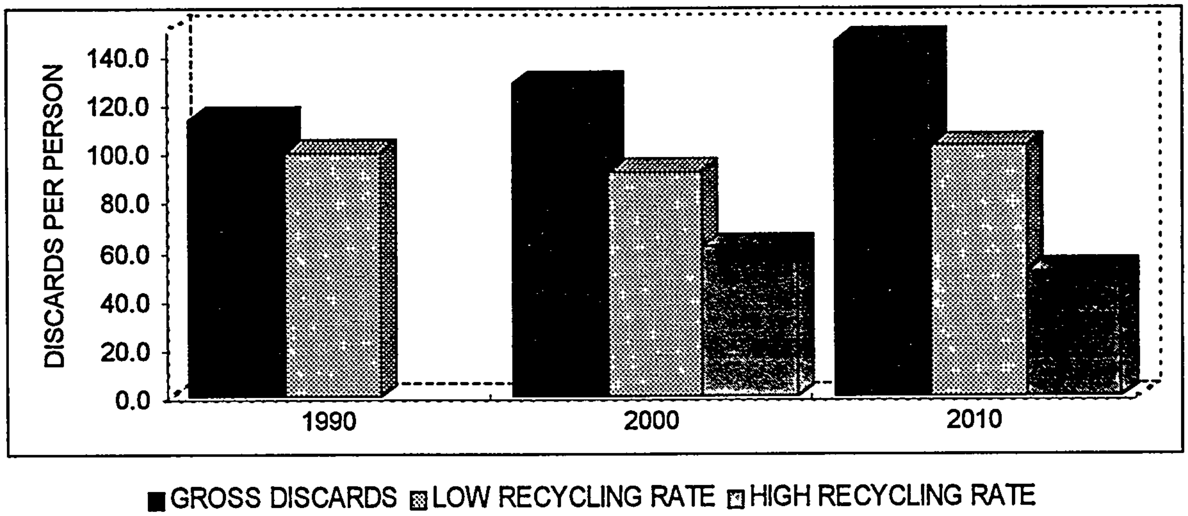

Figure 1. Impact of recycling on discard rate normalized to 100 pounds today.

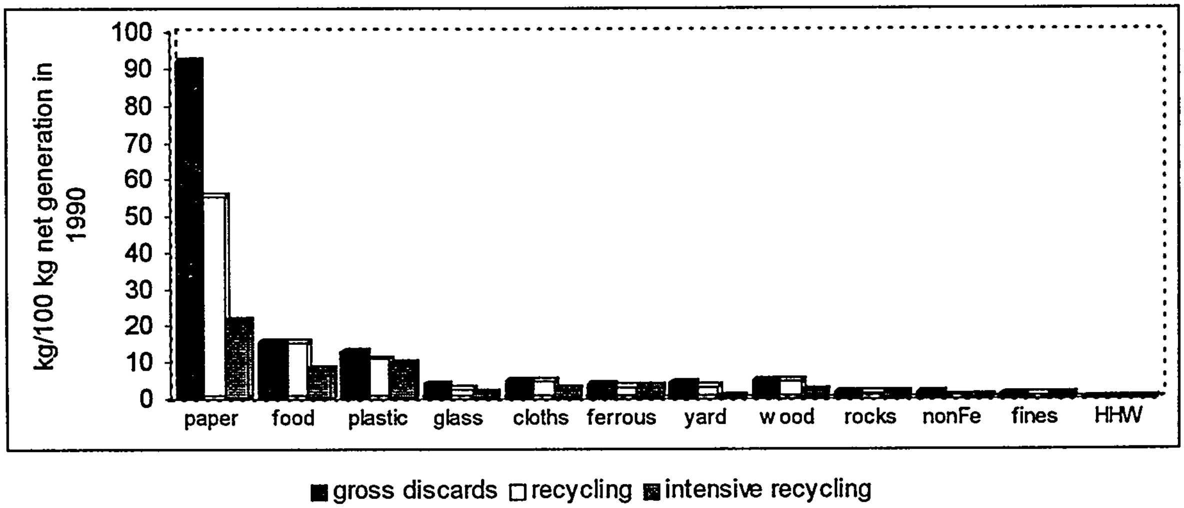

Figure 2. Solid waste composition in 2010 as generated and after 3-Rs.

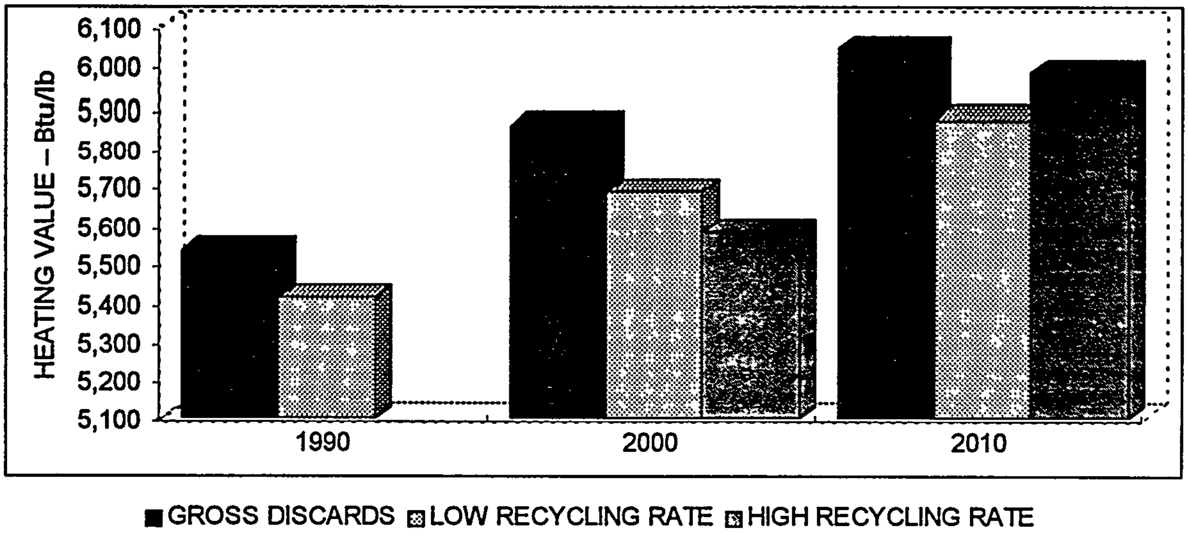

Figure 3. Impact of recycling on heating value.

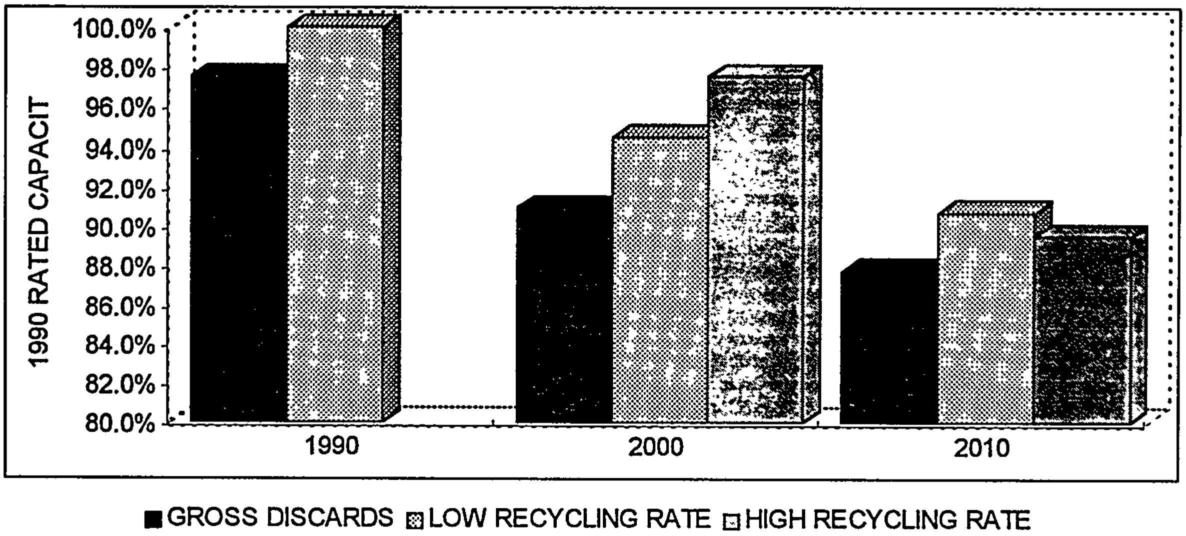

Figure 4. Impact of 3-Rs on EFW capacity normalized to today's new discards.